

MEMORANDUM

To: Mr. Sanjay Barik, Technical Unit Manager, Central Region Water Quality Program, Washington State Department of Ecology

From: David Kliegman, Executive Director, Okanogan Highlands Alliance and Ann Maest, PhD, Buka Environmental

Re: Hydrologic Closure for the Buckhorn Mine

Date: October 3, 2016

1. Introduction and Overview

The purpose of this memorandum is to provide input and recommendations related to water management, reclamation, and closure of the Buckhorn Mine. The memorandum contains Okanogan Highland Alliance's (OHA) review of Crown Resources Corporation's (Crown) Hydrologic Closure Plan (the "Plan"), which consists of a cover letter by Kinross Gold Corporation (Kinross), the Czarnowsky Inc *Hydrologic Closure Plan*, and the Golder Associates Technical Memorandum, *Buckhorn Hydrologic Closure Plan*.

Kinross states in its cover letter that it is "committed to proper and appropriate closure" and has "completed many of its mitigation and closure commitments." However, the long history of permit violations and the ineffectiveness of mitigation measures installed to control mine contaminants does not instill confidence in these statements. In particular, any closure plan for the Buckhorn Mine must also include a plan to bring the mine into compliance with its current discharge permit, as described in the Department of Ecology (Ecology) Administrative Order #13638.

The cover letter states that Crown's objective is to expedite hydrologic closure with the goal of attaining state groundwater and surface water criteria. Ecology should immediately send this Plan back and require one that is premised on bringing water resources into compliance with the current National Pollution Discharge Elimination System (NPDES) permit limits rather than the generally less stringent state water quality criteria. Crown/Kinross is hopeful that its appeal of the permit will be successful, but the fact is that the current permit¹ is in force. Crown/Kinross must submit a closure plan that is acceptable to Ecology, and this requires that it use the current NPDES permit as its basis. OHA makes the assumption that authorized discharges will be required during closure. In our comments, we use the term "water quality criteria" to refer to numeric state surface water and groundwater quality criteria and "permit limits" to refer to numeric NPDES permit limits.

An acceptable closure plan should be well documented and unambiguous. The submitted Plan makes contradictory statements and lacks detail in the areas of water management, long-term water treatment, hydrologic control through the use of bulkheads, and the water quality inputs and justification for water quality predictions. It is doubtful that anyone currently working on the mine will be around by the time closure is complete to clarify the Plan's meaning and intent. As

¹ Waste Discharge Permit No. WA0052434, Effective Date: March 1, 2014; Modification Date: April 29, 2014; Expiration Date: February 28, 2019.

agencies tasked with protecting the public trust, the hydrologic closure plan represents the primary opportunity to ensure the long-term protection of water quality downstream and downgradient of the Buckhorn Mine.

Our primary points are listed below, and further discussion of the points can be found in our specific comments that follow and in Appendix A, from Pacific Groundwater Group, which address hydrogeologic issues related to mine closure.

- Incorrect Closure Goals: The Plan refers to compliance with state water quality criteria and ignores the requirement to meet permit limits. Because of this, the Plan should be immediately rejected and returned for revision so that it complies with the NPDES permit limits. This change will markedly increase the predicted time to compliance during closure. Additionally, the Plan primarily focuses on meeting applicable water quality criteria in the underground mine water and does not adequately address coming into compliance with the permit at all monitoring locations. Meeting permit limits as soon as possible should be a primary goal of the closure plan.
- Avoid Raising and Lowering Water Levels in Mine Workings: The 2006 Final Supplemental Environmental Impact Statement (FSEIS) considered it critically important to flood the Gold Bowl Zone (GBZ) as quickly as possible to avoid acid development. The current Plan would raise and lower the water table and do exactly what the FSEIS was trying to avoid. Insufficient analysis has been presented to determine the environmental consequences of this proposed water management approach. Raising and lowering the water levels in the GBZ and Southwest Zone (SWZ) workings through water management should be completely avoided. Raising and lowering water levels in areas with known higher sulfide content and low neutralization potential will cause and perpetuate the formation of acid drainage and the mobilization of metals and other mine-related contaminants.
- Water-Budget Neutral Recirculation: Conceptually, recirculation could be performed without drawdown during all stages of the natural groundwater-level variation, as it can be practiced in a “water-budget neutral” manner (rate of withdrawal = rate of replenishment).
- Oversimplified “Steady-State” Groundwater Elevation. The Plan refers to a post-closure steady-state groundwater elevation of 5,000 to 5,020 feet (ft) above mean sea level (amsl), which is essentially a single elevation value for the entire mine area. However, the steep topography of Buckhorn Mountain results in variable groundwater elevations over short distances. Therefore, estimates of the extent of mine workings and areas that will be completely inundated during post-closure are likely incorrect.
- Consequences of Bulkheads and Hydraulic Barriers: Poorly designed bulkheads have resulted in serious blowouts at a number of mines around the world, most recently and notably at the Gold King Mine in Colorado in August 2015. The unintended consequences of using bulkheads should be carefully examined in the final Plan. Pressurized bulkheads need bleed valves that will send mine water to treatment. Portals with bulkheads should not be backfilled until the desired water quality is achieved

because long-term management of bulkheads will likely be required. Using bleed values, in combination with treatment and discharge, could eliminate the need to raise and lower the water level in the workings and will allow for more controlled water management and improved water quality during closure.

- Recirculation Based on Unattainable Effluent Discharge Rate: The timeframe to meet water quality criteria asserted in the Plan is based on achieving a constant 200 gallons per minute (gpm) rate of flushing, a rate that is not supported by either the mine's historical effluent production or the known limits of the Mine Water Treatment Plant (MWTP). Based on information provided by Crown, the *inflow* to the MWTP operating as a two-pass reverse osmosis (RO) system seasonally fluctuates between 170-200 gpm and operates at an estimated 80 percent efficiency, resulting in effluent production of 136-160 gpm. The MWTP has never maintained a production of 200 gpm, even during the freshet. Furthermore, even though the outfalls have been approved for high discharge rates, the average annual effluent *discharge* rates achieved since the use of RO treatment began have ranged from roughly 50 to 70 gpm. Thus, the projected timeframe described in this Plan, including the seven flushes of the mine in the first year of flushing, is unrealistic and is contrary to the institutional knowledge gained from the previous years of operation at the mine.
- Poorly Detailed Plan: The submitted Plan is largely conceptual. A more detailed plan is needed before approval can be considered. Such a plan should include, at a minimum:
 - o a plan for operating the "MWTP during the rehabilitation and post closure phase" (such a plan is required 90 days in advance of closure, according to S-16 of the NPDES permit)
 - o the strategies and engineering specifics used to achieve goals
 - o metrics to determine when goals are met
 - o specific methods used to recirculate water (including points of withdrawal and delivery)
 - o the algorithm used by the water budget model along with schematic diagrams to illustrate volumes, flows, and decision points; and
 - o graphs of the model results (flow and volumes) vs. time.
- Treatment and Closure Phases: The existing MWTP should continue operating until the entire site meets permit limits, which would be through Phase 2 of hydrologic closure. Clear, numeric criteria are needed for the transition between the phases, and such descriptions are not present in the current Plan.
- Lack of Closure Adaptive Management: An Adaptive Management Plan (AMP) should be required for the closure and post-closure period. The options presented in the Plan may or may not work. A Closure Plan AMP is needed to provide clear direction for determining if closure is working as predicted and what actions should be implemented if various aspects of the closure plan do not produce the projected results.
- Poor Conceptual Model for Predictions: The predicted time to meet water quality criteria is based on a number of inputs and assumptions that are poorly defined. Errors in the

conceptual model will result in unrealistic predictions. The conceptual model used for predictions ignores or does not fully consider the following elements:

- the potential for acid drainage to develop in the mine workings and the damaged rock zone (DRZ)
- the underground mine as a potential source of contaminants to the NLF-3 fault zone
- the likely addition of flushed solutes from the workings, the DRZ, and other sources that would occur early in the mine flooding period and during each subsequent flushing cycle (when water levels rise)
- the movement of contaminants flushed into fractures and released slowly over time
- the inability of the treatment plant to consistently produce 200 gpm
- the need to pump and treat in excess of 200 gpm to lower mine water levels prior to the freshet; and
- the inapplicability of the Younger (2000) iron removal model for a completely flooded coal mine to predict mine cleanup due to different chemical behavior (especially oxidation-reduction response) of iron vs. non-metals such as sulfate and nitrate.

