



**December 1, 2021**

**To: Joel Reynolds and Taryn Kiekow Heimer, Natural Resources Defense Council**

**From: Richard Borden, Midgard Environmental Services LLC**

**Subject: Review of the Pebble Mine Project Preliminary Economic Assessment**

A Preliminary Economic Assessment (PEA) of the proposed Pebble Mine Project with an effective date of September 9, 2021 was publicly released by project owner Northern Dynasty Minerals in October 2021. The following technical memorandum, prepared at the request of the Natural Resources Defense Council, summarizes my conclusions from a review of the PEA. The review focused on the PEA base case for the 20-year starter-mine, limited to development of roughly ten percent of the estimated ore body, which Northern Dynasty is seeking to permit. Key findings from the PEA review include:

- The PEA is not an independent study. Half of the authors work directly for the companies seeking to develop the mine.
- The PEA has an acknowledged low degree of accuracy (plus or minus 50%) for typical studies of this kind.
- The overall Net Present Value (NPV) of the 20-year starter-mine is almost certain to be less than \$700 million in value, which is less than a third of the base case NPV quoted in the 2021 Pebble PEA; and despite historically high commodity price assumptions, it is likely that the actual project NPV is negative.
- If short and consensus long-term metals prices returned to the values from 2019, the 20-year starter mine would almost certainly have a negative NPV measured in the many hundreds of millions to multiple billions of dollars.
- Larger mine plans evaluated in the PEA have much more favorable economics but would require a greater than ten-fold increase in environmental impacts and risks compared to the artificially reduced scale of the 20-year starter mine that Northern Dynasty is attempting to permit.

An evaluation of the Pebble PEA's financial assumptions that were used to calculate an overall project NPV identified the following key concerns:

- The PEA almost certainly understates indirect, owners and contingency costs. If more appropriate cost estimates are used, the base case project would lose between \$400 million and \$1 billion in value.

- The PEA speculatively assumes someone else will pay for \$2.8 billion dollars of pre-mining infrastructure. If these costs are added back into the initial capital requirements, the base case project would lose at least \$300 million in value.
- The PEA almost certainly overstates long-term copper prices and likely overstates long-term gold prices. If these price assumptions are adjusted appropriately, the base case project would lose between \$500 million and \$700 million in value.
- If short and consensus long-term metals prices returned to the values from 2019, immediately before the massive economic disruptions of the pandemic (\$3.00/lb for copper and \$1300/oz for gold), the project would lose more than \$1.5 billion in value.
- The PEA has anomalously low operating costs compared to the last independent economic evaluation of the Pebble Project completed in 2011. If the operating costs are aligned with the earlier independent study, the base case project would lose between \$500 million and \$1 billion in value.
- Given the extremely high environmental, social, permitting and engineering challenges faced by the project, it is likely to cost hundreds of millions of additional dollars, spent over many years to decades, before construction of any project could, if ever, begin.

The Pebble Mine Project PEA fails to meet even industry standard practice for financial evaluations and its conclusions are commonly based upon poorly supported and overly optimistic assumptions. Supporting detail and analysis are provided for each of these findings in the following sections of this technical memorandum.

#### Professional Background

I am an environmental scientist and manager with over thirty-five years of experience in the mining and consulting industries. During my 23 years with the global mining company Rio Tinto I was involved in the strategic environmental design of several new mines. I also performed environmental, permitting and closure 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 been involved in many economic evaluations of ore bodies and mines as part of due diligence activities. I am currently an independent consultant with Midgard Environmental Services LLC and have provided mining and environmental expertise to more than fifteen industry and NGO clients to date. I have published numerous papers on mine environmental performance and management in peer reviewed scientific journals, conference proceedings and books. I am intimately aware of the environmental challenges and issues posed by the responsible permitting, development, operation and closure of large copper mines.

#### Preliminary Economic Assessment Independence

**The PEA is not an independent study.** Four of the eight qualified persons responsible for completing the study are or were recently employed by Northern Dynasty and/or its parent company Hunter Dickenson (PEA pages 56 and 57). As such they have a direct financial interest in successful

development of the Pebble ore body. Although not legally required in all circumstances, it is industry standard practice to ensure that all qualified persons responsible for preliminary technical and economic evaluations are independent, and most PEAs make this very clear with statements such as:

“None of the Qualified Persons employed in the preparation of this report has any beneficial interest in the project;”

“All Qualified Persons are independent as defined in Canadian National Instrument 43-101 – Standards of Disclosure for Mineral Projects;” and

“The results of this PEA are not dependent upon any prior agreements concerning the conclusions to be reached”.

