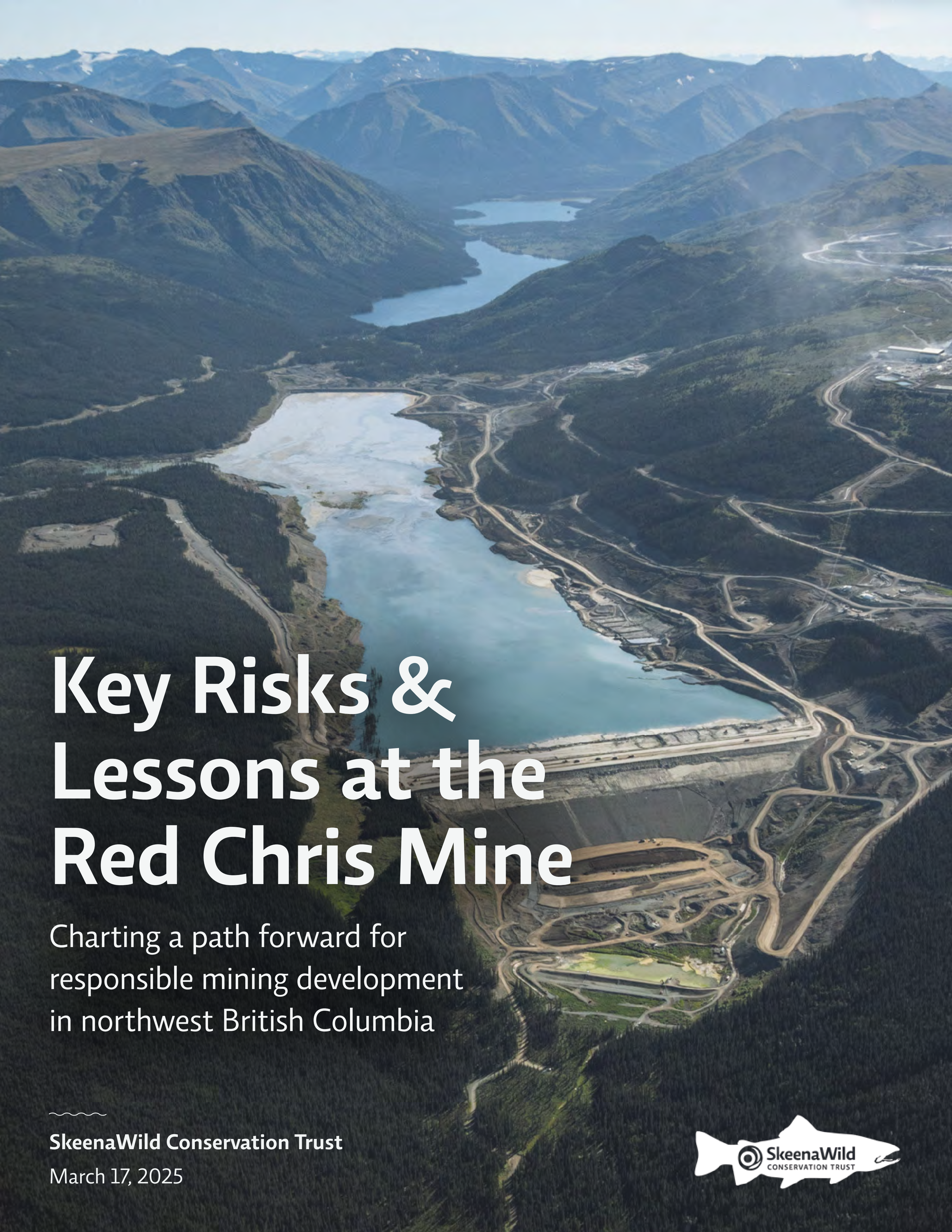

Key Risks & Lessons at the Red Chris Mine

Charting a path forward for responsible mining development in northwest British Columbia

SkeenaWild Conservation Trust

March 17, 2025

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SkeenaWild

Founded in 2007, SkeenaWild Conservation Trust is committed to securing a future where the Skeena Watershed and northwest British Columbia as a whole are a global example of balance and sustainability. Here, the roots of Indigenous Nations, local communities, and the natural rhythms of wild salmon are intertwined; our job is to ensure that all can flourish together. By collaborating with all communities, we are working to safeguard the stability and long-term health of our local lands and waters. Our mission is to ensure that fish continue to return to our rivers now and for future generations to support job and food security and people's connection to wild salmon.

skeenawild.org

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Cover photo: Red Chris Mine tailings facility with Kluea and Todagin Lakes in background, by Colin Arisman | colinarisman.com.

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Summary

In northwest British Columbia (BC), home to some of the world's last remaining salmon stronghold watersheds, exploration and investment in large-scale open-pit mining is rapidly expanding and is supported by infrastructure advancements, federal financial support, and provincial commitments to expedite permitting. Several open-pit mines producing "critical minerals"—copper and other metals considered necessary to support the renewable energy transition—are proposed or already permitted but not yet operating. Many will also produce gold, a luxury commodity, not a critical mineral. Large-scale mining development exacerbates risks to wild salmon populations vulnerable to rapid climate change and could contribute to the "undocumented extinction" of certain populations. Physical disruption of habitat, chemical water pollution, and the possibility of tailings dam failures from mining in remote northwest BC watersheds jeopardize recreation and tourism, world-class Pacific salmon fisheries, and salmons' ability to adapt to climate change.

The Red Chris Mine, an open-pit copper-gold-silver mine in the headwaters of the salmon-bearing Iskut and Stikine Rivers, began operating in 2015. In 2023, its owners began pursuing an expansion of its operations. In February 2025, in response to US tariff threats, the provincial government included the Red Chris expansion project on its list of projects to fast-track. SkeenaWild Conservation Trust's review of the Red Chris operation offers valuable insights into potential issues at future mines in the region, helping to ensure that mining for critical minerals does not compromise human health, clean water, healthy ecosystems, or wild salmon populations. Now is also a critical time to address outstanding problems at Red Chris' existing operations prior to any expansion.

Based on mine monitoring data and reporting, this report reviews key technical and scientific issues at Red Chris Mine, focusing on its impacts on downstream aquatic ecosystems, tailings facility, and proposed expansion. It also relates these issues to potential additional mines in the region. Most records related to Red Chris Mine are not publicly available and were accessed via requests under the *Freedom of Information Act*. Based on the information obtained, our review discusses the following key findings:

AQUATIC ECOSYSTEM IMPACTS

- Significant gaps exist in data transparency, understanding of mine site conditions, environmental monitoring, and mitigation thresholds for preventing negative aquatic impacts.
- An unexpected water deficit has complicated site water management and amplified aquatic impacts.
- The mine is releasing significantly more contaminated seepage from its tailings facility and waste rock pile to the environment than was predicted.
- The mine has caused documented physical degradation and elimination of productive fish habitat.
- Numerous mine contaminants, such as selenium, copper, nitrate, and sulphate, are increasing in surrounding creeks and lakes and are often high enough to negatively affect aquatic life.
- Selenium concentrations in local fish tissues are increasing in two lakes affected by the mine, and this may negatively affect both the fish and the humans consuming them.
- The mine will generate widespread acid rock drainage (low-pH mine effluent containing very high contaminant concentrations).
- Effective water treatment plans to protect the downstream environment have not been developed.

TAILINGS SAFETY

- The tailings dam foundations contain glaciolacustrine layers, the same foundation materials associated with the Mount Polley dam failure.
- Construction of the tailings dams has repeatedly failed to meet construction targets, which may increase the likelihood of a dam failure due to overtopping.
- Seepage from the tailings facility poses risks to physical dam stability and may increase the severity of acid rock drainage from the tailings.
- A major tailings dam failure at Red Chris would significantly destroy or deteriorate critical fish or wildlife habitat and could result in the loss of human life.
- Multiple shortcomings in dam failure modelling and emergency planning at Red Chris increase risks to downstream human populations and the environment.

MINE EXPANSION

- The expansion of Red Chris Mine will shift the mine's focus from copper to gold extraction.
- The mine's initial proposed shift to underground mining would have fewer environmental impacts than open-pit mining; however, risks and uncertainties related to landslides, degradation of aquatic habitat, and significant pre-existing issues remain.
- Mine operators are considering additional future expansions that would further destroy aquatic habitat and raise the consequences of a tailings dam failure.

Many of the above issues can be directly tied to shortcomings in provincial regulatory requirements and oversight, resulting in:

- inadequate monitoring, predictions, and planning,
- failure to minimize the scope and scale of the project,
- disregard of independent expert advice, and
- delays in thoroughly assessing and managing mine environmental effects.

Ultimately, the risks and impacts of the Red Chris Mine to fish, aquatic ecosystems, and humans are greater than necessary. Without more attention, these risks and impacts will persist long after Red Chris closes and be compounded by regional stressors like climate change and other extractive development. To remedy current issues at Red Chris, especially as mine expansion is pursued, we recommend that regulators strengthen their requirements relating to:

- understanding of site conditions and mine contamination sources,
- aquatic monitoring,
- mitigation of greater-than-expected mine seepage and the mine's impacts on water, fish, and other aquatic resources,
- planning for acid rock drainage and future water treatment needs,
- reducing risk factors associated with the tailings facility, and
- planning for tailings dam failures and other emergencies.

Regulators must also ensure that addressing the mine's existing problems and rigorously assessing future risks—including trade-offs between social and environmental risks in exchange for producing non-essential commodities like gold—is prioritized over fast-tracking the mine's expansion.

Many large-scale open-pit mines similar to Red Chris aspire to operate in watersheds of northwest BC. All mining developments in this region will carry similar risk factors and face many of the same complex issues revealed in this report, which could create far-reaching consequences for high-value wild salmon habitats and local communities. This is especially true for the many mine projects under development close to salmon-bearing rivers, human settlements, and international borders. It is ultimately the responsibility of provincial and federal decision-makers to do what is needed to reduce the direct and cumulative pressures of further mining in northwest BC. This includes more substantial requirements at current and future mines for:

- public transparency about mining risks and impacts,
- preventing environmental risks by understanding site conditions before approving mine designs,
- precautionary approaches to predicting, monitoring, and mitigating environmental effects,
- accountability to independent expert recommendations, and
- reducing the overall scope, scale, and risk profile of mine projects.

Environmental Assessments must also be based on strong data, meaningful engagement with the public, and full consideration of cumulative effects. Decision-makers must not permit risks or impacts to the environment or human safety in exchange for mining gold and other precious metals, which are not critical minerals.

A balance must be struck between pursuing economic prosperity, procuring metals to support daily technology requirements and the renewable energy transition, and the essential need to safeguard the natural resources that sustain our communities. Based on this review of the last ten years of operations at Red Chris Mine, it is clear that current approaches to mine planning, design, operations, and oversight in northwest BC put downstream environments and people at unnecessary risk. However, solutions are available to ensure more responsible future mining development throughout the region that will protect the long-term health and strength of these world-class watersheds. See below for a complete list of the recommendations made in this report.

Tailings facility at Red Chris Mine with open pit, waste rock pile, and Kluea and Todagin Lakes in background. COLIN ARISMAN | COLINARISMAN.COM

Recommendations

General Recommendations

These recommendations apply to any mine projects in northwest British Columbia (BC), including Red Chris.

Aquatic Ecosystem Impacts

- Make key environmental monitoring reports—including Aquatic Effects Monitoring Program, Water Quality Monitoring Program, and Groundwater Monitoring Program reports—and all raw environmental data, including pre-mining baseline data, publicly accessible. Data must be provided in file formats that enable independent data analysis.
- For proposed projects to proceed through the Environmental Assessment (EA) process, robust data collection must be required regarding project site conditions, such as baseline hydrology and groundwater conditions. This requirement should be enforced as part of the EA Readiness Determination and maintained as an ongoing requirement through mine permitting stages, such as during EA Certificate approval and *Mines Act* and *Environmental Management Act* permitting.
- At higher-risk and dynamic monitoring sites: Require continuous monitoring of basic water quality data (i.e., pH, temperature, conductivity, turbidity) using sondes and daily sampling for the full suite of potential contaminants, including metals, nitrate, sulphate, etc.
- Require an assessment of intra-annual variation in sediment quality and tissue chemistry of aquatic vegetation, zooplankton, benthic invertebrates, and fish. Based on the results of this assessment, increase sampling frequency to a) improve statistical power and b) ensure sampling is performed when contaminant loads are typically highest.
    - Given that contaminants reside in fish tissues on the scale of months, twice-yearly sampling for fish tissue chemistry would be appropriate. Non-lethal sampling techniques should be employed to reduce sampling impacts on local fish populations.
- Detailed tissue chemistry analyses must be performed to assess changes from pre-mining conditions for *all* metals.
- Site Performance Objectives and trigger levels must be set to maintain receiving environment conditions at pre-mining background levels or no-effect concentrations.
- Monitoring of site conditions, predictions of environmental effects, design and implementation of mitigations, and development of contingency plans must be i) thorough, precautionary, and

proactive, and ii) a condition of mine construction and operations permitting.

- Independent expert recommendations must be followed, or detailed rationale must be provided to regulators and the public when recommendations are not followed.
- Prioritizing mine production must not be considered an appropriate rationale for disregarding independent expert advice or delaying action to understand and prevent environmental effects.
- Monitoring of groundwater quality must be spatially and temporally extensive so as to accurately delineate the extent of seepage plumes and understand their loading sources. This must include robust baseline sampling in all potentially affected receiving areas—even where there is uncertainty as to whether that receiving area will ultimately receive mine inputs—and consistent, ongoing sampling through the life of the mine. Additional monitoring wells must be installed as soon as it is evident seepage will extend past the existing monitoring system. Further monitoring must also be pursued to understand groundwater interactions with surface water systems.
    - The appropriate groundwater quality sampling frequency to detect change must be established based on a site-specific assessment that considers multiple factors such as hydrogeological conditions, contaminant residence times, and the number of monitoring wells in each potentially affected area. Based on available research, quarterly sampling should be the minimum frequency (Moreau-Fournier & Daughney 2012); however, monthly to daily sampling is strongly recommended, especially where groundwater velocities and contaminant dispersion rates are greater or monitoring wells are fewer—such as outside the mine site (Papapetridis & Paleologos 2012; Saraceno et al. 2018).
- Mitigations must be designed and constructed before environmental effects thresholds (i.e., Trigger Response Plan and/or Site Performance Objective thresholds) are exceeded.
- Trigger Response Plans must be reviewed and updated annually as monitoring networks are expanded and/or knowledge of mine interactions with the receiving environment (such as via seepage or surface discharge inputs) evolves.
- Adaptive management plans and mitigation designs must be developed before mining for all potential discharges from all mine waste facilities, even where there is uncertainty about whether such discharges will occur.
- Monitoring of surface water quality and other aquatic indicators must be spatially and temporally extensive so as to identify mine-related changes. This must include robust baseline sampling in all potentially affected receiving areas—even where there is uncertainty as to whether that receiving area will ultimately receive mine inputs—and consistent, ongoing sampling through the life of the mine.
- Maintenance and upkeep of monitoring and water management infrastructure must be prioritized, especially where there is potential for direct impacts to downstream aquatic habitat.
- Regulators must take enforcement actions when legal limits, such as surface water quality Site Performance Objectives, are exceeded.
- Mitigations of mine-related impacts must be implemented even where some observed downstream changes may be naturally occurring.
- The existence of potential or known natural mechanisms for increasing contaminant loads in the receiving environment, particularly in fish, must not be used as a rationale to not proceed with mitigation of mine-related impacts. Where natural

loading mechanisms occur, mitigation of mine-related loading sources should be strongly prioritized to reduce cumulative stress on surrounding aquatic systems.

- Any observed increase in contaminant loads in downstream fish must be followed by further assessment and mitigative actions.
- Mine environmental monitoring must follow the Precautionary Principle. Lack of statistical power or uncertainty in the data cannot be used as a rationale for not proceeding with additional assessments and mitigation actions.
- Mitigations, management approaches, and contingency plans for acid rock drainage (ARD), including seepage capture, water treatment, and waste covers, must be designed and developed well in advance of ARD generation.
- The entire lifecycle costs and risks of long-term or perpetual water treatment must be incorporated into financial and regulatory project assessments.
- Mine water treatment plans must employ target discharge limits equal to receiving environment background conditions or no-effect thresholds. Given uncertainties about the complexity of natural systems, the potentially long-term nature of heavy metal contamination, and the possible effects of combined elevated metals on aquatic life, effluent discharge limits that exceed BC Water Quality Guidelines and/or rely on dilution by the receiving environment are unacceptable.

Tailings Management

- Detailed reports regarding Independent Tailings Review Board activities must be publicly available to increase transparency and public confidence that best practices are being followed at mine sites.
- More thorough geologic studies should be conducted to identify tailings dam foundation materials prior to the issuance of Environmental Assessment Certificates and *Mines Act* and *Environmental Management Act* permits.
- Estimates of available dam construction materials must be conservative to avoid unexpected shortages.
- Controlling seepage at the source is the most environmentally protective approach. When seepage concerns are understood—as they were at Red Chris during the permitting and early construction stages—tailings dam designs should be developed to prevent seepage. This must be a condition of mine permitting to safeguard the downstream biotic environment.
- Tailings dam designs should be overly conservative to account for water balance and seepage rate uncertainties, including planning for water shortages and surpluses.
- Precautionary seepage mitigations should be well developed prior to permitting so they can be implemented without delays. All mitigations should have clear performance objectives and monitoring plans.
- Dewatered tailings should be aggressively pursued at new mines (and assessed for feasibility at all currently operating mines) in BC. This approach must be prioritized despite any additional costs.
- Robust site-specific data related to hydrology, climate, terrain, and groundwater must be collected to reduce uncertainties that may compromise mine design and functionality, such as during the development of site water balance and climate-related modelling and predictions. These datasets should be a requirement early in the EA process, such as at the EA Readiness Determination stage.

- Independent third-party future climate scenario assessments should be performed for project EAs and on a recurring basis throughout the life of the project.

- Detailed and conservative contingency plans for drier- and wetter-than-expected conditions must be developed prior to approvals and permitting of proposed mines and at all currently operating mines, given that future climatic conditions are increasingly uncertain and continue to depart from historical conditions.

- Potential groundwater withdrawals should be established during the EA and permitting stages. Assessments of sustainable limits must be considered during the EA and incorporated into mine design and groundwater extraction during operations.

- Tailings dam inundation studies should be made publicly available in a readily accessible summary format by the Province or mining companies operating in BC.

- The scale of tailings facilities and mobility of tailings should be reduced at Red Chris and other mines in BC through waste backfill, tailings dewatering, and other emerging technologies.

- Emergency response plans must be updated regularly to address plans for increasingly extreme weather events and unprecedented climatic conditions.

- Clear procedures and feasibility assessments should be developed for all emergency response plans.

- Emergency response plans should be publicly available and developed in partnership with local stakeholders and affected communities, as previously recommended by others (Golder 2019d; Emerman 2022).

Mine Expansion

- Alternatives to permanent water covers on tailings must be aggressively pursued. This recommendation aligns with those made by the Mount Polley Independent Expert Engineering Investigation and Review Panel (IEEIRP 2015) and the Global Industry Standard on Tailings Management (Global Tailings Review 2020) to minimize the volume of water stored in tailings facilities.

- Independent third-party future climate scenario assessments should be required for all major EA amendment assessments.

- Selective mining methods must be aggressively pursued over bulk mining methods to reduce mine waste generation and other risks associated with large-scale mining operations.

- The EA amendment process must require detailed assessments—based on quantitative data—to support proponent conclusions about effects on downstream water and aquatic indicators.

- Decision materials related to EA amendments must provide detailed rationales supporting amendment decisions.

- Complex EA Amendment review processes must include public engagement on the Application Information Requirements, Amendment Application, and Amendment Assessment Reports. They must also include the opportunity to form a Community Advisory Committee.

- Phased mine expansion approvals should be avoided, and where they are not avoided, potential cumulative effects related to phased mine expansions must be thoroughly considered during all EA permitting processes.

- Expansion of mine waste storage facilities must be avoided however possible.

- Any major mine expansion or major change to tailings facility design must undergo an in-depth regulatory review that includes comprehensive public and stakeholder engagement.
- Evaluations of new mines and mine expansions must prioritize the development of mines providing critical minerals and essential commodities over precious metals (i.e., silver and gold) mining.
- Evaluations of new mines and mine expansions must not permit risks or impacts to social and environmental values in exchange for producing non-essential commodities like gold.

Red Chris Recommendations

These recommendations apply specifically to Red Chris Mine based on the issues identified in this assessment (please see main body of report for more details).

Aquatic Ecosystem Impacts

- Further assessment and mitigation actions must be initiated in response to trigger level exceedances that have occurred at monitoring wells installed after the last Red Chris Trigger Response Plan update in 2016.
- The spatial extent of all tailings seepage plumes must be fully delineated, and all mine loading sources to waterways downstream of the tailings facility must be identified.
- Seepage interception should be activated at Red Chris unless there are environmental rationales to delay this action—in which case, such reasoning must be provided publicly.
- Mitigation measures to reduce waste rock seepage, such as liners or pile covers, must be pursued.
- Groundwater monitoring must be expanded in the Lost Creek drainage, sufficient to empirically determine to what extent Red Chris waste rock seepage impacts it.
- Monitoring of surface water quality and other aquatic indicators in Lost Creek and White Rock Canyon Creek must be expanded and made more frequent. Lost Creek and Ealue Lake must be considered potentially impacted locations, not reference locations.
- Future Red Chris Trigger Response Plan updates must include thresholds for Lost Creek and Ealue Lake.
- All available measures must be taken to reduce long-term site water demand, such as reducing the overall volume of tailings and the need for a tailings water cover, within the constraints of measures needed to prevent geochemical impacts from metal leaching and acid rock drainage.
- Response actions must be required to address Trigger Response Plan and Site Performance Objective exceedances in Trail Creek.
- Assessments must be performed immediately to determine definitively i) what mine loading sources contribute to Camp Creek water quality and ii) what relative contribution different loading pathways (e.g., Camp Creek, tailings seepage, etc.) are making to Trail Creek water quality.
- Assessments must be performed immediately to establish the possibility of reproductive effects on rainbow trout in Trail Creek from increasing water selenium concentrations. Our suggestions include: i) laboratory bioassays exposing rainbow trout to Trail Creek water and ii) in-situ assessments of egg and juvenile rainbow trout morphology and health indicators.
- Ealue Lake must not be considered a reference lake or an indicator of natural regional variability.

As a potentially mine-affected lake, assessments of rainbow trout behaviour, lake food webs, and selenium bioaccumulation must be performed in Ealue Lake to assist in identifying mine-related changes.

- Assessments must be performed immediately to establish the possibility of reproductive effects on rainbow trout in Kluea and Ealue Lakes from increasing water selenium concentrations. Our suggestions include: i) laboratory bioassays exposing rainbow trout to lake water and ii) in-situ assessments of egg and juvenile rainbow trout morphology and health indicators.
- Mitigative actions must be enacted immediately at Red Chris in response to increasing selenium in rainbow trout tissue in Kluea and Ealue Lakes.
- Measures must be taken to increase statistical power, including pooling sexes in fish tissue analyses, fast-tracking rainbow trout population assessments in monitoring lakes, and investigating non-lethal fish tissue sampling approaches.
- Lake benthic invertebrates must be monitored regularly for selenium and metal tissue loads to improve understanding of potential accumulation pathways to resident fish.
- Mitigations, management approaches, and contingency plans for acid rock drainage, including seepage capture, water treatment, and waste covers, must be designed and developed well in advance of ARD generation. These approaches must be conservative, proactive, and thorough, especially given the site's poor track record of seepage predictions and management.
- Water treatment must be designed to address all site contaminants of concern, including selenium, metals and sulphate.
- Detailed assessments must be performed now to anticipate how groundwater pumping will change over time, including the post-closure phase of the mine life, and what effect these changes could have on seepage behaviour and quality, as well as downstream environmental effects.
- An improved understanding of current and future site conditions is needed to reduce uncertainty related to future risks and impacts. This includes an improved understanding of groundwater flow estimates, site water balance modelling, seepage behaviour and quality predictions, and short- and long-term effects of climate change on site conditions. Seepage capture and water treatment systems must be tested well in advance to ensure their efficacy during the post-closure period.

Tailings Management

- Routine updates to geologic models and stability analyses must be implemented to monitor the stability of weak glaciolacustrine dam foundation layers.
- Red Chris dam designs and construction activities should be regularly updated to account for new information related to dam foundation conditions and stability.
- Materials shortages and challenges with cyclone sand production require adequate prioritization and planning. Contingency planning—such as conducting stability analyses for minimum dam elevations *before* construction and prioritizing borrow material investigations—should be diligently carried out regarding any issues that may increase the risk of dam failure.
- Construction and/or testing of the North and South Valley Seepage Interception Systems should be accelerated to ensure appropriate mitigations are in place to manage water quality impacts of hydraulic cyclone sand placement. Pressure to compensate for past deferrals of dam construction

targets may result in the placement of cyclone sand without appropriate field testing and management protocols.

- Updated water modelling and contingency planning must occur now to ensure that closure plans, such as a permanent water cover over tailings, are feasible and appropriate mitigations are developed and ready for implementation under various water management scenarios. Water shortages may limit the feasibility of maintaining a water cover over potentially acid-generating (PAG) tailings post-closure. Conversely, seepage interception may result in a water surplus in the tailings facility post-closure.
- Inundation modelling showing impacted areas after a dam failure should map the extent of potential South Dam failure scenarios, including a description of potentially affected lodges, cabins, and campgrounds.
- Undertake a survey of the population at risk surrounding the Red Chris tailings impoundment, including an assessment of how mine workers will be impacted in the event of a dam failure.
- Red Chris inundation modelling should be performed such that it:
    - Models up to 100% of tailings and mine water released from the facility.
    - Quantifies the extent and effects of tailings runout and chemical effects of PAG tailings to the extent current technology allows.
    - Employs endpoints beyond the 1-in-200 year flood event.
    - Employs high-resolution topographic data to aid in mapping the physical impacts of dam failures. Descriptions and high-resolution maps of the potential flood path should include the number of dwellings potentially affected, the length of highway and number of bridges affected, and the population in the inundation zone.
- The Emergency Preparedness and Response Plan (EPRP) should clarify plans related to a failure at the South Dam, North Dam, or Northeast Dam and must include protocols for worst-case scenarios (e.g., sudden, unexpected catastrophic failure of a tailings dam).
- The EPRP requires an increased level of detail, including:
    - Evacuation plans for workers with maps and muster points.
    - Names or phone numbers for the agencies and communities to be contacted during an emergency.
    - Specifying response plans for a Level 2 (emergency) vs. Level 3 (crisis) scenario.
    - Designating a crisis room equipped with emergency response supplies.

Mine Expansion

- Assessment and approvals of the proposed expansion must not be expedited at the expense of robust consideration of existing and future environmental risks.
- The following must be incorporated into the assessment and permitting of the proposed expansion:
    - Improved understanding of potential seismic hazards and potential effects of terrain instability (i.e., landslides and debris slides) on fish and fish habitat.
    - Contingency water supply plans and related impacts to aquatic ecosystems.

  - Potential impacts to resident fish of accelerated downstream water contamination; specifically, an assessment of project effects on selenium bioaccumulation that takes into account the site-specific effects thresholds presented in Golder (2019c) is needed.
  - Improved understanding of groundwater-surface water interactions.
  - Water quality effects assessments considering scenarios in which natural attenuation of nitrate and selenium is reduced or ceases to occur.
  - Incorporation of project effects on surface water in Camp Creek and how these might affect Trail Creek and Kluea Lake.

- Effects assessments for the proposed expansion must evaluate trade-offs between social and environmental risks from mining activities in exchange for producing non-essential commodities like gold.
- Mine operators and decision-makers must ensure pre-existing issues are not de-prioritized in favour of mine expansion. Decision-makers must require the following pre-existing issues to be more fully understood and addressed as a condition of any further amendment approvals:
  - Gaps in environmental monitoring and mitigation thresholds.
  - Tailings and waste rock seepage.
  - Mine-related effects in Trail Creek, White Rock Canyon Creek, Kluea Lake, and Ealue Lake. This should specifically include issues highlighted by our report, such as: potential mine impacts to Trail Creek via Camp Creek, and selenium accumulation in rainbow trout tissue in Ealue Lake and Kluea Lake.
  - Water discharge and treatment plans.
  - Issues related to tailings dam construction, failure modelling, and emergency preparations.
- A study of the technical and financial viability of the current proposal to mine only MB1 must be required prior to proceeding with EA amendment permitting. This study should incorporate assessments of the viability of needed social and environmental mitigations.
- Potential cumulative effects from future mine expansion phases must be rigorously assessed during the review of the mine's current expansion application.
- Mine plans that reduce or eliminate the need to add additional tailings storage capacity must be aggressively pursued.
- All pre-existing challenges and risks associated with the existing tailings facility must be addressed and managed prior to any consideration of mine changes that could increase the facility's size or add additional tailings storage at the site.

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Acronyms

ARD	Acid Rock Drainage
BC	British Columbia
CDA	Canadian Dam Association
CSR	BC Contaminated Sites Regulation
EA	Environmental Assessment
EAO	Environmental Assessment Office
EMA	Environmental Management Act
EMLI	Ministry of Energy, Mines, and Low Carbon Innovation (now known as the Ministry of Mining and Critical Minerals)
EMS	Environmental Monitoring System
ENV	Ministry of Environment and Climate Change Strategy (now known as the Ministry of Environment and Parks)
EPRP	Emergency Preparedness and Response Plan
FOI	Freedom of Information
IEEIRP	Mount Polley Independent Expert Engineering Investigation and Review Panel
ITRB	Independent Tailings Review Board (alternately referred to as the Independent Engineering Review Panel)
MB	Macro Block
Mt	Million tonnes
NAG	Non-Acid-Generating
NRCM	Newcrest Red Chris Mining
NTL	Northwest Transmission Line
PAG	Potentially Acid-Generating
PFS	Pre-Feasibility Study
PMF	Probable Maximum Flood
RCDC	Red Chris Development Company
RSA	Waste Rock Storage Area
SIS	Seepage Interception System
SPO	Site Performance Objective
SQG	BC Sediment Quality Guideline for the protection of aquatic life
TCG	Tahltan Central Government
TIA	Tailings Impoundment Area
TRP	Trigger Response Plan
WQG	BC Water Quality Guideline for the protection of aquatic life

1. Introduction

Northwest British Columbia (BC) is home to some of the world's last remaining salmon stronghold watersheds. These watersheds contain high biodiversity values, including abundant wildlife populations and world-class fisheries for all five wild Pacific salmon (*Oncorhynchus* spp.) species. Their existence is central to Indigenous and non-Indigenous cultures and offers both intrinsic and economic value in terms of recreation and tourism, fisheries, and climate resilience. However, the region's geology also contains areas of high mineral concentrations, presenting mineral exploration and mining opportunities. In particular, copper, a metal currently under increasing global and domestic pressure for development as a "critical mineral" to support renewable energy transitions (Natural Resources Canada 2022; Bauer et al. 2023; European Commission 2023), and gold, the vast majority (92%) of demand for which is driven by luxury uses like jewelry and financial investment (Lezak et al. 2023), are prevalent.

While the mining industry can offer significant contributions to the employment and economy of some northern communities and First Nations and supports the development of technologies that many of us use daily, large-scale mining also entails risks to environmental and human safety. It exacerbates risks already faced by wild salmon populations vulnerable to rapid climate change and could contribute to the "undocumented extinction" of certain populations in northwest BC (Peacock et al. 2024; Greene 2025). Most potential mining projects in northwest BC are open-pit mines, which typically create large physical disturbances and produce high volumes of waste rock[1] and tailings[2] that require long-term storage and management. Some of the most prominent risks from mining are those to aquatic environments, such as flow regime alteration, habitat modification and loss, and pollution from toxic contaminants (Sergeant et al. 2022), as well as the risk of potential tailings facility failures, which can result in environmental damage, sociocultural damage, infrastructural damage, and/or the loss of human lives (BC Ministry of Energy, Mines, and Low Carbon Innovation [EMLI] 2024). Such impacts have the potential to be felt far downstream of a mine, potentially crossing political borders, and can have serious ramifications for salmon and overall watershed health.

Historically, exploration and mining in northwest BC was restricted by a lack of supporting infrastructure. Encouraged by the Mining Association of BC and other industry advocates, however, the potential for expanded mining development across the salmon-bearing Nass, Unuk, and Stikine watersheds was given a significant boost in 2011 with the approval of the government-funded Northwest Transmission Line (NTL) (EMLI 2011). The NTL came into service

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[1] Waste rock is uneconomic rock surrounding the ore that is treated as mine waste.

[2] Tailings are waste produced from ore processing. Typically, they contain finely ground ore and rock, processing chemicals, and water.

in 2014 and provides access to the power grid from Terrace north to the community of Iskut (BC Hydro 2014). Following NTL development, several mines and advanced exploration projects in the region were proposed and/or became more feasible to develop (Figure 1). These include Red Chris, KSM, Galore Creek, Schaft Creek, and Turnagain—all of which would be developed as open-pit mines, are likely to use (or are already using) power from the NTL, and will mine copper or other critical minerals. Notably, many of these projects will also mine gold, which is not a critical mineral but drives the majority of mineral exploration spending in northwest BC (Thompson et al. 2025); depending on geology and economic factors, gold—not copper—may be these projects' primary commodity by value. The Canadian government has further supported development of these projects via financial support to improve infrastructure, such as $20 million to build a road to Galore Creek (Natural Resources Canada 2024). In response to US tariff threats, the provincial government is also fast-tracking approvals and permitting of several resource development projects in the northwest region, including the Red Chris Mine (Kurjata 2025).