Because of these omissions, other issues detailed in our comments, and the application of incorrect water quality goals, the application of the Glover/Younger method will severely underestimate the time to meet closure water quality criteria for many mine-related contaminants both within the workings and the adjacent fractured bedrock aquifer and should not be used.

- Two Closure Plans. Having two closure plans, one from Czarnowsky and one from Golder Associates, is confusing. The cover letter does not describe the relationship between the two plans and does not even mention that there are two plans in “the Plan.” In places the Czarnowsky and Golder plans contradict each another. Crown should be required to submit an integrated, detailed, comprehensive plan for hydrologic closure.

A checklist for addressing these and other issues related to hydrologic closure of the Buckhorn Mine is included as Appendix B.

2. Specific Comment Regarding the Crown/Kinross Closure Plan by Czarnowsky Inc.

The following comments refer to sections in the Czarnowsky Inc. memorandum.

2.1 Introduction

The Buckhorn Mine’s permit was designed to maintain all mine-related contaminants within the capture zone, yet this fundamental objective was not accomplished during operation. Crown’s Plan states that “The overall purpose of hydrologic closure is to return the mine site to a condition where surface water and groundwater resources support the long-term post-mining land uses of the region.”

The Plan should include measurable objectives that clearly articulate what closure will achieve. A specific example of objectives includes: “Groundwater and surface water quality in all areas impacted by the Buckhorn Mine meets current NDPEs values.” In addition, the Plan should include strategies to reduce the further spread of mine contaminants into the environment.

2.2 Background

It is understandable that Crown/Kinross and its consultants would portray a history of the mine that puts the company in the best light possible, but for the purpose of developing an effective closure plan it is important to provide an even-handed portrayal of past events. This report section describes Crown’s stormwater controls as comprehensive, yet the effectiveness of the stormwater controls has not been evaluated. This is especially important for the leachate collection measures installed for the construction fill. A plan for analysis of stormwater monitoring data should be included in the closure plan so that the mass of contaminants captured and the effectiveness of the system are known. Without this information, the timing of removal of the stormwater facilities cannot be objectively determined.

Instead of “careful handling of development rock and ore material, use of shotcrete, cement backfill, lined sumps, and other measures,” as described in the Czarnowsky report, for most of the mine life, hundreds of thousands of cubic yards of waste rock and ore were stored on inadequate liners, and contaminants were spread outside the capture zone. Shotcrete was only applied to potentially acid generating (PAG) DRZ areas in capital headings and not in expense headings, as required, and this significantly reduced the effectiveness of the shotcrete program and will likely increase the closure time. Crown/Kinross finally did line the mine sumps with cement, but only after it became obvious that mine water was escaping capture. Many more examples could be cited of Crown/Kinross not employing management safeguards that are protective of the environment.

The Plan states that Crown will continue monitoring through the hydrologic closure and post-closure periods, yet the submittal proposes that monitoring frequency would drop dramatically, as shown in Golder Associates’ Table 5-1. The monitoring of most locations would drop from monthly to quarterly in Phase 2 of closure, yet this does not coincide with surface water or groundwater meeting “applicable criteria.” Monthly monitoring should continue until permit limits are reached. Monitoring frequency will be also be addressed in our comments on the Golder memorandum.

2.3 Hydrologic Closure Tasks (Section 4.0)

This section of the Plan focuses on returning the site to a hydrologic condition that complies with the “applicable regulatory framework.” It is unclear if the tasks, especially C-11 and C-12, are aimed at meeting state water quality criteria or current NPDES permit limits. Comments on selected closure tasks are included as follows.

Task C-2, Transfer of Selected Properties to Okanogan Land Trust: This part of the Plan is misleading. It states that conservation easements have been transferred. While that requirement may have been fulfilled, Crown/Kinross is required to transfer fee title to the properties, and this has not been done.

Task C-4, Stormwater Management and Controls: The different phases of Site Stormwater Reduction are not based on water quality. The Plan should include descriptions of which stormwater controls will be removed, and their removal should be based on meeting specific water quality benchmarks.

Task C-6, Underground Shotcrete Work: The agencies should require shotcrete to be placed on all exposed ore and PAG development headings above the long term water table. In addition, if the Plan includes drawing down water levels in the SWZ and GBZ annually, which OHA recommends against, shotcreting of all workings above the deepest extent of predicted mine pool drawdown should also be required.

Task C-7, Removal of Ore and Development Rock Stockpiles: This section states that the underlying liners will be rinsed, **and either** buried in place **or** removed from site. This kind of ambiguous language should be removed from the Plan. Removal of the liners should not be optional. The liners should be removed from the site. It is also likely that mine contaminants have permeated the soil and rock below the liners and that not all affected soils and rock have been removed. It is inadequate for the Plan to state (as it does) that “Crown does not anticipate contamination in the soils underlying the liners.” The soil and rock below the sub-liner material should be characterized for leachable metals, sulfate, and other mine-related contaminants and removed if they present an ongoing threat to groundwater quality.

Task C-8, Construction Fill Management: This section states that the majority of the construction fill will be used for regrading and that mineralized fill will be identified by a geologist. No detail is included on how the degree of mineralization will be characterized, and the implication is that a geologist will examine the material visually and make a decision in the field. All construction fill should be characterized for its acid generation and contaminant leaching potential, and decisions about final placement should be based on those results.

Task C-9, Operation of Dewatering Wells: More will be said on this subject when discussing Attachment A, but additional dewatering wells are needed within the capture zone to prevent the continued spread of mine contaminants.

Task C-10, Installation of Hydrostatic Bulkheads and Barriers: As OHA expressed in its initial scoping comments, the idea that a hydraulic barrier will effectively separate the SWZ from the GBZ needs more thorough analysis, including what the potential unintended consequences may be if it were successful (e.g., a blowout or development of mine-influenced seeps across the site). Considerably more detail is needed on the installation of the bulkheads between the SWZ and the GBZ and in the Main and Gold Bowl portals. See OHA’s Initial Scoping Comments (8-16-16), herein incorporated by reference. Crown has not made a convincing case or explained why they want a hydrostatic barrier between the GBZ and the SWZ. In addition, backfilling the portals to eliminate access will also eliminate access to the bulkheads, which will likely require maintenance over an extended period of time. Because of the potential adverse consequences, bulkheading is one of the most important issues in mine closure, and its

treatment in the Plan is entirely inadequate. If pressurized bulkheads are used, bleed values should be installed to allow greater control over water management and water treatment during closure and post-closure.

Task C-11, Water Management and Treatment: This section contains a crucial ambiguity that should be removed. The Plan states that Crown will continue operation of the existing onsite water treatment plant **and/or** other infrastructure to support hydrologic closure activities. The mine should continue operating the current highly effective MWTP until the mine water quality is certified by Ecology as meeting permit limits. Since it is now considered likely that the MWTP is not sited on contaminated construction fill, the MWTP should continue to operate at full capacity until the entire mine pool meets NPDES water quality limits. The Plan presented by Crown/Kinross separates closure into three phases. As written, the GBZ is projected to meet “approved” water quality, while the SWZ meets “improved” water quality. The SWZ of the mine should be required to meet the same permit limits as the GBZ. The tasks in the Czarnowsky phases are somewhat different from those in the Golder memorandum, and no clear numeric criteria separate the phases. A single, comprehensive closure plan should be submitted with clear phases, tasks, and goals. More comments on Golder’s water management approach will be addressed in the following section.