There are, of course, no such assurances within the Pebble PEA, because half of the reviewers are or were recently employed by Northern Dynasty or Hunter Dickinson. The independence of the qualified persons is clearly in the best interest of mine developers because it minimizes real or perceived conflicts of interest. Independence gives the investment community, regulators and the general public greater confidence in and assurance of the reliability of the PEA’s conclusions.

#### Preliminary Economic Assessment Accuracy

**The PEA has an acknowledged low degree of accuracy.** The PEA cost estimates have only been completed to a “preliminary level” (PEA page 51), and the stated accuracy of the cost estimates is only plus or minus 50% (PEA page 289). PEA estimates typically have an accuracy range of  $\pm 25$  to  $\pm 50\%$ , so the Pebble PEA falls at the lowest end of this range. Table 1 lists twelve PEAs issued in the past eight years for precious and/or base metals projects in Alaska, British Columbia and the Yukon. As such, all of these projects are in a similar geographic, geologic, cultural and regulatory setting to Pebble. Consistent with Pebble, they were all produced in compliance with Canadian National Instrument 43-101 requirements (Canadian Securities Authority). The most significant difference is that, unlike the Pebble PEA, all twelve of these other PEAs were developed by fully independent qualified persons. All of these PEAs have a higher degree of accuracy than Pebble, with a mean accuracy of -30% to +35% for the capital and operating cost estimates.

The Pebble PEA explicitly acknowledges the limitations of its analysis in several areas. As stated on page 51: “Additional analysis and engineering are required to confirm these results.” Section 1.23 of the PEA estimates an additional \$46 million in studies will be required to address identified data gaps and would presumably be required to advance the project to a pre-feasibility level of assessment. Northern Dynasty also acknowledges that its forward looking statements in the PEA “should not in any way be construed as guarantees that the Project will secure all required government permits, establish commercial feasibility of the Project, achieve the required financing or develop the project” (PEA page 20). The document also states that: “The 2021 PEA includes the use of inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. There is no certainty that the 2021 PEA results will be realized” (PEA page 49).

It is unusual for a mine developer to try to complete an Environmental Impact Statement and the broader permitting process when the actual project is so poorly defined and has so much acknowledged uncertainty.

Table 1 – Comparison of the Pebble PEA to Some Recent Precious/Base Metal PEAs in the Alaska Region

Project Name	Capital Cost Estimate Accuracy	Indirect and Owners Costs as a % of Direct Costs	Contingency as a % of Direct Costs
Peak Gold	±30%	50.9%	30.2%
Palmer	-20%/+30%	36.9%	18.4%
Lik Deposit	-5%/+25%	36.2%	18.3%
Ambler Mining District	±35%	31.4%	19.3%
Tiger	-25%/+40%	31.2%	24.3%
Caribou Gold	±30%	30.4%	14.2%
Turnagain	-25%/+40%	28.9%	20.7%
Spanish Mountain	±40%	26.8%	16.3%
Baptiste Nickel	±35%	25.8%	22.5%
MacMillan Pass	±35%	25.6%	21.3%
Akie	±35%	24.8%	22.2%
Wellgreen Platinum	±30%	21.2%	25.0%
<b>MEAN</b>	<b>-30%/+35%</b>	<b>30.8%</b>	<b>21.1%</b>
<b>Pebble Project PEA</b>	<b>±50%</b>	<b>28.2%</b>	<b>16.2%</b>

#### Preliminary Economic Assessment Indirect and Contingency Costs

**The PEA almost certainly understates indirect, owners and contingency costs.** Direct capital costs are the material and labor costs that can be directly tied to the purchase and construction of mining infrastructure such as mobile equipment, processing facilities, earthworks, roads, power supply systems, pipelines and ports. However, to allow for construction, indirect and owners costs must also be incurred for items such as permitting, field characterization studies, design, engineering, procurement, project management, administration, temporary support facilities, logistics, training, freight, insurance, commissioning and startup.

The Pebble project would be expected to have very high indirect and owners costs because of 1) the substantial study and design work still required; 2) the substantial and costly legal and permitting requirements of the project which could stretch for many years or decades before construction could begin; 3) the very remote project setting far from transportation and infrastructure hubs; and 4) the extreme complexity of the project construction and operation given its very challenging and sensitive environmental setting. However, as shown on Table 1, the Pebble PEA actually assumes lower indirect and owners costs than most other recent PEAs completed in the Alaska region.

The last truly independent economic analysis of the Pebble project was completed by Wardrop in 2011 (Preliminary Assessment of the Pebble Project; Wardrop – A TetraTech Company; February 2011).