The Red Chris Mine, a copper-gold-silver mine near the headwaters of the Stikine River, is so far the only major open-pit mine to become operational in northwest BC since the construction of the NTL. The project includes a large wet tailings facility, a feature many of the other proposed mines in the region—such as KSM and Galore Creek—will also share (Nova Gold Resources 2011; Klohn Crippen Berger [KCB] 2012). Red Chris Mine is entirely within the Tahltan Nation's traditional territory, which covers much of the area surrounding the NTL. The development of Red Chris was not without controversy. For example, a federal court case determined that the mine's destruction of fish habitat received improper federal environmental assessment (West Coast Environmental Law 2010); widespread concern about the similarity of the Red Chris tailings facility in terms of design, engineering, and ownership to the failed Mount Polley tailings facility (Davis 2018); strong resistance to the Red Chris project by the Klabona Keepers, an organization of Tahltan elders and families who occupy and use traditional lands in the area (Berman 2014). Nevertheless, the Red Chris Mine received provincial and federal authorization and has been operating since 2015. In 2023, the mine's owners began pursuing an expansion of its operations, which is undergoing review by the BC government and Tahltan Central Government (TCG) (Environmental Assessment Office [EAO] 2024a). TCG has expressed frustration with the Province's decision to fast-track the project's approval (Tahltan Central Government 2025).

Tailings dam at Red Chris Mine.
COLIN ARISMAN | COLINARISMAN.COM

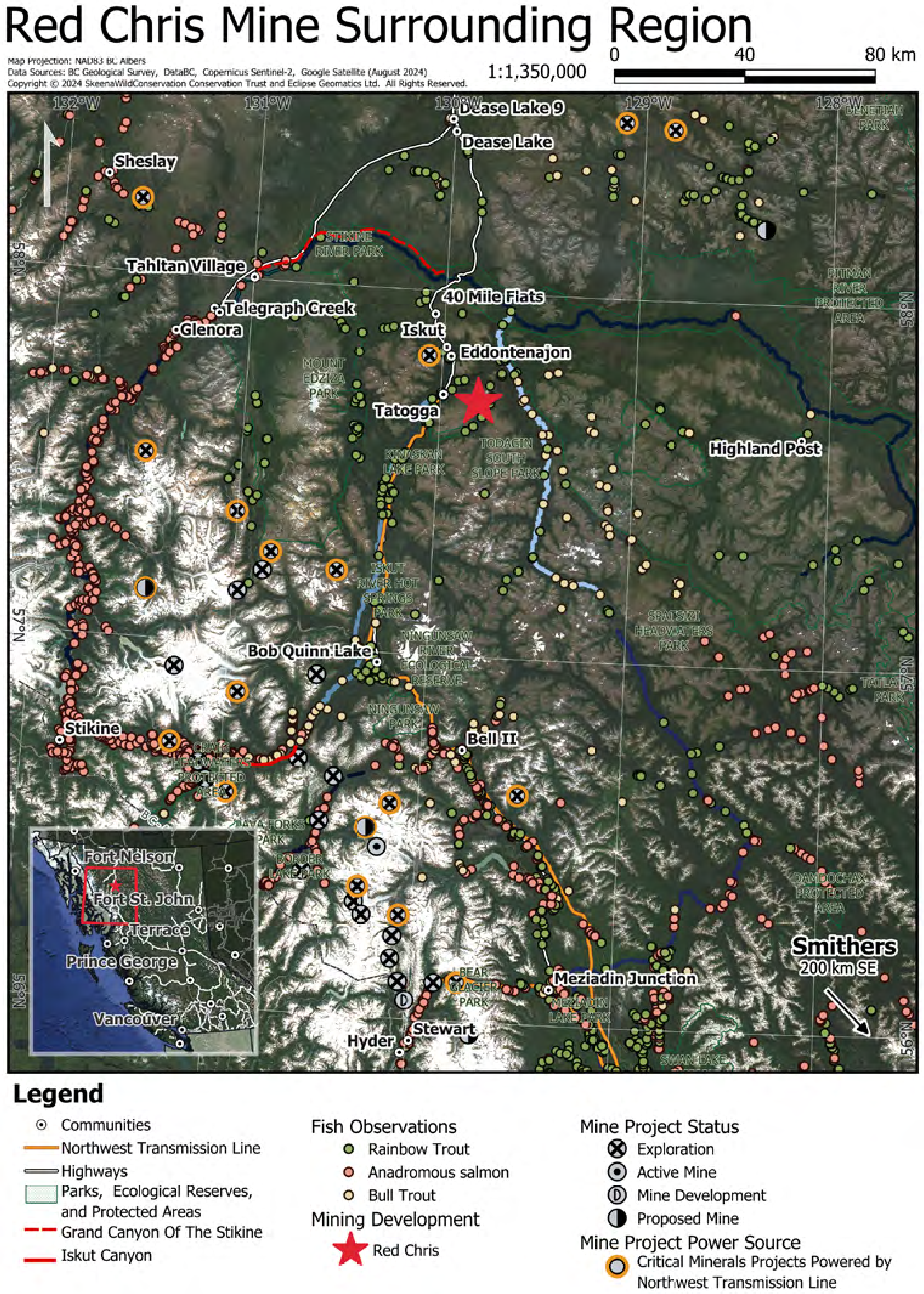


Figure 1. Map of the surrounding region of the Red Chris Mine, including select fish species observations, fish passage barriers, key infrastructure, regional mining development, and populated areas.

Sockeye salmon. DEREK FLYNN

As part of SkeenaWild Conservation Trust's work to protect salmon, salmon habitat, and watershed health in northwest BC, we investigate policies and practices related to large-scale mining and make recommendations for industry and regulatory improvement to ensure mining does not come at the cost of clean water, healthy ecosystems and wild salmon populations. Having been in operation for nearly ten years, the Red Chris Mine provides a key opportunity to assess what to expect and/or what issues to address at other future mines in the region that may begin due to expanded infrastructure and pressure to develop critical minerals. Red Chris' location amongst key tributaries to the salmon-bearing Stikine River makes it relevant in terms of potential impacts on salmon, and the lessons learned at this site may aid in protecting downstream values at mines being proposed in closer proximity to salmon habitat. Similarly, lessons learned at Red Chris can be applied to large-scale mines being developed that are closer to the border with Alaska and/or have a greater likelihood of directly impacting internationally shared water and salmon resources. Additionally, the proposed plans to expand Red Chris offer a critical opportunity to address outstanding problems and make improvements prior to any expansion approvals or permitting. Based on monitoring data and reporting from the Red Chris site and its owners, this report reviews key technical and scientific issues at the Red Chris Mine and highlights needed improvements at the site itself and other potential future mines in the region. We focus on downstream aquatic ecosystem impacts and their mitigation, the safety and management of the mine's tailings facility, and the benefits and risks of its potential expansion. Recommendations are provided throughout that can be applied at Red Chris and/or to the industry as a whole to improve the protection of environmental values and human safety.

2. Mine Description

Red Chris Mine is an open-pit mine located approximately 18 km south of Iskut, 80 km south of Dease Lake, and 450 km north of Smithers. It is located entirely within the Tahltan Nation's traditional territory. The mine processes approximately 30,000 tonnes of ore per day to produce copper, gold, and silver (Newcrest Red Chris Mining Ltd. [NRCM] 2023a). It employs about 460 people, 20% identifying as Tahltan (SLR Consulting [SLR] 2024). The mine received its provincial Environmental Assessment Certificate in 2005, federal environmental approval in 2006, and provincial *Mines Act* and *Environmental Management Act* permits to operate in 2012 (NRCM 2023a). In 2016, Red Chris was issued *Fisheries Act* approval to expand the tailings facility over top of fish-bearing habitat (NRCM 2023a). The mine was primarily constructed from 2012–2014 and has been operating at full production since mid-2015. Under the current mine plan, ore extraction will continue until 2038, with processing of ore stockpiles continuing until 2043 (SRK Consulting [SRK] 2021). Acquired by Vancouver-based Imperial Metals Corp. in 2007, who oversaw permitting, construction, and early operations, the mine's operatorship and a 70% financial interest were sold to Australia-based Newcrest Mining Ltd. in 2019 (Imperial Metals 2019). In November 2023, Newcrest was sold to Newmont Corp., the world's largest gold mining corporation (Newmont 2023). The permitting of Red Chris occurred before the introduction of the 2018 *Environmental Assessment Act* and the *Declaration on the Rights of Indigenous Peoples Act*, both provincial legislations enabling consent-based decision-making processes with affected First Nations. However, the Tahltan Nation did sign an Impact, Benefit and Co-Management Agreement in 2015 with Imperial Metals, providing the Nation with environmental oversight of the project and several other economic benefits. Newcrest updated and sustained this agreement (Imperial Metals 2020; NRCM 2023a).

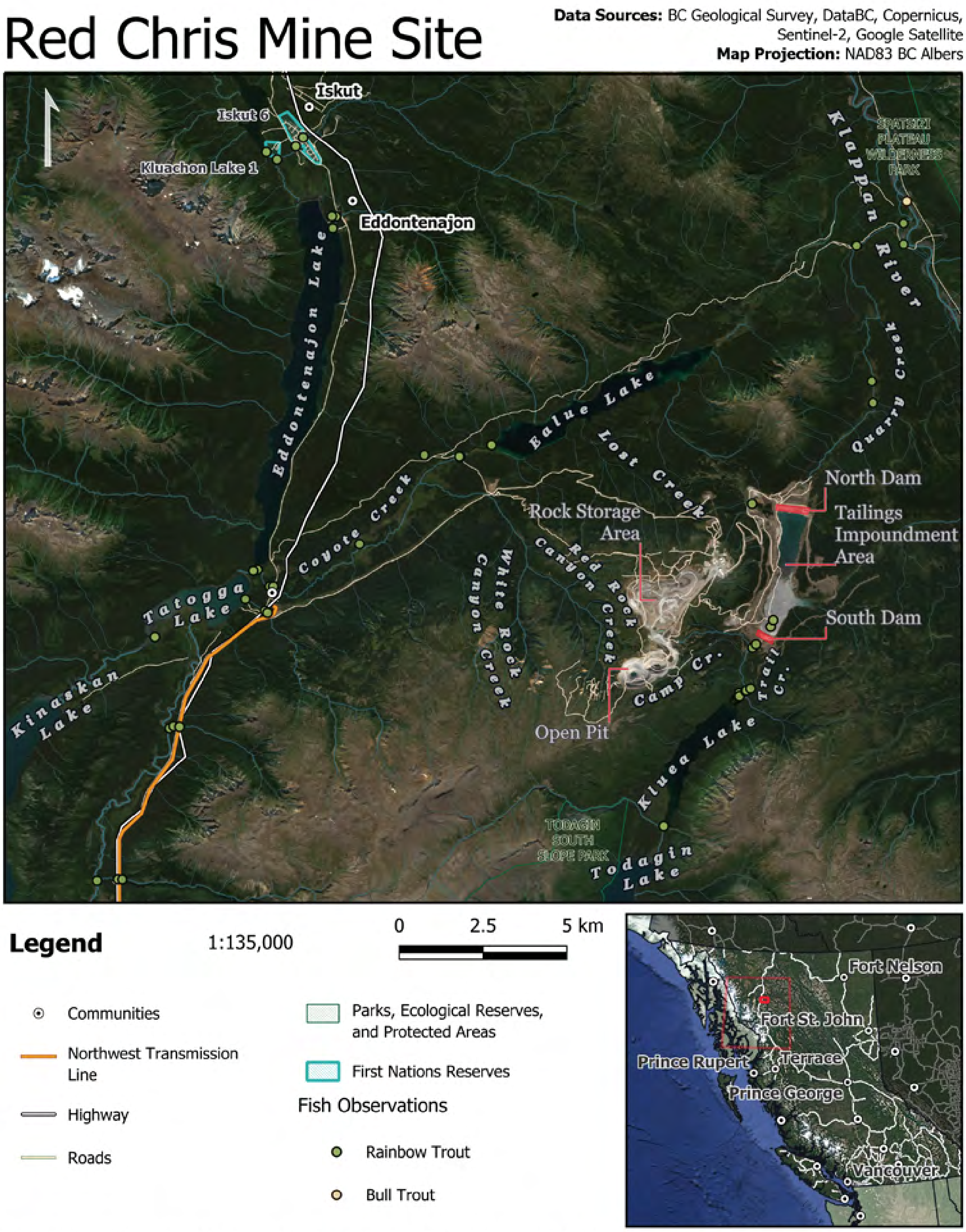
Major infrastructure at Red Chris includes an Open Pit that is expected to reach 370 m deep by 2026, a 320-hectare above-ground Waste Rock Storage Area (RSA) containing 145 million tonnes (Mt) of potentially acid-generating (PAG) waste rock and 11 Mt of non-acid-generating (NAG) waste rock, and a 790-hectare tailings facility, the Tailings Impoundment Area (TIA), holding 8.6 Mt PAG and 68 Mt NAG wet tailings between three earthen dams, with an additional two seepage reclaim dams to the north and south of the impoundment (NRCM 2023a) (Figure 2). All facilities will continue to expand, and by the currently permitted end of operations in 2043, the RSA will hold 370 Mt waste rock, and the TIA will hold 302 Mt tailings (SRK 2018; BGC Engineering [BGC] 2014). The tallest current tailings dam at Red Chris is approximately 70 m high (BGC 2023a) and is permitted to reach an ultimate height of 105 m (BGC 2014). The tailings are held in slurry form and are approximately 54% water by volume (SRK 2021).

Red Chris is situated southwest of Klappan River, southeast of Ealue Lake, and north of Kluea Lake. Ealue and Kluea Lakes are fish-bearing headwater lakes of the Iskut River (Figure 2). The Iskut and Klappan are major tributaries of the Stikine. The RSA, as well as mine access road and topsoil stockpiles, are in the surface water and/or groundwater catchments of Lost Creek, which drains to Ealue Lake (SRK 2021; WSP Canada [WSP] 2023a), and they are also in the White Rock Canyon Creek catchment, which includes Red Rock Canyon Creek closer to the mine site, and ultimately drains to Coyote Creek and toward Iskut River via other headwater lakes (WSP 2023a). The Open Pit and southern portion of the TIA are in the catchment for Camp Creek and Trail Creek, which drain to Kluea Lake (WSP 2023a); this area is called the South Valley (BGC 2023b). The northern portion of the TIA is in the catchment for Quarry Creek, which drains to Klappan River (WSP 2023a); this area is referred to as the North Valley (BGC 2023b). The TIA is built over naturally occurring streams, including previously fish-bearing habitat in Trail Creek (EAO 2005) (Figure 2). Red Chris is located in an area of high mineralization, where metals like aluminum, cadmium, and copper can be naturally elevated in many surrounding watercourses (EAO 2005). Below mine infrastructure lies a complex groundwater system, including layered shallow, intermediate, and deep aquifers under the TIA, that ultimately discharge to surrounding surface waters. Red Chris does not currently release mine-affected water directly to surface water systems but is permitted to discharge mine-affected water via ground (i.e., seepage) to the receiving environment from the RSA and TIA (EMLI 2022).

Surrounding the mine are various fish habitats and human land use areas (Figures 1 & 2). Ealue and Kluea Lakes support resident rainbow trout (*Oncorhynchus mykiss*) populations, and rainbow trout are also known to use Trail Creek and Coyote Creek for spawning and rearing (Red Chris Development Company [RCDC] 2004; WSP 2023a). Rainbow trout are found in the majority of Quarry Creek, and Klappan River, which is about 13 km downstream of the mine, hosts numerous fish species like rainbow trout, bull trout, mountain whitefish, longnose sucker, arctic grayling, Dolly Varden, cutthroat trout and burbot (RCDC 2004; BC Data Catalogue 2024). Lost Creek and Red Rock Canyon Creek are not known to be fish-bearing, though rainbow trout have been recorded in White Rock Canyon Creek (RCDC 2004). The upper Iskut River and its headwater lakes are populated by rainbow trout, while the middle reaches of the Iskut also contain bull trout (a provincially-listed species of special concern; BC Conservation Data Centre 2011) (Hagen & Decker 2011; Tahltan Fisheries 2019). Pacific salmon use the lower Iskut River up to a fish passage barrier at the Lower Iskut Canyon and Forrest Kerr Hydroelectric Project, approximately 150–200 km downstream from Red Chris (RCDC 2004). The Stikine is a major producer of wild salmon, such as sockeye and Chinook; however, salmon are blocked from passage beyond the Grand Canyon of the Stikine, about 120 km downstream from Red Chris (RCDC 2004). The upper Stikine River hosts arctic grayling, mountain whitefish, bull trout, rainbow trout, and Dolly Varden, among other species (RCDC 2004; Hagen & Decker 2011). The Iskut and Stikine Rivers are major migratory routes for fish used for First Nations food fishing, as well as commercial and recreational fishing. The nearest major community to Red Chris is Iskut (population = 478; Statistics Canada 2022), about 18 km northwest of the mine; however, cabins, lodges, and campgrounds exist closer to the mine on the shores of nearby lakes like Ealue, Tatogga, Eddontenajon, and Kinaskan. Tahltan members use areas surrounding the mine for camping, hunting, fishing, access trails, plant and berry harvesting, and trapping (NRCM 2023a), and the Red Chris project area itself was constructed over multiple Tahltan archaeological and traditional use sites (EAO 2005). Other known populated areas in the vicinity include Dease Lake (population = 475; Tahltan Band 2024) and Telegraph Creek (population = 400; Tahltan Band 2024), 105 and 215 km from Red Chris by road, respectively. Tahltan Village is a culturally significant historic dwelling site located approximately 134 km along the Stikine River from Red Chris. The Stikine River ultimately discharges in southeast Alaska near Wrangell (population = 2,127; U.S. Census Bureau 2020).

Before exploration and mining, the Red Chris area was wildlife habitat that supported hunting, guide outfitting, trapping, and general outdoor recreation (NRCM 2023a). (Though not a focus of this report, it is notable that the Red Chris Mine is located within the Todagin Plateau, an area of high wildlife value, especially for Stone's sheep, and reports by local guide outfitters indicate possible adverse impacts to sheep and other wildlife via visual and auditory effects of the mine (SLR 2023)). When mining is complete, the site will be reclaimed to wildlife habitat in practicable areas; however, some mining infrastructure, such as the tailings facility, will remain in perpetuity (NRCM 2023a). The mine's post-closure period will last over 200 years, during which active water treatment will be required (EAO 2005). The mine's reclamation liability was last estimated to be $127.5 M, and a total of $134.6 M is currently held (an excess of $7.1 M) (EMLI 2023). The next reclamation plan update for Red Chris, including updated liability estimates, will be submitted on or before Dec 31, 2026 (EMLI 2022).

Open pit and waste rock pile at Red Chris Mine with White Rock Canyon Creek drainage and Ealue Lake in background. COLIN ARISMAN | COLINARISMAN.COM


Red Chris Mine Site

Data Sources: BC Geological Survey, DataBC, Copernicus, Sentinel-2, Google Satellite
Map Projection: NAD83 BC Albers

Figure 2. Map of Red Chris Mine site, including major mine infrastructure, mine receiving drainages, and select fish species observations. Anadromous salmon are not found within the immediate vicinity of the mine.

3. Aquatic Ecosystem Impacts

3.1 Introduction

Mining can affect the surrounding aquatic environment via many pathways, such as the alteration of flow regimes and water temperature, modification or elimination of physical habitat, and intentional or unintentional release of toxic contaminants into downstream waters (Sergeant et al. 2022). At the extreme, these changes may make habitat entirely unavailable or unsuitable to fish and other aquatic life. In the case of toxic contaminants, even relatively small increases in metal or other mine pollutant concentrations in water pose risks to sensitive aquatic life, particularly fish. They can affect fish's success at many essential tasks, such as finding food, avoiding predation, growing, and reproducing (Wood et al. 2011a, 2011b; Price 2013). If contaminant concentrations exceed provincially designated water quality guidelines for the protection of aquatic life, the likelihood of such chronic adverse effects is increased (BC Ministry of Environment and Climate Change Strategy [ENV] 2023a); however, there are additionally instances where provincial guidelines are not sensitive enough to avoid chronic adverse effects to salmonids (Price 2013). Often, mines rely on the dilution of their discharges by the receiving water body to meet certain thresholds, such as local regulations, guidelines, or permit limits (e.g., ENV 2019a). However, most available research informing these thresholds is based on laboratory studies of individual metals over relatively short time frames, which disregards the complexity of natural systems, the potentially long-term nature of heavy metal contamination, and the possible effects of combinations of elevated metals on aquatic life (e.g., Couture & Pyle 2011; Price 2013; Balistrieri & Mebane 2014; ENV 2019b; Mebane et al. 2020; BC Ministry of Water, Land, and Resource Stewardship 2023a). Additionally, where metal water concentrations are naturally elevated, as they are in the Red Chris area, the aquatic system should be considered as already under stress and having a lower tolerance to further contaminant inputs from mining; this phenomenon has been demonstrated in highly mineralized areas of western USA (e.g., Schmidt et al. 2012). For these reasons, it is possible that any mine-related increases above background water quality, even those that do not exceed provincial guidelines, may negatively affect sensitive aquatic life and that dilution of mine discharges in natural waters may not be a sufficiently protective approach.

Comprehensive environmental monitoring is needed to identify and ideally prevent harmful effects on aquatic life due to mining activities. All potential contaminant pathways from the mine must be well understood in order to properly manage site water and discharges and ensure that environmental monitoring is implemented in appropriate locations (Sharpe 1998; ENV 2016).

This is especially important in highly mineralized environments because mine effects may be falsely interpreted as naturally occurring elevations without monitoring of all mine loading sources. In the case of Red Chris—which is located in a highly dynamic system where considerable seasonal and/or interannual variation in factors such as precipitation, temperature, water flows, and water quality are observed (RCDC 2004)—identifying mine-related effects requires performing sufficiently replicated sampling across space and time to capture variability and identify trends. These monitoring standards should be applied to water and sediment—nonliving ecosystem components that can accumulate and expose aquatic life to mine contaminants—and multiple levels of the food web in the receiving environment. Such robust monitoring enables understanding of diet-based contaminant pathways (where relevant), identification of high contaminant loads that would otherwise be missed by less frequent sampling, and may also support identification of mine effects in nonliving ecosystem components and/or lower trophic species before species of higher value, such as salmon or other fish, become significantly impacted.

If mines are expected to impact or are actively impacting the receiving environment, mitigation actions must be taken to minimize environmental harm. Typically, mine permits will specify thresholds in the receiving environment (e.g., for surface water or groundwater quality) beyond which the mine must take additional actions to address potential harm. Following the Precautionary Principle,[3] mitigations should be designed and implemented proactively, and thresholds for action should be conservative.

Given the above, our assessment aims to review key issues related to Red Chris Mine's impact on the receiving aquatic environment, as well as monitoring and mitigation of those impacts, and to provide recommendations to address or improve these issues. Importantly, actions at the mine related to potential environmental effects are the responsibility of mine ownership under the guidance and oversight of the Province of BC (the Province), especially the Ministry of Energy, Mines, and Low Carbon Innovation (EMLI—now known as the Ministry of Mining and Critical Minerals) and Ministry of Environment and Climate Change Strategy (ENV—now known as the Ministry of Environment and Parks). Accordingly, our review focuses on both regulatory oversight of Red Chris and management decisions by its owners. The following questions guided the performance review:

Guiding Questions

- What effluent discharges leave the mine? What are the chemical characteristics of those discharges? How are discharges managed and regulated?
- What aquatic monitoring is performed? Are potential contamination pathways understood? Is monitoring sufficient to detect environmentally relevant impacts of the mine?
- Is there evidence of mine-related aquatic impacts occurring in the receiving environment of the mine? Are mine-related aquatic impacts predicted to occur in the future? What is the potential significance of these impacts?
- Are aquatic impacts effectively mitigated?
- Are current and future aquatic impacts being mitigated? Are the triggers for taking action sufficiently protective of aquatic life? Are mitigations proactive, reactive, adaptive?

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[3] Canada has committed to implementing the Precautionary Principle, which states: *Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation* (e.g., Canadian Environmental Protection Act 1999).

3.2 Methods

Our report aims to synthesize key issues related to aquatic ecosystem impacts and their monitoring and mitigation at Red Chris Mine. A review of all documentation and information pertaining to these topics was outside the scope of this assessment. Accordingly, we reviewed key monitoring reports, government documents, and other records produced for the Red Chris Mine for information related to the guiding questions above, focusing on overarching issues and/or information that was interpreted to be most pertinent to the potential for mine-related downstream aquatic ecosystem impacts. Key documents reviewed for this assessment are listed below (full citations for these and other referenced documents are provided in section 8.0):

- Red Chris Lake Monitoring Program reports (2018–2019)
- Red Chris Aquatic Effects Monitoring Program reports (2018–2022)
- Red Chris Groundwater Monitoring Program reports (2019–2022)
- Red Chris Annual Reclamation reports (2018–2022)
- Red Chris Site-wide Water Quality Models (2018, 2021)
- Red Chris *Environmental Management Act* Permit PE-105017 (2022)
- Letter from British Columbia Ministry of Environment to Newcrest regarding immediate items of concern (2019)

Many of these and other records we assessed are not publicly available and needed to be accessed via requests to ENV and EMLI under the *Freedom of Information (FOI) Act*. Due to delays in the fulfillment of these requests (up to 1 year in some cases), the most recent reports obtained were published in Q1 2023, which correspond to environmental monitoring and other studies performed in 2022. Of note, this time frame limitation means any reporting or decision-making under Newmont operatorship (which began in late 2023) is not directly covered by this assessment; however, because Newmont purchased the entire company of Newcrest, and not the Red Chris Mine alone, it is assumed that many of the key plans and decision-makers associated with the Red Chris site have remained in place through this latest ownership transition.

When describing trends in the receiving environment related to potential contaminants in water, sediment, or tissue chemistry, the reports we obtained often use the terms "increasing," "potentially increasing," and "elevated." Definitions are not provided for the first two, while "elevated" is defined as measured values that are greater than 20% above baseline (i.e., pre-mine) values (Golder Associates [Golder] 2021a, 2022). We use the same language in this report as that found in mine reports when discussing their findings.

Mine reporting sometimes only presents summaries of environmental monitoring and does not always provide comprehensive descriptions of all data or other evidence related to mine-related effects. Accordingly, we obtained raw environmental monitoring data to independently assess the presence of temporal trends post-mining in the Red Chris receiving environment. Due to limitations imposed by the poor quality of documents obtained through FOI request, we restricted our raw data analysis to the following indicators: i) surface water quality and ii) fish tissue chemistry.

Surface Water Quality

Surface water quality data were obtained from the Environmental Monitoring System (EMS), a publicly accessible BC government data catalogue where some water quality data collected at Red Chris is required to be submitted (ENV 2022). Data were only assessed for monitoring sites outside the mine site (i.e., in the receiving environment) and where sampling had occurred regularly since the introduction of that site to the monitoring program. Based on these criteria, some surface water quality data were available for the following Red Chris receiving areas: Trail Creek, Quarry Creek, Lost Creek, White Rock Canyon Creek, Coyote Creek, Kluea Lake, and Ealue Lake. Based on numerous mine monitoring reports stating that water quality has not changed post-mining in Klappan River or creeks and other lakes beyond Kluea Lake (Golder 2019a, 2019b, 2020a, 2020b, 2021a, 2022; WSP 2023a), raw data for these waters were not assessed. Some data were evaluated at reference (i.e., not mine-influenced) locations for comparison with potentially mine-influenced sites; however, there are few reference sites at Red Chris, and many have dissimilar characteristics (i.e., in terms of substrate, flow, etc.) to the potentially mine-influenced sites. Trends in water quality at mine-influenced sites were not interpreted as potential mine effects where similar trends were observed in the data from appropriate reference locations.

Surface water quality samples are collected at regular intervals, with frequency varying across sites from annual to monthly. Data from EMS were imported into R Statistical Software (v4.3.2; R Core Team 2023) using the *rems* package (Teucher & Harker 2024). Temporal trends were then visually assessed using scatterplots of each water quality parameter vs. sampling date to look for increasing or decreasing trends and seasonal fluctuations. We evaluated the following water quality parameters: pH, total dissolved solids, total suspended solids, nitrate (NO3), sulphate (SO4), and dissolved and total concentrations of aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), and zinc (Zn). Because many mine reports described erroneous water quality results for iron (Fe), this metal was excluded from our assessment. Where trends were visually identified, and there was no indication of seasonality in the data, a Mann-Kendall test (Mann 1945; Kendall 1975; Gilbert 1987) was performed to assess whether the trend was statistically significant. Where trends were visually identified, and seasonality was present, a Seasonal Kendall test (Hirsch et al. 1982; Gilbert 1987; Helsel & Hirsch 1995) was performed on monthly averages. Following significant Seasonal Kendall results, Mann-Kendall tests were used to identify the months during which a statistically significant temporal trend occurred. Mann-Kendall and Seasonal Kendall were chosen for their appropriateness for non-normal data and were performed using the *rkt* (Marchetto 2024) and *EnvStats* (Millard 2013) packages in R, respectively. Tests returning $p < 0.05$ were considered statistically significant, while $p < 0.10$ indicated a "potential" trend. All plots were created in R using the *ggplot2* package (Wickham 2016), and trend lines were added using Theil-Sen robust regression lines (Theil 1950; Sen 1968). We considered any value recorded on EMS below its detection limit to be at the detection limit (i.e., a value reading <1.0 mg/L on EMS was assessed by us as 1.0 mg/L) because this is how EMS data automatically imports into R. Any identified trends were later re-verified from datasets with values below their detection limits transformed to half the detection limit (i.e., a value reading <1.0 mg/L on EMS was converted to 0.5 mg/L) and to 10% of the detection limit (i.e., a value reading <1.0 mg/L on EMS was converted to 0.1 mg/L) to ensure treatment of non-detect data was not biasing our interpretations. Red Chris surface water quality data were assessed from the earliest date available on EMS, which was most often in 2016—but at times was as recent as 2021—to the date of last retrieval from EMS, January 6, 2025. In cases where two samples were taken on the same date (this was common in lake water quality data), the sample returning the lower value was discarded from the dataset prior to analysis.

Background surface water quality conditions in the Red Chris receiving environment were also calculated for comparison with receiving environment permit limits and effluent discharge quality targets and to calculate

Rainbow trout

condition-dependent provincial water quality guidelines (i.e., guidelines that vary depending on background pH, hardness, and/or dissolved organic carbon). Background conditions were calculated as the average of all samples recorded during only the first three years of data available on EMS (2016–2018) to minimize incorporation of potential mine influence. At sites where sampling had not been performed during this period, or data were not uploaded to EMS, background data from the nearest monitoring site on that water body in a similar environmental condition (i.e., creek, wetland, or lake) was substituted. We note, however, that mine-related effects on water quality have been detected as early as 2016 in both Trail and Quarry Creeks (SRK 2021); therefore, the data available on EMS do not provide actual background conditions. True background conditions for some parameters are likely even lower than what has been calculated in this assessment, meaning the strength of mine-related effects may be stronger than we were able to interpret.

Fish Tissue Chemistry

Muscle tissue chemistry data were manually extracted from Red Chris Aquatic Effects Monitoring Reports for rainbow trout in Kluea, Ealue and Todagin Lakes. Our assessment focused on dry-weight tissue concentrations to reduce possible inconsistencies associated with tissue water content of wet tissue samples (Adrian & Stevens 1979). Where only wet weight concentrations were available for a sample, dry weight concentrations were calculated based on the moisture content recorded for that sample. As with surface water, any readings below their detection limit were replaced with the detection limit for that parameter, and identified trends were later re-verified with values below the detection limit transformed to half the detection limit and 10% of the detection limit. Because multiple fish tissue samples are taken at the same time each year from each lake, temporal trends were visually assessed using boxplots of the parameter vs. sampling year to allow for easier visualization of both temporal trends and variation within each sampling year. If an increasing or decreasing temporal trend was visually identified, a Mann-Kendall test was performed to assess whether the trend was statistically significant. Mann-Kendall was performed on both annual mean and median fish tissue values due to, at times, considerable variation and the presence of extreme values within the annual samples. Sexes were pooled for all analyses. Evaluating the influence of fish sex or body length on tissue chemistry was not possible as sex was not recorded for all sampled fish in the FOI documents received. Plots were created using the *ggplot2* package and Mann-Kendall tests were performed using the *rkt* package in R. Fish tissue chemistry data for concentrations of aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), and zinc (Zn) were assessed from the beginning of sample collection in 2003 to the end of 2022.

3.3 Results

The results of our assessment highlight issues at Red Chris Mine related to monitoring and predictions of mine-related aquatic ecosystem impacts, as well as planning and implementation of mine effects management. We also find clear indications that mine-related aquatic impacts are already occurring in local receiving waters. Key issues include:

- Gaps in data transparency, environmental monitoring, and thresholds applied for triggering environmental mitigations,
- Prediction and management of mine-contaminated seepage from the Red Chris tailings facility,
- Prediction and management of mine-contaminated seepage from the Red Chris waste rock pile,
- Mine-related impacts on fish-bearing Trail Creek,
- Potentially mine-related increases in selenium concentrations of fish tissue in mine-impacted lakes, and
- Shortcomings in prediction and preparation for significant future risks, including acid rock drainage.

These six issues are discussed in detail in the following sections.

3.3.1 Gaps in Data Transparency, Monitoring & Mitigation Thresholds

Many of the key issues identified in this assessment relate to specific facilities or receiving environments of Red Chris; however, some overarching gaps in the mine's environmental monitoring programs and thresholds for implementing mitigations also exist and are described here first as they provide some relevant background for the following sections. It is important to clarify that not all of these overarching issues are specific to Red Chris, and some may indeed reflect common practice across mines in BC; however, they are highlighted here because they increase uncertainty in terms of understanding and identifying mine-related effects, and may enable some aquatic ecosystem impacts at Red Chris to go unidentified or unaddressed.

Gaps in Data Transparency

We faced numerous barriers throughout our assessment, namely related to the accessibility of environmental reporting and raw monitoring data, almost none of which is publicly available. Even the public water quality data on EMS are available only for some sites and, at times, only for one monitoring site for an entire receiving creek or lake. The need to complete FOI requests and perform manual data transfer from the PDF reports provided added significant delays to the assessment process and made it impossible to independently review all mine environmental monitoring data. In light of the need for public transparency surrounding potentially damaging resource extraction industries, mining companies and/or the Province should make key monitoring reports and all raw environmental data publicly accessible and in file formats that enable independent data analysis.

