

REPORT**Nalunaq Gold Mine***Task 1 - Tailings Disposal Options*

Submitted to:

Nalunaq A/S

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Table of Contents

1.0 INTRODUCTION	1
1.1 Context	1
1.2 Background	1
1.3 Scope of Work.....	1
2.0 TAILINGS DISPOSAL OPTIONS ASSESSMENT	2
2.1 General.....	2
2.2 Scoring System	2
2.3 Underground Slurry Tailings Disposal	3
2.4 Underground Paste Tailings Backfill	3
2.5 On Surface Slurry Tailings Disposal	4
2.6 On Surface Filter cake (Dry Stack) Tailings Disposal	5
2.7 Marine Tailings Deposition.....	5
3.0 CONCLUSIONS AND RECOMMENDATIONS	6

TABLES

Table 1: Scoring System Details	2
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APPENDICES

APPENDIX A

Tailings Disposal Options Assessment

1.0 INTRODUCTION

1.1 Context

Nalunaq A/S has engaged Golder Associates (UK) Ltd (“Golder”) to provide support for the water and tailings management at their Nalunaq mine in southern Greenland. Golder submitted a proposal (reference P20136781/3/V.2, dated July 2020) which outlines several tasks which would be carried out to Pre-feasibility Study (PFS) level where the information allows.

As part of the scope of work covered by the proposal, Task 1 entailed Golder collaborating with Nalunaq A/S to review the options available for tailings disposal. Confirmation and documentation of the tailings disposal options assessment process is the focus of this report.

1.2 Background

Following discovery in the early 1990s and development and operation by Crew Gold Corporation (“Crew Gold”), development was continued by Angus & Ross plc and Angel Mining (Gold) A/S, between 2004 and 2013. Subsequently additional exploration work has been undertaken in the Nalunaq area. It is understood that Nalunaq A/S are aiming to restart mining operations in 2022.

Golder was engaged by the previous owners to provide support on the project with regards to tailings disposal, geotechnical engineering and water management between 2002 and 2009. The key reports prepared by Golder at the time are as follows:

- Review of Surface Tailings Options – 2002 – Kvaerner Engineering & Construction UK Ltd;
- Geotechnical Review – 2003 – McIntosh Engineering on behalf of Crew Developments;
- Waste Management and Mineral Processing – 2009 - Angus Ross PLC;
- Geotechnical Assessment of Proposed Mineral Processing Chamber – 2009 - Angus Ross PLC;
- Geotechnical Assessment of Proposed Mineral Processing – 2009 – Angel Mining (Gold) A/S; and
- Site Visit – 2009 - Angel Mining (Gold) A/S.

1.3 Scope of Work

The scope of work for this phase is to review and report the high-level discussions of the following options for tailings disposal at the Nalunaq mine:

- Underground Slurry;
- Surface Slurry;
- Marine Deposition;
- Dry Stack; and
- Paste Backfill.

2.0 TAILINGS DISPOSAL OPTIONS ASSESSMENT

2.1 General

The advantages and disadvantages of the different options for the tailings disposal options for the Nalunaq mine has been assessed. The analysis has been undertaken using a multi account system where a simple scoring system was adopted to evaluate the preferred option to be developed.

The multi account system was focussed on four main accounts as follows:

- Environmental;
- Socio Economic;
- Project Economics; and
- Technical.

Each of these main accounts was subdivided into sub accounts against which the scoring system was applied.

2.2 Scoring System

The scoring system is designed to work in combination with a weighting system applied to each subaccount where the relative importance of each sub account and every particular aspect considered in the assessment is granted a percentage (%) weight in the overall assessment.

Table 1 below presents a general view of the scoring system applied in the assessment.

Table 1: Scoring System Details

Score	Performance Description	Comment
1	Very Poor	Presents very poor performance against the criteria or is very unlikely to be beneficial to the project
2	Poor	Presents poor performance against the criteria or is unlikely to be beneficial to the project
3	Average / Neutral	Presents average performance against the criteria or is likely to be neutral in respect to project benefits
4	Good	Presents good performance against the criteria or is likely to be beneficial to the project
5	Very Good	Presents very good performance against the criteria or is very likely to be beneficial to the project
-100	Fatal Flaw	The option presents a fatal flaw against this criteria and should not be considered further

APPENDIX A presents the results of the options assessment undertaken. The following section present details of the analysis discussed leading to the detailed assessment of the five tailings disposal options considered.

2.3 Underground Slurry Tailings Disposal

The main advantages of underground slurry tailings disposal (not cemented) are the following:

- Low visual impact;
- Low environmental impact on surface water, although potential impacts on ground water may pose challenges; and
- There may be cost advantages to this option (lower capital expenditure ["CAPEX"]) but has not been developed to a point at which this can be confirmed.