Task C-12, Water Monitoring during Closure: Crown proposes that the frequency of monitoring during closure would be reduced, even though criteria for the reduction are not clearly articulated. The Plan’s monitoring frequency would move from the current monthly water quality monitoring to quarterly during Phase 2 of closure, and again to semi-annually for an ever shrinking number of sites. Reduction in monitoring frequency and locations is warranted if water quality goals (NPDES permit limits) have been met for at least ten years, according to the only authorized Hydrologic Monitoring Plan (Golder Associates, 2009), but no clear criteria for reducing monitoring frequency and locations have been established in the Plan. Clear numeric criteria for moving from Phase 1 to Phase 2 and for reducing the frequency and locations of monitoring should be established in the final hydrologic closure plan.

2.4 Post Closure Tasks (Section 5.0)

Crown’s Plan contains no clear criteria for movement to Phase 3 (post-closure) of hydrologic closure. During post closure, the MWTP will be dismantled and the area reclaimed. An auxiliary treatment unit of similar capacity to the MWTP should be available if water quality degrades.

Rather than permanently closing all monitoring locations, Crown and Ecology should examine the possibility of another entity, such as the U.S. Geological Survey, Ecology, or OHA, retaining monitoring responsibility for a limited number of sites, with funding from Crown Resources and potentially other sources. Monitoring wells are especially expensive to install, and even limited monitoring of field parameters could provide important indications of changes in water quality over time. Long-term environmental data are useful for many purposes that may not be fully imagined at the time of post-closure.

2.5 Site Management and Personnel (Section 6.0)

The discussion of site management and personnel suggests that only one part-time person would be employed during post-closure. Having only one part-time person at the site is a safety issue and would not be sufficient to operate the auxiliary water treatment, if necessary. Additional personnel should be included. No mention is made of the use of consulting staff, such as Golder Associates, during post-closure, yet on-going monitoring will be required. The lack of careful thinking on post-closure management and personnel is reflective of the general lack of care and attention to detail throughout the submitted Plan.

3. Comments on Attachment A: Golder Technical Memorandum: Hydrologic Closure Plan

Our comments on the Golder Associates Hydrologic Closure Plan are addressed by section in their memorandum, as follows.

Introduction (Section 1.0)

- **Regulatory Compliance:** Golder’s hydrologic closure submittal states that “At closure, engineering controls will remain to ensure that water discharged to the environment will meet the required water quality criteria and water quantity limits, as defined in the applicable permits.” Fairly rapidly the memo devolves to focus on water quality criteria rather than applicable permit limits and makes no mention of the current and applicable NPDES permit. Ecology should immediately reject the submittal and insist that it be based on the current NPDES permit limits.
- **Schedule:** The submittal states that water treatment will be required “for a period of time” until applicable water quality criteria are met. Treatment should be maintained until all monitoring locations, including water in the underground workings, meet permit limits for ten years, as noted in the approved Hydrologic Monitoring Plan (Golder Associates, 2009).

Water Management Approach (Section 1.1)

Golder explains various aspects of the Buckhorn Mine water management system (WMS) that are designed to “maintain compliance during operations” but fails to mention that compliance has not been achieved during operations. This is an important factor that should be considered during closure. The current WMS at the mine has not been able to control unpermitted discharges; unless the WMS is expanded during closure, we expect that mine contaminants will continue to discharge to the environment outside the capture zone. Expansion of the water management approach would include adding water quality monitoring locations, by, for example, converting certain piezometers to monitoring wells, to track the fate and transport of contaminants; reporting water quality data from the construction fill stormwater trenches; and adding deep and shallow dewatering wells to intercept contaminants before they exit the capture zone.

We now know that many of the assumptions used in the groundwater flow model for the FSEIS were flawed, and additional dewatering wells were established to try to maintain the capture zone. However, throughout mine operations contaminants continued to escape the capture zone. It should be expected that as groundwater elevations are raised by filling the underground mine,

mine-influenced water would continue to escape capture by moving along faults and fractures in the bedrock. Ecology should insist that additional groundwater controls be established to ensure protection of the environment during closure until all groundwater meets applicable permit limits.

Golder opens a loophole by using the phrase “and/or” in the Phase 1 and Phase 2 descriptions of water management approach to closure: “Collect, treat, and discharge water from GBZ workings using existing *and/or new* infrastructure as needed.” As written, it could mean that Crown would install additional dewatering wells, or it could mean that Crown would use a mobile, one-pass reverse osmosis system, or even a passive treatment system. Ecology should insist that the existing high quality water treatment system be used until all water quality meets NPDES permit limits. These limits should apply equally to the GBZ and the SWZ workings. After hydrologic equilibrium is established, all water in the former workings will flow downgradient to areas outside the designated capture zone. Therefore, water in the former workings should meet NPDES limits during closure.

Phase 1: Golder’s Phase 1 water management approach is inadequately described: “To the extent practicable, [Crown will] maintain a consistent water elevation in the GBZ workings.” Yet, in other sections of the memorandum, Golder describes raising and lower levels in the GBZ (and even SWZ) workings annually. This is a rather large deviation from what was planned and analyzed in the FSEIS, which called for flooding the underground mine with water as quickly as possible to avoid the formation of acid drainage. The closure plan should include, to the extent practicable, an explanation of what the water elevations would be under various seasonal and climatic conditions and should identify, using cross sections or the 3D visualization tool, the ore and PAG development headings and DRZ areas that will be exposed to alternating aerated and inundated conditions. Alternatives to this approach, whereby the underground workings would remain inundated, should also be examined and described in the closure plan.

The end of Phase 1 is not clearly defined. An unambiguous, numeric condition should signal the end of Phase 1 and the beginning of Phase 2. We propose that the first bullet in Phase 2 be moved to be the last bullet in Phase 1. *When Gold Bowl water meets NPDES permit limits, Phase 1 will end.* Gold Bowl water quality will meet permit limits more rapidly if the workings remain flooded, even if recirculating with treated water, rather than raising and lowering water levels to accommodate the spring freshet. This issue is addressed in more detail in Appendix A from Pacific Groundwater Group. One option, proposed in the Czarnowsky memorandum (p. 8), is to add dewatering wells to the GBZ workings. The final closure plan should describe in detail the steps involved in reaching the end of Phase 1.

Phase 2: The Golder memorandum does also not clearly state what numeric values will be used to signal the end of Phase 2. The second bullet discusses continuing to collect, treat, and manage water from the SWZ but does not mention meeting applicable water quality criteria or permit limits. *We propose that Phase 2 should end when the Southwest Zone and all other monitoring locations meet NPDES permit limits.* Until that time, the existing water treatment plant should be maintained and used.

Phase 3: Phase 3 of the closure plan represents the post-closure period. The beginning and end of Phase 3 are not clearly defined in the Golder memorandum. *Phase 3 should begin when all water*

quality monitoring locations meet permit limits and should end when that water quality has been maintained for a period of ten years, as noted in the 2009 Hydrologic Monitoring Plan, which is incorporated into the NPDES permit by reference.

Golder Associates predicts the time to reach applicable water quality criteria using the Glover method, which was relied upon in the 2006 FSEIS (Volume III)². It is unlikely that this approach is applicable to the change in mine contaminant concentrations in the underground workings at the Buckhorn Mine during closure for the following reasons: 1) the Glover method does not account for inputs from acid drainage from the vadose zone, as noted in the FSEIS (p. 4 of the Golder August 16, 2006 memorandum), and we know from recent Development Rock Management Plan (DRMP) reports that underground workings (declines) in the GBZ and much of the SWZ contain areas above the long-term water table that are potentially acid-generating; 2) the Golder closure water management plan calls for raising and lowering the water level in both zones, but especially in the GBZ, and the Glover method applies to fully flooded workings; 3) the Glover method and the Younger (2000) reference examined the behavior of iron, and non-metals such as sulfate and nitrate will not respond as well or as quickly to inundation and changes in oxidation-reduction conditions as does iron. Additional comments on Golder's closure mine water quality predictions are presented in the section on water quality predictions.