Gaps in Monitoring

First, Red Chris has experienced chronic problems with collecting and interpreting hydrologic (i.e., surface water level and flow) data. Sub-standard hydrology monitoring equipment at numerous stations has been an issue since installation, resulting in limited and often very uncertain site data (RCDC 2004; NRCM 2020a). In some cases, regional data from monitoring outside the mine area were used to supplement limited site data and/or make projections about site conditions; however, dissimilarities were often observed between the regional datasets and actual site conditions (RCDC 2004; KCB 2014; SRK 2018). Despite early identification of data issues in 2005 during the EA permitting process (EAO 2005), poor hydrological data quality for Red Chris has persisted throughout mine construction and operations and was identified as an issue of immediate concern by ENV in 2019 (ENV 2019c). A key problem arising from this data gap has been an underprediction of the mine site's water balance, which has resulted in an unexpected water deficit (SRK 2018); hence, many aspects of the mine's water management and interactions with the environment have not functioned as planned. In combination with poor quality groundwater data (discussed in sections 3.3.2 and 3.3.3), hydrology data gaps have contributed to a high degree of uncertainty in Red Chris' water quality models and predictions (SRK 2018; SRK 2021; also see Independent Tailings Review Board [ITRB] 2016a), ultimately leading to a lack of clarity regarding anticipated long-term mine effects to surface water quality, and questions related to the types of mitigations required to manage those effects. While our report does reference the mine's water quality models in later sections, those predictions may be inaccurate and could overestimate or underestimate the mine's long-term effects on water quality in downstream environments due to such uncertainties.

Secondly, monitoring for mine contaminants in surface water, sediment, and other aquatic indicators near Red Chris may not consist of sufficient sample collection frequency to detect mine-related trends. Surface water sites in creeks surrounding the mine—even those considered most likely to show evidence of mine effects—are sampled monthly at most for water quality (ENV 2022; WSP 2023a). While this sampling frequency is typical for mine monitoring programs, research suggests that monthly sampling in dynamic creek and river systems is insufficient to fully capture variation, such as extreme values and annual loads, in surface water quality (Nagorski et al. 2003; Birgand et al. 2010; Jones et al. 2012; Sergeant & Nagorski 2014) and that as sampling frequency decreases (e.g., from daily to monthly) there is increased error in identifying exceedances of water quality criteria (Jones et al. 2012; Thompson et al. 2014; Reynolds et al. 2016). Red Chris may, therefore, be missing extreme contaminant values and/or threshold exceedances by not sampling receiving area creeks more frequently. Similarly, other aquatic indicators—including sediment quality and tissue chemistry of aquatic vegetation, zooplankton, benthic invertebrates, and fish—are sampled once per year, typically in August (NRCM 2022b; WSP 2023a). Sampling on an annual basis neglects potential seasonal fluctuations in contaminant loadings in these indicators and likely misses annual maximums, which often occur during non-summer months (Hare & Campbell 1992; Cain et al. 2018; Martyniuk et al. 2020). Once-annual sampling also provides fewer data overall, ultimately decreasing the ability to identify trends. For example, mine reporting has been inconclusive regarding trends in benthic invertebrate tissue chemistry due to high variability across years (Golder 2021a, 2022), variability that could be reduced with increased sampling frequency. Once-annual sampling has also been recognized as a limiting factor in understanding dietary pathways by which selenium may accumulate and contaminate fish in the mine's receiving environment (Golder 2018). An increase in sampling frequency across aquatic indicators, especially in high-risk receiving areas, could significantly improve confidence in assessing the presence of mine-related aquatic ecosystem impacts.

Lastly, constraints placed on analyses of tissue chemistry trends in fish, benthic invertebrates, and aquatic vegetation in the Red Chris receiving environment may result in monitoring oversights. Though tissue chemistry laboratory analyses provide tissue concentrations of a wide range of minerals and metals, the mine only performs detailed analyses to assess changes from pre-mining conditions on contaminants that show increasing trends in surface water or sediment at the location where the tissue sample is collected, or on bio-accumulative contaminants like mercury and selenium (Golder 2022; WSP 2023a). Such restricted methodology makes it possible for increasing trends in tissue contamination to be missed. As an example, Kluea Lake rainbow trout spawn, rear, and forage in Trail Creek (Schell 2004; Golder 2019c), where they are exposed to increasingly elevated concentrations of several metals, including aluminum, chromium, and copper, in surface water (see section 3.3.4); however, these fish are not assessed for contaminant loadings of any of those metals because the tissue samples are acquired from Kluea Lake, where those metals have yet to show evidence of an increase in water or sediment (Golder 2022). Broadly, trends in tissue contamination might also be missed as a secondary consequence of trends in surface water or sediment going undetected, which can occur where monitoring frequency is insufficient (see above) and/or environmental monitoring sites are not plentiful enough or properly located to capture mine inputs (see section 3.3.3 and 3.3.4).

Gaps in Mitigation Thresholds

An additional key overarching issue is that the thresholds assigned at Red Chris for acting in response to mine aquatic ecosystem impacts are not sufficiently protective of downstream values. The mine uses a Trigger Response Plan as required by their *Environmental Management Act* (EMA) permit, issued by ENV (2022), which identifies surface water and groundwater concentrations at specific locations in the receiving environment beyond which the mine is required to implement mitigation responses. The primary stated goal of the Red Chris Trigger Response Plan is to prevent receiving environment water quality from exceeding Site Performance Objectives (SPOs), which are legally enforceable water quality limits set in the EMA permit for certain parameters in Trail Creek and Quarry Creek, or BC Water Quality Guidelines, which are not legally enforceable but are used as guidelines in the EMA permit where SPOs have not been set (ENV 2022). Using trigger levels and legally enforceable water quality objectives is appropriate, but the assigned thresholds are not low enough. For example, the SPO set for selenium in Quarry Creek is 0.005 mg/L (ENV 2022), which is 2.5 times greater than the provincial guideline for the protection of aquatic life of 0.002 mg/L (ENV 2014). Additionally, research performed specifically on the Red Chris receiving environment suggests that if selenium SPOs are met in either Trail or Quarry Creeks, adverse effects to the growth and/or reproduction of rainbow trout feeding in these creeks should be expected (Golder 2019c). Therefore, the selenium SPO limits allow negative effects to occur to downstream fish before mitigations are required and do not allow sufficient buffer in case mitigations fail to work as planned. More generally, trigger levels and SPOs at Red Chris for other parameters of concern are far above observed background surface water conditions (Table 1), which could similarly lead to negative effects occurring to sensitive species due to the complexity of natural systems, the potentially long-term nature of heavy metal contamination, and the possible effects of combinations of elevated metals on aquatic life. A more environmentally protective approach would be setting SPOs and other trigger levels for mitigative action closer to background conditions and/or based on proven no-effect thresholds.

Table 1. Red Chris Trigger Response Plan (TRP) thresholds (TRP 1 = lower threshold, TRP 2 = upper threshold), Site Performance Objectives (SPOs), and background (i.e., pre-mining) surface water quality in Trail Creek and Quarry Creek.

	Trail Creek (mg/L)				Quarry Creek (mg/L)			
Parameter	Background	TRP 1	TRP 2	SPO	Background	TRP 1	TRP 2	SPO
Sulphate	49	247	**278**	–	62	320	360	**400**
Nitrate	0.03	2.4	**2.7**	–	0.25	2.4	2.7	**3.0**
Total Chromium	0.0004	0.0008	**0.0009**	–	0.0002	–	–	–
Total Copper	0.0018	0.0042	0.0053	–	0.0009	0.008	0.009	**0.010**
Total Selenium	0.0009	0.0016	0.0018	**0.0020**	0.0004	0.0040	0.0045	**0.0050**
Total Zinc	0.0035	–	–	–	0.0039	0.0600	0.0675	**0.0750**
Dissolved Aluminum	0.008	0.040	**0.045**	–	0.002	0.040	0.045	**0.050**
Dissolved Cadmium	0.00001	–	–	–	0.00001	0.00024	0.00027	**0.00030**

Where the upper permit limit exceeds background conditions, it is in **bold**.

Recommendations[4]

GENERAL[5]

- Make key environmental monitoring reports—including Aquatic Effects Monitoring Program, Water Quality Monitoring Program, and Groundwater Monitoring Program reports—and all raw environmental data, including pre-mining baseline data, publicly accessible. Data must be provided in file formats that enable independent data analysis.

- For proposed projects to proceed through the Environmental Assessment process, robust data collection must be required regarding project site conditions, such as baseline hydrology and groundwater conditions. This requirement should be enforced as part of the EA Readiness Determination[6] and maintained as an ongoing requirement through mine permitting stages, such as during EA Certificate approval and *Mines Act* and *Environmental Management Act* permitting.

- At higher-risk and dynamic monitoring sites: Require continuous monitoring of basic water quality data (i.e., pH, temperature, conductivity, turbidity) using sondes and daily sampling for the full suite of potential contaminants, including metals, nitrate, sulphate, etc.

- Require an assessment of intra-annual variation in sediment quality and tissue chemistry of aquatic vegetation, zooplankton, benthic invertebrates, and fish. Based on the results of this assessment, increase sampling frequency to a) improve statistical power and b) ensure sampling is performed when contaminant loads are typically highest.

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[4] For brevity, each recommendation is written only once; however, the reader should note that many recommendations are relevant to more than one section of the report.

[5] General recommendations apply to any mine projects in northwest BC, including Red Chris.

[6] The EA Readiness Determination stage is the stage at which the BC Environmental Assessment Office makes a decision as to whether a proposed project should proceed to an Environmental Assessment evaluating the effects of the project (EAO 2019).

  - Given that contaminants reside in fish tissues on the scale of months, twice-yearly sampling for fish tissue chemistry would be appropriate. Non-lethal sampling techniques should be employed to reduce sampling impacts on local fish populations.

- Detailed tissue chemistry analyses must be performed to assess changes from pre-mining conditions for *all* metals.
- Site Performance Objectives and trigger levels must be set to maintain receiving environment conditions at pre-mining background levels or no-effect concentrations.

3.3.2 Contaminated Tailings Seepage

The most pervasive environmental issue at Red Chris Mine appears to be the release of contaminated seepage from mine infrastructure to surrounding groundwater. Plumes of tailings seepage[7] containing highly elevated and increasing concentrations of sulphate and chloride have been identified in all groundwater aquifers north and south of the tailings facility and an additional cadmium seepage plume has been identified in the South Valley shallow aquifer (BGC 2023b; Supplementary Figures). In some areas of the tailings facility, sulphate groundwater concentrations have reached 625 mg/L, far exceeding assigned trigger levels (BGC 2023b; NRCM 2023a). In South Valley groundwater, selenium is also increasing and exceeding upper trigger levels, and nitrate is elevated; both trends are at least partially attributed to tailings seepage (BGC 2021b, 2023b). Mapping as of late 2022 indicates tailings seepage has extended far beyond the mine site, with sulphate plumes in aquifers within the Quarry Creek drainage extending up to 1,000 m beyond the North Reclaim Dam, and increasing trends and/or elevations of sulphate, cadmium, selenium, and nitrate in aquifers south of the tailings facility that extend beyond the South Reclaim Dam into the area of upper Trail Creek (BGC 2021b, 2023b). There is also early indication that the sulphate plume in the South Valley has spread to the area of lower Trail Creek (BGC 2023b; NRCM 2023a). Sulphate in mine-impacted groundwater is positively correlated with heavy metals such as cadmium and copper (BGC 2021b), meaning these elements may also begin to increase in groundwater surrounding the tailings facility as tailings seepage progresses.

Seepage has been escaping the tailings facility since the initial deposition of tailings in 2015 (BGC 2023b), and the volume of seepage has been increasing over time (RCDC 2019a). A degree of mine-impacted seepage from the Red Chris tailings facility was expected to occur and is authorized by the mine's EMA permit (ENV 2022); however, the facility's hydraulic containment has underperformed, and seepage rates far exceed what was initially predicted. For example, seepage rates at the North Dam were predicted to be 20 L/s during the facility's initial operations; instead, they reached 75 L/s during the first year of tailings placement, with an unknown quantity of that seepage bypassing the North Reclaim Dam and entering the receiving environment (ITRB 2016b). Recent studies estimate that approximately 23% of the total water lost from the facility each year (which includes water retained in tailings pore space, evaporation, reclaim water used for mine operations, etc.) consists of seepage (Golder 2019d; BGC 2020a, 2020b). Because groundwater aquifers ultimately discharge to downstream surface water systems, these groundwater quality trends can impact surface water and aquatic life in receiving systems like Trail Creek, Kluea Lake, and Quarry Creek, and increasing tailings seepage

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[7] Tailings facilities can release seepage from different locations (e.g., through the dams or laterally through valley walls). This report addresses seepage risks and impacts generally and does not distinguish among different types of tailings seepage.

rates were identified as an issue of immediate concern in 2019 by ENV, stating "infiltration of mine water from the [tailings facility] to ground is occurring at a rate that is likely to increase the risk of adverse effect to surface and groundwater resources" (ENV 2019c, pg. 2). As is discussed in later sections, there is evidence that tailings seepage already contributes to aquatic ecosystem impacts in Red Chris receiving systems (see sections 3.3.3 and 3.3.4).

Many of the problems related to tailings seepage at Red Chris appear to originate from overly optimistic predictions, a lack of contingency planning, and a tendency to disregard or delay addressing independent expert opinions. Warnings arose from an independent expert in a third-party review in 2012 (before mine operations)—and have continued from the mine's Independent Tailings Review Board (ITRB)[8]—that tailings seepage rates and effects on receiving environment water quality were being underpredicted and that the owners—Imperial Metals at that time—had insufficiently prepared for potential inaccuracies or operational upsets that could cause greater contaminant loadings (Robertson Geoconsultants [Robertson] 2012; ITRB 2016b). These same experts also repeatedly advised that additional hydrogeological characterization, hydraulic testing, and investigations of seepage movement and groundwater quality were needed to protect the receiving environment (Robertson 2012; ITRB 2016a, 2016b; RCDC 2019b; NRCM 2019, 2020b). Ultimately, Newcrest did initiate large-scale hydraulic testing of the tailings facility aquifer systems in 2020 (BGC 2022a)—their first full year as mine operator—and the most recent EMA permit amendment from ENV now requires that a greater focus be placed on improving hydrogeological monitoring and modelling (ENV 2022). However, earlier implementation of these measures could have prevented many of the issues that Red Chris now faces. Additionally, Newcrest deferred some remaining ITRB recommendations related to tailings seepage to prioritize instead activities that maintain mine production operating at full scale (NRCM 2019, 2020b), and in their very first meeting with the ITRB in late 2019, they rejected a recommendation to more thoroughly evaluate potential pathways of tailings seepage to receiving environments, stating that mine contamination pathways were outside the ITRB's scope (NRCM 2019). Thus, despite some improvements, long-standing issues with planning and de-prioritization of environmental effects management have continued to persist, which increases the threat of contamination of Quarry Creek and Trail Creek/Kluea Lake systems by Red Chris tailings seepage.

While the development of accurate groundwater seepage projections was always going to be a challenge due to the hydrogeological complexity present at the Red Chris site, many inaccuracies in the mine's seepage projections are also likely related to limitations in site-specific monitoring performed during the early stages of the mine. During early project design and permitting, minimal site-specific data were collected for parameters such as climate (e.g., temperature, precipitation), hydrology, underlying terrain, and the groundwater regime itself (RCDC 2004; KCB 2014; SRK 2018), and these limited data were then used in multiple early groundwater flow models for the mine (AMEC Americas [AMEC] 2010; ITRB 2016a, 2016b). Data from regional watersheds were used to supplement and/or project Red Chris site data for all of these parameters but did not prove to be accurate proxies for actual site conditions (RCDC 2004; KCB 2014; SRK 2018). This lack of a robust site-specific dataset resulted in many uncertainties; in particular, when

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[8] The Independent Tailings Review Board (ITRB) consists of independent experts who provide periodic technical review of the Red Chris tailings facility. Gerritsen et al. (2023) describe that the purpose of an ITRB is to challenge the assumptions of the mine operator's tailings team, and offer independent guidance, opinion, and recommendations that reflects international best practices. The ITRB for Red Chris is alternatively referred to as the Independent Engineering Review Panel.

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reviewing the mine's groundwater flow, water balance, and water quality models, the ITRB highlighted "concern for prediction of seepage from the tailings impoundment" (ITRB 2016a, pg. 10) and "significant water quantity and water quality uncertainties [related to] future tailings construction and operations" (ITRB 2016a, pg. 13). As discussed above, these uncertainties also contributed to poor prediction and planning for the mine's water deficit (see section 3.3.1)—a phenomenon that has translated to less freshwater available in the tailings pond to dilute seepage contaminant concentrations (BGC 2020a). These early failings in site-specific monitoring collectively contribute to the ongoing struggle to understand groundwater patterns and potential impacts on surface water at Red Chris, as well as the greater seepage impacts than expected.

Of concern, sparse groundwater monitoring has continued in the receiving environment, where few monitoring wells and limited sampling now prevent an accurate understanding of the spatial extent of tailings seepage plumes. For example, the extent of nitrate and selenium contamination in the North Valley shallow aquifer is uncertain due to infrequent historical sampling and a complete lack of recent sample collection at the most downgradient wells from the tailings facility (BGC 2021b, 2023b). Similarly, the full extent of sulphate contamination in the North Valley deep aquifer is unknown because the plume had spread beyond the furthest downgradient well in 2020, and no additional monitoring wells have been installed to continue tracking it (BGC 2023b). In the South Valley, there is no groundwater quality monitoring performed in aquifers under lower Trail Creek at all, and mine reporting acknowledges that even in the area of upper Trail Creek, groundwater quality sampling has been limited and insufficient to capture trends, understand loading sources, and accurately delineate the extent of seepage plumes (BGC 2021b, 2022a). Thus, while it is known that Red Chris releases numerous potentially harmful contaminants via tailings seepage, which may ultimately impact downstream aquatic life, there is a lack of robust data to understand the extent of this contamination. Despite the Tahltan's expressed desire for improved tailings seepage plume delineation (EAO 2021) and more detailed assessments of tailings seepage plumes and pathways initiated under Newcrest's operatorship (BGC 2022a), Newmont will still need to expand the Red Chris groundwater monitoring network to achieve improvement on this issue in coming years.

Few effective mitigations have been implemented at Red Chris to slow or prevent tailings seepage thus far, contradicting the independent expert guidance mine operators have received. In 2016 and 2018, the ITRB recommended that Imperial Metals extend the liner installed on the South Dam to a higher elevation to more effectively prevent seepage (ITRB 2017; RCDC 2019b); however, this recommendation was not followed, and the liner remains at its original elevation to this day (BGC 2023a). Also contrary to expert advice, Imperial and Newcrest both delayed the installation and/or operation of the mine's long-stated primary seepage mitigation strategy: a groundwater seepage interception system (SIS)—which essentially is a series of groundwater pumps surrounding the mine that will capture seepage and redirect it back to the tailings facility. In the South Valley, Imperial was advised by a third-party review to install the SIS prior to tailings placement (Robertson 2012), which they failed to do, and the ITRB later urged that South Valley seepage interception begin in 2017 (ITRB 2017); ultimately, Imperial installed a single South Valley SIS pumping well in 2017, and Newcrest later expanded this seepage capture network, but none had ever been activated according to the reports we accessed for this review (BGC 2022a; NRCM 2023a). Similarly, the ITRB has repeatedly recommended (as early as 2015) that the Red Chris Mine be more prepared to capture seepage in the North Valley (ITRB 2016a, 2016b, 2017; NRCM 2019, 2020b, 2022a). While Newcrest did initiate design scoping studies in 2020 for the North Valley SIS (BGC 2022a), the system was still under construction as of late 2022 (NRCM 2023a) and will need to undergo assessments before it can be verified as an effective mitigation strategy.

Surprisingly, Red Chris has not been required to improve their mitigation of tailings seepage under provincial permits. Because tailings seepage is a diffuse (i.e., non-point) discharge, the mine's EMA permit does not place limits on seepage discharge volume, time period, or chemical characteristics (ENV 2022). The only tangible restriction on mine seepage comes from the mine's Trigger Response Plan and SPO thresholds, which require mitigations to be activated when thresholds are exceeded. However, these thresholds are not always sufficiently protective of aquatic life (see section 3.3.1). The implementation of the Trigger Response Plan is also reactive; for example, rather than a requirement for mitigation systems to be designed and ready in the event of threshold exceedances, the initial design of the North Valley SIS was only required *after* sulphate groundwater trigger levels had already been exceeded in the receiving environment (BGC 2022a). Lastly, and most importantly, the Red Chris Trigger Response Plan has not been updated since 2016, which means that the plan does not cover any monitoring wells installed beyond 2016 and will not trigger mitigation actions (BGC 2023b). In fact, there have been multiple ongoing trigger level exceedances in recent years, including those of nitrate and selenium in the South Valley shallow aquifer (BGC 2022a, 2023b) and sulphate in the North Valley shallow aquifer (BGC 2023b), yet none of these exceedances have directly resulted in SIS activation, or other follow-up actions because they occurred at wells that were installed after the Trigger Response Plan was written. Concerningly, some exceedances occurred at wells in the receiving environment, as opposed to within the mine site (BGC 2022a, 2023b). Although recent information indicates that the mitigation of tailings seepage at Red Chris may be progressing—the mine's most recent EMA permit amendment includes a new requirement for a seepage effects mitigation program (ENV 2022), the Trigger Response Plan is in the process of being updated (NRCM 2023a), and Newcrest proposed alternative seepage mitigation measures, such as a tailings thickener to reduce tailings water content and installation of physical barriers along seepage migration pathways (NRCM 2023a)—this comes several years after seepage issues first arose at the site and even longer after seepage was recognized as a concern. Thus, for now, Red Chris tailings seepage is not being actively mitigated, based on decisions by mine owners and the BC government, despite consistent evidence of increasing tailings seepage rates, worsening groundwater quality in the receiving environment, and multiple recommendations by independent experts to advance seepage mitigations.

Seepage concerns will be ongoing at Red Chris, and the risk of tailings seepage impacts will likely increase over time. As the tailings facility grows, and the tailings and tailings pond encounter greater surface area of the impoundment valley walls, it is generally understood that seepage rates will increase (BGC 2020a, 2022b, 2023b). The latest modelling predicts the portion of total water lost from the facility (which includes water retained in tailings pore space, evaporation, reclaim water used for mine operations, etc.) consisting of seepage will increase from the current level of 23% (Golder 2019d; BGC 2020a, 2020b) to 40% by 2040 (BGC 2022b), with total groundwater flows from tailings to the receiving environment of 16,415 m^3—the equivalent of 6.5 Olympic-size swimming pools—per day by 2043 (SRK 2021). After mine closure, maintaining a permanent water cover over tailings will increase seepage rates greater than those seen during mine operations (SLR 2024). Contaminant plumes will also continue to advance downgradient of the mine, with some plumes progressing up to 600 m/year (BGC 2021b). Lastly, worsened tailings seepage chemistry is expected (BGC 2021b, 2022a; NRCM 2020a) and may be contributed to by factors such as the continuing water deficit, use of cyclone sand in tailings dam construction (see section 4.3.2), and the fact that selenium concentrations in ore increase as the mine digs deeper (NRCM 2021a). Currently, groundwater concentrations of some parameters, such as selenium and nitrate, are reduced between the mine and the receiving environment by a natural attenuation mechanism (BGC 2021b; SRK 2021); however, there is uncertainty as to whether this mechanism can sustain indefinitely (SRK 2021), and there is already evidence that it is no longer occurring in the South Valley shallow aquifer (BGC 2023b). If natural attenuation does not continue and effective mitigation measures are not implemented, selenium concentrations could strongly affect Quarry Creek, Trail Creek, and Kluea Lake in the future, including exceedances of SPOs in Trail and Quarry Creeks (SRK 2018, 2021). Concerningly, when the South Valley SIS was tested for effectiveness, it did not effectively reduce selenium concentrations downgradient, and it also appeared to interfere with the natural attenuation of selenium (BGC 2022a). These results demonstrate the importance of proactively pursuing mitigations to allow enough time to make improvements and indicate that more investment at Red Chris is needed now to establish an effective mitigation plan to control tailings seepage and the associated risks of aquatic ecosystem impacts that are expected to grow.

Recommendations

GENERAL

- Monitoring of site conditions, predictions of environmental effects, design and implementation of mitigations, and development of contingency plans must be i) thorough, precautionary, and proactive, and ii) a condition of mine construction and operations permitting.
- Independent expert recommendations must be followed, or detailed rationale must be provided to regulators and the public when recommendations are not followed.
- Prioritizing mine production must not be considered an appropriate rationale for disregarding independent expert advice or delaying action to understand and prevent environmental effects.
- Monitoring of groundwater quality must be spatially and temporally extensive so as to accurately delineate the extent of seepage plumes and understand their loading sources. This must include robust baseline sampling in all potentially affected receiving areas—even where there is uncertainty as to whether that receiving area will

ultimately receive mine inputs—and consistent, ongoing sampling through the life of the mine. Additional monitoring wells must be installed as soon as it is evident seepage will extend past the existing monitoring system. Further monitoring must also be pursued to understand groundwater interactions with surface water systems.

  - The appropriate groundwater quality sampling frequency to detect change must be established based on a site-specific assessment that considers multiple factors such as hydrogeological conditions, contaminant residence times, and the number of monitoring wells in each potentially affected area. Based on available research, quarterly sampling should be the minimum frequency (Moreau-Fournier & Daughney 2012); however, monthly to daily sampling is strongly recommended, especially where groundwater velocities and contaminant dispersion rates are greater or monitoring wells are fewer—such as outside the mine site (Papapetridis & Paleologos 2012; Saraceno et al. 2018).

- Mitigations must be designed and constructed before environmental effects thresholds (i.e., Trigger Response Plan and/or Site Performance Objective thresholds) are exceeded.
- Trigger Response Plans must be reviewed and updated annually as monitoring networks are expanded and/or knowledge of mine interactions with the receiving environment (such as via seepage or surface discharge inputs) evolves.

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- Further assessment and mitigation actions must be initiated in response to trigger level exceedances that have occurred at monitoring wells installed after the last Red Chris Trigger Response Plan update in 2016.
- The spatial extent of all tailings seepage plumes must be fully delineated, and all mine loading sources to waterways downstream of the tailings facility must be identified.
- Seepage interception should be activated at Red Chris unless there are environmental rationales to delay this action—in which case, such reasoning must be provided publicly.

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3.3.3 Unexpected Waste Rock Seepage

In addition to seepage from tailings, contaminated seepage has also occurred from the Red Chris Waste Rock Storage Area (RSA) since at least 2017 and is spreading into surrounding groundwater to the southwest, west, and potentially to the north of the facility (RCDC 2019a; BGC 2021b, 2022a). None of the seepage from the RSA was expected or planned for, and it was initially characterized as an unauthorized discharge and an issue of immediate concern by ENV (ENV 2019c). Effects of this seepage include increases in concentrations of sulphate, nitrate, and selenium in groundwater outside the RSA, with all parameters exceeding BC Contaminated Sites Regulation (CSR) drinking water standards, and selenium also exceeding CSR freshwater aquatic life standards (BGC 2021b, 2022a, 2023b). As of 2021, the leading edge of the waste rock seepage plume was estimated to be at wells 750–900 m beyond the perimeter of the RSA, along the apparent seepage plume migration path (BGC 2022a). At least some portions of the plume are interpreted to be migrating at a rate of ~350–450 m/year (BGC 2022a), suggesting its maximum extent may markedly expand in coming years. Over time, heavy metals may begin increasing in waste rock seepage as well because sulphate concentrations in the seepage are positively correlated with other parameters like copper and zinc (BGC 2021b), and copper is already increasing in surface water chemistry within the RSA facility (NRCM 2023a).

Seepage from the RSA appears to be affecting nearby surface water systems. In Red Rock Canyon Creek and White Rock Canyon Creek, where most waste rock seepage is directed, surface water concentrations are increasing in nitrate and selenium (SRK 2021; Golder 2022), particularly during the spring months of April (nitrate: t = 0.9, p = 0.007; dissolved selenium: t = 0.9, p = 0.01; total selenium: t = 0.8, p = 0.02; Figure 3a–c) and May (nitrate: t = 0.9, p = 0.02; dissolved selenium: t = 0.7, p = 0.04; total selenium: t = 0.9, p = 0.02; Figure 3d–f). Mine reporting also notes these creeks are elevated in copper (Golder 2022). Copper and selenium in these creeks more frequently exceed BC Water Quality Guidelines for the protection of aquatic life than in other nearby watercourses (Golder 2022; NRCM 2023a) and are additionally elevated in the tissue chemistry of aquatic organisms (i.e., periphyton) (Golder 2022). In the Lost Creek–Ealue Lake drainage, which the RSA is likely to also influence (SRK 2021; BGC 2023b; WSP 2023a), our raw data assessment indicates that nitrate is potentially increasing in Lost Creek surface water (t = 0.7, p = 0.06); insufficient data were available to determine during which months this trend is occurring. Mine reporting also notes that waste rock seepage is a potential source of increasing copper in Lost Creek sediment and benthic invertebrate tissue (WSP 2023a) and that selenium is elevated in Lost Creek periphyton and benthic invertebrate tissue (Golder 2021a, 2022), another possible effect of RSA seepage. Lastly, some mine-affected water from the RSA may be flowing south and contributing to selenium contamination in South Valley groundwater (see section 3.3.2) and/or Trail Creek surface water (section 3.3.4) (BGC 2022a, 2023b). These trends suggest the potential for aquatic impacts due to waste rock seepage.

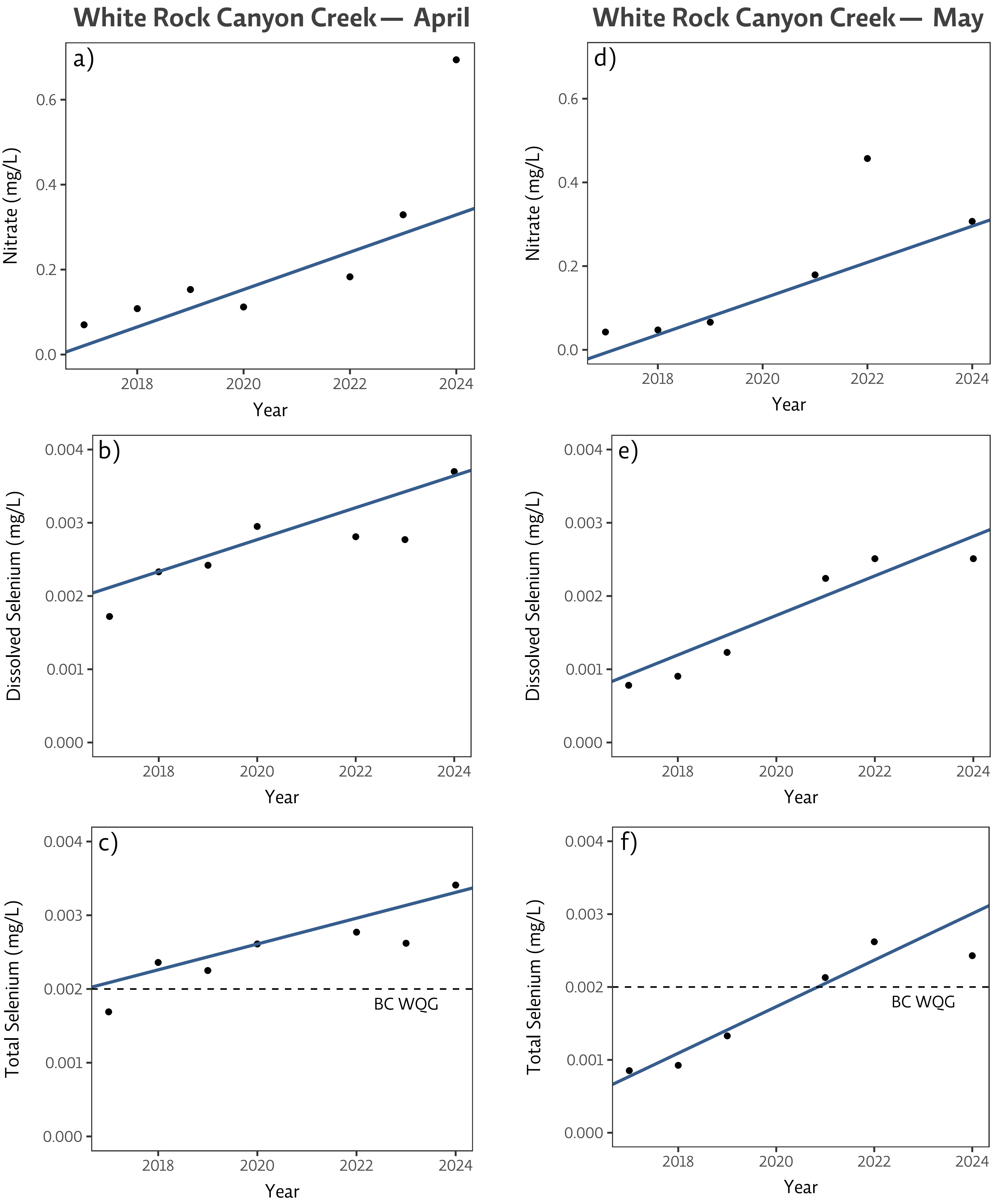

Figure 3. Monthly average concentrations of dissolved nitrate (top) and dissolved and total selenium (middle and bottom, respectively) during April (Figures 3a to 3c) and May (Figures 3d to 3f) in surface water at White Rock Canyon Creek (EMS ID: E303970; ENV 2022) over time. Solid lines indicate the Theil–Sen robust regression line. The dashed line indicates the long-term chronic BC Water Quality Guideline (WQG) for the protection of aquatic life for total selenium.