Although direct capital costs appear to have been reasonably escalated from 2011 to the 2021 PEA to account for inflation, the related indirect costs have been significantly decreased without any justification. The Wardrop analysis assumed that indirect and owners costs would be 40% of the capital costs, substantially higher than the 2021 PEA assumption of only 28.2%. Similarly, the 2011 Donlin Creek Feasibility Study assumed indirect costs of 42%.

Contingency costs are applied to capital costs to account for project uncertainties related to permitting, design and construction. Capital costs almost always increase as a project advances from a preliminary economic analysis through prefeasibility, feasibility and into construction. This is a well-established fact in cost engineering. Therefore, the lower the accuracy of a cost estimate the greater the assumed contingency costs typically are. Further, projects such as Pebble that face substantial permitting, design and construction risk will typically require a higher contingency. For example, despite the acknowledgement that an alternative and likely much more costly transportation route may be required due to local opposition (PEA page 50), the PEA does not account for this substantial financial risk. Finally, despite having the lowest degree of accuracy of any of the recent PEAs reviewed from the Alaska region, the Pebble PEA assumes an unusually low contingency (Table 1). This is in large part because it only applies contingency to direct costs, while many other studies apply contingency to both the direct and indirect capital costs. The independent Wardrop 2011 analysis assumed a contingency of 24.9% of direct capital costs and Donlin (2011) assumed 24.5%, both substantially higher than the 2021 PEA assumption of only 16.2%.

Given the unusually high financial risk of the Pebble project, and the very low degree of accuracy acknowledged by the 2021 PEA, it is clear that higher contingency, owners and indirect costs should have been applied to the project. If the mean of the indirect, owners and contingency costs of recent PEAs in the Alaska region is applied to the Pebble initial capital estimate, the estimated project capital cost would increase by more than \$300 million. All of these new costs would occur before any revenue is generated, so this refinement would actually decrease project NPV by an estimated \$400 million. If the Wardrop 2011 indirect, owners and contingency assumptions are applied to the Pebble initial direct capital estimate, the project capital cost would increase by over \$800 million. Again, because these costs would occur during the 4.5 year construction period, well before any project revenue, this refinement would decrease project NPV by an estimated \$1 billion.

#### Preliminary Economic Assessment Initial Capital Costs

**The PEA speculatively assumes someone else will pay for \$2.8 billion of pre-mining infrastructure.** The base case financial evaluation of the 20-year starter mine assumes some other company or entity will develop, finance, own and operate the port, access road and power plant, leasing the assets back to Pebble over the life of the mine. The estimated capital cost of these facilities is \$1.7 billion. Further, the Pebble PEA assumes that the lease or tolling agreement would be tilted in their favor such that it improves the mine's value by \$300 million compared to a scenario in which Pebble itself builds and operates the infrastructure (PEA page 42). It is unclear what entity would consider putting so much capital at risk for the benefit of the mine, and the Pebble PEA does not identify any potential partners in the venture. This assumption is, therefore, highly speculative and insufficiently justified in the financial evaluation. None of the other recent PEAs that were reviewed proposed such a speculative financial arrangement.

The Pebble PEA also assumes that some other company will provide \$1.1 billion of up front capital for the right to buy gold at a reduced price in the future (gold streaming). Although this is not an uncommon practice in the industry, the Pebble PEA does not identify any potential gold streaming partners. It is also unclear how gold streaming is addressed in the financial evaluation, because it would necessarily reduce sales revenues during the operational period.

#### Long Term Copper and Gold Price Assumptions

**The PEA almost certainly overstates long-term copper prices and likely overstates long-term gold prices.** The Pebble PEA financial evaluation assumes long-term copper and gold prices of \$3.50/lb and \$1600/oz respectively. These values are based on “published consensus long-term pricing estimates and previous market analysis.” The PEA also states, however, that “a recent consensus published from major banks estimates a long-term copper price in the \$3.20 to 3.70/lb range, with a median of \$3.30 and average of \$3.37 (page 263).” A survey of fourteen recently published mining project financial evaluations also yielded an assumed mean long-term copper price of \$3.08 (Table 2). Thus, the Pebble PEA has almost certainly overstated the consensus long-term copper price in its financial evaluation and is out of step with recently published copper prices for other copper projects. Sensitivity analyses performed by the Pebble PEA predict that even a \$0.25 drop in long-term copper price to \$3.25/lb results in a loss of \$500 million from predicted project NPV. A \$0.50 drop in assumed long-term copper price results in a \$900 million reduction in project NPV (page 328).

