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Subject: Pebble Mine Draft EIS Comments on Geotechnical and Spill Risks

Dear Mr. McCoy,

Given the very high innate geotechnical risk of the Pebble Mine setting and the extreme sensitivity of the downstream receiving environment, the Draft Environmental Impact Statement (DEIS) analysis of tailings and untreated water release is clearly inadequate. The DEIS fails to definitively demonstrate the geotechnical stability of tailings embankments, water storage facilities and pit walls throughout operation and closure. Large-scale catastrophic release of tailings and contact water is one of the most significant risks posed by the Pebble project and the DEIS' intentional failure to evaluate the impacts of any catastrophic release events cannot be justified. Even a release of just five percent of the bulk or pyritic tailings is likely to have profound, permanent negative impact on downstream aquatic ecosystems and fisheries.

In particular, by ignoring all potential catastrophic failure events, the release scenarios evaluated by the DEIS are anomalously small, representing only 1) 0.004% of produced bulk tailings which must be contained on-site forever; 2) 0.6% of produced pyritic tailings which must be contained on-site during operation; and 3) 0.4% of untreated process water which must be contained on-site during operation. The only bulk tailings release scenario that is evaluated by the DEIS assumes a brief six-hour pipeline break and therefore does not even consider containment failure associated with the tailings storage facility itself. There is also no DEIS evaluation of the significant perpetual closure risk of post-flooding pit wall failure which creates a seiche wave that would destroy water management infrastructure, could result in employee fatalities and could release billions of gallons of untreated pit lake water to the environment.

It is certainly acknowledged that, if implemented as designed, the proposed centerline and downstream construction techniques (with slopes of 2.6:1 or less) will reduce but not eliminate the likelihood of embankment geotechnical failure. The large-scale catastrophic release of tailings and/or of untreated mine contact water would thus represent a low probability but very high consequence event. These sorts of risks are routinely identified and analyzed within the mining industry so that appropriate controls can be implemented. The intentional omission of large-scale catastrophic geotechnical failure scenarios from the Pebble evaluation is particularly difficult to justify given the 1) acknowledged "early phase conceptual level" of the embankment designs (DEIS Section 4.27.6) and 2) lack of any geotechnical evaluation of seismic events specific to the proposed embankment designs or to the fully-flooded open pit in this extremely active seismic setting. Given the extremely wet climate and highly variable precipitation at Pebble, the lack of any catastrophic overtopping release scenarios related to insufficient water storage capacity is also not justified.

Professional Background

I am an environmental scientist and manager with over thirty years of experience in the mining and consulting industries. During my 23 years with the global mining company Rio Tinto I participated in tailings review boards and was a primary or contributing author on several mineral waste and tailings management standards and guidance documents. I have performed environmental and permitting work at over fifty mines, projects and operations. This included over seven years as Head of Environment for Rio Tinto's Copper, Copper & Diamonds and Copper & Coal Product Groups. I have published numerous papers on mine environmental performance and management in peer reviewed scientific journals, conference proceedings and books. I am experienced in the management of environmental challenges, issues and costs posed by the responsible design, operation and closure of large tailings and water storage facilities.

Pebble Project's High Innate Geotechnical Risk

Pebble's active seismic setting, wet climate, sensitive receiving environment and large mass of chemically reactive tailings all contribute to a very high innate risk of catastrophic release.

As noted in Appendix K (4.15) and Chapter 3.15 of the DEIS: "the mine site is situated in a seismically active area" and "both shallow crustal earthquakes and deeper earthquakes associated with the subduction zone megathrust affect this region". The active Lake Clark - Castle Mountain Fault is only 15 miles away and there are several potential seismic events which could trigger earthquakes of magnitude 7.5 or greater. The maximum credible earthquake has been estimated to produce ground accelerations of 0.61 g at the mine. According to the United States Geologic Survey, ground accelerations of 0.34 to 0.65 g will typically produce severe shaking and moderate to heavy damage.