Background (Section 2.0)

Facilities and Operations (Section 2.1)

Southwest and Gold Bowl Workings – Geologic Description (Section 2.1.1.1)

The overall sulfide content of the Buckhorn skarn is described as ~2% in ore and development rock. However, not all the rock mined is skarn, and the sulfide percent of much of the recently mined material is higher than 2%. As an example, in the First Quarter Water Year 8 DRMP report (Kinross Gold Corporation, January 2015), 41% of the rounds (from both the SWZ and the GBZ) tested had sulfide contents higher than 2%, and values were listed up to 13.35%. The reports states that in that quarter, 971 ft of PAG DRZ were exposed above the 4,950 ft elevation and no previously exposed PAG DRZ in development headings was shotcreted. The composite samples had sulfide sulfur contents higher than 2%, and all were identified as PAG after conducting acid-base accounting testing. The lack of shotcreting increases the long-term potential for the workings, declines, and DRZ areas – both above and below 4,950 ft elevation – to serve as an ongoing source of contaminants to groundwater after closure.

Shotcrete of PAG (Section 2.1.1.4)

This section describes what Crown has done regarding shotcreting of PAG rock but fails to describe what was required and what has not been done. This is relevant because it will affect the long-term closure of the mine. The DRMP required that shotcrete be applied to all PAG headings above 4,950 ft amsl (50 ft below the predicted post-closure water table). Crown unilaterally decided, against the opinion of Ecology, that only development (capital) headings needed to have shotcrete applied because cemented rock fill (CRF) was an adequate substitute.

As explained in Section 2.1.1.1 of the Golder memorandum, sulfides exist in both ore and development rock. The FSEIS described shotcrete passivation as mitigation that would reduce

² Attachment C: Golder Associates Inc., 2005c. Buckhorn Mt. Project – Prediction of Long-Term Mine Water Quality. August 16, 2005.

the amount of time it would take to achieve water quality. The decision to not shotcrete below 4,950 ft elevation was based on the assumption that there was a considerable lag time between the beginning of humidity cell tests and the production of acidic drainage. However, considering the time PAG rock has already been exposed in the GBZ and SWZ workings during mining *and* the time it will continue to be exposed to oxygen if water levels are continually raised and lowered in the workings, as proposed in the Plan, sufficient time will likely have elapsed to form acid drainage *below* 4,950 ft during closure. Results from recent humidity cell testing of CRF indicate that its buffering capacity decreases within a fairly short period of time (approximately one year in the tests). However, no testing has been done or is planned to determine if acid drainage is already forming in the exposed, unpassivated workings. The testing of these workings, using techniques such as acid-base accounting and wall washing, should be included in the Plan.

Crown's failure to passivate ore headings above 4,950 ft and PAG areas below 4,950 ft will lengthen the time it will take to close the mine. The closure plan should include information on the linear ft of PAG workings and headings shotcreted and not passivated above and below 4,950 ft elevation. This information should be used to estimate the potential addition of mine-related contaminants to the workings during closure and how these inputs would affect the time to meet closure goals.

Water Treatment (Section 2.1.2)

Golder describes the water treatment system as two separate systems, yet the main MWTP is a stand-alone system. The auxiliary water treatment system (AWTS) is just what the name implies – an auxiliary system. At times it has supplemented the MWTP, but at times it has not. To state that the MWTP and the AWTS can be considered one system continues the “and/or” ambiguity discussed previously in these comments. The statement that “in the future the AWTS may be maintained or another system meeting the required treatment capacity may be implemented” promotes uncertainty. The closure plan should provide a clear and more detailed description of the treatment approach that will be used during closure and post-closure. The AWTS is not a stand-alone system, it is a single-pass RO with half the capacity of the WTP. Using the auxiliary system during closure would increase the time needed to clean up the mine, and Ecology should reject this approach.

Further, and as noted in Appendix A by the Pacific Groundwater Group, the Buckhorn treatment system has not been able to consistently treat 200 gpm. The inability of the current system to treat 200 gpm affects Golder's estimates of the time to meet closure goals because the predicted number of rinses will not be possible. To change the treatment system to an auxiliary system that will treat even less mine water will increase the time to meet closure goals even further.

Water Quality Criteria (Section 2.1.4)

This section describes Washington State groundwater quality criteria (WAC 173-200) and surface water criteria (for aquatic health, WAC 173-201A) but includes a caveat that they “are presented as reference points for water quality discussions.” This misleading statement adds confusion to what the numeric cleanup goals should be for closure. This fatal flaw continues throughout the submittal. Water quality during closure should meet NPDES permit limits. The submittal should be immediately rejected by Ecology so that Crown has sufficient time to correct the problem and meet the permit timeframe for submitting an approvable closure plan.

Potential Sources and Water Quality (Section 2.2)

This section begins with a statement that water quality in the vicinity of the Site *may have been* affected by mining and other activities. The numerous permit violations and administrative orders from Ecology, and an examination of the available information, make it clear that water quality has been adversely affected by mining activity. For example, no mention is made of water quality impacts from the development rock stockpiles that have been identified as mine-related contaminant sources by Golder in several of its own reports. While the development rock and the ore are “naturally mineralized,” the use of this term implies that Crown’s blasting and deposition of development rock and ore on the surface had nothing to do with the release of contaminants from these materials. The leaching of contaminants has also occurred from the construction fill, which has been identified by Crown as a mining-related contaminant source, and they have undertaken a number of actions to minimize its impact on water quality. Similarly, when the ion-exchange system was in use, state water quality criteria were regularly exceeded. A more realistic description of mining-related impacts would address ongoing permit violations outside the capture zone and should include approaches to attain compliance with the NPDES permit. Subsequent sections in the Golder memorandum do discuss mining-related sources, but their effect on water quality is minimized by the language used.³

Golder also lists locations that will not meet applicable water quality criteria at the end of mining. Many surface water and groundwater locations that are out of compliance with the NPDES permit are not included in this list. If Crown has a plan to bring these sites into compliance, as required by Administrative Order #13638, it should be discussed. Otherwise, these sites should be added to the list, and an approach for managing them during closure should be added to the Plan.

Ecology should require a closure plan that realistically examines the fate and transport of contaminants at the Buckhorn Mine site. In order to understand the sources and movement of contaminants affecting water quality at the Site, it would be helpful to create a realistic list of potential sources and pathways in the Plan and then examine the effectiveness of actions to minimize contaminant movement and the effects on water quality. Some examples of sources and pathways include:

- Development rock and ore stockpiles – The FSEIS considered that contaminants would migrate vertically into the mine pool and be captured by dewatering wells. Contaminants have also been hypothesized by Golder to travel horizontally through fractured bedrock to monitoring locations outside the capture zone. In the last years of mining, a synthetic liner was installed to minimize this contaminant flowpath. Although some soil and rock below the pile was removed, the rock remaining below the stockpile has not been characterized for leachable contaminants.
- Underground mine and the DRZ – The FSEIS considered the underground mine as a potential source, which the dewatering wells were supposed to capture. A comparison of water levels in dewatering wells and nearby piezometers indicate that dewatering wells

³ e.g., for Marias Creek water, on p. 14 of the Golder memorandum: “With the exception of a period between 2012 and 2013 when nitrate concentrations in JJ-14 and JJ-26 increased to approximately 3 mg/L (below the groundwater quality criterion of 10 mg/L), the stations are not influenced by site operations.” Again, exceedences of the applicable permit limits are not mentioned. The nitrate permit limit for groundwater and seeps is 1.33 mg/L.

are not effective in producing a capture zone around the workings and the associated DRZ.