Red Chris waste rock seepage does not appear to have been well prepared for and is not well monitored. The possibility of waste rock seepage affecting the receiving environment was highlighted by an external review in 2012 as an issue requiring more conservative planning (Robertson 2012); however, the fact that seepage occurred from the RSA within three years of initial waste rock placement, and was not initially incorporated into mine permitting (ENV 2019c), suggests that the Precautionary Principle was not implemented. As with tailings seepage, it is possible that insufficient site-wide characterization during early project stages contributed to the lack of preparation for waste rock seepage. Now, these historical problems are exacerbated by a continued lack of seepage monitoring. The current groundwater monitoring network surrounding the RSA is deficient, and wells have only been placed close to the facility, which mine reports acknowledge prevents an accurate delineation of waste rock seepage plumes (BGC 2021b, 2023b). To the southwest of the RSA—where seepage is most prevalent—trends of degrading groundwater quality have been observed at the furthest extent well (BGC 2023b), which suggests that waste rock seepage may have spread farther than the monitoring network is currently able to track. Additionally, there is only one well regularly monitored for groundwater quality in the Lost Creek drainage, and baseline (i.e., pre-mining) data were not collected at this site (BGC 2022a), which makes temporal trends and mine-related impacts in groundwater quality challenging to identify in the Lost Creek drainage. While Newcrest had indicated an intention to expand the RSA monitoring well network in upcoming years (BGC 2023b), it is not clear whether such plans will be implemented by Newmont or where those wells would be installed. There has been little discussion of addressing potential seepage to Lost Creek–Ealue Lake. This level of monitoring is insufficient to fully track potential mine contamination surrounding the RSA.

Similarly, surface water monitoring in receiving areas near the RSA is limited, which challenges our ability to adequately assess any potential impacts. Imperial did not include any aquatic monitoring sites in Red Rock Canyon Creek or in the upper reaches (i.e., reaches closer to the mine) of White Rock Canyon Creek, and Newcrest did not introduce monitoring in these areas until 2022—at least five years after waste rock seepage began and three years after Newcrest took over mine operatorship (NRCM 2023a). A lack of baseline and historical data in these watercourses due to their delayed inclusion in the monitoring program will make it challenging to confirm the presence of mine-related temporal trends in a timely manner. Conversely, Lost Creek, which is potentially influenced by the Red Chris access road, soil stockpiles, and RSA, has always received some monitoring; however, there remain many road crossing and stockpile exposure sites in the Lost Creek drainage that are not directly monitored, and the key site furthest downstream on Lost Creek that should capture *all* potential mine inputs is only sampled for water quality on a quarterly basis, which is likely not frequent enough to detect all mine-related changes (see section 3.3.1). Strangely, both Lost Creek and Ealue Lake are regularly categorized as reference (i.e., not mine-influenced) locations in the mine's environmental monitoring programs (RCDC 2109; Golder 2021a, 2022; WSP 2023a) despite clear reports that these locations are within possible mine contamination pathways (e.g., BGC 2023b; WSP 2023a) and that some amount of waste rock seepage is likely occurring in this system (SRK 2021); this discrepancy may lead to mine impacts being overlooked. Though some evidence of mine-related influences in the RSA receiving environments is being detected, the abovementioned issues with the current aquatic monitoring program are likely underestimating waste rock seepage impacts on surrounding aquatic systems. The mine's provincial regulators must share responsibility for these monitoring shortfalls given that they ultimately approve mine monitoring programs and should require additional monitoring of groundwater, surface water, and aquatic life in the White Rock Canyon Creek and Lost Creek watersheds in the future.

Regulatory oversight and mitigation efforts related to waste rock seepage have thus far been minimal. Although seepage from the RSA to the receiving environment was initially viewed as an unauthorized discharge of concern (ENV 2019c), the mine's EMA permit (last amended in 2022) now lists it as allowable, and, as a non-point discharge, there are no limits applied to its volume, timing, or chemical characteristics (ENV 2022). Additionally, no Trigger Response Plan or Site Performance Objective thresholds are currently applied to the RSA and its receiving environment that would trigger seepage mitigations (BGC 2022a; ENV 2022). While Newcrest reported plans in 2020 to expand the Trigger Response Plan to include the RSA (NRCM 2020a), that work remains incomplete (NRCM 2023a). Early design stages have recently been initiated for a seepage interception system to be installed in the southwest portion of the RSA (BGC 2023b); however, the system is likely multiple years from implementation. As with tailings seepage, waste rock seepage is expected to worsen in quality and volume as the mine progresses and generates further waste, and the RSA is expected to be a long-term source of acid rock drainage that will significantly impair site water quality (see section 3.3.6) (SRK 2021; NRCM 2022a). Leachable selenium in waste rock may also increase as ore extraction progresses to deeper deposits (NRCM 2021a). Additional measures to minimize and mitigate waste rock seepage, such as liners or pile covers, should pursued. Prompt action is required to prevent widespread impacts over the term of the mine's life and lengthy post-closure period.

Recommendations

GENERAL

- Adaptive management plans and mitigation designs must be developed before mining for all potential discharges from all mine waste facilities, even where there is uncertainty about whether such discharges will occur.
- Monitoring of surface water quality and other aquatic indicators must be spatially and temporally extensive so as to identify mine-related changes. This must include robust baseline sampling in all potentially affected receiving areas—even where there is uncertainty as to whether that receiving area will ultimately receive mine inputs—and consistent, ongoing sampling through the life of the mine.

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- Mitigation measures to reduce waste rock seepage, such as liners or pile covers, must be pursued.
- Groundwater monitoring must be expanded in the Lost Creek drainage, sufficient to empirically determine to what extent Red Chris waste rock seepage impacts it.
- Monitoring of surface water quality and other aquatic indicators in Lost Creek and White Rock Canyon Creek must be expanded and made more frequent. Lost Creek and Ealue Lake must be considered potentially impacted locations, not reference locations.
- Future Red Chris Trigger Response Plan updates must include thresholds for Lost Creek and Ealue Lake.

Fish eggs. BROOKLYN DESOUSA

3.3.4 Mine-Related Aquatic Ecosystem Impacts in Trail Creek

Construction and operation of the Red Chris Mine are resulting in known and potential aquatic ecosystem impacts in Trail Creek via both physical and chemical pathways.

Physical Effects

The Red Chris tailings facility was constructed over top of a fish-bearing portion of Trail Creek, thereby directly eliminating aquatic habitat (EAO 2005). In addition, the tailings facility intercepts large quantities of water, significantly reducing flows to what remains of Trail Creek south of the facility. Areas of upper Trail Creek (i.e., closer to the tailings facility) are now completely dry (NRCM 2023a), and, in some years, lower Trail Creek (i.e., closer to Kluea Lake) experiences water flow only during peak freshet and heavy autumn rains (NRCM 2020a). Importantly, wetland area associated with lower Trail Creek, which likely provides nursery, foraging, and spawning habitat for fish (Schell 2004; Golder 2019c), has also dried up, prompting ENV to highlight mine-reduced flows to Trail Creek as an issue of immediate concern (ENV 2019c).

Though some water reductions to Trail Creek due to Red Chris were expected (EAO 2005), a series of monitoring, prediction, oversight, and mitigation issues have heightened these physical effects. For example, one consequence of the mine's unexpected water deficit has been that Red Chris has consumed more clean water than predicted to support its milling operations and maintain its tailings pond; thus, less clean water has been diverted downstream to Trail Creek than predicted (BGC 2021c). Additionally, the primary diversion ditch meant to move clean water to Trail Creek has been ineffective, resulting in reduced flows to rainbow trout habitat in upper Trail Creek (ENV 2019c). Under Imperial's operatorship, problems with the mine's hydrology monitoring equipment prevented identifying where diversion ditch flows were being lost (NRCM 2020a). Under Newcrest, improvements were made to the hydrology monitoring network; however, planned diversion ditch upgrades were repeatedly delayed (NRCM 2021a, 2022b, 2023a), and the mine was issued a non-compliance warning as recently as 2024 for failure to divert sufficient water flows to Trail Creek (EAO 2024b). Thus, an overall lack of effective monitoring and management—some of which continues today—has led to documented degradation and elimination of productive fish habitat in Trail Creek.

Additional physical impacts to fish habitat south of the Red Chris tailings facility may occur in the future. Annual flows to Kluea Lake are predicted to decrease during mine operations, which has the potential to reduce the lake's productivity (EAO 2005). Because a hydrology monitoring station in Kluea Lake was only installed in 2022 (NRCM 2023a), it is currently unclear whether these effects have occurred already. Additionally, reduced flows to Trail Creek may be exacerbated if there is an increased need for water to cover the mine's growing tailings facility. Lastly, if and when seepage interception systems become operational to control tailings seepage, a trade-off to these mitigations will be a further loss of fish habitat because groundwater inputs of water to lower Trail Creek and Kluea Lake will be reduced (SRK 2018). As climate change leads to more intense droughts in BC, these mine-related impacts will contribute to cumulative pressures on the quality and quantity of downstream habitat. The mine's needs for tailings water cover and seepage interception are anticipated to persist for decades after mine closure (BGC 2020c; SRK 2021), making the existing and anticipated future physical effects on Trail Creek fish habitat long-term as well.

Chemical Effects

Several chemical changes have occurred in Trail Creek surface water since mining began at Red Chris, many of which are evident in both the upper and lower reaches of the creek. Concentrations of selenium are increasing (SRK 2021), particularly during the autumn months of September (dissolved selenium: $t = 0.7$, $p = 0.04$; total selenium: $t = 0.8$, $p = 0.02$; Figure 4a-b) and October (dissolved selenium: $t = 0.6$, $p = 0.06$; total selenium: $t = 0.6$, $p = 0.04$; Figure 4c-d). The raw data across all samples show that on multiple occasions in 2023, total selenium exceeded the mine's Site Performance Objective (SPO) in lower Trail Creek of 0.002 mg/L—equivalent to the BC Water Quality Guideline (WQG) for the protection of aquatic life (Figure 5). Despite this SPO being a legal limit at the monitoring site where the exceedances were observed, we could not find evidence that any enforcement action was taken to address this breach of the mine's permit. Our raw data assessment additionally indicates that sulphate is increasing over time in Trail Creek water during September ($t = 0.9$, $p = 0.007$; Figure 6). Lastly, mine reports noted several metals—including aluminum, chromium, and copper—showing increasingly extreme seasonal spikes post-mining. During these spikes, aluminum and copper have exceeded their respective trigger levels and WQGs, and chromium has been exceeding the mine's upper trigger level (meaning it is approaching its WQG) (Golder 2022; NRCM 2023a; WSP 2023a). Such post-mining changes, especially those that involve threshold exceedances, indicate the possibility of chronic adverse effects on aquatic life.

In addition to the degradation of surface water and South Valley groundwater quality (section 3.3.2), Trail Creek is experiencing changes in other aquatic indicators. Sediment is increasing in copper and nickel concentrations in upper and lower Trail Creek, respectively (Golder 2022; WSP 2023a), and several parameters are also elevated in Trail Creek sediment, including mercury, selenium, manganese, zinc, and sulphate (Golder 2022). Many of these contaminants, particularly copper and selenium, exceed BC Sediment Quality Guidelines (SQGs) for the protection of aquatic life (Golder 2022). Additionally, Trail Creek periphyton tissue is increasing in aluminum, chromium, and nickel (WSP 2023a), and macrophyte (aquatic plant) tissue is elevated in cadmium, chromium, nickel, selenium, and zinc (Golder 2021a, 2022). Lastly, benthic invertebrate tissues appear to be increasing in aluminum, chromium, and nickel (Golder 2021a, 2022). These chemical changes could present stressors to aquatic life, and mine monitoring has documented impairment of the benthic invertebrate community in Trail Creek (Golder 2022).

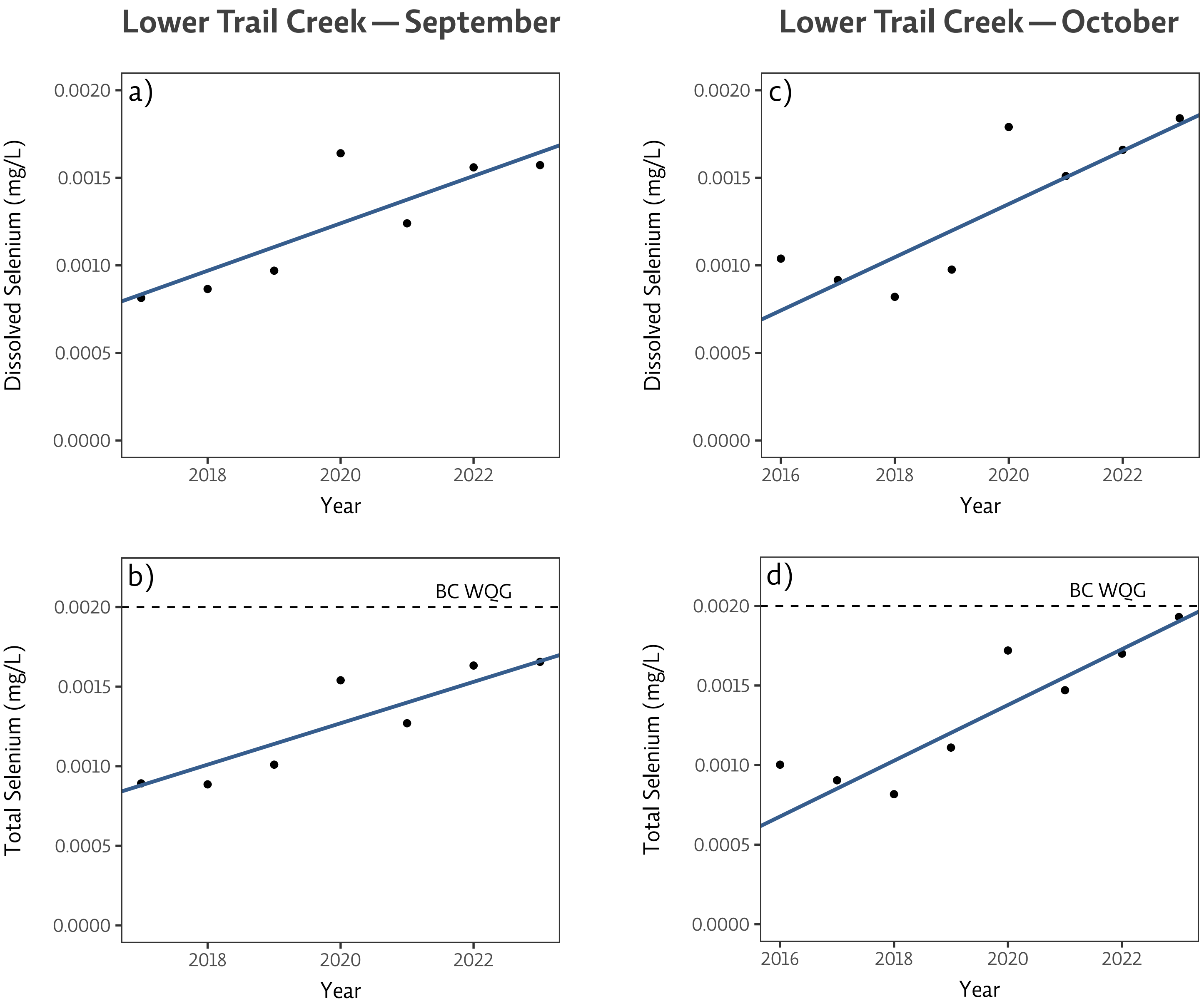

Figure 4. Monthly average concentrations of dissolved and total selenium (top and bottom, respectively) during September (Figures 4a, 4b) and October (Figures 4c, 4d) in surface water at lower Trail Creek (EMS ID: E304670; ENV 2022) over time. Solid lines indicate the Theil–Sen robust regression line. The dashed line indicates the long-term chronic BC Water Quality Guideline (WQG) for the protection of aquatic life for total selenium, which is equivalent to the Red Chris Site Performance Objective at this site.

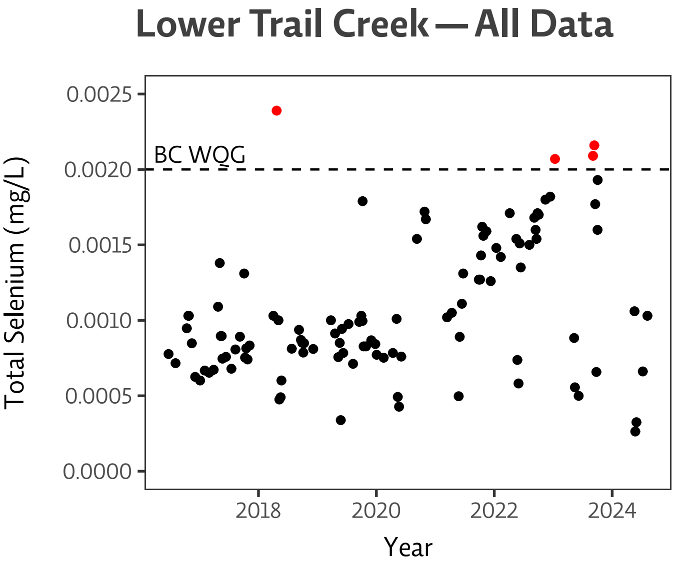
Lower Trail Creek — All Data

Figure 5. Concentrations of total selenium in all surface water samples from lower Trail Creek (EMS ID: E304670; ENV 2022) over time. Exceedances of the long-term chronic BC Water Quality Guideline (WQG) for the protection of aquatic life (dashed line), equivalent to the Red Chris Site Performance Objective at this site, are shown in red.

Further downstream, conditions in Kluea Lake appear to be changing. Sulphate concentrations are increasing in the lake's surface water near the outlet of Trail Creek (t = 0.7, p = 0.01; Figure 7) and are potentially increasing in lake sediment (WSP 2023a). Our raw data assessment additionally noted a potential increasing trend in dissolved selenium in Kluea Lake water near the outlet of Trail Creek (dissolved selenium: t = 0.5, p = 0.08; Figure 8). Kluea Lake water concentrations of selenium currently are near or above the 0.001 mg/L threshold, beyond which about 20% of Kluea Lake rainbow trout are predicted to experience negative effects on juvenile growth and adult reproduction (Golder 2019c). As discussed in the next section (3.3.5), selenium also appears to be increasing in rainbow trout tissue chemistry over time. Thus, numerous parameters associated with mine-affected surface water and groundwater are becoming more prevalent in the Trail Creek–Kluea Lake system and may be negatively affecting local fish populations and other aquatic life.

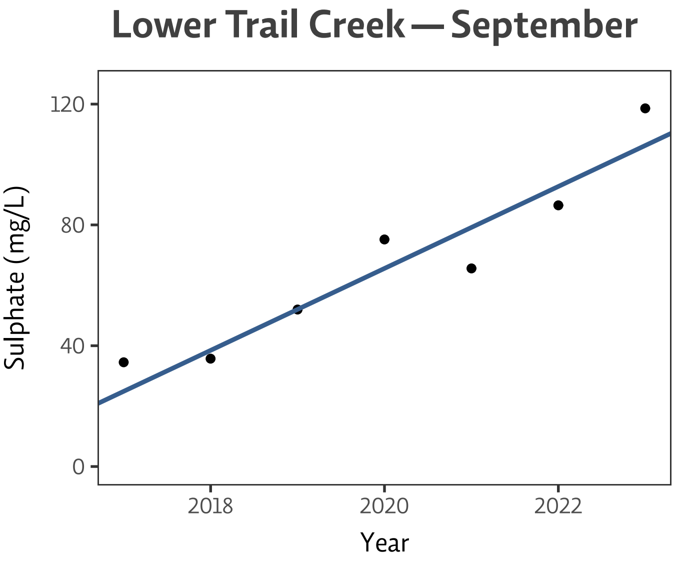
Lower Trail Creek — September

Figure 6. Monthly average concentrations of dissolved sulphate during September in surface water at lower Trail Creek (EMS ID: E304670; ENV 2022) over time. Solid lines indicate the Theil–Sen robust regression line.

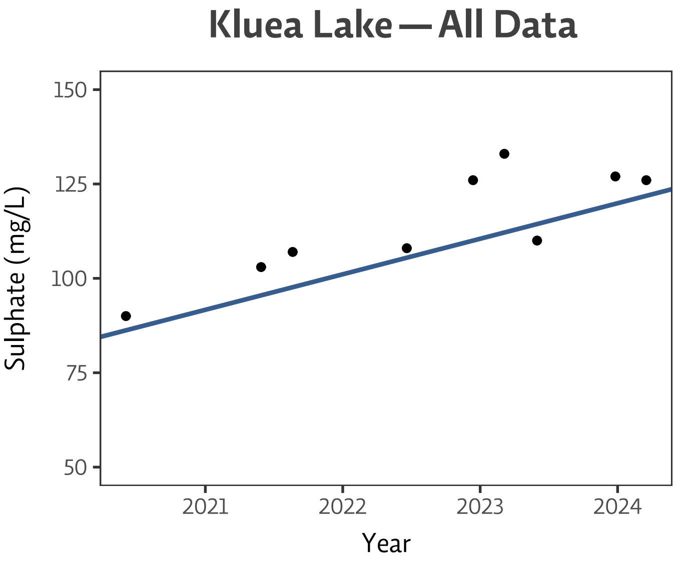
Kluea Lake — All Data

Figure 7. Concentrations of dissolved sulphate in all surface water samples from Kluea Lake near the outlet of Trail Creek (EMS ID: E305474; ENV 2022) over time. The solid line indicates the Theil–Sen robust regression line.

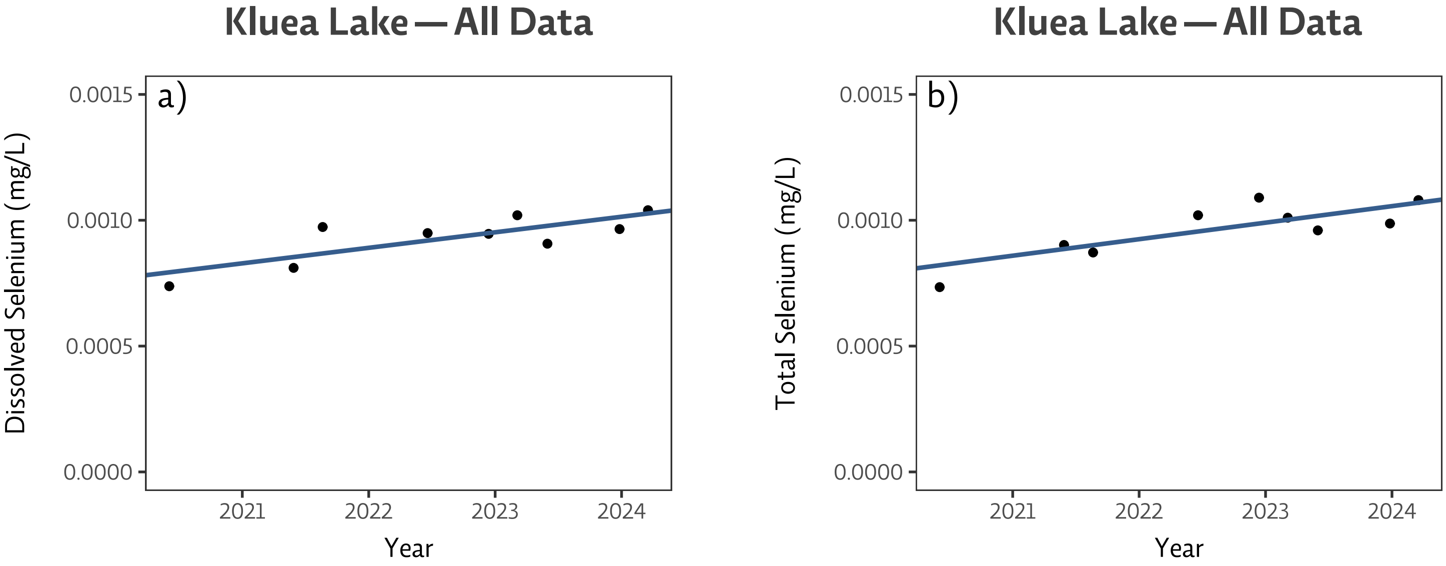

Figure 8. Concentrations of dissolved and total selenium (Figure 8a and 8b, respectively) in all surface water samples from Kluea Lake near the outlet of Trail Creek (EMS ID: E305474; ENV 2022) over time. Solid lines indicate the Theil-Sen robust regression line.

Previous monitoring reports on Red Chris acknowledge that some of the observed changes in the Trail Creek system are likely related to mining activities; however, at least one potentially significant source of mine contaminant loadings has not been thoroughly addressed: Camp Creek. Camp Creek flows from the mine site to upper Trail Creek just south of the tailings facility and has historically been impacted by contact water from the Open Pit (NRCM 2020a). Red Chris' Environmental Assessment and a recent site water quality model both recognize that Trail Creek could be affected by mine seepage via Camp Creek (EAO 2005; SRK 2021), and there is evidence that this is occurring. For example, Camp Creek's water chemistry has been worsening throughout mine operations in elements like sulphate and selenium (Golder 2021a; WSP 2023a), and—due to mine diversions of other clean water sources—Camp Creek is now Trail Creek's primary source of surface flows (NRCM 2023a). However, mine reports maintain uncertainty as to whether the ultimate source of contaminant loadings to Camp Creek is mine infrastructure or a natural source (NRCM 2022b, 2023a). While Newcrest commissioned an assessment in 2023 that confirmed Camp Creek is indeed a direct loading source to Trail Creek, as well as a contributor to South Valley groundwater quality (which could then indirectly influence both Trail Creek and Kluea Lake water quality; NRCM 2023a; WSP 2023a), the assessment did not attempt to definitively determine whether metal loadings coming from Camp Creek are attributed to the mine. This omission contradicts the guidance of independent experts, who advised that potential mine influences on Camp Creek should be investigated (NRCM 2019). Groundwater sampling performed near the Open Pit for the first time in 2021 indicated highly elevated sulphate concentrations in the Camp Creek valley (BGC 2023b), which could be an indication of mine seepage. However, sampling was intended to support mine expansion plans, not seepage monitoring; thus, more purposeful monitoring is required. Given Trail Creek's value as fish habitat, and a source of flow to fish-bearing Kluea Lake, this deficiency is a significant current gap in environmental monitoring at Red Chris.

To our knowledge, mitigation approaches have not yet been introduced to address chemical effects in Trail Creek and Kluea Lake. Though tailings seepage interception in the South Valley is available, it has not been activated (section 3.3.2), perhaps because the relative impacts of different contaminant loading pathways to Trail Creek—such as Camp Creek and tailings seepage—are not adequately understood. Overly optimistic projections early in the mine's life that underestimated the extent and likelihood of downstream effects (section 3.3.2) also have likely contributed to a lack of prepared mitigation. We are surprised that neither the Province nor mine operators have responded with meaningful action to the trigger level exceedances occurring in Trail Creek surface water, which have been recorded for aluminum, copper, chromium, and selenium (NRCM 2023a; WSP 2023a). While mine reporting has acknowledged that seepage interception from Camp Creek may be needed to protect Trail Creek water quality (SRK 2021), there is no information yet on if, how, or when that might be implemented. Importantly, because mitigation thresholds at Red Chris are at times significantly above background water quality conditions (section 3.3.1), adverse changes could occur in the receiving environment before mitigations are legally required. We believe early measures are necessary to protect downstream water quality by maintaining it as near background conditions as possible and to address those contaminants that already exceed thresholds.

It is likely that metal loadings in the Trail Creek system will continue to occur and increase over time. Tailings seepage is accelerating (see section 3.3.2), Camp Creek inputs continue to worsen (WSP 2023a), and reduced inputs of clean freshwater to Trail Creek will persist beyond mine closure. Additional contaminated inputs to Trail Creek may also occur after mine closure, such as direct discharges of waste rock seepage (BGC 2020c). Water quality models for Red Chris predict that without effective mitigations, selenium and copper in Trail Creek will increase significantly, exceeding WQGs for over one hundred years post-closure (SRK 2021). Kluea Lake is also predicted to experience increasing concentrations of copper and selenium (SRK 2018, 2021). These parameters are known to impair resident fish and other aquatic life (Wood et al. 2011a, 2011b; Price 2013). For example, one mine assessment indicated that if selenium SPO exceedances in lower Trail Creek (which have already begun) become regular occurrences, negative effects on the reproduction of rainbow trout feeding in Trail Creek wetland areas will result (Golder 2019c). Even if some of the current chemical changes in Trail Creek are naturally occurring, conditions observed in water quality and other aquatic indicators suggest that the system is under stress and likely will have less tolerance to withstand the effects of mine-related contaminated inputs. Thus, the operators and regulators of Red Chris Mine must take swift action to address the chemical trends being observed in Trail Creek and the mitigation of downstream mine impacts.

Recommendations

GENERAL

- Maintenance and upkeep of monitoring and water management infrastructure must be prioritized, especially where there is potential for direct impacts to downstream aquatic habitat.
- Regulators must take enforcement actions when legal limits, such as surface water quality Site Performance Objectives, are exceeded.
- Mitigations of mine-related impacts must be implemented even where some observed downstream changes may be naturally occurring.

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- All available measures must be taken to reduce long-term site water demand, such as reducing the overall volume of tailings and the need for a tailings water cover, within the constraints of measures needed to prevent geochemical impacts from metal leaching and acid rock drainage.

- Response actions must be required to address Trigger Response Plan and Site Performance Objective exceedances in Trail Creek.
- Assessments must be performed immediately to determine definitively i) what mine loading sources contribute to Camp Creek water quality and ii) what relative contribution different loading pathways (e.g., Camp Creek, tailings seepage, etc.) are making to Trail Creek water quality.
- Assessments must be performed immediately to establish the possibility of reproductive effects on rainbow trout in Trail Creek from increasing water selenium concentrations. Our suggestions include: i) laboratory bioassays exposing rainbow trout to Trail Creek water and ii) in-situ assessments of egg and juvenile rainbow trout morphology and health indicators.

3.3.5 Increasing Selenium in Fish Tissue

One of the most concerning trends observed in the Red Chris receiving environment is that selenium concentrations in rainbow trout have increased over time in Kluea and Ealue Lakes. Selenium is a trace element commonly associated with mineral and coal deposits that causes reduced growth, altered behaviour, physical deformity, and increased early-life mortality in fish when it accumulates excessively in their tissues (Janz 2011; ENV 2014; Lemly 2014). Public concern about selenium toxicity in fish due to mining at Red Chris has existed for years (Hume 2016). Recently, Red Chris environmental monitoring reported that Kluea Lake rainbow trout muscle tissue selenium concentrations are significantly greater than they were prior to ore extraction (Golder 2022; WSP 2023a) and are exhibiting a significant increasing trend over time in both male and female fish (WSP 2023a) (Figure 9). Similar analyses have not been performed in mine reports for Ealue Lake; however, an overall increasing trend in rainbow trout muscle selenium concentrations is visually evident (Figure 9). Our analysis of raw fish muscle tissue data using the Mann-Kendall test confirms a statistically significant increase of selenium in rainbow trout from both Kluea Lake ($t = 0.6$, $p = 0.02$) and Ealue Lake ($t = 0.5$, $p = 0.05$) based on annual median tissue concentrations. A statistically significant increasing trend based on annual mean tissue concentrations was also observed in Kluea Lake ($t = 0.6$, $p = 0.02$) but not in Ealue Lake ($t = 0.4$, $p = 0.11$). Additionally, selenium concentrations in the ovary tissue of female rainbow trout are increasing in both lakes and are strongly correlated with muscle tissue concentrations, indicating that maternal selenium transfer is occurring directly from adult female fish to their eggs (Golder 2021a, 2022). Given that selenium loadings in the muscle tissue of fish from both lakes were already above the provincial guideline for the protection of aquatic life (4 mg/kg; ENV 2014) before mining began, such increases to these loadings are resulting in even larger exceedances of that threshold (Figure 9), which ultimately may translate to an increased risk of sublethal negative effects to fish from Kluea Lake and Ealue Lake. Additionally, as selenium levels in rainbow trout increase, they more frequently exceed human consumption guidelines for moderate and high fish intake diets (14.5 mg/kg and 7.3 mg/kg, respectively; ENV 2014)[9] (Figure 9). Overall, the observed increasing trends—and advancing threshold exceedances—of rainbow trout body burdens of selenium suggest the potential for chronic negative effects on aquatic life in Kluea and Ealue Lakes and possible risk for human communities that consume these fish.

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[9] Human consumption guidelines are based on a moderate fish intake diet of 0.11 kg fish/day and a high fish intake diet of 0.22 kg fish/day (ENV 2014).