The mine site receives between 50 and 57 inches of precipitation on average each year which is at least four times greater than the annual evaporation. This extremely wet climate produces abundant excess water for runoff and infiltration. According to the Pebble project description (Appendix N), the mine will need to treat and release an average of 13,000 gallons per minute of excess water. Precipitation is also highly variable with almost half occurring in August through October. Available environmental baseline data show monthly precipitation as high as 12.2 inches measured in September, 2007 (Chapter 2, Pebble Environmental Baseline Document 2004-2008). Much longer-term precipitation records at Iliamna indicate that annual precipitation may vary by almost a factor of three from year to year. This very wet and highly variable climatic setting will make it very challenging for Pebble to consistently contain contact water on-site so that it can always be treated and released in a controlled manner. It also ensures that the majority of the bulk tailings will remain saturated in perpetuity after closure.

Any untreated water or tailings released from site will discharge directly into the North and/or South Forks of the Koktuli River. Although this release would occur near the river's headwaters, both have substantial flow which could rapidly transport released tailings downstream. Immediately downstream of the proposed mine, both rivers' annual average flow is more than 100 cubic feet per second (>45,000 gallons per minute) and peak flows in excess of 700 cfs (>300,000 gpm) have been recorded (Section 3.16). These rivers, which are at the heart of the Bristol Bay ecosystem and fishery, would be unavoidably impacted by any release due to sedimentation and water quality degradation. Unfortunately, aquatic ecosystems in general and salmon in particular are very sensitive to dissolved copper. Any untreated water release will almost certainly contain dissolved copper concentrations that are tens to hundreds of times greater than allowable limits (Appendix K, 4.18). Similarly, any tailings release will almost certainly contain copper concentrations that are an order of magnitude greater than sediment quality guidelines. Sulfide minerals in any released tailings are likely to become hydrologically sorted in the river system and may become concentrated on bars and beaches where they would be more prone to rapid acidification and metals release.

The Pebble twenty-year mine plan will generate 1100 million tons of bulk tailings and 155 million tons of pyritic tailings. Almost 400 million additional tons of specially quarried rock will be required to construct all necessary embankments for tailings and contact water containment on site (Appendix K, 4.15). Given the topographic constraints this will necessitate construction of a 545 ft tall main embankment to contain the bulk tailings. This will be among the tallest tailings storage facilities on Earth and will almost certainly be taller than 99% of the tailings impoundments constructed to date. The pyritic tailings impoundment will be up to 425 feet tall and will also almost certainly be taller than 90% of existing tailings impoundments. The total length of all major embankments will ultimately exceed 12 miles. The construction, monitoring and maintenance of these embankments will represent a huge engineering, operational and financial commitment. The level of effort required for the embankments is a particular concern given Northern Dynasty Minerals' complete lack of experience in this area, and the almost certain marginal economics of the DEIS mine plan (Borden Pebble DEIS comments letter dated March 28, 2019).

Tailings and Water Storage Facility Catastrophic Containment Failure

As noted in Section 4.27.6 of the DEIS, there are typically one to two major tailings dam failures per year around the world and furthermore that "other recent tailings dam failures in China, Mexico and Australia demonstrate that modern, well-engineered tailings facilities are subject to failure". The five largest and best documented tailings dam failures over the past five years are listed in the table below and are compared to the anomalously small bulk tailings release scenario evaluated in the DEIS:

Name	Date	Location	Responsible Company	Volume Released (m^3)[1]	Volume Compared to DEIS Bulk Tailings Release Scenario
Mount Polley	Aug, 2014	Canada	Imperial Metals	25 million	560 times larger
Samarco	Nov, 2015	Brazil	BHP/ Vale	32 million	720 times larger
Cieneguita	June, 2018	Mexico	Minera Rio Tinto[2]	0.44 million	10 times larger
Candia	Mar, 2018	Australia	Newcrest Mining	1.3 million	30 times larger
Corrego do Feijao	Jan, 2019	Brazil	Vale	12 million	270 times larger

[1] Includes both tailings solids and untreated contact water; [2] Note this is a different company than the large global mining corporation Rio Tinto LLC.

Several of these large incidents are not described in the DEIS discussion of recent tailings dam failures despite their clear pertinence to the risks at Pebble. All five events are one to two orders of magnitude larger than the anomalously small bulk tailings scenario evaluated at Pebble, despite the fact that the proposed bulk tailings dam at Pebble will be larger than the dams at these other locations. Several of these incidents also released tailings into river systems with similarities to Pebble's setting, and the tailings were rapidly transported far downstream. In the case of Samarco, tailings reached the ocean 400 miles away within three weeks.