- Preferential pathways - Uncertainties exist about the locations and importance of all faults and fractures that serve as preferential pathways for contaminants. In 2010, D-10 (now MW-17) was drilled inside the capture zone to intercept contaminants in the NWF-1 fault. It currently is being pump tested and is intercepting contaminants that would have been escaping the capture zone. It is likely that additional dewatering wells strategically placed in faults could also reduce the spread of contaminants.
- Construction fill – Construction fill is a type of development rock that is currently affecting water quality. In 2007, Ecology made it clear that Crown was not permitted to discharge pollutants from construction activity and ordered any development rock that could leach contaminants to be placed on liners. Crown should have characterized construction fill before it was used to ensure that it would not leach contaminants.

This section states that stormwater will be collected and tested prior to discharge. The Plan should require testing and reporting of stormwater quality and volumes, and this requirement should be added to an updated Hydrologic Monitoring Plan (HMP) and an updated Stormwater Pollution Prevention Plan (SWPPP).

Operational Groundwater Quality Monitoring (Section 2.2.2) and Operational Local Surface Water and Groundwater Quality Monitoring (Section 2.2.3)

For discussion purposes, Crown's Plan compares measured operational water quality data to Washington State groundwater and aquatic life criteria (Section 2.1.4) However, the discussion should instead be focused on the applicable NPDES permit limits, which Crown should assume will apply during closure. As stated previously, because of this fatal flaw, the Plan should be immediately rejected by Ecology. Crown should be required to submit a closure plan that compares water quality concentrations and predictions to the applicable limits in the NPDES permit.

NWF-1/NLF-3 Fault Zone Groundwater (Section 2.2.2.4)

This section states that pump testing of MW-17, which was installed in 2013, is being conducted to better understand groundwater flow in the area. The MW-17 pump test has been underway for over a year. Crown/Golder may not have concluded testing, but MW-17 monitoring data should be included in Appendix E or F; water quality data have not been made publically available since November 2014. Since the pump test began, contaminant concentrations in some of the nearby wells have decreased, suggesting that strategic placement of dewatering wells in the faults could help attain compliance. In addition, piezometers in this area should be converted to water quality monitoring points to increase the understanding of contaminant flow paths.

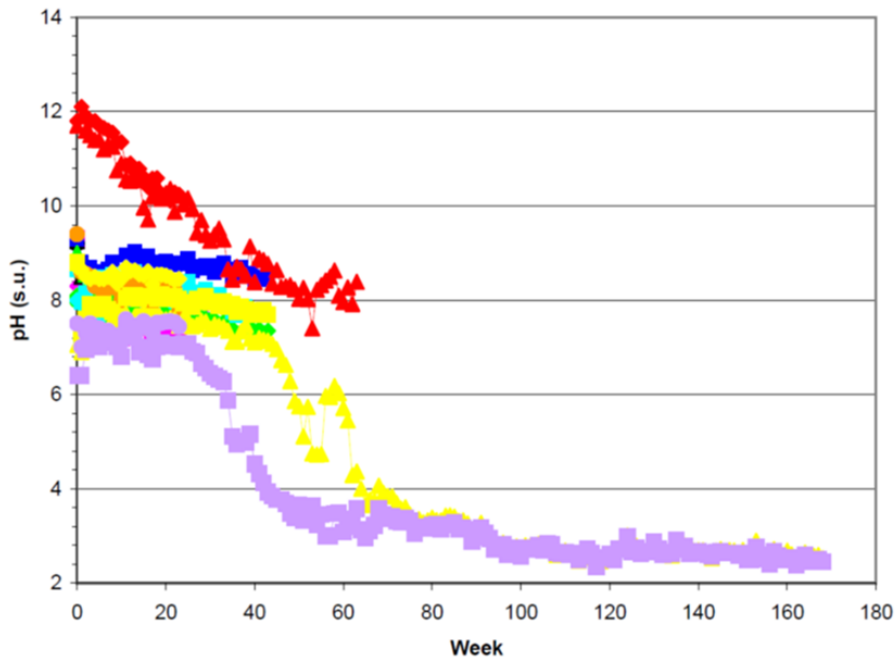
South and North Fork Bolster Creek (Sections 2.2.3.6 and 2.2.3.7)

The description of water quality changes over time in the Golder memorandum suggests that conditions are improving in these drainages. However, nitrate and chloride concentrations have been increasing in SW-11 in North Fork Bolster Creek, and it is not clear that values are consistently decreasing in South Fork Bolster Creek. The water quality in these locations and others that exceed permit limits should be discussed in a transparent manner, and approaches to bring them into compliance should be included in the Plan.

Geochemical Testing (Section 2.2.4)

Unlike the statements on p. 14 of the Golder memorandum, the long-term effectiveness of the CRF as a neutralizing agent has not been confirmed by the kinetic testing or by field conditions. On the contrary, the kinetic testing results of the CRF show that initial pH and alkalinity values are high, as they are currently in water from the mine sumps, but pH and alkalinity decrease after about one year of kinetic testing to levels that are similar to those in uncemented materials.⁴ Cemented fill is continuing to be added to the underground mine, so we may not see a lowering of buffering capacity until the mine is in the closure period. In addition, arsenic and uranium concentrations have increased somewhat in recent CRF kinetic testing results, suggesting that the leaching of at least some contaminants may not be improved by cementing the waste rock.

While it is true that only two samples during FSEIS testing produced acidic leachate, the memorandum fails to mention that these were the only tests carried out for longer than one year, as shown in the following figure from the Golder Associates, 2007, Kinetic testing update: Week 165. The figure also shows that the relatively rapid decrease in buffering ability of the CRF was known before mining began.



Based on the results from kinetic testing, at least under the aerobic conditions of the test, the cement added to the underground mine cannot reliably control acid drainage over the long term. In addition, many parts of the mine are not filled with CFR and contain only waste rock with varying sulfide content and ability to generate acid and leach metals. Mine sump water contains elevated concentrations of certain metals (e.g., copper, arsenic [especially in the SWZ], chromium, lead, manganese, and zinc) and occasionally very high levels of petroleum hydrocarbons (measured as oil and grease) from the use of ammonium nitrate-fuel oil (ANFO) as a blasting agent. Oil and grease values in mine sumps have not been reported for over two years,

⁴ See, e.g., Golder Associates, 2007, Kinetic testing update: Week 165 and Golder Associates, 4th Qtr 2014 DRMP Report.

but values in the GBZ sump were as high as 2,820 mg/L in 2013. The results from kinetic testing and water quality sampling in the mine sumps suggest that the underground mine and downgradient locations will need to be carefully managed and frequently monitored throughout the closure and post-closure period.

Water Management - Water Balance Model (Section 3.0)

More detailed comments on this section are contained in Appendix A by the Pacific Groundwater Group.

The water balance approach in the Crown/Golder Closure Plan is **unacceptably** vague. It discusses model results but not the operational conditions that would drive actual conditions. It models one scenario when numerous possible conditions exist.

One assumption relied on by the model is that the MWTP would be able to produce effluent at a rate of 200 gpm. As discussed elsewhere in these comments, this rate is not attainable by the current MWTP. In addition, for the first few years of closure the mine pool will be filling. The intensive rinsing described in the Plan would only occur for two months of the year. For the other 10 months, the mine pool is proposed to be drawn down to make room for the spring freshet. Consequently, treated water will need to be discharged to the outfalls for an extended period of time during closure under the proposed scenario, and the NPDES permit will remain in force.

Underground Workings Water Management During Closure (Section 3.6)

As noted on the bottom of p. 24 of the Golder memorandum, the Younger (2000) model assumes no additional input of contaminants to the underground workings. As noted previously in our comments, this assumption is invalid if the proposed closure approach for the GBZ workings is carried out. Because water levels would be raised and lowered in the GBZ, a “first flush” of contaminants would occur each time water levels rise again. To account for the additional constituent input, Golder very unconservatively assumes a 95% reduction for ten pore volumes of treatment and recirculation. Results from mines with similar geochemical conditions and closure approaches should be examined to help estimate the time needed for recirculation and treatment. The majority of the GBZ workings are well below the long-term water table, and this zone has the best potential to return to near-baseline conditions. However, instead of flooding the workings and leaving them flooded, the Plan proposes to raise and lower water levels and promote the formation of acid drainage and enhanced metal leaching.