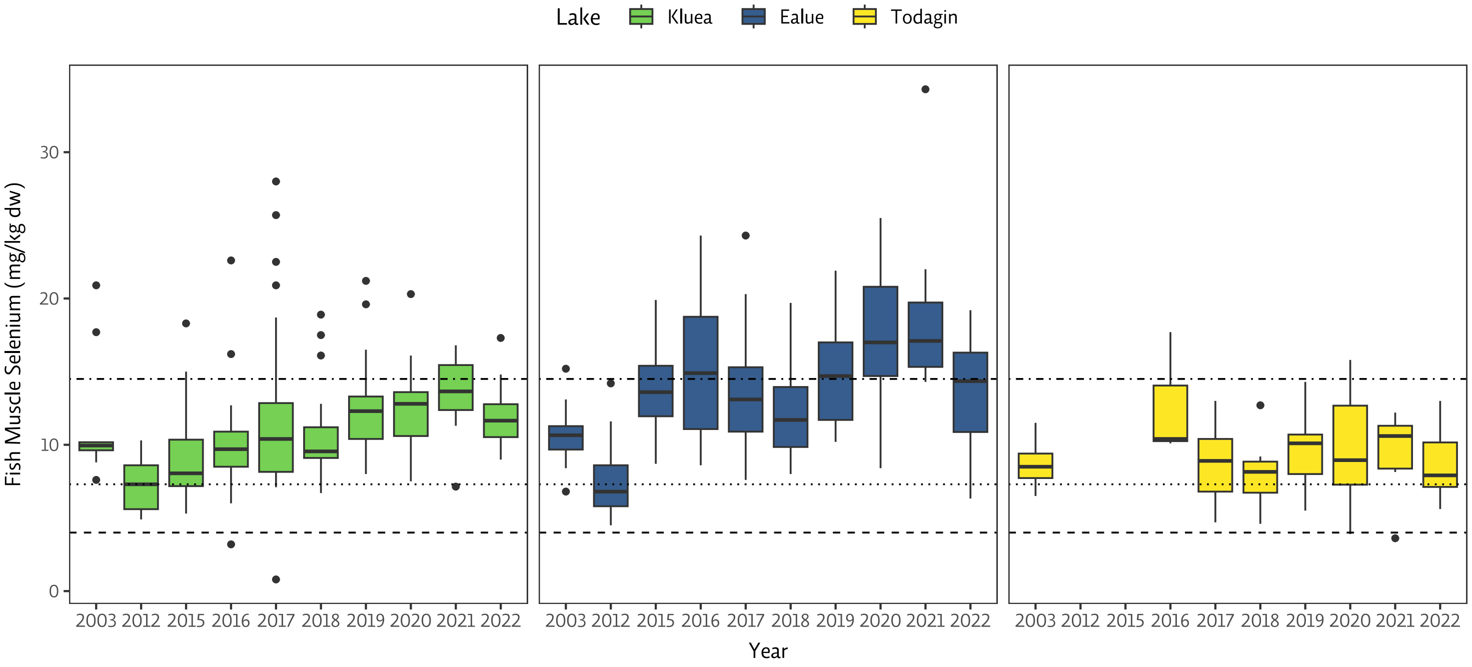

Figure 9. Dry weight (dw) selenium concentrations in rainbow trout muscle tissue in Kluea, Ealue, and Todagin Lakes over time. For each box, the horizontal line indicates the median value, and the filled area indicates the interquartile range (IQR), which is the 25th to 75th percentile, of that year's data. Vertical lines on each box extend to the minimum and maximum values within the range of ±1.5*IQR, and individual points indicate values outside that range. The dashed horizontal line indicates the muscle tissue selenium BC Water Quality Guideline for the protection of fish (4 mg/kg dw). The dotted horizontal line indicates the BC human consumption guideline for high fish intake diets (7.3 mg/kg dw), and the dot-dash horizontal line indicates the BC human consumption guideline for moderate fish intake diets (14.5 mg/kg dw).

Evidence suggests that the increasing trends of selenium concentrations in Kluea Lake and Ealue Lake fish tissue are partly due to the Red Chris Mine. As mentioned, both lakes are connected to known mine-related sources of selenium, where selenium has spread to downstream groundwater and/or surface water systems (sections 3.3.2–3.3.4). Evidence of mine-related selenium uptake in the Trail Creek-Kluea Lake system of numerous aquatic indicators—such as surface water, sediment, and aquatic vegetation (section 3.3.4)—supports the possibility of a mine-related selenium pathway to fish. Conversely, monitoring has failed to show evidence of selenium impacts on other aquatic indicators in the Lost Creek-Ealue Lake system, except for elevated selenium in benthic invertebrate tissue in Lost Creek (Golder 2022). However, monitoring efforts are much less in the Lost Creek-Ealue Lake system. Also, selenium, which primarily accumulates in fish tissue via dietary pathways, has the potential to biomagnify up the food web (Janz 2011); as such, species like rainbow trout that are at the top of their food web might show signs of selenium contamination before strong increasing trends in lower trophic levels. Thus, mine-related contributions of selenium in fish from Ealue Lake should not be ruled out. We are not surprised that the trend of increasing selenium concentrations in fish appears stronger in Kluea Lake, as there are more direct pathways of mine influence to this system, and given that rainbow trout in Kluea Lake are known to feed in mine-impacted Trail Creek up to the tailings facility (Schell 2004). Mine reports speculate the presence of an undescribed regional (i.e., not related to Red Chris) mechanism for elevated selenium loadings in fish based on the facts that tissue concentrations were high prior to mining and some of Kluea Lake's rainbow trout population show evidence of a high selenium diet type (Golder 2018). Even if this is true, any additions from the mine would exacerbate regional effects and should be managed diligently. However, selenium concentrations in rainbow trout from neighbouring Todagin Lake, which does not receive any mine influence but should be affected by any regional mechanisms, have *not* increased (Mann-Kendall results on annual median values: t = 0, p = 1, and annual mean values: t = 0, p = 1; Figure 9). Therefore, the evidence strongly suggests that Red Chris contributes to increasing selenium concentrations in rainbow trout from Kluea Lake and Ealue Lake.

Based on the reports we reviewed, Red Chris Mine operators have not taken adequate steps to understand better the observed increase in selenium uptake by lake fish or the source(s) of these trends. Such lack of action is, at least in part, because incorrect thresholds have been applied during environmental monitoring and assessment. For example, Ealue Lake has been incorrectly assigned as a "reference" lake despite known potential mine influences on this system. Thus, selenium concentrations in the tissue of fish from Kluea Lake have been deemed to be within the range of regional natural variability, which itself is calculated with the inclusion of tissue data for fish from Ealue Lake (Golder 2022; WSP 2023a). Had Ealue Lake fish tissue data been omitted as they should have, the calculated "normal range" would have been considerably lower, and the observed increase in selenium in fish from Kluea Lake would have exceeded the reference threshold and triggered further assessment. Ealue Lake should not be considered "normal" for two primary reasons: 1) it is a potential receiver of mine-contaminated water, and 2) a previous assessment concluded that the Ealue Lake rainbow trout population is an inappropriate reference for Kluea Lake rainbow trout due to differences in fish growth and condition (Schell 2004). A second key issue is that monitoring reports on Red Chris imply that selenium trends in fish tissue are not a concern because fish that were sampled "did not display abnormalities or lesions in the gill, liver, or kidney tissues that can be associated with selenium uptake" (Golder 2021a, pg. 161). Visible tissue damage or deformity, however, may be a more advanced symptom of chronic selenium toxicity than other known symptoms, such as impaired bone chemistry, growth and survival (ENV 2014), and is not an adequate threshold to trigger further assessment and action. Provincial regulators must not accept such shortcomings with environmental monitoring thresholds. We believe that the mine's current operator—Newmont—must proactively address the potential for selenium contamination of fish from Kluea Lake and Ealue Lake and ensure that appropriate measures of regional variability are applied to future assessments of the extent of the mine's contribution to these trends.

Some additional monitoring gaps may also be contributing to the lack of response to fish tissue selenium trends at Red Chris. In 2021 and 2022, the monitoring program was altered to assess fish tissue chemistry temporal trends by sex, whereas males and females had been previously pooled for this analysis (Golder 2022; WSP 2023a). The number of fish analyzed together was thereby reduced, and a scientific rationale was not provided for the new methodology. This change occurred amidst a considerable reduction to the total number of fish sampled from monitoring lakes—from 25–30 fish per lake to 10 fish per lake—so as to not overharvest, given that

Rainbow trout

lake population sizes have not been estimated (Golder 2022; WSP 2023a). As a consequence of these changes, there is "increased uncertainty and lower statistical power" (WSP 2023a, pg. 159) to detect changes in contaminant levels and data that "may not be representative of lake-wide or population conditions" (Golder 2022, pg. 181). Indeed, the noted increasing trend of selenium concentrations in fish from Kluea Lake and Ealue Lake has weakened during these two years (Figure 9). This deviation from the long-term trend may have encouraged Newcrest to dismiss selenium toxicity as a natural occurrence when, in fact, it could simply be an artifact of low statistical power. In reality, the available literature is inconsistent as to whether sex is a relevant factor in fish tissue accumulation of selenium (Saiki 1987; Linares-Casenave et al. 2014; Knott et al. 2022), and when sex effects are identified in fish contaminant loads, they are typically attributed to differences in size between males and females (Peakall & Burger 2003). Particularly in light of reduced lake sampling overall, Newmont should report temporal trends in metal accumulation across all fish to improve statistical power. Additional analyses by sex or using body length as a covariate could still be employed to address potential confounding factors. Another important gap in monitoring is that selenium concentrations are not regularly tested in lake benthic invertebrates. This is an issue of concern because lake benthic invertebrates may be the most informative indicator of selenium uptake by rainbow trout, as they are the primary prey of rainbow trout in Kluea Lake and are an important dietary component for rainbow trout in Ealue Lake (Golder 2018). Deficiencies in monitoring also include: i) once-annual sampling of lower trophic levels in potential selenium dietary pathways (e.g., sediment and creek benthic invertebrates), which adds additional uncertainty regarding patterns of, and potential mine influences on, selenium accumulation and transfer (Golder 2018), and ii) too few assessments of rainbow trout behaviour, lake food webs, and selenium bioaccumulation have been performed in Ealue Lake, all of which would assist in identifying potential mine-related changes. Amid such monitoring deficiencies, selenium concentrations in fish are already beyond thresholds related to chronic effects and human consumption in Kluea Lake and Ealue Lake. Existing evidence further suggests that selenium discharges at Red Chris will continue to be a concern over the long term. More robust monitoring and planning must be implemented immediately to understand better the mine's role in selenium uptake by fish, whether negative aquatic ecosystem impacts are indeed occurring from selenium exposure, and how best to mitigate mine contributions of selenium loadings to resident fish populations.

Recommendations

GENERAL

- The existence of potential or known natural mechanisms for increasing contaminant loads in the receiving environment, particularly in fish, must not be used as a rationale to not proceed with mitigation of mine-related impacts. Where natural loading mechanisms occur, mitigation of mine-related loading sources should be strongly prioritized to reduce cumulative stress on surrounding aquatic systems.

- Any observed increase in contaminant loads in downstream fish must be followed by further assessment and mitigative actions.
- Mine environmental monitoring must follow the Precautionary Principle. Lack of statistical power or uncertainty in the data cannot be used as a rationale for not proceeding with additional assessments and mitigation actions.

RED CHRIS

- Ealue Lake must not be considered a reference lake or an indicator of natural regional variability. As a potentially mine-affected lake, assessments of rainbow trout behaviour, lake food webs, and selenium bioaccumulation must be performed in Ealue Lake to assist in identifying mine-related changes.
- Assessments must be performed immediately to establish the possibility of reproductive effects on rainbow trout in Kluea and Ealue Lakes from increasing water selenium concentrations. Our suggestions include: i) laboratory bioassays exposing rainbow trout to lake water and ii) in-situ assessments of egg and juvenile rainbow trout morphology and health indicators.
- Mitigative actions must be enacted immediately at Red Chris in response to increasing selenium in rainbow trout tissue in Kluea and Ealue Lakes.
- Measures must be taken to increase statistical power, including pooling sexes in fish tissue analyses, fast-tracking rainbow trout population assessments in monitoring lakes, and investigating non-lethal fish tissue sampling approaches.
- Lake benthic invertebrates must be monitored regularly for selenium and metal tissue loads to improve understanding of potential accumulation pathways to resident fish.

3.3.6 Likely Future Risks and Impacts to Aquatic Ecosystems

Several future risks and/or impacts to the receiving environment downstream of Red Chris are also probable. Despite a proposed shift to underground mining (section 5.0), such future risks—detailed below—will likely remain relevant even under an altered mine plan.

With near certainty, the primary future risk of the Red Chris Mine site to the receiving environment will be the generation of acid rock drainage (ARD), a form of low-pH mine effluent that contains very high contaminant concentrations. Under the currently permitted mine plan, the prevention of ARD from tailings will be attempted through the use of a permanent water cover over the acid-generating tailings, which is a common method to prevent mine wastes from oxidizing and becoming acidic (International Network for Acid Prevention 2009). However, this strategy may be complicated over the long term at Red Chris by an increase in evaporation and periods of drought with the advance of climate change, which could pose challenges to maintaining sufficient water cover (BGC 2020a). Additionally, ARD will still be generated from the mine's Waste Rock Storage Area (RSA) and Open Pit, areas of which are expected to become acidic within currently permitted mine operations (i.e., before 2038; EAO 2005; NRCM 2023a). Acid rock drainage will be long-lasting once it occurs and is expected to heighten metal concentrations in mine-affected water by several orders of magnitude (SRK 2018, 2021). Once the mine is closed, some ARD-contaminated water will directly seep into receiving areas surrounding the RSA (i.e., Lost Creek, White Rock Canyon Creek) and to Camp Creek and Trail Creek (RCDC 2019a; BGC 2020c). Other portions of ARD will be collected and directed to the tailings facility, which will then significantly affect tailings water quality and compromise Quarry Creek, Trail Creek, and Kluea Lake (SRK 2021). Elevations of heavy metals like copper and zinc are typically associated with ARD. In addition, selenium and nitrate should be expected to increase in the receiving environment because the natural attenuation mechanisms downstream of the tailings facility that are currently reducing their concentrations will become ineffective with the onset of ARD (SRK 2021). Even minor quantities of ARD-affected seepage may significantly affect the water quality of all receiving drainages (SRK 2018, 2021); thus, all receiving areas of the mine could be heavily impacted if appropriate and effective ARD mitigations are not implemented.

The generation of ARD at Red Chris will require active mitigation of seepage and runoff, as well as perpetual water treatment. At the RSA—expected to be the largest source of ARD—a highly effective interception system capable of capturing over 99% of seepage, along with a seepage treatment system, is required to prevent heavy metal and selenium contamination of the White Rock Canyon Creek and Lost Creek-Ealue Lake drainages in the post-closure period (SRK 2021). Capture of virtually all seepage from the RSA will be challenging to achieve, and even minor failures of this system could have significant downstream impacts (SRK 2021). Placement of an engineered cover over the top of the waste rock will improve post-closure RSA seepage (EMLI 2022); however, cover designs are only conceptual at this stage (Golder 2021b). Water treatment will additionally be required at the Open Pit when it becomes full of water decades after mine closure and may be needed for the tailings facility even before ARD begins (Golder 2021b; SRK 2021).

There are many risks associated with plans for water treatment at Red Chris. Broadly, mines requiring perpetual water treatment are inherently risky because these technologies may not operate as designed and/or may not receive adequate ongoing oversight and maintenance over the lifetime (hundreds of years) of treatment required. (Examples of these issues have already been observed at other mines in BC, such as Elk Valley coal mines and Tulsequah Chief.) These risks must be taken seriously before permitting mines where ARD and perpetual water quality concerns are expected. In the case of Red Chris, which is already in operation, and where ARD generation and resulting long-term water quality concerns are now inevitable, implementing the necessary mitigations to avoid negative effects must be prioritized, and the risks associated with those mitigations must be managed diligently. Unfortunately, the water treatment designs under consideration at Red Chris have omissions that make additional downstream aquatic ecosystem impacts probable. An assessment commissioned by Newcrest of water treatment technologies for the Red Chris tailings facility using Quarry Creek as the location for discharge of treated effluent employed a set of target discharge limits that exceed long-term chronic WQGs for nitrate, selenium, and cadmium in Quarry Creek, and exceed the short-term acute WQG for manganese (Golder 2021b) (Table 2). The target discharge limits may also exceed long-term chronic and/or short-term acute WQGs for aluminum, copper, and zinc in Quarry Creek (see Note a of Table 2), and all target discharge limits far exceed Quarry Creek background water quality conditions. Additionally, the assessed treatment technology only focuses on removing sulphate and metals and is *not suitable* as a treatment for selenium (Golder 2021b). Ultimately, the proposed water treatment plan for Red Chris will rely on dilution of mine effluent in a fish-bearing creek, some of which could be acutely lethal, and will not address selenium contamination of the mine's receiving environments. Mine discharges of this nature clearly threaten local fish and other aquatic life, and more extensive treatment mitigations are required to avoid ecological harm.

Table 2. Target water treatment discharge limits at Red Chris, compared with background surface water quality, long-term chronic BC Water Quality Guidelines (WQGs), and short-term acute WQGs in the Quarry Creek discharge receiving environment.

Parameter	Units	Target Discharge Limit	Background	Chronic WQG	Acute WQG
Sulphate	mg/L	400	62	429	–
Nitrate	mg/L	**6.0**	0.25	3.0	32.8
Total Arsenic	mg/L	0.0050	0.0006	0.0050	–
Total Copper	mg/L	0.0200	0.0009	0.0029[a]	0.0160[a]
Total Manganese	mg/L	**4.97**	0.014	1.67	3.21
Total Selenium	mg/L	**0.0100**	0.0004	0.0020	–
Total Zinc	mg/L	0.100	0.004	0.019[a]	0.107[a]
Dissolved Aluminum	mg/L	0.100	0.002	0.302[a]	–
Dissolved Cadmium	mg/L	**0.00110**	0.00001	0.00041	0.00146

Where the proposed discharge limit exceeds a long-term chronic and/or short-term acute WQG, it is in **bold**.

[a] Copper and zinc chronic and acute WQGs are calculated for dissolved concentrations, and the aluminum chronic WQG is calculated for total concentration (ENV 2019b; BC Ministry of Water, Land, and Resource Stewardship 2023a, 2023b); due to the discrepancy between the composition of WQGs and proposed discharge limits, it is unclear whether target discharge limits for these metals exceed WQGs.

The Quarry Creek drainage (located north of the tailings facility) has thus far experienced only mild mine-related effects on surface water (i.e., increasing sulphate; Golder 2022) and sediment (i.e., increasing copper and arsenic, and elevated selenium; WSP 2023a), but such impacts could worsen in the future. Tailings seepage is anticipated to continue impacting Quarry Creek, and, without effective mitigations, sulphate, multiple heavy metals, and selenium are predicted to rise above WQGs, primarily after the onset of ARD (SRK 2018, 2021). While tailings seepage interception and treatment are intended to mitigate impacts, Quarry Creek may still be at risk of chemical toxicity, given that it is the planned receiving environment for the mine's treated effluent. Additionally, negative chronic effects on the growth and reproduction of rainbow trout in Quarry Creek could occur if water treatment to address selenium at Red Chris is not implemented (Golder 2019c). Effective seepage mitigations and water treatment must be implemented at Red Chris to ensure the long-term health of the Quarry Creek drainage.

An additional future risk at Red Chris relates to groundwater withdrawals and seepage. Currently, the mine extracts large volumes of groundwater from aquifers surrounding the tailings facility to supply its milling operations and maintain water cover in the tailings facility. Approximately 16,000 m^3 is extracted daily from deep aquifers in the North and South valleys (BGC 2023b). While the capture and pumping of seepage is predicted to continue after mine closure to protect downstream water quality (Golder 2021b), pumping rates will likely decrease from current levels due to reduced operational needs (SRK 2021). Such reduction in groundwater pumping could lead to several effects, including a shift in groundwater seepage southward to Trail Creek and Kluea Lake (RCDC

2019a; BGC 2022a). Additionally, groundwater quality may worsen, and seepage rates may increase (BGC 2021b, 2022a, 2023b); thus, the long-term risks related to tailings seepage may intensify after mine closure. Further assessment is required to define how groundwater pumping will change over time at the mine and how this could affect seepage behaviour and quality.

Admittedly, there is enormous uncertainty associated with some of the abovementioned scenarios, making it difficult to fully characterize the future impacts of Red Chris Mine. While there is near certainty that Red Chris will continue to discharge mine-affected water to the receiving environment through to the post-closure period, the extent to which those discharges will occur via groundwater seepage or surface water discharge is relatively unknown due largely to a lack of hydrogeologic understanding of site conditions and poorly constrained groundwater flow estimates (SRK 2021). Substantial questions remain regarding the site's future water balance and seepage rates, pathways, and quality, all of which will interact with the site's need for seepage capture, groundwater pumping, and/or treated effluent discharge to the environment. Potential changes to the site water balance brought on by climate change will intensify uncertainties, such as the time required for the mine site to stabilize after closure. Notably, there are uncertainties regarding the efficacy of planned mitigations (i.e., seepage capture and water treatment) for protecting downstream environmental values. Further defining of future site conditions is needed to better understand future risks and plan and implement effective mitigations.


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Recommendations

GENERAL

- Mitigations, management approaches, and contingency plans for ARD, including seepage capture, water treatment, and waste covers, must be designed and developed well in advance of ARD generation.
- The entire lifecycle costs and risks of long-term or perpetual water treatment must be incorporated into financial and regulatory project assessments.
- Mine water treatment plans must employ target discharge limits equal to receiving environment background conditions or no-effect thresholds. Given uncertainties about the complexity of natural systems, the potentially long-term nature of heavy metal contamination, and the possible effects of combined elevated metals on aquatic life, effluent discharge limits that exceed WQGs and/or rely on dilution by the receiving environment are unacceptable.

RED CHRIS

- Mitigations, management approaches, and contingency plans for ARD, including seepage capture, water treatment, and waste covers, must be designed and developed well in advance of ARD generation. These approaches must be conservative, proactive, and thorough, especially given the site's poor track record of seepage predictions and management.
- Water treatment must be designed to address all site contaminants of concern, including selenium, metals and sulphate.
- Detailed assessments must be performed now to anticipate how groundwater pumping will change over time, including the post-closure phase of the mine life, and what effect these changes could have on seepage behaviour and quality, as well as downstream environmental effects.
- An improved understanding of current and future site conditions is needed to reduce uncertainty related to future risks and impacts. This includes an improved understanding of groundwater flow estimates, site water balance modelling, seepage behaviour and quality predictions, and short- and long-term effects of climate change on site conditions. Seepage capture and water treatment systems must be tested well in advance to ensure their efficacy during the post-closure period.

Dolly Varden. DEREK FLYNN

4. Tailings Management

4.1 Introduction

The Tailings Impoundment Area (TIA) at Red Chris Mine is situated in a valley that drains north to Quarry Creek, south to Trail Creek, and northeast to an unnamed creek, which flows into the Klappan River (Figure 2). The facility will ultimately be constrained on these three respective creeks by three earthen dams: 1) the North Dam, 2) the South Dam, and 3) the Northeast Dam, which will reach approximately 105 m, 80 m, and 10 m in height, respectively (BGC 2014). The North Dam and South Dam are being constructed using the centerline construction method;[10] both dams are raised annually to accommodate the tailings, operating pond, inflow design flood, and two metres of freeboard[11] (BGC 2022b). The Northeast Dam will not be constructed until the volume of stored tailings and water requires it, which is estimated to occur in 2035 (Stewart et al. 2021). The North and South dams are designed to be constructed primarily of cyclone sand (a coarse sand fraction produced from the mine's non-acid generating tailings; BGC 2014). Tailings beaches of 100 m and 300 m are maintained upstream of the North and South Dams, respectively (BGC 2023a). The South Dam is partially lined by Linear Low-Density Polyethylene to limit tailings seepage (BGC 2023a). Tailings deposition near the North Dam was initiated in 2015 and was expanded to the area near the South Dam in 2017. On the downstream side of the North and South Dams exist two smaller dams: 1) North Reclaim Dam and 2) South Reclaim Dam, the purpose of which is to collect runoff, groundwater discharge, and a portion of tailings seepage from the main dams, and pump this water back into the tailings pond (BGC 2023a).

The TIA is designed to hold 302 million tonnes (Mt), or approximately 203 million m^3,[12] of tailings waste retained in wet-slurry form (BGC 2014). Approximately 15% of the tailings are potentially acid generating (PAG) and are meant to be stored in the central area of the impoundment and permanently covered by at least two metres of water to prevent them from oxidizing and producing acid rock drainage (ARD).

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[10] Centreline tailings dam construction is a method by which the dam is sequentially raised in a vertical direction from a starter dam. Centreline construction is a hybrid of downstream construction, in which dam raises are built on the downstream slope of the previous dam section, and upstream construction, in which dam raises are built on top of deposited tailings (Global Tailings Review 2024).

[11] Freeboard is generally defined as the distance between the maximum tailings pond elevation anticipated during extreme flood conditions and the lowest point on the perimeter of the tailings facility (Narainsamy 2018). Freeboard is intended as a safety measure to prevent dam overtopping.

[12] This volume is estimated based on partial data provided by BGC (2014).

The other 85% of predicted non-acid-generating tailings are stored in different sections of the impoundment or used to construct the tailings dams (BGC 2022b). The facility is expected to hold a free water pond of 35 million m^3 at closure (BGC 2014).

Some of the other major mines proposed in northwest BC, particularly KSM and Galore Creek, share many of the same general tailings facility design parameters as Red Chris, such as: i) dams above 100 m tall, ii) storage of several hundreds of millions of tonnes of wet tailings (including PAG tailings), iii) earthen dams constructed with cyclone sand, and iv) centreline dam construction (Nova Gold Resources 2011; KCB 2012).

Many concerns have been raised related to tailings facilities. A global study found that 10% of tailings facilities reported notable stability issues at some point in their history (Franks et al. 2021). The rate of those issues generally increased with facility age, height,[13] and stored volume; for example, roughly 20% of facilities with stored volumes greater than 100 million m^3 reported stability issues (Franks et al. 2021). Weakened stability can lead to dam failure, catastrophic flooding, and enormous environmental damage. Indeed, Piciullo et al. (2022) found that taller tailings dams and facilities with greater storage volumes release more waste material (i.e., tailings and water) to the environment when they fail. Dam failure consequences may be exacerbated by tailings storage in and beneath free-standing water because water increases the volume and mobility of contaminated material released during a dam failure (Independent Expert Engineering Investigation and Review Panel [IEEIRP] 2015; Rana et al. 2021). The use of water in tailings can also increase the potential for contaminated seepage from the facility (IEEIRP 2015). Lastly, tailings facilities typically are designed to remain on the landscape in perpetuity, making some form of future failure inevitable (Vick 2014).

There are two primary failure modes for the tailings dams at Red Chris Mine: 1) dam collapse by overtopping — this may happen if a large landslide or slump occurs within the tailings reservoir, if the inflow rate overwhelms the outflow and storage capacity of the reservoir, or if construction shortfalls lead to an inadequate storage capacity, and 2) dam collapse by loss of internal or external strength — this could result from: a seismic event; internal erosion and/or excessive seepage; inadequate design, maintenance, or construction quality; or an increase in piezometric levels in the foundation or upstream of the dam (Golder 2019d). Public concern has been raised regarding the safety of the Red Chris tailings facility because its dam construction was overseen by the same owner (Imperial Metals) and engineering firm (AMEC) as the failed Mount Polley tailings dam (KCB 2014). The dam failure at Mount Polley released 25 million m^3 of wastewater and tailings (EMLI 2014). As of December 31, 2021, there were approximately 76.2 Mt, or 50.8 million m^3,[14] of tailings stored in the Red Chris TIA (BGC 2023a)—not including the free water pond—and this number is projected to increase yearly. A dam failure at Red Chris is predicted to have a much more substantial environmental impact than the failure that occurred at Mount Polley (KCB 2014).

This assessment aims to document the potential risks and issues associated with the Red Chris tailings impoundment and propose recommendations to reduce its social and environmental risks and/or impacts. Some issues and recommendations also relate to industry practices more broadly in British Columbia. While

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[13] Franks et al. (2021) found that stability issues increase with height of a facility up to 100 m; above 100 m, they found stability risk does not increase with height, and suggested this may be due to higher engineering standards at these dam heights.

[14] When converting tonnes to m^3, average tailings density was estimated to be 1.5 tonnes/m^3 based on partial data provided by BGC (2014).

Newmont is exploring plans for potential mine expansion that could increase the size of the tailings facility, this report section focuses only on the Red Chris tailings facility as currently permitted. (A discussion regarding potential Red Chris Mine expansion can be found in section 5.0.) As with the previous discussion of aquatic impacts, our review focuses on the responsibilities of both mine owners and regulatory bodies (primarily the Ministry of Energy, Mines, and Low Carbon Innovation, EMLI—now known as the Ministry of Mining and Critical Minerals—in the case of tailings management). Guiding questions informing this review were as follows:

Guiding Questions

- What are the primary risks associated with the Red Chris tailings facility in terms of both physical and chemical stability? Are these challenges being adequately prioritized and managed?
- Are the potential environmental impacts of a dam failure well understood? Are appropriate emergency responses in place?

4.2 Methods

The information that we present here is a broad review of the tailings facility at Red Chris Mine and is not intended to address in detail all geotechnical and environmental concerns at this complex facility. Based on author expertise, our assessment does not aim to provide a technical evaluation of studies characterizing geological models, dam foundation conditions, or dam designs; instead, we aim to provide an overview of select concerns at the tailings facility that may represent long-term impacts or risks to the surrounding environment and/or communities. While some records required to evaluate site conditions at Red Chris Mine effectively are publicly available,[15] many had to be obtained by Freedom of Information (FOI) requests. This assessment, therefore, highlights conditions to the end of 2022 (corresponding to reports published in Q1 2023). Of note, the time constraint means that any reporting or decision-making under Newmont operatorship (which began in late 2023) is not directly covered by our assessment; however, we assume that many of the key plans and decision-makers associated with Red Chris have remained in place through this latest ownership transition because Newmont purchased the entire company of Newcrest (and not simply Red Chris Mine).

Third-party reviews have been conducted regarding the Red Chris tailings impoundment, and we interpreted the recommendations provided in these reviews as indicating potential issues at the facility. For example, the Tahltan Central Government (previously named the Tahltan Central Council) requested a third-party review of the design of tailings disposal at Red Chris Mine due to concerns related to the Mount Polley failure, which was completed by Klohn Crippen Berger Ltd. (KCB 2014). Red Chris Mine also has an Independent Tailings Review Board (ITRB, also called the Independent Engineering Review Panel) that was established in 2015 and typically convenes twice per year. The Engineer of Record for the Red Chris tailings facility is BGC Engineering Inc., who is responsible for annual Dam Safety Inspections of Red Chris tailings dams. A third-party Dam Safety Review was performed by Golder Associates in 2019 (Golder 2019d). The following key documents were reviewed for this assessment (full citations for these and other referenced documents are provided in References):

- Third-Party Review of Red Chris Tailings Impoundment Design (2014)
- Red Chris Dam Safety Inspection reports (2016–2022)
- Red Chris Dam Safety Review (2019)

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[15] Available at https://mines.nrs.gov.bc.ca/.

- Red Chris Independent Tailings Review Board Meeting Summary reports (2015–2016)
- Managers Annual Reports Related to Red Chris Mine Independent Tailings Review Board (2017–2021)
- Red Chris Tailings Impoundment Area Operation, Maintenance and Surveillance Manuals (2016–2021)
- Red Chris *Mines Act* Permit M-240 (2022)

4.3 Results

The results of our assessment highlight potential concerns related to physical stability, environmental outcomes, and prediction and management of potential dam failures associated with the Red Chris tailings facility, including:

- The presence of glaciolacustrine layers in the dam foundation,
- An ongoing shortage in the production of cyclone sand, which could increase the likelihood of dam overtopping, and environmental concerns associated with the use of cyclone sand,
- Potential dam stability impacts of tailings seepage and related uncertainties about the water available at the mine site to maintain a permanent water cover over PAG tailings,
- Shortcomings in modelling the potential impacts of a tailings dam breach, and
- Shortcomings in emergency response planning related to the tailings facility.

These five issues are discussed in detail in the following sections.

4.3.1 Glaciolacustrine Foundation Layers

Geologic models performed for the Red Chris tailings facility after mining began have indicated the presence of glaciolacustrine layers in the dam foundations (BGC 2017). This is a concern because glaciolacustrine layers can be relatively weak foundation materials; for example, the Mount Polley dam failure occurred in a glaciolacustrine layer (IEEIRP 2015; KCB 2015). Though the presence of glaciolacustrine layers was known at the time of Mount Polley's permitting, these materials were incorrectly deemed by the mine owner—Imperial Metals—and EMLI to be sufficiently stable (IEEIRP 2015). At Red Chris, foundation conditions at the time of permitting the tailings facility were thought to consist entirely of more stable foundation materials, such as dense glaciofluvial sand and gravel (KCB 2014), and glaciolacustrine layers were not identified until after dam construction had been initiated (BGC 2017). Information obtained through FOI requests is insufficient to determine whether the stability impacts of glaciolacustrine layers in the foundation have been appropriately modelled and corrective measures incorporated into the dam design.

The ITRB has issued several recommendations to measure dam deformation and monitor the stability of the glaciolacustrine units at the Red Chris tailings facility, highlighting the importance of collecting additional data to reduce uncertainties regarding these dam foundation layers, and to update dam stability analyses accordingly (RCDC 2017a; NRCM 2019, 2022a). Details regarding whether and how these recommendations have been followed are not available because EMLI only requires mine owners to submit summary reports of ITRB activities,[16] and such reports do not

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[16] According to Section 10.4.3 of the Health, Safety and Reclamation Code for Mines in British Columbia (EMLI 2024), a mine owner, agent or manager is only required to submit annual reports in a summary form about activities of the ITRB.

contain detailed explanations of actions taken at the mine in response to independent expert recommendations. Consequently, it is not possible to determine whether the discovery of glaciolacustrine units and any associated dam stability concerns are being adequately managed. Comprehension of dam foundation conditions will continue to evolve, and Golder (2019d) recommended that a routine program be developed to update stability analyses of all structures, especially for the North and South Dams, which are raised annually. Dam designs and construction activities for the tailings impoundment should be updated regularly to account for new information related to dam foundation conditions and stability.

Recommendations

GENERAL

- Detailed reports regarding ITRB activities must be publicly available to increase transparency and public confidence that best practices are being followed at mine sites.
- More thorough geologic studies should be conducted to identify tailings dam foundation materials prior to the issuance of Environmental Assessment Certificates and *Mines Act* and *Environmental Management Act* permits.

RED CHRIS

- Routine updates to geologic models and stability analyses must be implemented to monitor the stability of weak glaciolacustrine dam foundation layers.
- Red Chris dam designs and construction activities should be regularly updated to account for new information related to dam foundation conditions and stability.

4.3.2 Cyclone Sand Materials Shortages and Environmental Risks

The North and South Dams of the Red Chris tailings impoundment are designed to be predominantly constructed of cyclone sand; however, the quantity and quality of cyclone sand produced at the site has not been sufficient. There have been reported challenges with obtaining materials for the dams at the mine since the onset of construction, which are a legitimate concern because the facility could fail to maintain adequate capacity without additional construction materials, which subsequently increases the likelihood of a dam failure by overtopping (BGC 2016a, 2018, 2022b). To compensate for the shortage of cyclone sand, natural deposits of sand and gravel near the impoundment (termed “borrow materials”) have been used for dam construction, which has exacerbated tailings seepage due to the high porosity of some borrow pits (BGC 2020a; NRCM 2020b) and created additional physical land disturbances. Additionally, these natural deposits are nearly depleted (BGC 2022b), which means that further shortages will likely be faced at Red Chris in the near future.