The Pebble PEA also states that “current analyst consensus for long-term gold prices are in the range of \$1400 to \$1800/oz, with a median and average forecast long-term gold price of \$1600/oz.” However, a survey of twenty-two recently published mining project financial evaluations yielded a mean long-term gold price of \$1425/oz (Table 2). Interpolation of the sensitivity analyses results presented by the Pebble PEA predicts that even a \$100 drop in assumed long-term gold price to \$1500/oz results in a loss of \$200 million from predicted project NPV. A \$200 drop in assumed long-term gold price results in a \$400 million reduction in project NPV (page 328).

If pre-pandemic short and long-term metals prices from 2019 are assumed (\$3.00/lb for copper and \$1300/oz for gold), there would be a greater than \$1.5 billion reduction in project NPV (page 328).

Table 2 – Long-Term Copper and Gold Price Assumptions from Recent Mine Financial Evaluations

Project Evaluation	Year	Assumed Long Term Gold Price (US \$/oz)	Assumed Long Term Copper Price (US \$/lb)
Salave Gold	2019	1250	Na
Spanish Mountain	2019	1250	Na
Palmer	2019	1296	2.82
Bam Mountain	2019	1300	Na
Agua Rica	2019	1300	3.00
Eagle Mountain	2019	1300	Na
Caribou Gold	2019	1325	Na
White Pine North	2019	Na	3.00

Arctic	2020	1300	3.00
Kino Hills	2020	1325	Na
Seabridge Gold KSM	2020	1340	2.80
Eva Copper	2020	1362	3.04
Tiger Project	2020	1400	Na
Congrejos Gold	2020	1400	2.75
Klaza	2020	1450	Na
Elk Gold	2020	1600	Na
Marimaca	2020	Na	3.15
Marathon Pd-Cu	2021	1400	3.20
El Cubo/El Pinguico	2021	1527	Na
Kone Gold	2021	1600	Na
Casino	2021	1600	3.35
Las Minas	2021	1625	3.25
North Island	2021	1650	3.25
Cerro Caliche	2021	1750	Na
Mason Copper	2021	Na	3.10
Boa Esperanca	2021	Na	3.40
<b>MEAN</b>		<b>1425</b>	<b>3.08</b>
<b>Pebble PEA</b>		<b>1600</b>	<b>3.50</b>

#### Preliminary Economic Assessment Operating Costs

**The 2021 PEA has anomalously low operating costs compared to the last independent economic evaluation completed in 2011.** There has been 24% net inflation from early 2011 to mid-2021 (U.S. Bureau of Labor Statistics, data.bls.gov). If the operating costs calculated in the 2011 Wardrop study are inflated to 2021 dollars, the net operating costs are about 20% higher than those quoted in the 2021 PEA (Table 3). General and administrative (G&A) costs in particular are almost twice as high (\$0.88 in the 2021 PEA versus \$1.73 per ton of ore processed for the escalated Wardrop estimate). This is surprising because the ten percent higher ore production assumed in the Wardrop study would actually be expected to reduce relative G&A cost/ton. The Pebble mine would be located in one of the most sensitive and challenging environmental settings in the world. Inexplicably, however, the 2021 PEA does not assume any operating costs for environmental monitoring and protection (exclusive of the water treatment plant). Operating costs for processing and transportation also appear to be anomalously low in the 2021 PEA compared to the Wardrop Study.

When the operating cost deficiency is applied to the 180,000 tons per day processing plan, the resulting operating cost shortfall in the 2021 PEA is \$126 million per year for twenty years. Discounted at 7% per year over the construction period and full mine life, this equates to a \$1 billion reduction in overall project NPV.

Table 3 – Operating Cost Corrections

Operating Cost Area	2021 PEA Cost/Ton Milled	2011 Wardrop Cost/Ton Milled	2011 Wardrop Inflated to 2021 dollars (3)	Annual Operating Cost Difference at 180,000 tpd milled
General and Admin	0.88	1.39	1.73	+56 million
Open Pit Mining	1.75	1.35	1.67	-5 million
Processing	4.17	3.93	4.88	+47 million
Tailings	0.16	0.51	0.63	NA (4)
Water Treatment Plant	0.33	0.10	0.12	NA (5)
Transportation	0.89	0.89	1.10	+14 million
Environmental	0.00	0.18	0.22	+14 million
<b>TOTAL</b>	<b>8.18 (1)</b>	<b>8.35 (2)</b>	<b>10.35</b>	<b>+126 million/year</b>

- (1) This is the quoted 2021 PEA (page 298) unit operating cost per ton milled (\$10.98) minus the quoted unit operating cost per ton milled associated with infrastructure leases (\$2.80).
- (2) This is the quoted 2011 study unit operating cost per ton milled (\$11.16) minus a mining correction per ton milled (\$2.81) to account for the much lower stripping ratio of the 2021 PEA mine plan.
- (3) There has been 24% inflation from January 2011 to August 2021 (Wardrop study effective date February 11, 2011 versus Pebble PEA effective date September 9, 2021).
- (4) It appears that the Pebble PEA allocated some of the tailings management costs to sustaining capital rather than operating costs, so valid comparison is difficult.
- (5) Recent geochemical, hydrologic and hydrogeologic studies have demonstrated that the water treatment liabilities are much larger than predicted in 2011, so valid comparison is difficult.