There is good reason the Golder memorandum contains the disclaimer that the return to baseline conditions in the GBZ workings will “depend(ing) on time to reach equilibrium water level, climatic conditions and the residual concentration of constituents released from the backfill and exposed rock.” These caveats are so extensive as to render the model meaningless.

As noted previously in our comments, treatment should not cease until NPDES permit limits are maintained for a period of ten years.

Water Quality Predictions (Section 4.0)

The water quality predictions in Section 4.0 of the Golder memorandum are based on a return to

state water quality standards rather than the applicable NPDES permit limits. Ecology should immediately send the Plan back to Crown to be revised and based on NPDES permit limits.

Estimated Time for Water Quality to meet Surface and Groundwater Quality Criteria Post Mining (Section 4.1)

Golder predicts it would take one to three years to fill the GBZ underground workings to the estimated post-closure water level, depending on climatic conditions, and recirculation over a one-year period will result in the exchange of up to seven pore volumes in the GBZ workings and up to one pore volume in the SWZ workings. These estimates are inconsistent with the proposed plan to lower the mine pool to accommodate the spring freshet each year during closure.

Golder is using the Glover (1983) and Younger (2000) models to predict closure water quality, and, as noted previously in our comments, these approaches are not relevant to the methods proposed for closure of the Buckhorn Mine. Table 4-1 in the Golder memorandum shows that they only predict the time to meet water quality criteria (that is, state water quality standards) for pH, total dissolved solids (TDS), ammonia, and nitrate in the GBZ and SWZ workings and the dewatering wells. Even though TDS is derived largely from sulfate, it presents no estimates for attainment of sulfate criteria. It also provides no estimates for attainment of iron criteria, even though the Younger (2000) model is only based on iron. Although it says on p. 25 that the table includes estimates for Gold Bowl Creek, it is not included in Table 4-1.

A more recent article published by Younger and Robins in 2002⁵ emphasizes that Younger's 2000 article "cannot be regarded as being anything more than a 'first approximation.'" Yet Golder is applying a model that is based on iron concentrations in a completely flooded underground coal mine to estimate rebound values of pH, TDS, ammonia, and nitrate at a metal mine in workings that are proposed to be continually drained and filled (GBZ) and those that are largely above the long-term water table (SWZ).

Water quality information from the literature or other reliable sources for mines with similar hydrogeologic and geochemical conditions should be used to help estimate closure water quality, and a commitment should be made to continue treatment until all mine-related contaminants meet applicable NPDES permit limits for a period of ten years. Hydrologic closure should be a process that is driven by small, applied research projects that are specific to the mine site, and by adaptive management. The final closure plan should include a Closure Adaptive Management Plan that will help ensure protection of downgradient and downstream state waters.

Hydrologic Monitoring Recommendations (Section 5.0)

This section states that "closure will continue until the cessation of WTP operations." This should be corrected to read that the MWTP will continue to operate throughout closure. The closure plan should clearly articulate that the post-closure period will last until water quality limits have been consistently met for ten years, and that if water treatment is needed, a treatment system capable of maintaining NPDES permit limits will be used.

⁵ Younger, P.L. and Robins, N.S., 2002. Challenges in the characterization and prediction of the hydrogeology and geochemistry of mined ground. In: Younger, P.L. & Robins, N.S. (eds) 2002. Mine Water Hydrogeology and Geochemistry. Geological Society, London, Special Publications, 198, 1-16. Available: <http://sp.lyellcollection.org/>

Table 5-1 lists the proposed hydrologic closure monitoring schedule. Monitoring is generally proposed to decrease to quarterly during Phase 2 of closure, with a decreased list of sites and parameters, and to decrease to semi-annually during Phase 3. During Phase 1 of closure, monitoring should continue according to the NPDES permit. During Phase 2 of closure, monthly monitoring should continue at all sites that do not meet NPDES limits, for the parameters that do not meet the limits. Any monitoring site/parameter that maintains NPDES permit limits for five years may be reduced to quarterly monitoring and discontinued after ten years, upon approval from Ecology.

Other Comments

Additional comments on the Plan are based on our scoping comments for hydrologic closure that were not addressed.

Bulkheads and Unintended Consequences: The Buckhorn Mine operates in a fractured bedrock environment. Any assumption that a bulkhead or hydraulic barrier alone will effectively separate the SWZ from the GBZ needs more thorough analysis, including what the potential unintended consequences would be if it were successful (e.g., a blowout or development of mine-water seeps across the site). One should examine the problems with bulkheads experienced at two mines in Colorado: most recently, a bulkhead that was built at Kinross's Sunnyside Mine that flooded the Gold King Mine, and in the 1990s, a bulkhead approach at the Summitville Mine resulted in the creation of numerous contaminated seeps after closure that were difficult to collect and treat.⁶

Sediment Quality: Mine water has entered Gold Bowl Creek and North and South Fork Bolster Creeks for a number of years. However, no testing of stream sediment has been conducted in any of these streams. Habitat condition and stream sediment quality (for mining-related metals) should be conducted as part of reclamation and closure to evaluate whether these discharges have adversely affected stream habitat. Testing of stream sediments and stream reclamation should be included in the final Mine Closure Hydrologic Reclamation Plan.

⁶ See, among other sources: US Geological Survey, 2015. Technical Evaluation of the Gold King Mine. Available: <https://assets.documentcloud.org/documents/2475483/technical-evaluation-of-the-gold-king-mine.pdf>. In Appendix B, this document contains a non-exhaustive listing of the use of hydraulic mine bulkheads from the late 1950s to 2005 and issues associated with the bulkheads.

**Appendix A. Technical Memorandum, Pacific Groundwater Group, September 29, 2016:
Review of Hydrologic Closure Plan for the Buckhorn Mine (September 2016).**

Technical Memorandum

To: David Kliegman, Okanogan Highlands Alliance (OHA)
Ann Maest, Buka Environmental

From: Peter Schwartzman – Pacific Groundwater Group (PGG)

Re: Review of Hydrologic Closure Plan for the Buckhorn Mine (September 2016)

Date: September 29, 2016

1.0 INTRODUCTION

This memorandum provides comments based on PGG's review of Kinross Gold Corporation's (Kinross) September 19, 2016 submittal of two documents relating to hydrologic closure of the Buckhorn Mine: *Hydrologic Closure Plan* (Czarnowsky Inc.) and *Technical Memorandum, Buckhorn Hydrologic Closure Plan* (Golder Associates). PGG's comments are considered to be preliminary given the short (one-week) period available for review. More detail can be provided at a later date if needed.

2.0 SUMMARY OF MAIN POINTS

1. The submitted hydrologic closure plan does not employ the regulatory water quality limits set up in the current NPDES Permit and will need to be revised using those values.
2. The hydrologic closure plan (i.e. both documents) is presented on a purely conceptual level and is therefore neither useful for rigorously guiding actual closure operations at the mine nor will it allow a rigorous review of the proposed closure approach. The provided documentation is insufficient and is missing description/definition of key elements such as:
 - a. Goals of closure;
 - b. Strategies and guidelines to achieve goals;
 - c. Metrics to determine when goals are met;
 - d. Algorithm used by the water budget model;
 - e. Schematic diagrams to illustrate volumes, flows and decision points; and
 - f. Graphs of model results (flows and volumes) vs. time.
3. The methods and approaches for achieving water recirculation are poorly explained and sometimes inconsistent.
4. While there is discussion of maintaining a high water level in the Gold Bowl workings, the practice of drawdown prior to the freshet does not accomplish this goal. Instead it exposes

rock faces within the workings to oxidation and further mobilization of contaminants. No justification is provided for this proposed practice.