Challenges associated with cyclone sand production and the potential for related materials shortages have been reported; however, this issue does not appear to have been prioritized in the design and construction process. In 2019, Golder recommended that the minimum elevation for the next several tailings dam raises be determined prior to construction in case materials shortages arise (Golder 2019d). In the fall of 2020, the ITRB recommended that the identification of locations for borrow materials be progressed diligently and that contingency plans be developed to address potential shortfalls in cyclone sand production (NRCM 2020b). However, shortfalls in both cyclone sand production and borrow material acquisition proceeded to occur in 2021, during which the total volumes of construction materials placed on the downstream shells of the North and South Dams were only 53% and 46% of their 2021 design targets, respectively[17] (BGC 2022b). Following the construction shortfall in 2021, the ITRB recommended that mine ownership prioritize resources to investigate sources of sand and gravel to provide a "greater-than-normal margin error" and to be more conservative in the construction process (NRCM 2022a, pg. 11); despite these recommendations, shortfalls occurred again in 2022 (BGC 2023a). Such repeated materials shortages indicate that Newcrest may not have followed independent expert recommendations or developed adequate planning. Additional stability analyses in response to construction shortfalls indicated that the dams still generally met minimum stability criteria (BGC 2022b). However, construction volume shortfalls were deferred to future construction seasons, which adds further pressure to improve cyclone sand production or find additional sand and gravel near the TIA to increase dam height to the intended design (BGC 2022b, 2023a). Every year that construction volume shortfalls persist, additional risks are created for dam stability.

In 2022, approval was granted to install a tailings thickener at Red Chris, which is designed to recover water from tailings before discharging to the impoundment, thereby reducing storage volume needs (EMLI 2022; NRCM 2023a). Proposed expansion plans for the mine also include the construction of a new cyclone sand plant (Stewart et al. 2021). While such upgrades may address some of the current issues with dam construction materials acquisition, materials shortages will likely be ongoing because construction targets have been deferred (thus, missed) several years in a row.

Beyond the concerns associated with materials shortages and dam stability, the use of cyclone sand for dam construction also raises water quality concerns. The stated intention by mine ownership has been to deposit cyclone sand on the downstream shells of the North and South Dams via a method called hydraulic placement, which involves the use of water (NRCM 2021b; BGC 2023a). Hydraulic placement of cyclone sand will increase the volume of water downstream of the dam, thus increasing the potential for seepage of construction water (NRCM 2019). The ITRB recommended the delay of cyclone sand placement at the North Dam until the North Valley seepage interception system (SIS) is in place and has been tested for various cyclone sand placement methods, including hydraulic placement (NRCM 2019, 2020b). This recommendation clearly has been ignored, as cyclone sand placement has already begun (BGC 2023a) despite the North Valley SIS remaining under construction (see section 3.3.2). The ITRB further recommended that mine ownership prioritize plans for managing construction water and that mine regulators be proactively engaged to accelerate the approval process for construction water management associated with cyclone sand placement to ensure that the dams are built to their intended designs (NRCM 2022a). Appropriate studies and field trials regarding the management of cyclone sand and construction water must be performed amidst this expedited approval process. Not doing so may ultimately result in construction delays that further impact dam stability and/or construction seepage that adversely affects the downstream aquatic environment.

Recommendations

GENERAL

- Estimates of available dam construction materials must be conservative to avoid unexpected shortages.

RED CHRIS

- Materials shortages and challenges with cyclone sand production require adequate prioritization

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[17] In 2021, the volume placed on the downstream shell of the North Dam was 424,000 m^3, compared to the target volume of 794,000 m^3, and the volume placed on the downstream shell of the South Dam was 93,500 m^3, compared to the target volume of 203,500 m^3 (BGC 2022b).

and planning. Contingency planning—such as conducting stability analyses for minimum dam elevations *before* construction and prioritizing borrow material investigations—should be diligently carried out regarding any issues that may increase the risk of dam failure.

- Construction and/or testing of the North and South Valley SISs should be accelerated to ensure appropriate mitigations are in place to manage water quality impacts of hydraulic cyclone sand placement. Pressure to compensate for past deferrals of dam construction targets may result in the placement of cyclone sand without appropriate field testing and management protocols.

4.3.3 Risks Related to Tailings Seepage and the Mine's Water Balance

As previously described, seepage from the Red Chris tailings impoundment has been a substantial issue since tailings deposition began in 2015. Beyond the impacts of tailings seepage on the aquatic environment (see sections 3.3.2 and 3.3.4), seepage through the tailings dams may also have geophysical and geochemical consequences at the tailings facility. Seepage flows through dams and abutments can lead to internal erosion, which is a recognized potential failure mode for the tailings dams at Red Chris (Golder 2019d). For example, the ITRB expressed concern and issued multiple recommendations to evaluate the significant increases in seepage rates and mitigate changes to foundation pressures at the North Dam (RCDC 2019b; NRCM 2020b). Additionally, seepage from the tailings facility is a key contributor to the mine's water deficit, which is presenting challenges to the maintenance of a permanent water cover over PAG tailings to prevent ARD generation. Models predict that an increase in seepage rates will be accompanied by a substantial decrease in the tailings pond volume and that the tailings facility will be unable to consistently maintain a full pond beyond 2038 due to seepage losses (BGC 2020c, 2022b), which could lead to ARD generation. The acid-generating potential of Red Chris tailings under current operations also appears to be increasing over time (NRCM 2023a). Thus, tailings seepage presents multiple risks to the stability of the tailings facility, which could ultimately result in downstream effects from dam failure and/or contaminated discharges.

Seepage of contaminated water through the tailings dams at Red Chris was identified as a potential issue prior to dam construction. However, adequate dam design alterations and mitigations were not developed to address it. For example, a third-party review of the tailings impoundment design in 2014 (KCB 2014) noted that the dam foundation soils were highly permeable, calling this a "major design issue" (pg. i), and that insufficient work had been performed to support the facility's key design assumptions—such as, i) the presence of fine-grained tailings would be adequate to reduce seepage through the dams and valley walls, and ii) manufactured liners would not be required upstream of the dams. The reviewers recommended further investigation (KCB 2014). While it is unclear precisely what direct action Imperial took in response to this review, it does not appear that any significant dam design changes were made at that time. Imperial eventually altered the South Dam's design in 2016 in response to seepage concerns, including inserting a manufactured liner to control seepage (EAO 2016); however, several notable oversights prevailed. First, the liner was not constructed with adequate surface area to sufficiently prevent seepage (ITRB 2017; RCDC 2019b). Second, a Dam Safety Review of the facility in 2019 noted that there was no evidence that quantitative performance objectives were assigned to monitor the liner's performance (Golder 2019d). Additionally, while Imperial assessed alternate tailings technologies as part of the Environmental Assessment (EA) amendment application to approve South Dam

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design changes, they did not adopt options to thicken or filter tailings—which could reduce seepage volumes and require a smaller pond over PAG tailings—at the time (RCDC 2016a). Despite the eventual introduction of a tailings thickener to dewater Red Chris tailings (EMLI 2022; NRCM 2023a), the adoption of this mitigation strategy when first considered likely would have reduced the challenges to water management and prevention of ARD that have since arisen due to tailings seepage from the Red Chris tailings facility. Tailings seepage cannot be managed without appropriate construction designs and ongoing mitigations; proactive and effective prevention objectives, designs, and mitigations must be developed before construction and consistently re-assessed during mining to adequately address this issue.

Seepage concerns at the Red Chris tailings facility also highlight the importance of adequately characterizing the water balance prior to construction and ensuring that contingency plans are in place in the event of wetter or drier conditions than predicted. The 2014 third-party review highlighted that the hydrology data supporting the tailings facility design consisted of limited site data and relied heavily on nearby weather stations and regional trends (KCB 2014). Because site-specific datasets were not improved at the time, the tailings impoundment has not functioned as planned. Design and construction of the Red Chris tailings facility were based on assumptions of a site water surplus, even under forecasted extreme dry conditions (i.e., a 1-in-200 dry year), and a planned surface water discharge to the receiving environment from the tailings facility to prevent overtopping of the dams (KCB 2014; SRK 2017; Golder 2019d). Instead, the facility has operated under a water deficit since operations began (previously highlighted in sections 3.3.1 and 3.3.2). Such a deficit has resulted in the tailings pond being upwards of 50% smaller than predicted (BGC 2020a). Importantly, discharges from the facility have been in the form of seepage rather than surface water. The region has experienced below-average rainfall, snowfall, and runoff since 2014, likely exacerbating water shortages (BGC 2020a). For example, the mine received 15% less annual precipitation in 2022 than historical averages (BGC 2023b). An independent assessment of what impacts climate change may have on the Red Chris project was not performed as part of its EA (RCDC 2004). The poorly characterized water balance has influenced other major decisions related to tailings management. For example, the incorrectly predicted surplus of site water was a key factor in Imperial's initial decision not to thicken or filter tailings (BGC 2016b). To meet the mine's water demand for operations and maintenance of water cover over PAG tailings, over 30 million m^3 of groundwater was extracted between October 2015 and December 2021 (BGC 2022a). Because the need for groundwater was not anticipated during mine permitting, there are no limits to groundwater withdrawals. Notably, there remains a paucity of information regarding the level of groundwater extraction deemed sustainable (Stewart et al. 2021). The process to acquire a permit for groundwater withdrawal—including drilling additional extraction wells on the Todagin Plateau—is currently underway (BGC 2022a). Overall, early uncertainties about the water balance at Red Chris resulted in long-term effects on mine operations that highlight the need for water resources, hydrogeological conditions, climate, and other relevant factors to be better characterized at mine sites before the permitting stage and continually during operations, including considering unexpected climatic conditions.

Substantial uncertainty remains regarding the future of contaminated water management at Red Chris Mine. Beyond the recently approved tailings thickener (mentioned above, which should reduce seepage rates and water cover needs in the facility), other measures to address tailings seepage at its source, such as additional liners and/or alternative tailings covers, have received some initial evaluation but none appear to have entered detailed design stages (BGC 2020a; Golder 2021b). If and when additional seepage mitigations become operational (either at the source or via downstream seepage interception and pumpback), enough mine-contaminated water may become retained in the tailings facility, particularly post-closure, to move it from a water deficit into a water surplus. This shift would entail new concerns regarding the need for surface water discharge of mine-affected water from the tailings facility to surrounding creeks (SRK 2021) and will complicate the management of water volumes and increase the risk of dam overtopping (BGC 2020c). All potential water balance and contaminated discharge outcomes must be addressed proactively ahead of time with thorough contingency plans.

Recommendations

GENERAL

- Controlling seepage at the source is the most environmentally protective approach. When seepage concerns are understood—as they were at Red Chris during the permitting and early construction stages—tailings dam designs should be developed to prevent seepage. This must be a condition of mine permitting to safeguard the downstream biotic environment.
- Tailings dam designs should be overly conservative to account for water balance and seepage rate uncertainties, including planning for water shortages and surpluses.
- Precautionary seepage mitigations should be well developed prior to permitting so they can be implemented without delays. All mitigations should have clear performance objectives and monitoring plans.
- Dewatered tailings should be aggressively pursued at new mines (and assessed for feasibility at all currently operating mines) in BC. This approach must be prioritized despite any additional costs.
- Robust site-specific data related to hydrology, climate, terrain, and groundwater must be collected to reduce uncertainties that may compromise mine design and functionality, such as during the development of site water balance and climate-related modelling and predictions. These datasets should be a requirement early in the EA process, such as at the EA Readiness Determination stage.
- Independent third-party future climate scenario assessments should be performed for project EAs and on a recurring basis throughout the life of the project.

- Detailed and conservative contingency plans for drier- and wetter-than-expected conditions must be developed prior to approvals and permitting of proposed mines and at all currently operating mines, given that future climatic conditions are increasingly uncertain and continue to depart from historical conditions.
- Potential groundwater withdrawals should be established during the EA and permitting stages. Assessments of sustainable limits must be considered during the EA and incorporated into mine design and groundwater extraction during operations.

RED CHRIS

- Updated water modelling and contingency planning must occur now to ensure that closure plans, such as a permanent water cover over tailings, are feasible and appropriate mitigations are developed and ready for implementation under various water management scenarios. Water shortages may limit the feasibility of maintaining a water cover over PAG tailings post-closure. Conversely, seepage interception may result in a water surplus in the tailings facility post-closure.

4.3.4 Dam Failure Impacts, Mitigations, and Modelling

Appropriate studies must be conducted to adequately understand the social and ecological impacts of a tailings dam failure at Red Chris, that this information be communicated clearly to the public, and that conservative dam design standards are adopted given the vast scale and potential seriousness of such a failure. The consequences of a breach at the Red Chris North, South, and Northeast tailings dams in their closure configurations (i.e., at maximum permitted heights and tailings storage volume) were modelled in an inundation study conducted by BGC Engineering (2014). While this report is publicly available,[18] it is highly technical and may not be easily understood by most people. Accordingly, we summarize the modelled consequences of a tailings dam failure at Red Chris below. We then discuss the consequence ratings assigned to the Red Chris tailings dams, the steps taken in the facility's design to manage downstream dam failure impacts, and the shortcomings in the failure consequence modelling performed for the facility thus far.

Dam Failure Impacts

The 2014 inundation study conducted for the Red Chris tailings facility (BGC 2014) modelled downstream consequences of dam failures in their closure configurations under two scenarios:

"Rainy-day"—in this scenario, the probable maximum flood (PMF) (i.e., the largest conceivable flood at that location from maximum rainfall and/or snowmelt), is already occurring, which overwhelms the tailings impoundment and causes it to fail by overtopping. Existing water levels and flows in surrounding streams and lakes are assumed to be abnormally high due to flood conditions.

"Sunny-day"—in this scenario, internal structural failure occurs to the dam, which causes it to fail. Existing water levels and flows in surrounding streams and lakes are assumed to be in average condition.

RAINY-DAY FAILURE IMPACTS

In a "rainy-day" overtopping scenario for the North Dam, a flood wave of contaminated mine water and tailings would travel along Quarry Creek, then flow into the Klappan River and down the Stikine River (Figure 10). The breach is predicted to reach the confluence of the Klappan and Stikine Rivers 2.0 hours after failure and increase water levels by 5.0 m above

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[18] Available at https://mines.nrs.gov.bc.ca/.

North Dam at the Red Chris Mine tailings facility.
COLIN ARISMAN | COLINARISMAN.COM

existing PMF levels. The breach would then continue to populated areas, arriving at Tahltan (134 km downstream) 4.5 hours after failure and increasing Stikine River water levels at Tahltan by 6.0 m above existing PMF levels (total water level = 23.5 m),[19] then arriving at Telegraph Creek (154 km downstream) 5.2 hours after dam failure and increasing Stikine River water levels at Telegraph Creek by 3.2 m above PMF levels (total water level = 24.3 m). The dam breach would result in greater physical effects relative to effects caused by the PMF alone, including the creation of a larger inundation area in Klappan River, Stikine River upstream of the Grand Canyon, and at Tahltan and Telegraph Creek.

In a "rainy-day" overtopping scenario for the South Dam, the flood wave of mine water and tailings would flow down Trail Creek, arrive at Kluea Lake (2 km downstream) in approximately 42 minutes, and raise lake levels by 18 m over PMF conditions (which was assumed to be a 3 m water level rise in all downstream lakes) (Figure 11). The flood wave then would reach all of Todagin, Tatogga, Eddontenajon, and Kinaskan Lakes—the final headwater lakes before the Iskut River—within 8 hours, and raise lake levels by an additional 10 m, 3 m, 2 m, and 1 m, respectively. Inundation areas were not projected for a South Dam failure scenario, but it is reasonable to assume the breach could cause significant additional physical effects, particularly in Kluea and Todagin Lakes, and along sections of Highway 37. The inundation study additionally does not specify how lodges, cabins, and campgrounds on the lakeshores would be affected. It is believed that the community of Iskut would not be affected in this, or any other, dam failure scenario.

A "rainy-day" overtopping failure at the Northeast Dam would follow a similar flood pattern as projected for the North Dam, but with relatively lower impact. The breach would arrive at Tahltan (132.5 km downstream) in 7.0 hours and add 1.3 m above PMF water levels (total water level = 18.7 m), and arrive at Telegraph Creek (153 km downstream) in 8.0 hours and add 1.4 m above PMF levels (total water level = 22.4 m). Additional physical effects from the dam breach may be noticeable in Klappan River, but appeared minimal elsewhere based on the inundation mapping provided.

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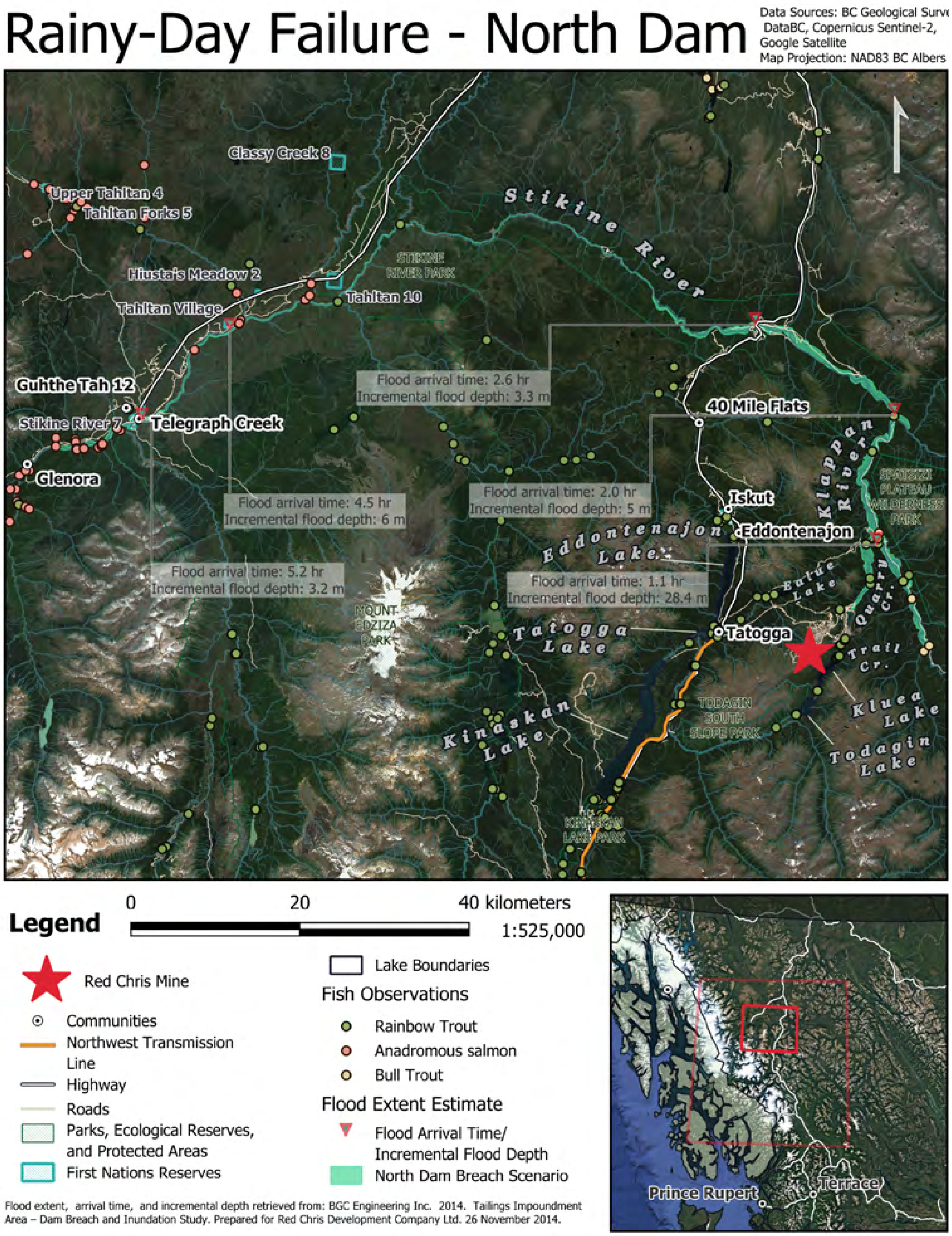
[19] Total water level refers to the base flows at that location under PMF conditions, plus the additional flows modelled from the tailings dam breach.

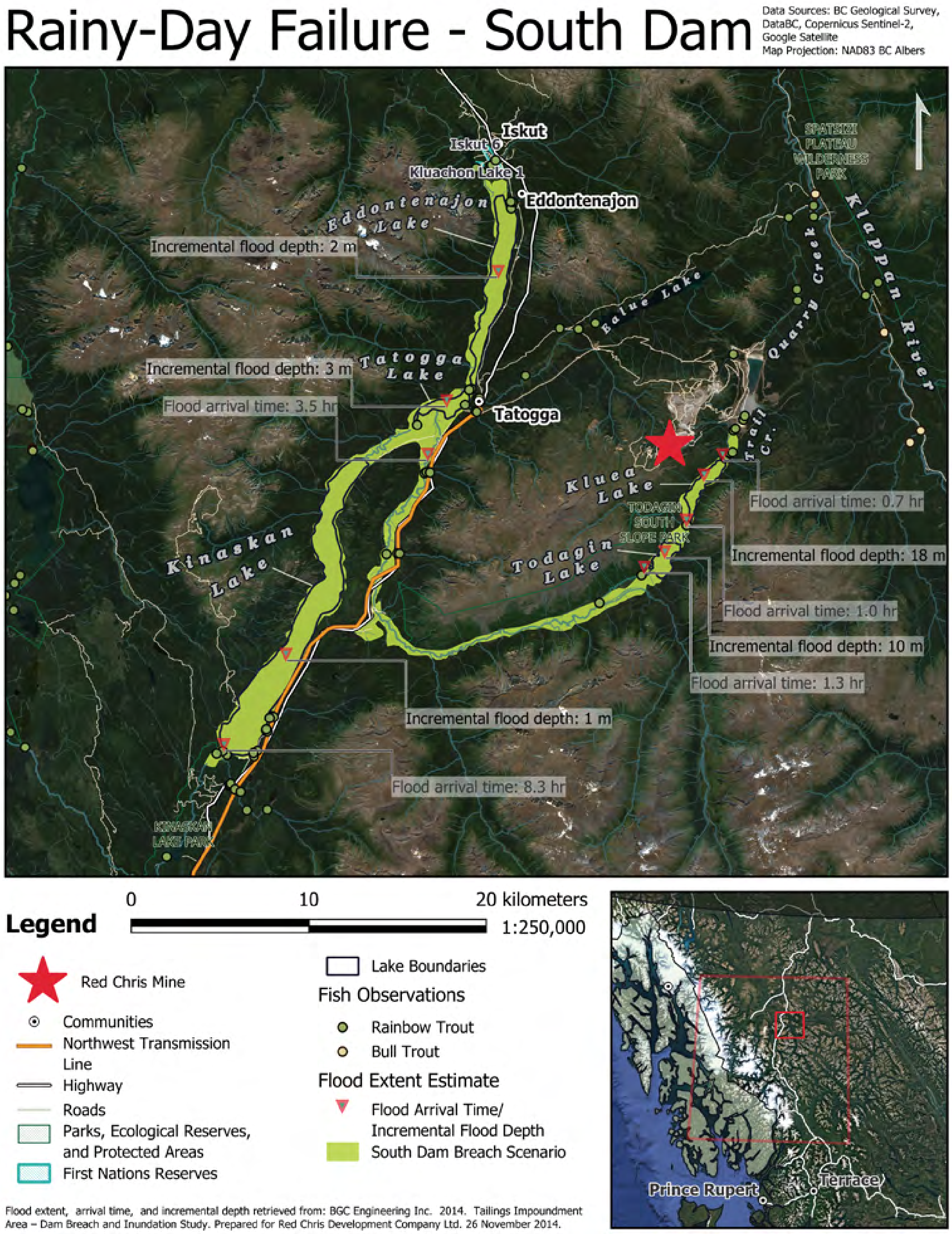


Rainy-Day Failure - North Dam

Data Sources: BC Geological Surve
DataBC, Copernicus Sentinel-2,
Google Satellite
Map Projection: NAD83 BC Albers

Flood extent, arrival time, and incremental depth retrieved from: BGC Engineering Inc. 2014. Tailings Impoundment Area – Dam Breach and Inundation Study. Prepared for Red Chris Development Company Ltd. 26 November 2014.

Figure 10. Map showing predicted impacts from a breach of the North Dam of the Red Chris Mine tailings impoundment in the event of a "rainy-day" failure (i.e., dam overtopping during the Probable Maximum Flood). Flood arrival times and incremental flood depths (i.e., additional breach flows on top of existing flood flows) are displayed. Please note that modelling ends at 1-in-200 year flood levels; therefore, the spread of tailings and/or mine-impacted water could extend beyond what is shown here.



Data Sources: BC Geological Survey, DataBC, Copernicus Sentinel-2, Google Satellite
Map Projection: NAD83 BC Albers

Flood extent, arrival time, and incremental depth retrieved from: BGC Engineering Inc. 2014. Tailings Impoundment Area – Dam Breach and Inundation Study. Prepared for Red Chris Development Company Ltd. 26 November 2014.

Figure 11. Map showing predicted impacts from a breach of the South Dam of the Red Chris Mine tailings impoundment in the event of a "rainy-day" failure (i.e., dam overtopping during the Probable Maximum Flood). Flood arrival times and incremental flood depths (i.e., additional breach flows on top of existing flood flows) are displayed. Please note that modelling ends at 1-in-200 year flood levels; therefore, the spread of tailings and/or mine-impacted water could extend beyond what is shown here.

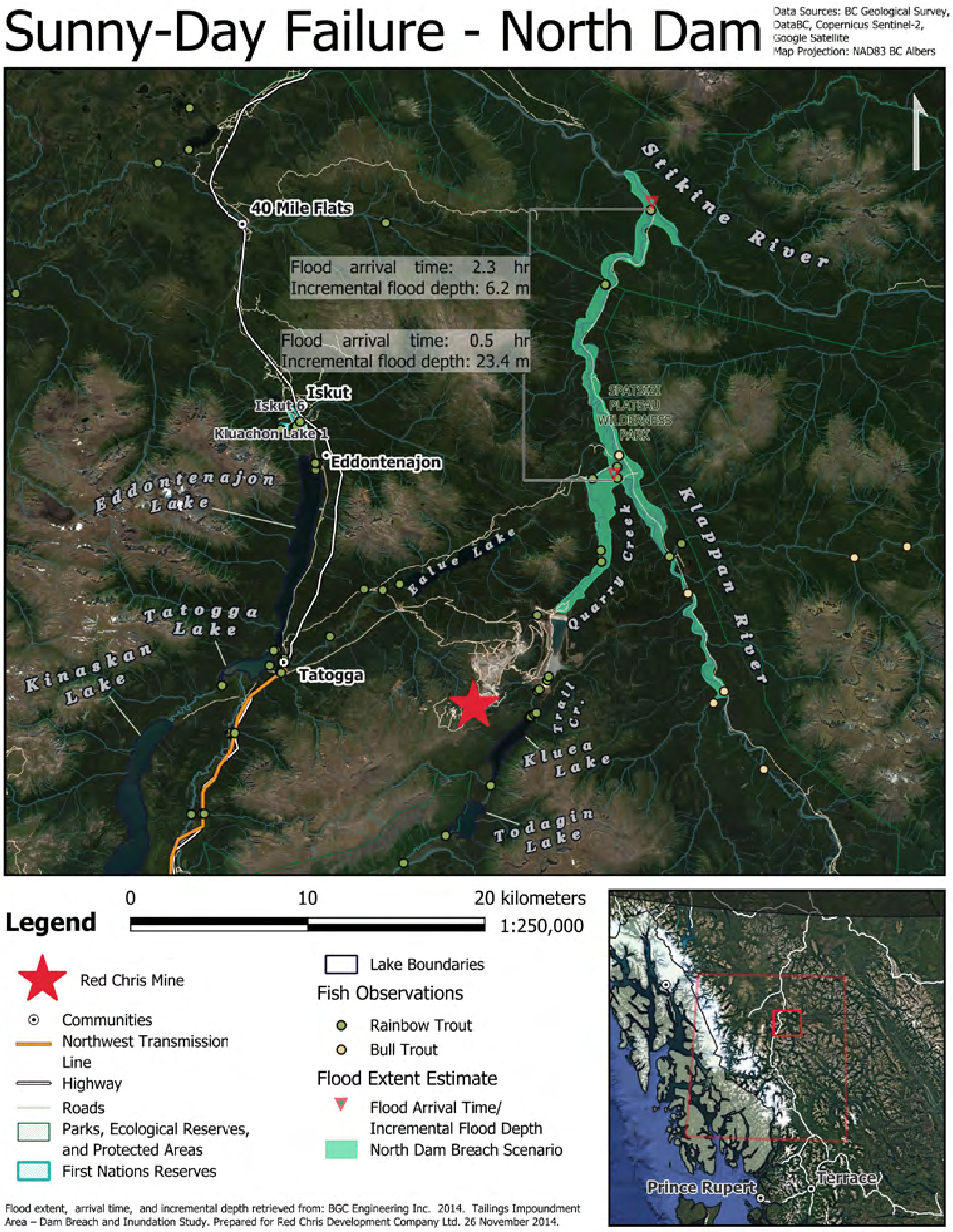
SUNNY-DAY FAILURE IMPACTS

In a "sunny-day" internal failure scenario for the North Dam, a flood wave of contaminated mine water and tailings would travel along Quarry Creek and Klappan River and is projected to subside around the confluence of the Klappan and Stikine Rivers (Figure 12). The breach would add 23.4 m and 6.2 m to normal water levels at Quarry Creek–Klappan River confluence and Klappan River–Stikine River confluence, respectively. Physical effects due to the breach would be significant along the Klappan River.

In a "sunny-day" internal failure scenario for the South Dam, the flood wave of mine water and tailings would reach Kluea and Todagin Lakes within one hour and raise lake levels by 16 m and 8 m above normal, respectively (Figure 13). Flows would continue on a smaller scale into Tatogga, Eddontenajon, and Kinaskan Lakes. Inundation areas were not projected for a South Dam failure scenario, but assuming the breach would cause significant physical effects in Kluea and Todagin Lakes is reasonable. The inundation study additionally does not specify how lodges, cabins, and campgrounds on the lakeshores would be affected.

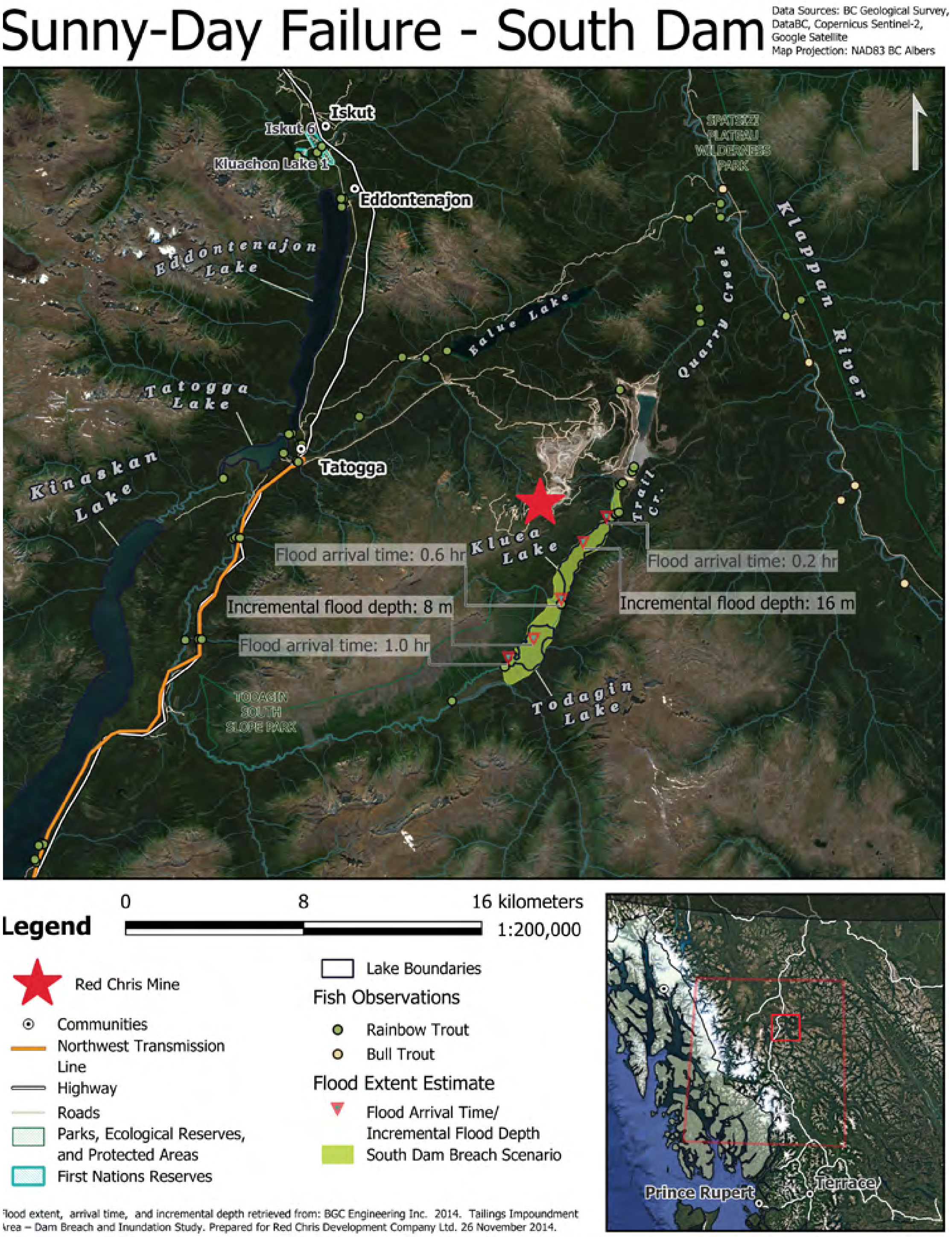
A "sunny-day" internal failure at the Northeast Dam would have the smallest effect, raising water levels above normal by 5.5 m in the Klappan River and 1.1 m at the Klappan River–Stikine River confluence. The greatest physical effects would be observed at the entry point of the breach to Klappan River, and effects would gradually subside from there towards the Stikine River.