#### Implications for Project Economics and Net Present Value (NPV)

**The NPV of the 20-year starter mine is almost certain to be less than 700 million dollars in value, which is less than a third of the base case NPV stated in the 2021 Pebble PEA; and despite historically high commodity price assumptions, it is likely that the actual project NPV is negative.** These NPV calculations also do not fully address the very substantial environmental, social and design risks associated with the project, which may make it impossible to ever permit or construct an economically viable project. Table 4 provides a summary of justified NPV modifications to the project. If only “almost certainly justified” modifications are applied to the quoted 2021 PEA base case NPV of \$2.3 billion, the calculated NPV falls to \$600 million. If “likely justified” modifications are also applied to the based case, the calculated NPV falls to negative \$700 million. **If short and assumed long-term metals prices returned to the values from 2019, immediately before the massive economic disruptions of the pandemic (\$3.00/lb for copper and \$1300/oz for gold), the 20-year starter mine would almost certainly have a negative NPV measured in the many hundreds of millions to multiple billions of dollars.**

**In summary, even with the current exceptionally favorable metals prices, the greater than \$6 billion that the Pebble PEA estimates will be required to build the 20-year starter mine represents an exceedingly risky investment that is unlikely to yield a positive rate of return even under exceedingly optimistic permitting and design assumptions.**



Given the legal, permitting, design and financial risks posed by the Pebble Project, it is almost certain that the 20-year starter mining project will never be built, and likely that construction of any mine design will be delayed by at least a decade. Furthermore, throughout this ten year period Northern Dynasty would need to spend money on legal costs, permitting costs, baseline studies, community outreach, general administration, design and offset programs. Even assuming a conservatively low \$25 million/year for these costs (Northern Dynasty reported a \$6.9 million loss just in the third quarter of 2021); the project NPV would lose an additional \$400 million over the next decade before the risks of the construction phase even begin.

Table 4 – Justified NPV Modifications to the 2021 Pebble PEA Estimate

<b>Almost Certainly Justified NPV Modifications</b>	<b>NPV Change</b>
Apply industry average PEA indirect and contingency cost assumptions given that project uncertainty and risk are above average	minus \$400 million
Apply full initial capital cost to project	minus \$300 million
Apply consensus and industry standard long-term copper price of \$3.25/lb	minus \$500 million
Apply 50% of operating cost shortfall compared to Wardrop 2011 study	minus \$500 million
<b>TOTAL ALMOST CERTAINLY JUSTIFIED NPV MODIFICATION</b>	<b>minus \$1700 million</b>
<b>Likely Justified NPV Modifications</b>	<b>NPV Change</b>
Apply Wardrop 2011 indirect and contingency cost assumptions	minus \$1000 million
Apply full initial capital cost to project	minus \$300 million
Apply consensus and industry standard long term copper price of \$3.25/lb and gold price of \$1500/oz	minus \$700 million
Apply full operating cost shortfall compared to Wardrop 2011 study	minus \$1000 million
<b>TOTAL LIKELY JUSTIFIED NPV MODIFICATION</b>	<b>minus \$3000 million</b>

Expanded Mine Plans Evaluated by the Preliminary Economic Assessment

**Although larger mine plans evaluated in the PEA have much more favorable economics, they would require a greater than ten-fold increase in environmental impacts and risks compared to the artificially reduced scale of the 20-year starter mine that Northern Dynasty is attempting to permit.** The larger mines evaluated in the 2021 PEA would run for 90 to 100 years and would produce over eight billion tons of tailings and 14 billion tons of waste rock (PEA page 44). This would be one of the largest mines ever constructed anywhere in the world and would produce 15 times more tailings and waste rock than the 20-year starter mine. The majority of the 22 billion tons of mineral waste would also be chemically reactive and prone to large-scale acid rock drainage formation in the wet climate of Bristol Bay. These chemically reactive mineral wastes would pose a risk to the Bristol Bay salmon fishery forever, because it would be nearly impossible from an economic and operational perspective to return over ten billion tons of material to the open pit where it could be permanently flooded to control the acid rock drainage risk.