Despite the significant seismic hazards at Pebble, there has been no seismic stability analysis conducted for the specific embankment designs proposed in the DEIS. The DEIS instead relies upon an old 2011 pseudo-static analysis performed on an outdated design for the main bulk tailings impoundment alone. No seismic stability analysis appears to have been completed on the current bulk tailings impoundment designs or the embankments required to contain the pyritic tailings and untreated contact water. As stated in Appendix K, Section 4.15: "Estimates of horizontal and vertical displacement for mine site embankments would be analyzed further for current embankment designs during future seismic analysis as part of the detailed design work undertaken in fulfillment of the ADSP review process. That work is anticipated to be performed after the EIS is complete." Furthermore, according to Knight Piesold (2018c) "The embankment designs and stability analyses will be updated accordingly to reflect actual foundation conditions". Thus, the stability of all key containment structures in response to seismic events and actual foundation conditions has not been definitively demonstrated and there are no plans to do so for the EIS. This is a potential fatal flaw for all impoundments, but for the bulk tailings impoundment in particular, because it must ensure containment forever, not just during operation. Given its long design life, it is much more likely to experience a very large seismic event which approaches the maximum credible earthquake in its intensity. Also given the extremely wet climate of the site and likely high infiltration rates through the planned soil cover, most of the bulk tailings mass is almost certain to remain saturated in perpetuity. The risk posed by a catastrophic geotechnical failure is unlikely to decline as significantly as implied by the term "dry closure" used in the DEIS.

As stated in Section 4.27.6 of the DEIS: "Massive catastrophic releases that were deemed extremely unlikely were also ruled out for analysis in the EIS". It is unclear how this statement can be justified given 1) the high innate risk posed by the site; 2) the acknowledgement that large-scale tailings failures regularly occur even for recently constructed facilities; 3) the lack of any seismic geotechnical analysis specific to the current DEIS embankment designs; and 4) the current low level of foundation knowledge and engineering design actually available for the embankments. As stated in the Pebble EIS-Phase Failure Modes and Effects Analysis Workshop Report (AECOM 2018l): "The current Pebble Project embankment designs are at an early phase conceptual level, with geotechnical investigations still under way at the major embankment sites. This current conceptual design level inherently results in uncertainties". Simply stating that no catastrophic failure scenarios need to be evaluated because the facilities will not be designed or built to fail is inadequate justification for ignoring one of the greatest risks posed by the project.

In order to fill these substantial deficiencies, the EIS process must at a minimum:

1) Conduct seismic analysis for the bulk tailings (both north and south embankments), pyritic tailings and all water management ponds in order to confirm the designs can withstand the operational basis earthquake and for the bulk tailings impoundment the maximum credible earthquake.
2) Perform additional environmental consequences analysis on larger bulk tailings, pyritic tailings and untreated contact water spills. In particular the impact of a catastrophic bulk tailings dam failure in response to a large post-closure earthquake needs to be evaluated. A large-scale overtopping event which releases untreated mine contact water during an exceedingly wet year or years would also be a critical failure scenario to evaluate.
3) The post-closure hydrogeologic behavior of the bulk tailings storage facility also needs to be evaluated. This will require much more detailed designs of how the upper surface is to be recontoured to avoid ponding, how water is to be transmitted off the tailings in a non-erosive manner and how the cover will be constructed and maintained in

perpetuity. Net infiltration and its impact on bulk tailings saturation will then need to be modelled.

4) Based on the results of the geotechnical and environmental consequences analyses for catastrophic failures, embankment designs may need to be refined. Even a release of just five percent of the bulk tailings (greater than 50 million tons) is likely to have profound, permanent negative impact on downstream aquatic ecosystems and fisheries. A low likelihood event which has such catastrophic consequences may warrant additional controls such as using downstream construction techniques for all tailings embankments (Action Alternative 2), paste or dry stacked tailings.

Catastrophic Pit Wall Failure and Seiche Wave Generation

The DEIS has failed to provide any analysis of post-closure fully-flooded pit wall stability and the potential for seiche wave generation. Once water levels in the pit are allowed to recover to the target elevation, a pit lake will form that covers about 500 acres, is over 500 feet deep and will contain over 60 billion gallons of untreated water. The surface of this pit lake will only be about 150 feet below the spill point for the pit. A large-scale failure of the pit wall, likely triggered by a seismic event, would create a large seiche wave. Such a wave would almost certainly damage the water management infrastructure required to maintain pit water levels, could result in worker fatalities and could instantaneously release billions of gallons of untreated water into the Koktuli River system.