The Sacred Headwaters. GREG HORNE



Flood extent, arrival time, and incremental depth retrieved from: BGC Engineering Inc. 2014. Tailings Impoundment Area – Dam Breach and Inundation Study. Prepared for Red Chris Development Company Ltd. 26 November 2014.

Figure 12. Map showing predicted impacts from a breach of the North Dam of the Red Chris Mine tailings impoundment in the event of a "sunny-day" failure (i.e., dam breach due to internal failure). Flood arrival times and incremental flood depths (i.e., additional breach flows on top of existing average flows) are displayed. Please note that modelling ends at 1-in-200 year flood levels; therefore, the spread of tailings and/or mine-impacted water could extend beyond what is shown here.



lood extent, arrival time, and incremental depth retrieved from: BGC Engineering Inc. 2014. Tailings Impoundment rea – Dam Breach and Inundation Study. Prepared for Red Chris Development Company Ltd. 26 November 2014.

Figure 13. Map showing predicted impacts from a breach of the South Dam of the Red Chris Mine tailings impoundment in the event of a "sunny-day" failure (i.e., dam breach due to internal failure). Flood arrival times and incremental flood depths (i.e., additional breach flows on top of existing average flows) are displayed. Please note that modelling ends at 1-in-200 year flood levels; therefore, the spread of tailings and/or mine-impacted water could extend beyond what is shown here.

Consequence Ratings and Facility Design to Manage Failure Impacts

Consequence ratings are assigned to tailings dams based on their potential downstream effects in the event of failure; design criteria and emergency response plans for the dams are required to be more robust with increasing ratings. In British Columbia, dam consequence classifications are defined based on the impacts of a dam breach on human life, the environment and cultural values, and economic losses from infrastructure damage (EMLI 2024), following the Canadian Dam Association (CDA) Dam Safety Guidelines (CDA 2013). Because the Red Chris tailings impoundment contains PAG tailings, significant loss or deterioration to critical fish or wildlife habitat would occur in the case of a breach of the North or South Dams (BGC 2022b). Additionally, some reports indicate loss of life to 10 persons or fewer is possible, but it does not appear that detailed population-at-risk studies have been performed, nor is it clear whether this estimate includes mine workers (Golder 2019d). Based on environmental and cultural impacts, the North and South Dams at Red Chris Mine are rated as "Very High" according to BC and CDA guidelines, the second highest consequence rating (BGC 2022b). Once constructed, the Northeast Dam will retain water only (i.e., no tailings) and will have a lower CDA consequence rating of "High" (BGC 2014, 2022b). However, mine owners have had all three dams designed and/or constructed consistent with an "Extreme" consequence classification, the highest possible consequence rating (BGC 2014, 2022b). Given the potential for loss of life and/or impacts to critical habitat in the event of dam failure, this design standard represents a positive step by Red Chris ownership that goes beyond provincial and Canadian requirements.

The "rainy-day" overtopping scenarios described above are estimates of worst-case scenarios for a dam failure at Red Chris, suggesting that a flood wave of contaminated mine water and tailings would quickly arrive near downstream communities and/or destroy critical fish habitat (BGC 2014). We acknowledge that this particular overtopping scenario is unlikely to occur, mainly because the environmental condition under which it is modelled (i.e., the PMF) is unlikely. The tailings facility is also designed to maintain enough extra capacity during operations to hold PMF flows (BGC 2014). However, this maintenance is prone to human error and may be sensitive to dam construction shortfalls and/or operational water management issues (sections 4.3.2 and 4.3.3). Therefore, overtopping scenarios remain possible, whether under the PMF or other less extreme flood conditions. A key finding of the 2014 inundation study is that downstream impacts are greatest in the event of a South Dam overtopping failure, presumably because there are

Spawning sockeye. KAIT YEHLE

fish habitats near this dam. To minimize the potential environmental impacts of an overtopping failure, the Red Chris dam heights have been designed such that the North Dam would overtop before the South Dam during mine operations (BGC 2022b). Post-mine closure, the Northeast Dam is designed to overtop before the North or South Dams, further reducing failure impacts (BGC 2014). Thus, while design modifications have been made to reduce failure impacts of a facility of this scale, significant impacts to the Quarry Creek, Klappan River, and Stikine River systems should still be expected if an overtopping incident were to occur, particularly during the mine's operational period.

"Sunny-day" internal failure scenarios—associated with smaller impacts than overtopping scenarios overall—are also a concern given that the tailings impoundment cannot be designed to prevent failure at one dam over the other. Internal failures, such as the one modelled in the 2014 inundation study, are among the most common causes of tailings dam failures (IEEIRP 2015). As described above, internal dam failure at Red Chris could negatively impact the Klappan River, Kluea Lake, and/or Todagin Lake. The likelihood of an internal failure at Red Chris will depend on the design, engineering, construction, and ongoing monitoring and management of all three dams, all prone to human error.

Importantly, reducing the scale of the Red Chris tailings facility and the mobility of its tailings (i.e., by reducing their water content) would minimize the impacts of a potential dam failure under all failure scenarios.

Inundation Modelling Shortcomings

There are several limitations to the 2014 inundation study (BGC 2014), which is the only tailings dam breach modelling conducted for the Red Chris tailings facility thus far. The study only modelled up to 47% of the total stored volume of tailings and water being released from the impoundment.[20] However, nearly one-third of known global tailings dam failures for which data are available released a greater proportion than this (based on data presented by Piciullo et al. 2022)[21]. At least four known tailings dam failures have released 100% of the stored tailings and pond water (Piciullo et al. 2022), leading some technical experts to recommend that worst-case scenarios should model complete loss of stored tailings and water from the facility (e.g., Morrill et al. 2022). The Red Chris tailings inundation study also did not examine the distance that solid components of the breach (i.e., tailings) would travel or where they would settle, despite a third-party review recommendation that an inundation study be performed for Red Chris that "considers both water and tailings release plus acid generation of [potentially acid generating] tailings" (KCB 2014, pg. 38). This recommendation was echoed in the 2019 Dam Safety Review, suggesting that the extent of tailings runout during a failure should be more fully evaluated (Golder 2019d). While the ITRB suggested that technologies have not yet advanced sufficiently to allow realistic tailings runout modelling (BGC 2022b), advancements are being made in this area of research that could potentially be used to update and improve Red Chris tailings dam breach modelling (CanBreach 2024). There are landforms along the failure flow paths where tailings might be stopped from further movement, such as lakes in the South Dam failure flow path or the Grand Canyon of the Stikine in the North Dam failure flow path. However, research on the Mount Polley failure demonstrates that tailings accumulations in natural waterbodies can contribute to long-term direct or cumulative chemical impacts

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[20] The inundation study modelled a maximum of 77 million m^3 tailings and 35 million m^3 pond water released from the facility, out of a total stored volume of 203 million m^3 tailings and 35 million m^3 water (BGC 2014).

[21] Piciullo et al. (2022) present a list of 71 global tailings dam failures for which both stored volume and released volume are known; in 22 of these failures, more than 47% of the total stored volume was released.

both within such reservoirs and further downstream (Hamilton et al. 2020; Granger et al. 2022; Pyle et al. 2022; University of British Columbia 2022). A Red Chris dam failure would be much larger and more detrimental than the Mount Polley failure, modelled to release up to 112 million m^3 of tailings and water to the downstream environment (based on a 47% loss of stored volume) (BGC 2014), and could release PAG tailings material. Thus, the long-term downstream chemical impacts of a tailings dam failure at Red Chris should be estimated to the level current technologies allow. Lastly, the 2014 inundation study only models Red Chris dam failure impacts to an endpoint equivalent to a 1-in-200 year flood, and acknowledges that failure effects may still be significant at that point (BGC 2014). Thus, additional downstream effects should be expected to occur beyond those described in the inundation study. As a result of these shortcomings, though not all may be possible to remedy currently, the complete potential environmental impacts of a Red Chris dam failure have not yet been quantified.

Additional limitations to the 2014 inundation study include that it: i) does not fully address the potential loss of life within the inundation area, ii) fails to quantify consequences to facilities, and iii) fails to calculate economic losses (which, it is important to note, are not covered by mine reclamation security bonds in BC). A detailed survey of the human population at risk surrounding the Red Chris tailings facility has not been completed (BGC 2023a), despite one being recommended (Golder 2019d). Additionally, inundation modelling was conducted with only low-resolution topographical tools outside the Red Chris Mine site. The effect of this final point is that the maps of potentially affected areas are difficult to read, do not provide a sense of elevation of potentially affected areas vs. dam breach flows, and detailed failure flow routes are not available for potentially populated areas, cabins, and campgrounds, nor are locations of cabins, facilities, recreation areas and campgrounds noted on the maps. Several improvements could easily be made to more comprehensively understand the physical and social risks of the Red Chris tailings facility, such as increasing the quality of topographic data and providing higher resolution maps of flood routes near the location of populated areas, cabins, and other infrastructure.

Recommendations

GENERAL

- Tailings dam inundation studies should be made publicly available in a readily accessible summary format by the Province or mining companies operating in BC.
- The scale of tailings facilities and mobility of tailings should be reduced at Red Chris and other mines in BC through waste backfill, tailings dewatering, and other emerging technologies.

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- Inundation modelling showing impacted areas after a dam failure should map the extent of potential South Dam failure scenarios, including a description of potentially affected lodges, cabins, and campgrounds.
- Undertake a survey of the population at risk surrounding the Red Chris tailings impoundment, including an assessment of how mine workers will be impacted in the event of a dam failure.
- Red Chris inundation modelling should be performed such that it:
    - Models up to 100% of tailings and mine water released from the facility.
    - Quantifies the extent and effects of tailings runout and chemical effects of PAG tailings to the extent current technology allows.
    - Employs endpoints beyond the 1-in-200 year flood event.

- Employs high-resolution topographic data to aid in mapping the physical impacts of dam failures. Descriptions and high-resolution maps of the potential flood path should include the number of dwellings potentially affected, the length of highway and number of bridges affected, and the population in the inundation zone.

4.3.5 Emergency Preparedness and Response Planning

Numerous emergencies could occur at a facility as large and complex as the Red Chris tailings facility, and appropriate precautions and emergency plans should be in place to address these events if/when they occur. Emergencies can develop rapidly and unexpectedly, and several may be more likely to occur under more variable weather conditions due to climate change. While an assessment of all potential emergencies at the Red Chris tailings facility was not feasible for our report, we highlight a few key issues related to emergency preparedness below.

First, we learned that very few changes with substance have been made to the Emergency Preparedness and Response Plans (EPRPs) published from 2016–2021 for Red Chris (RCDC 2016b, 2017b, 2018, 2019c; NRCM 2020c, 2021b). In light of rapidly evolving conditions related to climate change in BC since 2016—including unprecedented wildfires, floods, and heatwaves—the lack of substantial updates may indicate preparations at Red Chris are not keeping pace with such change. In 2021, for example, a five-day power outage during an extreme cold event caused an increase in the freezing of tailings lines and stress on hydraulic systems that Newcrest was unprepared for, which led to an increased number of tailing and contaminated water spills on site, as well as management of PAG tailings outside of normal operating procedures (NRCM 2022b). While this example is not as severe as a tailings dam failure, it demonstrates the importance of having an adequate plan in place to ensure that environmental harms do not occur amidst changing and unexpected climatic conditions.

Second, there are cases in which emergency planning at Red Chris lacks clear procedures and/or where the feasibility of plans has not been thoroughly verified. Plans developed to address excess water in the tailings facility provide a clear example. In the event of excess water in the tailings pond (which could pose risks to dam stability), the response plan is to stop tailings and groundwater discharges into the facility and then reverse the direction of flow in existing pipes to pump excess water out of the tailings impoundment and into the Open Pit (NRCM 2021b). Such a plan would require the evacuation of workers and equipment from the pit, yet the EPRP fails to provide a clear procedure as to how this evacuation would commence (NRCM 2021b). This plan also involves water flow reversal in the pipes from downhill to uphill because the Open Pit is at a higher elevation than the tailings facility. If such a scenario is associated with a power outage—as is common with extreme weather events—it's unclear whether the emergency power source on site could provide adequate power to reverse the flow uphill (NRCM 2021b; Stewart et al. 2021); thus, whether or not the plan to offload water to the Open Pit is feasible under all emergency scenarios remains uncertain. If excess water cannot be discharged to the Open Pit, contaminated mine water will be discharged to the receiving environment downstream of the tailings dams (NRCM 2021b). Such an example demonstrates how a lack of precise and robust emergency response planning increases the likelihood that the receiving environment will be negatively impacted during an emergency.

An emergency at the Red Chris tailings impoundment poses significant risks to surrounding communities and populated areas, and there are gaps in the Red Chris EPRP that could mean these risks will not be managed promptly and effectively. The EPRP identifies populated areas that may be affected by a dam failure, including: Highway 37 at its crossing with the Stikine River, Tahltan, Telegraph Creek, and lodges, cabins, and campgrounds along the shores of Kluea, Todagin, Tatogga, and Eddontenajon Lakes (NRCM 2021b). However, without more detailed mapping of populations at risk, including mine employees (see section 4.3.4), emergency planning may be inadequate to prevent consequences to human life due to dam failure. The EPRP also currently does not differentiate its plans for impacted areas of failure at the North Dam versus the South Dam (NRCM 2021b), which may lead to confusion during an emergency. Additionally, Highway 37 near Todagin Creek is not included in the EPRP's list of affected areas, even though it could be impacted by a failure of the South Dam (BGC 2014). The EPRP anticipates that a tailings dam failure would not develop instantaneously and, therefore, assumes that early warning signs will be noticeable and allow time for the required evacuations to occur (NRCM 2021b). However, the breach at Mount Polley occurred at night, suddenly with no warning or identified precursors, and caused a power outage that presumably challenged communications (IEEIRP 2015). The emergency plans at Red Chris clearly have not been developed for feasible worst-case scenarios, such as those observed at Mount Polley. Finally, the EPRP is not publicly available, and it appears that these plans have not been shared or co-developed with local communities or other stakeholders (Golder 2019d). In our view, EPRPs must be discussed and prepared with downstream communities, mine workers, first responders, and relevant government agencies, and emergency and evacuation drills should be conducted annually to ensure effective and maximum protection of human life (Emerman 2022). Overall, our assessment concludes that current emergency planning for a Red Chris tailings dam failure is falsely optimistic regarding plans to notify and evacuate potentially affected communities, and the plans lack details that may cause confusion and delays during an emergency. Some additional gaps in emergency planning at Red Chris are addressed in the following recommendations.

Recommendations

GENERAL

- Emergency response plans must be updated regularly to address plans for increasingly extreme weather events and unprecedented climatic conditions.
- Clear procedures and feasibility assessments should be developed for all emergency response plans.
- Emergency response plans should be publicly available and developed in partnership with local stakeholders and affected communities, as previously recommended by others (Golder 2019d; Emerman 2022).

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- The EPRP should clarify plans related to a failure at the South Dam, North Dam, or Northeast Dam and must include protocols for worst-case scenarios (e.g., sudden, unexpected catastrophic failure of a tailings dam).
- The EPRP requires an increased level of detail, including:
    - Evacuation plans for workers with maps and muster points.
    - Names or phone numbers for the agencies and communities to be contacted during an emergency.
    - Specifying response plans for a Level 2 (emergency) vs. Level 3 (crisis) scenario.
    - Designating a crisis room equipped with emergency response supplies.

Salmon run. MEL MACPHERSON

5. Proposed Mine Expansion

5.1 Introduction

During its operatorship of Red Chris Mine, Newcrest began pursuing an expansion of the mine that would increase ore production rates and transition from open-pit mining to underground mining using a method called block caving. The mine's latest operator, Newmont, has adopted these plans and continues to move them forward (Newmont 2023b, SLR 2024). The transition to block cave mining would reduce key environmental risks compared to open-pit mining—primarily due to reduced waste generation—but may also have negative implications for site water management and downstream aquatic ecosystem impacts, particularly in the event of an expansion of the tailings impoundment. It would also shift the mine's focus away from copper extraction and more toward the extraction of gold, which is not a critical mineral and is not needed to support the transition to renewable energy. The following summarizes information currently available regarding the key guiding questions about the proposed Red Chris Mine expansion:

Guiding Questions

- What are the details of the proposed expansion? Will there be notable changes to the current mine plan?
- What are the benefits and risks of the expansion? Will the expansion lessen or increase current risks faced at the mine or introduce new risks?
- What regulatory process will the expansion proposal follow? What opportunities will there be for public and stakeholder engagement?

5.2 Methods

We reviewed Newcrest's public market releases and recent technical reports, and documents submitted to the BC Environmental Assessment Office (EAO) by Newcrest and Newmont to assess questions related to the proposed Red Chris Mine expansion. The following key documents were reviewed for this assessment (full citations for these and other referenced documents are provided in section 8.0):

- Market Releases by Newcrest regarding Red Chris Mine (2021, 2023)
- Red Chris NI 43-101 Technical Report (2021)
- Red Chris Block Cave Production Phase Project Description (2023)
- Red Chris Block Cave Production Phase Application (2024)
- Letters from the Environmental Assessment Office to Newcrest regarding project changes (2021-2022)

5.3 Results

High-grade ore is present beneath the current Red Chris Open Pit at depths up to 1,200 m below the surface (NRCM 2021c). Mineral reserve statements indicate that compared to the mine's open-pit reserves, this deeper ore contains marginally increased copper grades (from 0.42% to 0.45%) but markedly increased gold grades (from 0.36 g/t to 0.55 g/t) (Stewart et al. 2021). To mine these resources, block cave underground mining—a bulk mining method similar in cost to open-pit surface mining—has been proposed. Block caving involves undercutting the ore and causing it to collapse upon itself. The removal of ore causes subsidence and leaves behind sinkholes at the surface (WSP 2023b). Newcrest completed a pre-feasibility study (PFS) to demonstrate the technical and economic viability of the block cave project in 2021 (Stewart et al. 2021) and received permit amendments from the EAO and EMLI for exploration and development of surface and underground infrastructure to support the expansion (NRCM 2023a; SLR 2023). These permit amendments also included permission to install a tailings thickener at the mine. In February 2023, Newcrest submitted a project description to the EAO, requesting permission for underground mining to commence (SLR 2023). This request has been advanced under Newmont's ownership, including the submission in 2024 of a detailed application and effects assessment (the Expansion Application; SLR 2024) that the EAO and Tahltan Central Government are currently reviewing and that the BC government has promised to fast-track approvals of (Kurjata 2025). While the 2021 PFS identified three separate areas beneath the Open Pit for underground mining, termed "macro blocks" (MBs) (Stewart et al. 2021), the Expansion Application is *only* to mine the first macro block (MB1), which contains the highest ore grades (SLR 2023, 2024) (section 5.3.1). Any block cave mining beyond MB1 would consist of a future mine expansion requiring additional regulatory approvals (section 5.3.2). Below, we describe the results of our assessment related to the current expansion proposal submitted to the EAO and potential future mine expansions at Red Chris.

5.3.1 Current Expansion Proposal for Initial Block Cave Deposit (MB1)

The expansion plan currently submitted to the EAO to mine MB1, the assessment and approvals of which are set to be expedited (Kurjata 2025), is termed the Red Chris Block Cave Production Phase (SLR 2023, 2024).[22] This plan aims to begin underground mining as early as 2025 and to increase the mill production rate to 15 million tonnes (Mt) per year (up from the current rate of 10–11 Mt per year). The project would involve mining an underground area of approximately 420 m x 260 m at about 1,000 m below the surface. The resultant sinkhole would be in the same area as the existing Open Pit and would be allowed to fill with water at closure to form a lake. Importantly, mining of MB1 alone would not alter the mine's currently permitted mine life (i.e., mine life ending in 2038), water discharges (i.e., seepage to groundwater from waste rock and tailings), or tailings storage capacity (i.e., 302 Mt). The primary benefit of this transition to underground mining would be reduced waste rock production, including a significant reduction in potentially acid-generating (PAG) waste rock stored at the surface. Thus, shifting to underground mining should reduce—though not eliminate—contaminated seepage and acid rock drainage (ARD) generation from the mine site, particularly from waste rock. Perpetual treatment of mine-contaminated water from the RSA, tailings facility, and the lake that will ultimately form in the Open Pit/block cave area will still be required post-closure. Additional benefits of the plan include reduced greenhouse gas emissions and increased ore extraction from an already developed site with limited additional surface disturbance. There has been some

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[22] Unless otherwise noted, information about the current expansion proposal in section 5.3.1 is from SLR 2023 & SLR 2024.

Open pit and area of future block cave at Red Chris Mine with Kluea Lake in background.
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discussion of potential future opportunities to reduce or eliminate the permanent water cover currently planned for the tailings facility—such as by blending PAG tailings with non-acid-generating tailings or using a dry cover (Stewart et al. 2021)—possibly related to the reduced generation of PAG waste. These are all generally positive changes that make the shift to underground mining an attractive option from the perspective of environmental and social safety.

Despite the potential positive changes, key risks associated with the proposed expansion must be considered, including those to: 1) landscape and terrain, and 2) water and aquatic ecosystems.

1) Subsidence from block cave mining may induce seismic events and mobilize landslides in geohazard risk areas surrounding the mine, such as the landslide complex near Kluea Lake that was characterized as "poorly understood" by external reviewers in 2014 (KCB 2014). The PFS describes the prediction of seismic hazards associated with the block cave mining expansion project as "difficult" (Stewart et al. 2021, pg. 141), and the Expansion Application acknowledges multiple uncertainties related to project effects on terrain instability, including whether or not project-induced seismicity will reach the Kluea Lake landslide complex (SLR 2024). The Expansion Application has not addressed the possibility for debris slides to affect fish habitat in the vicinity of unstable terrain areas.

2) Overall, the Expansion Application predicts neutral effects on surface water quantity and positive effects on surface water quality (due to reduced waste rock generation) compared to the mine as currently permitted. However, there are specific times during which negative effects could occur. The mine's demand for water during operations will increase to support increased production rates. This may lead to additional freshwater extractions from groundwater or surface water if the addition of the tailings thickener and other proposed water recycling techniques are insufficient. Additionally, the Expansion Application predicts reduced overall baseflows and winter streamflows in multiple receiving areas due to the dewatering of the Open Pit and block cave during construction and operations. These changes could directly affect aquatic habitat availability and reduce the capacity of these fish-bearing streams to dilute mine-contaminated discharges. Conversely, increased streamflows during freshet months are also expected at times, which could degrade aquatic habitat via scouring and erosion. Though worsened seepage quality is not expected, accelerated ore production and tailings deposition

under the block cave mine plan will lead to sulphate, copper, and selenium levels peaking earlier in the Quarry Creek and Trail Creek watersheds, with concentrations exceeding WQGs. Particularly given that selenium accumulation is already occurring in resident fish (section 3.3.5) and that previous assessments have predicted impacts will occur to fish in the receiving environment even before selenium water concentrations reach the WQG (Golder 2019c), this hastened timeline of water contamination could have negative consequences for fish health.

Another consideration is that gaps and uncertainties in the Expansion Application may result in inaccurate or underpredicted effects of a shift to block cave mining. Understanding of the mine site is still limited by a lack of robust data regarding streamflow and groundwater-surface water interactions, leading to uncertainty in predictions of block-caving effects on both surface water quantity and quality. The geochemical properties of the deeper ore in the block cave are not well understood, and the ore may contain higher contaminant levels than has been assumed. Additionally, the Expansion Application does not account for the likelihood that the natural attenuation currently reducing nitrate and selenium concentrations in groundwater will cease at some point, particularly when acid generation commences (SRK 2021), leading to higher loads of these contaminants reaching the receiving environment. There remains substantial uncertainty regarding mine seepage, the effectiveness of planned seepage mitigations, and how seepage pumping rates may fluctuate over time, all of which will affect downstream surface water quantity and/or quality. Lastly, the Expansion Application does not mention whether or how block cave mining could impact Camp Creek water quality and its influence on Trail Creek, nor does it address projected selenium bioaccumulation in rainbow trout in Kluea Lake and Ealue Lake.

While it seems likely that the current expansion proposal would have fewer environmental impacts than open-pit mining due to reduced waste and generally improved mine water quality, previous sections of this report demonstrate that the mine has already suffered from inaccurate predictions and is already not adequately addressing existing mine impacts. The proponent and decision-makers must more thoroughly evaluate the risks, uncertainties, and potentially overlooked or underpredicted negative effects described here, especially given the block cave mine's shifted focus to mining for gold, a non-essential luxury commodity. Contingencies and alternative mining methods should be explored to minimize risks; for example, employing a more selective method to extract underground ore could substantially reduce subsidence and risks to the aquatic environment. Approval and permitting of this expansion must not be expedited at the expense of overlooking the mine's current and potential future environmental impacts.

The current expansion proposal does not qualify for a new Environment Assessment (EA), but it is undergoing an amendment to the mine's current EA Certificate under the 2018 *Environmental Assessment Act*. Collison et al. (2022) reported that 98% (48/49) of requested EA amendments in BC were approved between 2002 and 2020. They also found that ~42% (20/48) of approved amendments were likely to impact water resources negatively, and amendment applications and approval documents often failed to provide sufficient information to support the claims or decisions made. The current expansion request for Red Chris has been categorized by the EAO as "complex," implying a high level of data gathering and Indigenous and public engagement will be required during the amendment review (EAO 2024c). In actuality, however, public engagement has been limited to a single opportunity to comment on the Expansion Application, with no opportunity provided to engage on what issues are addressed by the application (i.e., the Application Information Requirements) or on the EAO's interpretation and recommendations following review of the application (i.e., the Amendment Assessment Report), and no opportunity to develop a Community Advisory Committee (EAO 2024a). Additionally, previous permit amendments to support the exploration and early development of underground mining infrastructure at Red Chris have not involved public engagement (EAO 2020, 2022). Prior public engagement has improved mine design at Red Chris, such as by resulting in the installation of a manufactured liner during South Dam construction to reduce tailings seepage (EAO 2016). While an amendment that would effectively reduce waste volumes may alleviate some key environmental concerns, environmental risks remain, and this amendment may also set the stage for even riskier future expansions (see section 5.3.2). It is, therefore, essential that concerned stakeholders and potentially affected members of the public have extensive opportunities to participate in conversations and decision-making regarding the future of the mine.

The Tahltan Central Government (TCG) and the Province of BC signed a consent-based decision-making agreement in November 2023 regarding future operations at Red Chris (ENV 2023b). This agreement represents a commitment by the government of BC to obtain free, prior, and informed consent of the Tahltan people before any substantial changes are made to Red Chris, and it means that TCG is performing an independent assessment of the current block cave amendment proposal. The EA amendment request may present an opportunity to address existing issues at the Red Chris site, as TCG have already expressed an interest in addressing uncertainties related to the mine's water balance and seepage patterns, including the need to quantify the distance that tailings seepage has spread into the receiving environment (EAO 2021). We recommend that other issues highlighted in this assessment be addressed during the amendment review, such as: i) gaps in environmental monitoring and mitigation thresholds, ii) mine-related effects on surface water and fish in Trail Creek, Kluea Lake, and Ealue Lake, iii) water discharge and treatment plans, and iv) issues related to tailings dam construction, dam failure modelling, and emergency preparations.

It is important to include three final considerations regarding the current proposed expansion at Red Chris. First, the economic viability of the mine's current proposal to extract ore from a single macro block (MB1) has not been demonstrated. The only published economic study related to the expansion (the PFS; Stewart et al. 2021) was based on the development of all three macro blocks under the Open Pit. A study focused only on the technical and economic feasibility of the current expansion application should be required by the EAO before any assessments to ensure that the proposed expansion—including social and environmental mitigations—can be maintained by the operating company. Second, we are concerned that expanding the mine may hinder existing issues from being addressed. The ITRB stated that the pursuit of mine expansion "could be a distraction to the [tailings engineering team] and dilute the resources available to focus on the significant and high priority challenges that are currently facing the design and operation of the existing [tailings impoundment]" (NRCM 2022a, pg. 12). Such concern also is relevant for the area outside the tailings facility, related to waste rock seepage and downstream aquatic ecosystem impacts. Mine operators of Red Chris must ensure that these existing issues are not ignored in favour of expansion. To support this, regulators and decision-makers overseeing the project should specify as a condition that all existing issues be addressed before any further approvals. Third, approval of this initial expansion will open the door to additional phases of underground mine expansion at Red Chris (section 5.3.2), which may result in cumulative environmental effects that are challenging to predict. The cumulative effects of such a phased development approach must be considered during assessments of the current expansion proposal.

Recommendations

GENERAL

- Alternatives to permanent water covers on tailings must be aggressively pursued. This recommendation aligns with those made by the Mount Polley Independent Expert Engineering Investigation and Review Panel (IEEIRP 2015) and the Global Industry Standard on Tailings Management (Global Tailings Review 2020) to minimize the volume of water stored in tailings facilities.

- Independent third-party future climate scenario assessments should be required for all major EA amendment assessments.

- Selective mining methods must be aggressively pursued over bulk mining methods to reduce mine waste generation and other risks associated with large-scale mining operations.

- The EA amendment process must require detailed assessments—based on quantitative data—to support proponent conclusions about effects on downstream water and aquatic indicators.

- Decision materials related to EA amendments must provide detailed rationales supporting amendment decisions.

- Complex EA Amendment review processes must include public engagement on the Application Information Requirements, Amendment Application, and Amendment Assessment Reports. They must also include the opportunity to form a Community Advisory Committee.

- Phased mine expansion approvals should be avoided, and where they are not avoided, potential cumulative effects related to phased mine expansions must be thoroughly considered during all EA permitting processes.

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- Assessment and approvals of the proposed expansion must not be expedited at the expense of robust consideration of existing and future environmental risks.

- The following must be incorporated into the assessment and permitting of the proposed expansion:

  › Improved understanding of potential seismic hazards and potential effects of terrain instability (i.e., landslides and debris slides) on fish and fish habitat.

  › Contingency water supply plans and related impacts to aquatic ecosystems.

  › Potential impacts to resident fish of accelerated downstream water contamination; specifically, an assessment of project effects on selenium bioaccumulation that takes into account the site-specific effects thresholds presented in Golder (2019c) is needed.

  › Improved understanding of groundwater-surface water interactions.

  › Water quality effects assessments considering scenarios in which natural attenuation of nitrate and selenium is reduced or ceases to occur.

  › Incorporation of project effects on surface water in Camp Creek and how these might affect Trail Creek and Kluea Lake.

- Effects assessments for the proposed expansion must evaluate trade-offs between social and environmental risks from mining activities in exchange for producing non-essential commodities like gold.

- Mine operators and decision-makers must ensure pre-existing issues are not de-prioritized in favour of mine expansion. Decision-makers must require the following pre-existing issues to be more fully understood and addressed as a condition of any further amendment approvals:

  - Gaps in environmental monitoring and mitigation thresholds.
  - Tailings and waste rock seepage.
  - Mine-related effects in Trail Creek, White Rock Canyon Creek, Kluea Lake, and Ealue Lake. This should specifically include issues highlighted by our report, such as: potential mine impacts to Trail Creek via Camp Creek, and selenium accumulation in rainbow trout tissue in Ealue Lake and Kluea Lake.
  - Water discharge and treatment plans.
  - Issues related to tailings dam construction, failure modelling, and emergency preparations.

- A study of the technical and financial viability of the current proposal to mine only MB1 must be required prior to proceeding with EA amendment permitting. This study should incorporate assessments of the viability of needed social and environmental mitigations.

- Potential cumulative effects from future mine expansion phases must be rigorously assessed during the review of the mine's current expansion application.

5.3.2 Possible Future Expansion to Mine Additional Block Cave Deposits

An estimated 300 Mt of ore reserves will remain at Red Chris even if the current expansion proposal to mine MB1 is approved and completed (SLR 2024). Newmont's objective is to expand block cave mining to access these additional reserves, though they are not yet pursuing regulatory approval for such an expansion (SLR 2024). Additional block cave mining could occur from the second and third macro blocks identified underneath the Open Pit, or other high-grade ore deposits recently discovered further east of the Open Pit (NRCM 2023b). Such additional mining at Red Chris would bring continued economic and employment opportunities to the region due to an approximate 20-year increase to the life of the mine (Stewart et al. 2021). It would also increase the extraction of material from an already disturbed site, which may reduce the need to build additional mines elsewhere. However, further Red Chris expansions would cause additional negative impacts. Especially given the mine's decreasing focus on critical mineral production and increasing focus on gold production, these negative impacts may significantly outweigh any benefits. Additional block cave mining would amplify the risks associated with seismicity and water and aquatic ecosystems already anticipated from mining MB1 (see section 5.3.1) and may expand the mine's physical disturbance depending on the location of additional block caves. More importantly, however, any additional block caving beyond MB1 will require expanded or alternate tailings storage, resulting in potentially significant additional impacts to the receiving environment. The PFS evaluated an expansion of the Red Chris tailings facility to a capacity of 550 Mt (near doubling the currently approved capacity of 302 Mt), which would involve raising the final dam heights at North, South, and Northeast Dams by approximately 27 m each (Stewart et al. 2021). Such change would elevate the height of the North Dam to 132 m. Expanding the tailings facility also would involve: i) relocating the North and South Reclaim Dams further downstream on Quarry and Trail Creeks, ii) building a brand new Northeast Reclaim Dam on another tributary to the Klappan River, and iii) relocating monitoring wells, pumping wells, and seepage interception systems further downstream (Stewart et al. 2021). Conceptual studies for a tailings facility expansion to hold up to 800 Mt tailings were also completed in the PFS (Stewart et al. 2021), which presumably would require a further increase to the facility's height and footprint.