5. Conceptually, recirculation could be performed without drawdown during all stages of the natural groundwater-level variation, as it can be practiced in a “water-budget neutral” manner (rate of withdrawal = rate of replenishment).
6. The water-budget model is used to estimate cleanup times for the mine workings; however, it does not account for the fact that cyclic drawdown and refilling of the workings (changes in water level) would likely generate more contaminants (per above).
7. The hydrologic closure plan appears to focus on cleanup of the workings and the sumps but includes almost no mention of cleaning up the contaminants that have been (and would continue to be during cyclic flushing) driven out from the mine workings into fractured bedrock aquifer. This contaminant pathway is rarely acknowledged.
8. Whereas the hydrologic closure plan does mention maintenance of a groundwater capture zone, evidence presented to date (water-level and water-quality data) do not confirm that a true capture zone has been achieved.
9. The hydrologic closure plan refers to prior model predictions of the post-closure steady state groundwater elevation at 5,000-5,020 feet amsl. This is essentially a single elevation value for the entire mine area that does not consider the following conditions: 1) the steep topography of Buckhorn Mountain will affect the water table and how it intersects the mine workings, and 2) seasonal water-table variation is significant and is likely not accounted for in the prior steady-state modeling effort.
10. The hydrologic closure plan seems to rely on a recirculation rate of 200 gpm, which appears to be constrained by the capacity of the treatment plant. Historic records show that the treatment plant rarely reaches this capacity. Furthermore, if 200 gpm of recirculation is maintained during the pre-freshet “drawdown” phase, a total pumping/treatment rate in excess of 200 gpm will be needed to facilitate drawdown.
11. Discussion of groundwater quality in the NLF-3 Fault Zone points to infiltration of contaminated stormwater near MW-14 as the sole source of contamination to the fault zone. It does not discuss groundwater flow from the mine workings through the bedrock towards the zone, which is possible based on hydraulic gradients, as a potential source.

3.0 COMMENTS ON “HYDROLOGIC CLOSURE PLAN” BY CZARNOWSKY INC.

- A. While Crown does not anticipate contamination of the soils underlying liners for stockpiles, testing would be appropriate to confirm this assumption (Section 4.7). It also seems reasonable to treat construction fill like other PAG rocks and include testing of soils underlying this material as well (Section 4.8).
- B. Regarding installation of a hydraulic barrier between the Gold Bowl and Southwest workings, the potential for a blowout should be examined (Section 4.10).
- C. Description of the first phase of the water management program describes “restoration of groundwater equilibrium.” The natural groundwater condition is one of dynamic equilibri-

um; however, the natural equilibrium will not be restored during closure if additional dewatering (drawdown) and refilling of storage is conducted, as planned.

4.0 COMMENTS ON “BUCKHORN HYDROLOGIC CLOSURE PLAN” MEMO BY GOLDER ASSOCIATES

1. The definition of “water recirculation” (Section 1.1) remains unclear throughout the document, partly due to the lack of illustrative schematic diagrams, expected seasonal water management schedules, and “water balance model” explanations and quantitative results. Recirculation is initially defined as “temporary and/or seasonal,” yet other descriptions within the memo seem to imply a constant recirculation (e.g., Phase 1 goal of maintaining a “consistent water elevation” in the Gold Bowl workings on p. 3). In addition, the approach and locations for adding clean water during recirculation are never discussed or related to the points of pumping withdrawal (the Czarnowski report mentions new wells drilled down to the sumps, but this is not mentioned in the Golder memo).
2. The memo refers to model predictions of the “post-closure *steady-state* groundwater elevation” at 5,000-5,020 feet amsl (Section 1.1). This is essentially a single elevation value for the entire mine area which does not reflect real factors such as: 1) topographic influences on the water table (e.g., drop-off towards the flanks of the mountain) that could affect plans for keeping PAG rock underwater, and 2) the fact that a steady-state modeling analysis does not capture natural variation and therefore would not illustrate the seasonal lowest groundwater elevation expected under natural variations of recharge (e.g. driven by spring freshet).
3. Section 1.1 describes the maintenance of a capture zone to contain groundwater contamination by pumping of dewatering wells and sumps. This suggests contaminant sources include the workings; however, other sections of the memo seem to solely mention stormwater infiltration as the source of groundwater contamination. Lack of acknowledgement of contamination from the workings into the fractured bedrock aquifer is problematic throughout the memo. While this source is rarely stated directly, some statements imply its existence (e.g., “Groundwater inside the capture zone will therefore reflect both a mixture of native groundwater quality from meteoric contributions and water within the underground workings...” on p. 4). Furthermore, groundwater elevation maps generated by Golder have not demonstrated the formation of a hydraulic capture zone that keeps contaminated groundwater within the designated NPDES capture zone boundary.
4. In several instances, the memo mentions controlling groundwater levels (or water levels in the workings) associated with recharge from the spring freshet. There is discussion of maintaining a high water level in the Gold Bowl workings; however, this is contradicted by the proposed practice of drawdown prior to the freshet. Cyclic drawdown and refilling expose rock faces within the workings (and the adjacent damaged rock zone) to oxidation that could further mobilize contaminants. No justification is provided for the proposed cycles of drawdown and refilling. Conceptually, recirculation could be performed without drawdown during all stages of the natural groundwater-level variation, as it can be practiced in a “water-budget neutral” manner (rate of withdrawal = rate of replenishment). The plan does not provide justification for practices that create artificial pre-freshet storage, nor does it state why “rejected recharge” associated with the freshet (i.e. more runoff at the land surface) should be avoided.

5. The discussion of Phase 2 (pages 3-4) does not mention recirculation in the Southwest workings. However, it seems reasonable to assume that the same reclamation approach will be used for the Southwest Zone workings as for the Gold Bowl. More information is needed.
6. The first mention of cleanup times notes that “concentrations in the underground workings will halve with each pore volume” (p. 4). However, this assumption is not substantiated by calculations anywhere within the memo. A quick review of the abstract associated with Younger 2000 shows that the cleanup times predicted in this article are based on empirical observations of reductions in iron concentrations over time, and are based on mines that rebound such that they regain discharge to local streams (i.e. no mention of seasonal drawdown and replenishment in this version of recirculation). Even if the Glover (1983) approach is analytical rather than empirical, calculations should be provided that support estimation of cleanup times. For instance: 1) given seasonal water-level variation, what volume of workings was assumed to be subject to recirculation; 2) do the cleanup time estimates rely on continuous flushing or period dilution by intermittent inflows of clean(er) water; and 3) what assumptions were made about mixing during recirculation? In addition, the cleanup time estimates appear not to consider the addition of new contaminants that will likely result from periodic cycling of water-levels within the workings (see #4 above).
7. While discussion of “Potential Sources and Water Quality” (Section 2.2, first set of bullets) does mention the construction rock fill, it omits mentioning previous onsite storage of PAG development rock and ore. Also, while it does list “weathering of naturally-mineralized bedrock,” it does not explicitly relate this process to the large amount of new surface area created within the mine workings and the damaged rock zone. Omitting mention of weathering from newly created rock surfaces is similarly exemplified on the bottom of p. 10: “The primary influences on groundwater quality at the Gold Bowl dewatering wells are likely infiltration through the development rock and ore stockpiles, infiltration of stormwater through mineralized construction rock fill and infiltration of stormwater runoff.”
8. During review of the description of existing water quality, several instances were noted where statements were inconsistent with the data plotted in the appendices. For instance, one example occurs in Section 2.2.2.2, which notes that chloride concentrations are elevated in Well SDW-12 (not shown on Figure D-11). All discussion of water-quality data should be repeat fact-checked against the graphs, and other remaining errors corrected.
9. Discussion of groundwater quality in the NLF-3 Fault Zone points to infiltration of stormwater near MW-14 as the sole source of contamination to the fault zone. It does not discuss groundwater flow from the mine workings through the bedrock towards the zone, which is possible based on hydraulic gradients, as a potential source.
10. The water balance model is not sufficiently documented. Its assumptions, rules, algorithms, feedbacks and criteria are either poorly stated or (more commonly) unstated. There is no schematic to demonstrate the algorithm, limitations in flows, volumes and capacities. The timing of management actions is described, but with some lack of specificity and is not illustrated graphically. Model results showing the expected function of the system, including seasonal changes in flow, pumping, storage, treatment, discharge are not presented. There is no documentation that the model achieves a mass balance. There is no description of what the goal of the modeling is (i.e. what it is trying to illustrate) or the goals of the management approaches built in to the algorithm. The model domain is not defined (e.g., mine workings as

opposed to fractured bedrock aquifer). There is no statement of model limitations or uncertainty. All of these ingredients are common to modeling reports, either as text within the report or referenced to published documentation of model algorithms. In this case, given the general lack of documentation, the reader is asked to “just believe” in the model, with no opportunity for rigorous review.