This is not a hypothetical scenario. The flooded Berkeley open pit in Butte Montana has experienced at least two large seiche wave events. The first in 1998 deposited the pit lake sampling boat roughly 40 feet above the lake surface and the second in 2013 destroyed pit pumping infrastructure. Because of the high ongoing danger of new seiche waves, access to the pit is now severely restricted and all water samples are collected from an entirely remote-controlled sampling vessel. Modelling of post-flooding pit wall stability and seiche wave generation is becoming a common practice within the mining industry for planned large pit lakes. A brief internet search shows pit wall failure/seiche wave predictive analyses recently performed at the Martha Mine pit in New Zealand, the Black Lake pit in Quebec, the Mitchell pit in British Columbia and for a large un-named pit as detailed at the Golder Associates website.

Although both static and seismic geotechnical modelling has been performed for the open pit, it is not applicable to evaluation of the pit wall failure/seiche scenario highlighted above because:

- Only early closure conditions were evaluated when the open pit and surrounded bedrock were only about half-way reflooded. However, current plans are to allow the pit lake to reflood to within about 150 feet of the pre-mining surface. This will also raise the water table in the surrounding bedrock and could lead to increasing wall instability.

- The DEIS pit wall geotechnical evaluations for seismic events only considered ground accelerations of 0.14 and/or 0.2 g (there are inconsistencies between Appendix K, 4.15 and the original SRK memo dated August 9, 2018). These values may be appropriate for an assessment of risks during the 20-year operational period, but are clearly inadequate for a closure assessment when containment is required for centuries. It would be much more appropriate to perform the analysis using the maximum credible earthquake for closure which has an estimated ground acceleration of 0.61 g.
- Physical and accelerated chemical weathering of acidified, pyrite-bearing wall rock could significantly lower in situ rock strength in the decades after closure.
- The SRK geotechnical analysis was only completed on three cross sections in the pit. The geotechnical stability of the relatively shallow zone of weak rock on the west side of the pit was not evaluated under static or dynamic conditions.

This issue has strategic implications for mine design, operations and closure and needs to be addressed by the EIS process. If the pit walls are not stable under the maximum credible earthquake then containment of the more than 60 billion gallons of untreated pit lake water cannot be ensured after closure. This would almost certainly need to be mitigated by one of the following strategies:

- Maintaining the pit lake surface at a much lower elevation so there is additional freeboard to contain a seiche wave. However, this would increase the in perpetuity pumping rate and, because more of the acid-generating pit high walls would be exposed, would cause pit lake water quality to be worse than currently predicted.
- Performing in situ treatment of the entire pit lake so that if water were released by a seiche wave, it would have less of an environmental impact. However, this would be very costly, technically complex and would likely put workers in harm's way.
- Perpetual post-closure dewatering and depressurization of weaker portions of the pit wall that are prone to failure. However, this would increase the in perpetuity pumping rate and require constant active intervention for centuries.
- Refining acid-forming waste rock placement in the pit so that it remains below the lake surface, but more effectively buttresses weak zones on the pit walls; or moving sufficient non-acid forming waste rock back into the open pit in order to permanently buttress the pit walls. This could effectively control the risk but could represent a very large increase in the early closure costs.
- Reducing final pit slope angles to improve their stability during mining. However, this would dramatically increase the stripping ratio, increase the volume of waste rock that would need to be managed and increase the mine surface disturbance.

In order to address these substantial uncertainties, the EIS must at a minimum:

1) Perform a seismic analysis of pit wall stability for the fully flooded pit lake and wall rock, using ground accelerations associated with the maximum credible earthquake and including sufficient cross sections to characterize all zones of weakness in the ultimate pit. Issues associated with long term chemical and physical weathering which may lower the strength of the wall rock must also be considered.
2) Based on the results of the seismic analysis, perform seiche wave predictions for various pit lake flooding scenarios.
3) If failure-induced seiche waves are demonstrated to pose a credible risk to perpetual pit lake water containment, select and design appropriate mitigation strategies.
4) Evaluate the environmental, operational and closure impacts of the selected mitigation strategy including issues such as hydrogeologic evaluations of increased pumping rates, water quality predictions for changes in pit lake water chemistry and materials balances for new waste rock production and/or backfill requirements.

Sincerely,

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