The current tailings facility already has significant issues (see section 4.0), and a further expansion of the facility will elevate associated risks. For example, an increase in the size of the tailings facility would directly disrupt and/or destroy additional fish habitat downstream of the mine, raise the level of impact associated with a dam failure, and may exacerbate complications related to obtaining sufficient dam construction materials. Finally, expanding the tailings facility would very likely increase the rates of tailings seepage, further complicating the mitigation of that seepage by requiring the relocation of interception systems. Thus, the expansion of block cave mining beyond MB1 could threaten the stability of the Red Chris tailings dams and/or cause further environmental consequences downstream.

Any proposal to expand block cave mining beyond MB1 is expected to require a federal environmental assessment under the *Impact Assessment Act* and additional permits to allow impacts to fish habitat under the *Fisheries Act* (Stewart et al. 2021), as well as a subsequent provincial EA amendment (SLR 2024). Permitting for additional block cave mining beyond MB1 will likely not be pursued until after 2035 (Stewart et al. 2021). We urge that federal and provincial reviews of further mine expansions, especially major changes to the mine's tailings storage, include in-depth public and stakeholder consultation. As mentioned, the potential cumulative effects of phased mine development must be assessed early and continuously throughout current and future expansion permit applications. Lastly, when evaluating any new mine or mine expansion in northwest BC, decision-makers must prioritize the development of mines that provide critical minerals and essential commodities over precious metals (i.e., silver and gold) mining. Risks to social and environmental values must not come at the expense of producing non-essential commodities like gold.

Recommendations

GENERAL

- Expansion of mine waste storage facilities must be avoided however possible.
- Any major mine expansion or major change to tailings facility design must undergo an in-depth regulatory review that includes comprehensive public and stakeholder engagement.
- Evaluations of new mines and mine expansions must prioritize the development of mines providing critical minerals and essential commodities over precious metals (i.e., silver and gold) mining.
- Evaluations of new mines and mine expansions must not permit risks or impacts to social and environmental values in exchange for producing non-essential commodities like gold.

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- Mine plans that reduce or eliminate the need to add additional tailings storage capacity must be aggressively pursued.
- All pre-existing challenges and risks associated with the existing tailings facility must be addressed and managed prior to any consideration of mine changes that could increase the facility's size or add additional tailings storage at the site.

Open pit and waste rock pile at Red Chris Mine with Ealue Lake in background. COLIN ARISMAN | COLINARISMAN.COM

6. Conclusion

This report offers a broad scientific and technical review of key issues at Red Chris Mine, which sits in the headwaters of the salmon-bearing Iskut and Stikine Rivers and has the potential to impact lakes and streams containing resident fish populations immediately downstream. Based on the mine's environmental monitoring data and technical reporting, the review focuses mainly on the management of downstream aquatic ecosystem impacts and tailings safety at the mine, identifying several key themes that have amplified complications at the site and risks to environments and people downstream. From the early stages, mine planning at Red Chris has suffered from a lack of proper understanding of site conditions, overly optimistic predictions, and insufficient contingency planning, leading to wide-reaching and unexpected challenges such as those related to water management, mine seepage, and tailings dam construction. A tendency to disregard or delay addressing independent expert advice appears to have delayed addressing many of these issues. We also found a trend of environmental monitoring and mine effects management being insufficiently proactive, spatially and temporally robust, or environmentally protective. Broadly, this trend may result in mine effects and effect pathways not being fully understood and has already resulted in delayed assessment and mitigation of mine environmental effects. There is clear evidence of mine-related physical and chemical effects in fish and fish habitat local to the mine, which have frequently been worse than predicted and, in some cases, indicate the possibility for negative chronic effects on aquatic life. Additionally, our review questions whether preparations are adequate for several future risks faced by Red Chris, including acid rock drainage, climate change, and potential tailings dam failure. This report finishes with a review of current and possible future plans for expansion at Red Chris, noting that a shift to underground mining could have fewer environmental impacts than open-pit mining due to reduced waste production and acid rock drainage potential but that remaining risks and uncertainties—including i) expansion effects to the landscape and aquatic environment, ii) the significant pre-existing challenges facing the mine, iii) economic feasibility of the expansion, iv) the possibility of future increases to the mine's tailings storage, and v) trade-offs between social and environmental risks from mining activities in exchange for the production of non-essential commodities like gold—require further attention and must be prioritized over fast-tracking project approvals.

Operations at Red Chris are anticipated to continue until at least 2038, and a lengthy post-closure period is planned after operations do cease. Many of the abovementioned issues identified in this review will remain throughout the mine's operations and post-closure and will continue to influence its effects on the surrounding environment. In the immediate vicinity, of note are the multiple pathways by which Red Chris could be already contributing to chronic adverse impacts on resident rainbow trout populations and other aquatic resources, especially from mine-related elevations in selenium. Given the complexity of the mine site and its receiving environment—including multiple surface water and groundwater receiving drainages—monitoring and managing mine effects will continue to present challenges, which will be amplified by the shortcomings identified in this report if they are not addressed. Additionally, the possibility of tailings dam failure could have far-reaching consequences, including for salmon-bearing rivers in certain scenarios. Amidst stressors already faced in the region due to climate change and naturally elevated metals, Red Chris will contribute to cumulative pressures on the surrounding ecosystem. While some of the issues identified in this report are difficult to remedy retroactively (such as the lack of proper site characterization during mine planning), we highlight in our recommendations many opportunities at Red Chris to improve downstream protections and alleviate these pressures from mine impacts, especially as mine expansion is pursued. These recommendations include: i) enhancing delineation of mine loading sources, pathways, and seepage plumes and accelerating seepage mitigations, ii) expanding aquatic monitoring efforts, responses to mitigation threshold exceedances in surface water and groundwater, and assessment and mitigation of selenium in rainbow trout tissue, iii) improving site understanding, predictions, and planning to address future risks like acid rock drainage and water treatment needs, and to ensure closure plans are feasible, iv) reducing tailings volumes and water cover needs, and more thoroughly planning for dam construction material needs, and v) performing more extensive dam failure modelling and emergency response planning. Further assessment and reduction of potential impacts of the proposed mine expansion is also needed, and it is imperative that addressing the mine's existing problems is prioritized throughout any expansion works and approvals.

Stikine River. COLIN ARISMAN | COLINARISMAN.COM

This report focuses on the Red Chris mine because it represents an example for northwest BC, where mining development interest is high and likely only to increase as governments and industry pursue increased critical minerals extraction. The Red Chris Mine is the first of many large-scale open-pit mines aspiring to operate in the remote salmon-bearing watersheds of northwest BC. Many of the complex issues faced at Red Chris are not unique, and all mining development in the region will carry similar risk factors, such as metal leaching and acid rock drainage, seepage, physical disruption of habitat, and the potential for tailings dam construction complications and tailings dam failure. These risks could create far-reaching consequences for high-value salmon habitat and local and transboundary communities downstream, especially for the many projects under development close to salmon-bearing rivers, human settlements, and international borders. Ultimately, the mining industry adheres to the expectations and requirements of its regulators; therefore, it is the responsibility of provincial and, when relevant, federal decision-makers to implement the necessary changes to reduce the direct and cumulative pressures of further mining in northwest BC. This can be achieved through: i) increased public transparency related to mining risks and impacts, ii) more thorough requirements for site characterization and contingency planning, iii) more robust requirements for baseline and ongoing environmental monitoring, iv) implementation of comprehensive and environmentally protective receiving environment thresholds, and proper enforcement when thresholds are exceeded, v) more conservative and proactive requirements for effects prediction and mitigation, vi) policies to ensure proponent accountability to independent expert recommendations, vii) prioritization of mine designs that use selective mining methods, reduced waste footprints, and reduced water in tailings, and viii) prioritization of tailings facility designs with reduced size and physical risks, as well as requirements for more extensive dam failure modelling and emergency preparations. Regulators must also ensure that Environmental Assessment processes, including amendments to support significant mine changes and expansions, are data-based, transparent, meaningfully engage the public, fully consider cumulative effects, do not accept risks or impacts to social and environmental values in exchange for producing non-essential commodities like gold, and ensure pre-existing issues are addressed as a condition of approval.


MEL MACPHERSON

A balance must be struck between pursuing economic prosperity, procuring metals to support daily technology requirements and the renewable energy transition, and the essential need to safeguard the natural resources that sustain our communities. Northwest BC is home to some of the world's last remaining salmon stronghold watersheds; however, expanded mining activity in the region may exacerbate risks already faced by wild salmon populations and pose additional threats to the environment and human safety. Based on this review of the last ten years of operations at Red Chris mine, it is clear that current approaches to mine planning, design, operations, and oversight in northwest BC put downstream environments and people at unnecessary risk. However, solutions are available to ensure more responsible future mining development throughout the region that will protect the long-term health and strength of these world-class watersheds and the communities that rely on them.

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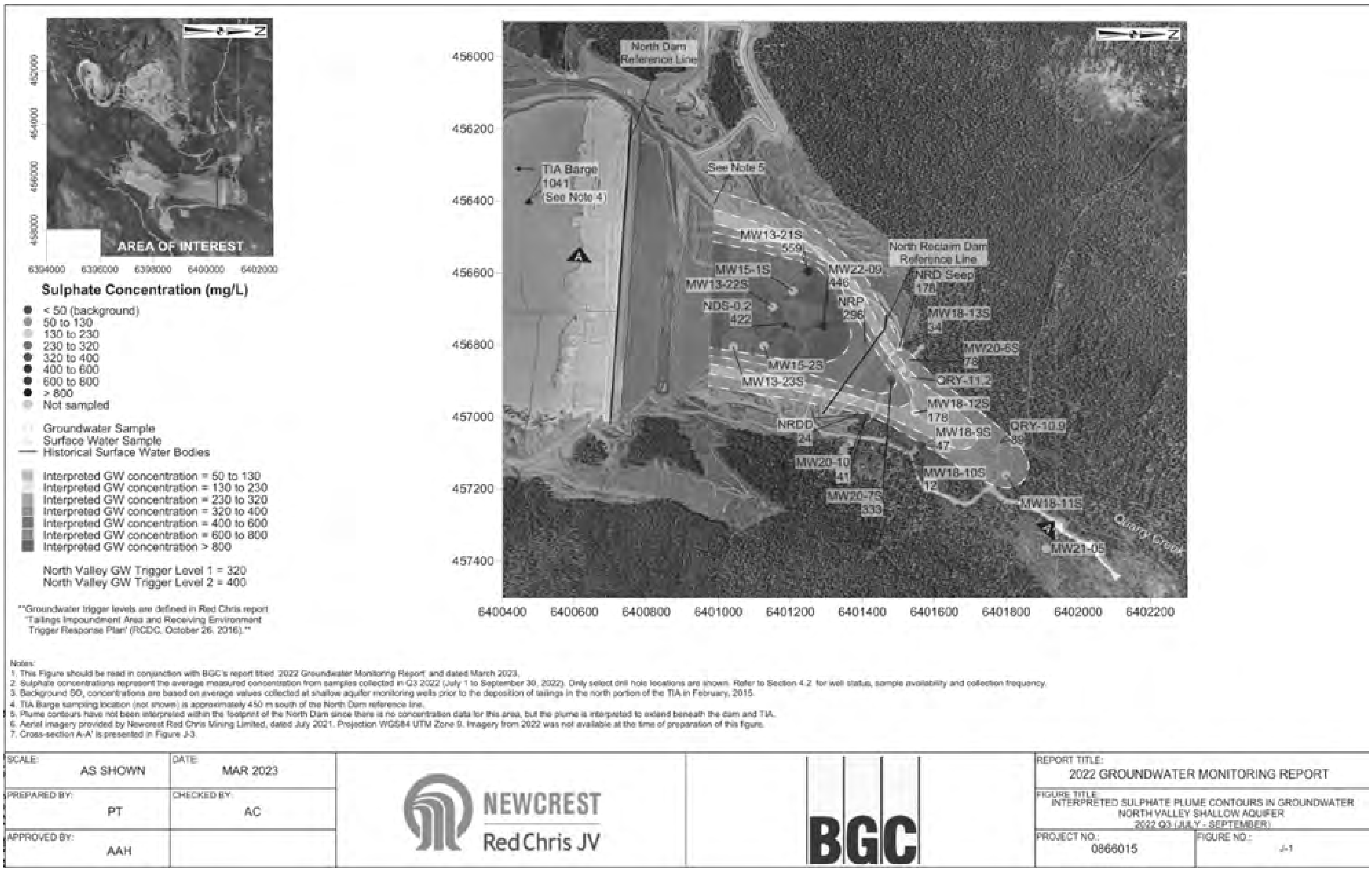
Supplemental Figures



Groundwater trigger levels are defined in Red Chris report "Tailings Impoundment Area and Receiving Environment Trigger Response Plan" (RCDC, October 26, 2016).

Notes:
1. This Figure should be read in conjunction with BGC's report titled "2022 Groundwater Monitoring Report" and dated March 2023.
2. Sulphate concentrations represent the average measured concentration from samples collected in Q3 2022 (July 1 to September 30, 2022). Only select drill hole locations are shown. Refer to Section 4.2 for well status, sample availability and collection frequency.
3. Background SO_4 concentrations are based on average values collected at shallow aquifer monitoring wells prior to the deposition of tailings in the north portion of the TIA in February, 2015.
4. TIA Barge sampling location (not shown) is approximately 450 m south of the North Dam reference line.
5. Plume contours have not been interpreted within the footprint of the North Dam since there is no concentration data for this area, but the plume is interpreted to extend beneath the dam and TIA.
6. Aerial imagery provided by Newcrest Red Chris Mining Limited, dated July 2021. Projection WGS84 UTM Zone 9. Imagery from 2022 was not available at the time of preparation of this figure.
7. Cross-section A-A' is presented in Figure J-3.

SCALE: AS SHOWN
DATE: MAR 2023
PREPARED BY: PT
CHECKED BY: AC
APPROVED BY: AAH
REPORT TITLE: 2022 GROUNDWATER MONITORING REPORT
FIGURE TITLE: INTERPRETED SULPHATE PLUME CONTOURS IN GROUNDWATER NORTH VALLEY SHALLOW AQUIFER 2022 Q3 (JULY - SEPTEMBER)
PROJECT NO.: 0866015
FIGURE NO.: J-1

Figure S1. Contaminant plume map displaying interpreted sulphate (SO4) plume contours in groundwater in the shallow aquifer north of the Red Chris Mine tailings facility. Point labels show the monitoring site and measured sulphate concentration in mg/L at that location. Contour shading indicates the estimated range of sulphate concentrations within that contour following the legend included in the image. Image copied from BGC (2023b), obtained by FOI request.

Groundwater trigger levels are defined in Red Chris report 'Tailings Impoundment Area and Receiving Environment Trigger Response Plan' (RCDC, October 26, 2016).

Notes:
1. This Figure should be read in conjunction with BGC's report titled '2022 Groundwater Monitoring Report' and dated March 2023.
2. Sulphate concentrations represent the average measured concentration from samples collected in Q3 2022 (July 1 to September 30, 2022). Only select drill hole locations are shown. Refer to Section 4.2 for well status, sample availability and collection frequency.
3. Background SO_4 concentrations are based on average values collected at deep aquifer monitoring wells prior to the deposition of tailings in the north portion of the TIA in February, 2015.
4. Interpreted deep aquifer extent from the site-wide numerical groundwater model. The model hydrostratigraphy was updated based on available site investigation data and reporting is in progress (BGC, in progress [b]).
5. TIA Barge sampling location (not shown) is approximately 450 m south of the North Dam reference line.
6. Plume contours have not been interpreted within the footprint of the North Dam since there is no concentration data for this area, but the plume is interpreted to extend beneath the dam and TIA.
7. Aerial imagery provided by Newcrest Red Chris Mining Limited, dated July 2021. Projection WGS84 UTM Zone 9. Imagery from 2022 was not available at the time of preparation of this figure.

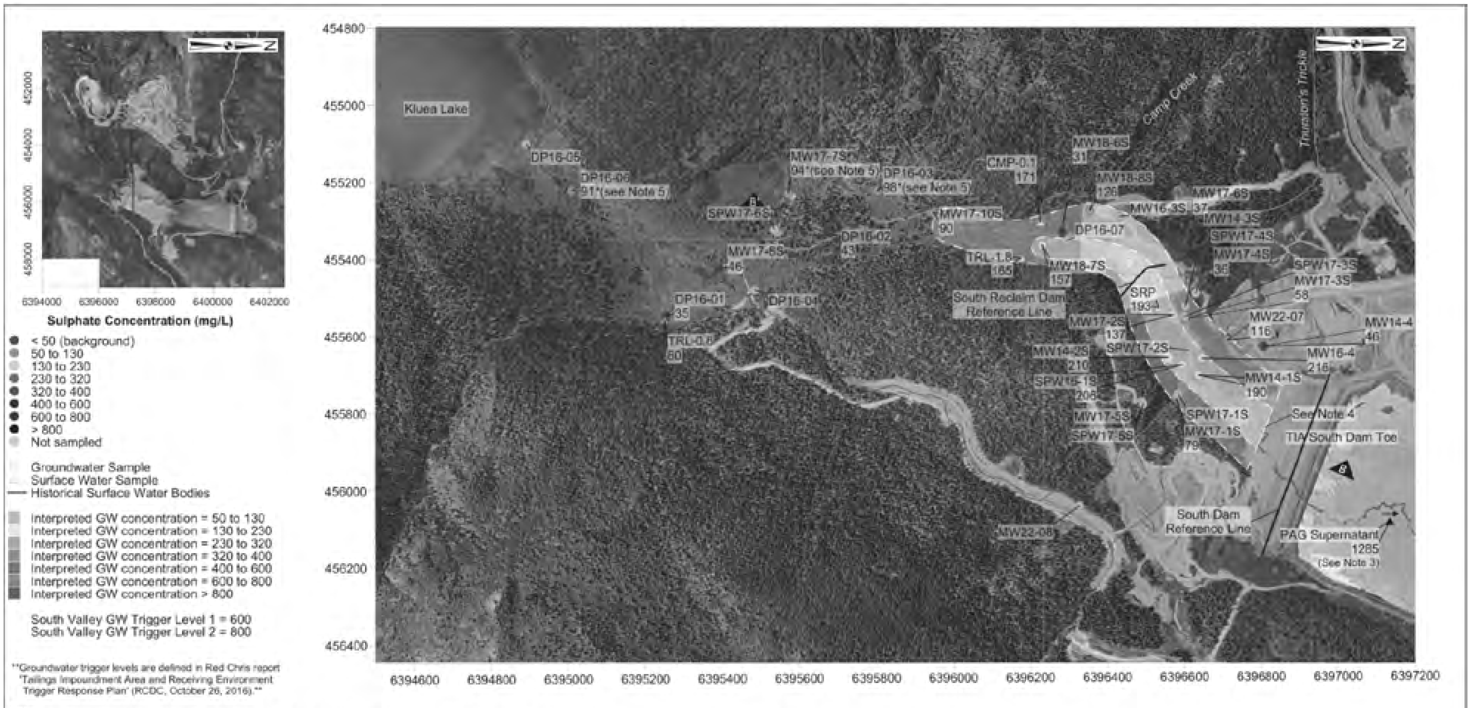
SCALE: AS SHOWN	DATE: MAR 2023
PREPARED BY: PT	CHECKED BY: AC
APPROVED BY: AAH	

REPORT TITLE: 2022 GROUNDWATER MONITORING REPORT

FIGURE TITLE: INTERPRETED SULPHATE PLUME CONTOURS IN GROUNDWATER NORTH VALLEY DEEP AQUIFER 2022 Q3 (JULY - SEPTEMBER)

PROJECT NO.:	FIGURE NO.:
0866015	J-2

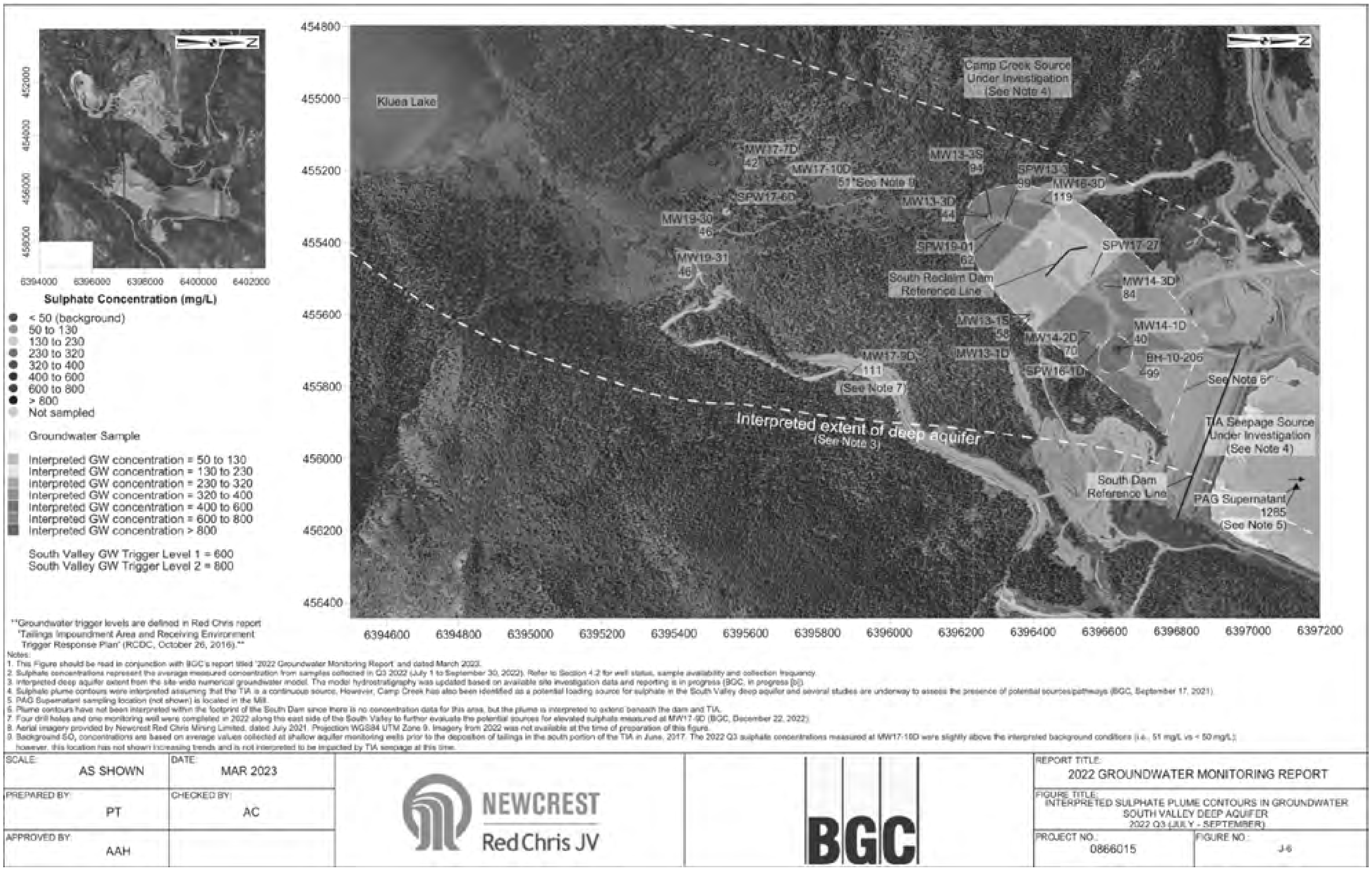
Figure S2. Contaminant plume map displaying interpreted sulphate (SO4) plume contours in groundwater in the deep aquifer north of the Red Chris Mine tailings facility. Point labels show the monitoring site and measured sulphate concentration in mg/L at that location. Contour shading indicates the estimated range of sulphate concentrations within that contour following the legend included in the image. Image copied from BGC (2023b), obtained by FOI request.



Notes:
1. This Figure should be read in conjunction with BGC's report titled '2022 Groundwater Monitoring Report' and dated March 2023.
2. Sulphate concentrations represent the average measured concentration from samples collected in Q3 2022 (July 1 to September 30, 2022). Only select drill hole locations are shown. Refer to Section 4.2 for well status, sample availability and collection frequency.
3. PAG Supernatant sampling location (not shown) is located in the Mill.
4. Plume contours have not been interpreted within the footprint of the South Dam since there is no concentration data for this area, but the plume is interpreted to extend beneath the dam and TIA.
5. Background sulphate concentrations are interpreted to be less than 90 mg/L in the Lower Trail Creek area. The 2022 Q3 sulphate concentrations measured at DP16-03, DP16-06, and MW17-7S were slightly above the interpreted background conditions (90 to 100 mg/L vs < 90 mg/L). However, these locations are not interpreted to be impacted by TIA seepage since sulphate concentrations do not show an increasing trend and do not show a concomitant increase in chloride.
6. Aerial imagery provided by Newcrest Red Chris Mining Limited, dated July 2021. Projection WGS84 UTM Zone 9. Imagery from 2022 was not available at the time of preparation of this figure.
7. Cross-section B-B' is presented in Figure J-7.

SCALE: AS SHOWN	DATE: MAR 2023	NEWCREST Red Chris JV	BGC	REPORT TITLE: 2022 GROUNDWATER MONITORING REPORT
PREPARED BY: PT	CHECKED BY: AC			FIGURE TITLE: INTERPRETED SULPHATE PLUME CONTOURS IN GROUNDWATER SOUTH VALLEY SHALLOW AQUIFER 2022 Q3 (JULY - SEPTEMBER)
APPROVED BY: AAH				PROJECT NO.: 0866015 FIGURE NO.: J-4

Figure S3. Contaminant plume map displaying interpreted sulphate (SO4) plume contours in groundwater in the shallow aquifer south of the Red Chris Mine tailings facility. Point labels show the monitoring site and measured sulphate concentration in mg/L at that location. Contour shading indicates the estimated range of sulphate concentrations within that contour following the legend included in the image. Image copied from BGC (2023b), obtained by FOI request.



Groundwater trigger levels are defined in Red Chris report 'Tailings Impoundment Area and Receiving Environment Trigger Response Plan' (RCDC, October 26, 2016).

Notes:
1. This Figure should be read in conjunction with BGC's report titled '2022 Groundwater Monitoring Report' and dated March 2023.
2. Sulphate concentrations represent the average measured concentration from samples collected in Q3 2022 (July 1 to September 30, 2022). Refer to Section 4.2 for well status, sample availability and collection frequency.
3. Interpreted deep aquifer extent from the site-wide numerical groundwater model. The model hydrostratigraphy was updated based on available site investigation data and reporting is in progress (BGC, in progress [b]).
4. Sulphate plume contours were interpreted assuming that the TIA is a continuous source. However, Camp Creek has also been identified as a potential loading source for sulphate in the South Valley deep aquifer and several studies are underway to assess the presence of potential sources/pathways (BGC, September 17, 2021).
5. PAG Supernatant sampling location (not shown) is located in the Mill.
6. Plume contours have not been interpreted within the footprint of the South Dam since there is no concentration data for this area, but the plume is interpreted to extend beneath the dam and TIA.
7. Four drill holes and one monitoring well were completed in 2022 along the east side of the South Valley to further evaluate the potential sources for elevated sulphate measured at MW17-9D (BGC, December 22, 2022).
8. Aerial imagery provided by Newcrest Red Chris Mining Limited, dated July 2021. Projection WGS84 UTM Zone 9. Imagery from 2022 was not available at the time of preparation of this figure.
9. Background SO_4 concentrations are based on average values collected at shallow aquifer monitoring wells prior to the deposition of tailings in the south portion of the TIA in June, 2017. The 2022 Q3 sulphate concentrations measured at MW17-10D were slightly above the interpreted background conditions (i.e., 51 mg/L vs < 50 mg/L); however, this location has not shown increasing trends and is not interpreted to be impacted by TIA seepage at this time.

SCALE: AS SHOWN	DATE: MAR 2023
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APPROVED BY: AAH	

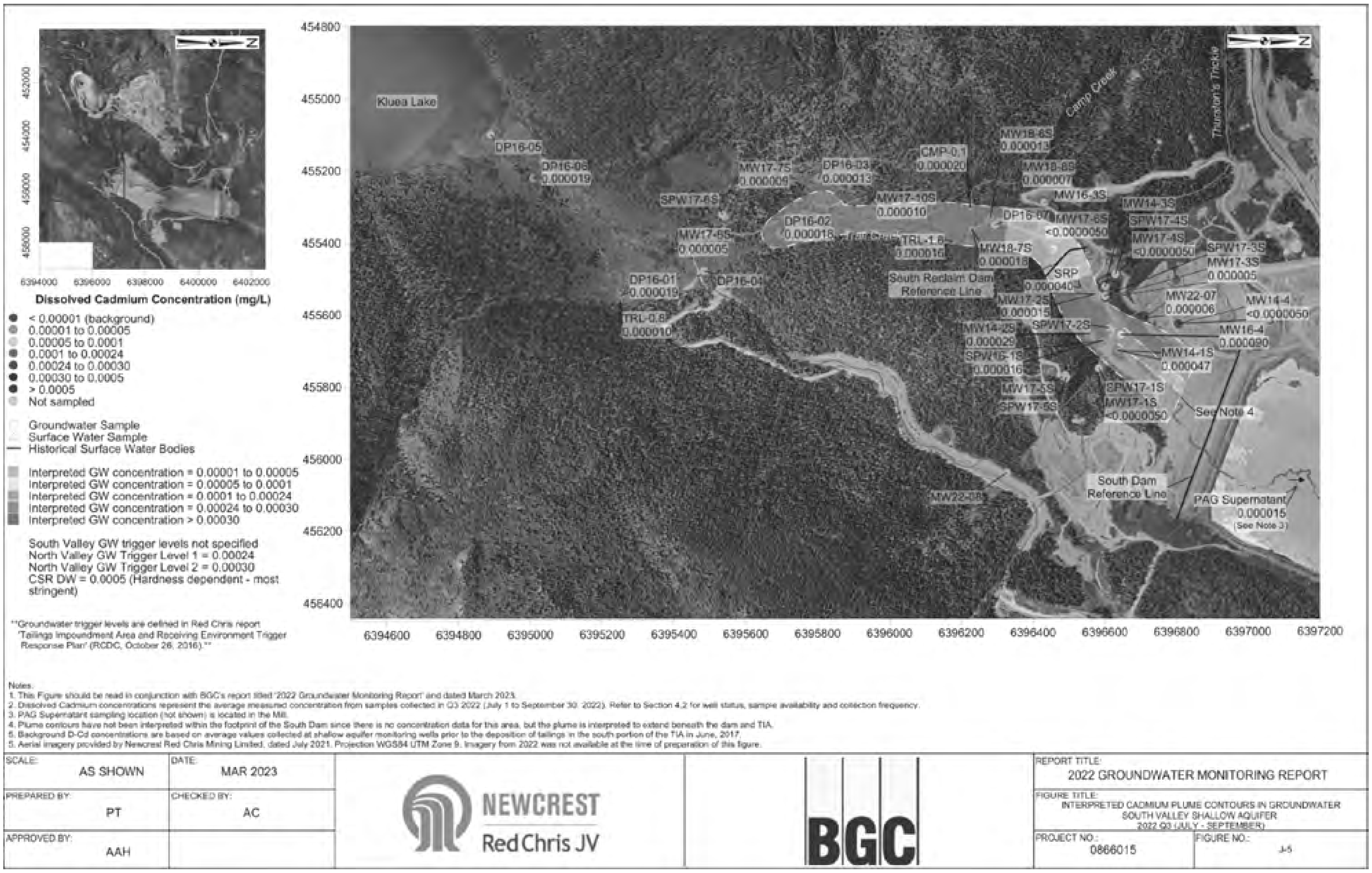
REPORT TITLE: 2022 GROUNDWATER MONITORING REPORT

FIGURE TITLE: INTERPRETED SULPHATE PLUME CONTOURS IN GROUNDWATER SOUTH VALLEY DEEP AQUIFER 2022 Q3 (JULY - SEPTEMBER)

PROJECT NO.: 0866015

FIGURE NO.: J-6

Figure S4. Contaminant plume map displaying interpreted sulphate (SO4) plume contours in groundwater in the deep aquifer south of the Red Chris Mine tailings facility. Point labels show the monitoring site and measured sulphate concentration in mg/L at that location. Contour shading indicates the estimated range of sulphate concentrations within that contour following the legend included in the image. Image copied from BGC (2023b), obtained by FOI request.



Notes:
1. This Figure should be read in conjunction with BGC's report titled '2022 Groundwater Monitoring Report' and dated March 2023.
2. Dissolved Cadmium concentrations represent the average measured concentration from samples collected in Q3 2022 (July 1 to September 30, 2022). Refer to Section 4.2 for well status, sample availability and collection frequency.
3. PAG Supernatant sampling location (not shown) is located in the Mill.
4. Plume contours have not been interpreted within the footprint of the South Dam since there is no concentration data for this area, but the plume is interpreted to extend beneath the dam and TIA.
5. Background D-Cd concentrations are based on average values collected at shallow aquifer monitoring wells prior to the deposition of tailings in the south portion of the TIA in June, 2017.
5. Aerial imagery provided by Newcrest Red Chris Mining Limited, dated July 2021. Projection WGS84 UTM Zone 9. Imagery from 2022 was not available at the time of preparation of this figure.

SCALE: AS SHOWN
DATE: MAR 2023
PREPARED BY: PT
CHECKED BY: AC
APPROVED BY: AAH
REPORT TITLE: 2022 GROUNDWATER MONITORING REPORT
FIGURE TITLE: INTERPRETED CADMIUM PLUME CONTOURS IN GROUNDWATER SOUTH VALLEY SHALLOW AQUIFER 2022 Q3 (JULY - SEPTEMBER)
PROJECT NO.: 0866015
FIGURE NO.: J-5

Figure S5. Contaminant plume map displaying interpreted dissolved cadmium (Cd) plume contours in groundwater in the shallow aquifer south of the Red Chris Mine tailings facility. Point labels show the monitoring site and measured dissolved cadmium concentration in mg/L at that location. Contour shading indicates the estimated range of dissolved cadmium concentrations within that contour following the legend included in the image. Image copied from BGC (2023b), obtained by FOI request.

SkeenaWild
CONSERVATION TRUST