In addition to the key points above, several specific (non-exhaustive) questions regarding the water balance model include:

- a. What is the model domain? Is it limited to the mine workings? How is cleanup of contamination in the fractured bedrock aquifer evaluated?
 - b. How is infiltration of stormwater tracked in the model?
 - c. What are the sources and mechanisms for recirculation inflows? Wells? Freshet? Other pathways?
 - d. What is the implication of assuming higher-than-average inflow during the freshet? Is this employed to demonstrate that the model predicts that mine water can be managed at available pumping and treatment rates? (*See prior comment about stating model objectives.*) Does the assumption of higher-than-average inflow overestimate the amount of system flushing that might be achieved?
 - e. Model assumptions (Section 3.3) include a recirculation rate of 200 gpm. Is this a maximum seasonal recirculation rate or a constant recirculation rate? The model description is inconsistent about this (for instance, p. 22 states that “the water management scenario modeled assumes continual re-circulation to the Gold Bowl Zone at a recirculation rate of 200 gpm”). What is the source of the recirculation at any time and where is it added to the system? The seasonal variation of pumping withdrawal and recirculation inflow should be described. If a recirculation rate of 200 gpm is to be achieved during a drawdown period prior to the freshet, a total withdrawal/treatment rate in excess of 200 gpm would be required and would thus likely exceed the capacity of the existing treatment plant. If this is the case, the existing treatment plant and additional treatment capacity could be required simultaneously during the drawdown phases of closure.
 - f. The description of how freshet inflows were estimated discusses using annual treatment plant and dewatering well volumes (p. 21). Clearly, annual volumes are not “freshet” volumes. Is the intent here to overestimate the freshet inflow for the purpose of modeling conservatively high inflow (see comment “d” above)? The second method of estimating freshet inflows employed 3 years of data to estimate a 95% probability. Three years of data are insufficient to estimate a probability with such accuracy, unless a probabilistic model is employed and stated.
11. The water balance model discussion does not address how cleanup efforts will achieve cleanup of the fractured bedrock aquifer, nor how cleanup efforts within the workings will affect contaminant concentrations in the adjacent aquifer. The concept that water from the workings affects water quality in the fractured bedrock aquifer is supported by the statement (p. 25) that “during this period, it is expected that the groundwater quality in the Gold Bowl dewatering wells would also improve since the wells would draw some water from the underground workings.” This statement suggests that water flows from the workings to the sur-

rounding aquifer, especially under the influence of dewatering wells. Will rinsing of the workings cause poor water of poor quality to be driven into the fractured bedrock aquifer? Similarly, discussion of cleanup of the NLF-3 fault zone focuses entirely on shallow storm-water as its source and does not consider groundwater flow from the workings to the fault zone through the fractured bedrock aquifer.

Appendix B. Checklist for Addressing OHA Points for the Final Hydrologic Closure Plan

Checklist for Addressing OHA Points for the Final Hydrologic Closure Plan

The following provides a checklist for addressing our primary points that should be included in a final closure plan. More detail can be found in our submitted comments.

- **Meeting Permit Limits**: The closure plan should be based on meeting current NPDES permit limits rather than state water quality criteria.
- **Hydraulic Barriers and Bulkheads**: The potential for a blowout and other potential adverse consequences should be examined.
- **Lowering Water Levels for Freshet**: An alternative approach that does not require lowering the mine pool each year should be evaluated. Water-budget neutral recirculation and use of bleed values on bulkheads should be considered as alternatives.
- **Stormwater**: A plan for analysis of stormwater monitoring data should be included in the closure plan so that the mass of contaminants captured and the effectiveness of the system are known. The Plan should require testing and reporting of stormwater quality and volumes.
- **Plan for Bringing All Water into Compliance**: Approaches for bringing all locations that exceed permit limits into compliance with the permit should be included in the Plan. All sites that currently do not meet permit limits should be added to the list on pg. 8 of the Golder memorandum.
- **Closure Adaptive Management**: A closure adaptive management plan should be included as an appendix to the hydrologic closure plan.
- **Groundwater Elevations during Closure**: The closure plan should estimate groundwater elevation changes during closure and interaction with ore and PAG development headings and DRZ areas using cross sections or the 3D visualization tool, and compare these levels with the predicted steady-state elevation of 5,000 to 5,020 ft.
- **Transitions between Closure Phases**: Phase 1 should end when the Gold Bowl Zone meets permit limits; Phase 2 should end when the Southwest Zone and all water quality monitoring locations meet NPDES permit limits. Phase 3 should end when that water quality has been maintained for a period of ten years. The final closure plan should describe in detail the steps involved in reaching the end of each phase.
- **Additional Dewatering and Monitoring**: Dewatering wells should be added to the workings during closure. Certain piezometers should be converted to monitoring wells to expand the network. Additional dewatering wells should be established to ensure protection of the environment until all groundwater meets applicable permit limits.
- **Treatment Approaches**: The existing MWTP should be maintained and used through Phase 2 of closure. An auxiliary RO or containerized RO unit treatment approach could be used during post-closure (Phase 3) as long as it can treat water to meet applicable permit limits.
- **Predicting Time to Closure**: Water quality changes during closure should be examined from mines with similar geochemical conditions and closure approaches and applied to the prediction of times needed to meet permit limits. Testing, using techniques such as wall washing and acid-base accounting, should be done to estimate contaminant additions from workings and DRZ areas that will be exposed during closure, and this information should be incorporated into predictions. Calculations should be provided that support estimation of cleanup times.

- **Recirculation and Water Balance:** Recirculation during closure is poorly defined and needs to include: a schematic showing the conceptual water balance and recirculation model; points of withdrawal and input and water sources; better estimates of how varying freshet inflow volumes (high, low, average) would affect infill rates; realistic MWTP production rates; pumping rates required to produce the proposed 200 gpm recirculation and drawdown; and all methods and approaches used for recirculation.
- **Monitoring Frequency:** During Phase 1 of closure, monitoring should continue according to the NPDES permit. During Phase 2 of closure, monthly monitoring should continue at all sites that do not meet NPDES limits, for the parameters that do not meet the limits. Any monitoring site/parameter that maintains NPDES permit limits for five years may be reduced to quarterly monitoring and discontinued after ten years, upon approval from Ecology.
- **Other Monitoring, Reclamation, and Reporting:**
 - Habitat condition and stream sediment quality monitoring should be conducted during closure for streams that have received mine water inputs. If needed, stream reclamation should be included as part of the closure process.
 - MW-17 monitoring data should be included in Appendix E or F.
 - The closure plan should include information on the linear feet of shotcreted and unshotcreted PAG workings and headings above and below 4,950 ft elevation. The information should be used to estimate the potential addition of mine-related contaminants to the workings during closure and how these inputs would affect the time to meet closure goals.
 - The discussions of water-quality data should be fact-checked against the graphs in the Plan.