The main disadvantages of this option are the following:

- Management of the contact (make-up) water pumped underground with the tailings will pose challenges, especially should the water quality be adversely impacted by the reagents used in the processing or the chemistry of the tailings. Return water will have to be collected and pumped back to the surface for re-use.
- Challenges with placement of the tailings and management of make-up water underground, especially with regards to tailings deposition in previously mined stopes situated at a higher elevation than one of the levels that will be mined as part of the project. Water-tight bulkheads will be required to retain water and tailings and these could be expensive to design and install.
- A survey of the underground space available for disposal together with a projection of future space to be created by ore extraction will be needed to ensure sufficient volume for Life of Mine disposal of tailings will be available.
- The required bulkheads to ensure tailings and tailings water containment would require maintenance with personnel and equipment required to work in direct contact with a potentially unstable structure. The risk to personnel directly involved in the maintenance of the structures and operating personnel in lower areas of the mine could be significant without a realistic prospect of the risk diminishing with time. Failure of any part of the system could lead to fatalities underground.
- An underground Rock Mechanics detailed assessment will be required to ensure no discontinuities exist in the rock mass surrounding previously mined out areas that could lead to uncontrolled migration of tailings into current working areas or other sectors of the underground workings¹.

2.4 Underground Paste Tailings Backfill

The main advantages of underground paste tailings backfill (cemented) are the following:

- Low visual impact.
- Low environmental impact on surface water, although potential impacts on ground water may pose challenges (e.g. metal leaching).
- Thickened or paste tailings disposal for underground backfill often with the addition of cement (e.g. 3% by weight) has been used successfully for stope support for a number of decades and is therefore considered proven technology.

¹ After the deluge: Appraising the 1970 Mufulira mine disaster in Zambia, Alfred Tembo, Historia vol.64 n.2 Durban Nov. 2019

- Paste tailings disposal is therefore deemed to be a much safer option for underground disposal, as the risk of uncontrolled migration is significantly reduced if not eliminated.
- This backfill system (if cemented paste is used) however also represents an attractive opportunity in that pillar mining may be possible once the cemented backfill has reached sufficient strength to provide stope support.

The main disadvantages of this option are the following:

- Thickening of tailings to create paste generally has a high capex for mechanical equipment, requiring thickeners, filters, cement addition (if cemented backfill is used), positive displacement pumps and high-pressure pipelines. Operating expense (“OPEX”) for power consumption and cement addition is also high.
- Management of the contact (make-up) water pumped underground with the paste may pose challenges, especially should the water quality be adversely impacted by the reagents used in the processing or the chemistry of the tailings. The volume of water in the paste is however much reduced when compared with slurry tailings.
- Challenges with paste deposition and management of bleed water underground, especially with regards to tailings deposition in previously mined stopes situated at a higher elevation than one of the levels that will be mined as part of the project. This is less of a risk than for hydraulic backfill as the risk is removed within a few hours after the initial cement set.

2.5 On Surface Slurry Tailings Disposal

On surface slurry tailings disposal was the third tailings disposal option discussed.

The main advantages of this option are the following:

- Moderate cost;
- Proven technology, with similar facilities being operated successfully in similar climates (Northern Europe, Canada etc).
- Relatively easy to develop using a phased approach, thereby reducing initial CAPEX;
- Ease of pumping tailings to the facility and return water back to the Processing Plant; and
- Easier monitoring of the facility should be possible, when compared to the underground disposal options, although monitoring during the winter months will also pose challenges.

The main disadvantages of this option are the following:

- Relatively large size (when compared to the alternatives) and associated high visual impact;
- Permitting of surface tailings storage facilities is expected to be more difficult than other options given the current climate influenced by recent tailings dam failures;
- Exposure to the environment and close proximity to potential erosive forces including snow avalanches and the river. This may also pose operating challenges during the cold winter months;
- Potentially higher maintenance requirements than alternatives, especially following closure due to long term degradation; and
- Higher risk profile (including potential for environmental contamination due to pipe burst or failure of the facility) than some of the alternatives (e.g. underground cemented paste backfill or on surface dry stacking).

2.6 On Surface Filter cake (Dry Stack) Tailings Disposal

The fourth option considered was on surface filter cake (dry stack) tailings disposal.

The main advantages of this option are the following:

- Medium visual impact when compared to alternatives for on surface tailings disposal;
- Proven technology, with similar facilities being operated successfully in similar climates (Northern Europe, Canada etc.);
- Reduced size and footprint when compared to alternatives for on surface tailings disposal;
- Reduced seepage from the facility when compared to on-surface slurry tailings disposal;
- Lower risk profile than for on-surface slurry tailings disposal;
- Relatively easy to develop using a phased approach, thereby reducing initial CAPEX;
- Reduced water volumes to be pumped back to the Processing Plant;
- Permitting considered more likely to be successful; and
- Easier monitoring of the facility should be possible, when compared to the underground disposal options, although monitoring during the winter months is expected to pose challenges.

The main disadvantages of this option are the following:

- Higher initial CAPEX due to the costs associated with the Filter Plant;
- Exposure to the environment and close proximity to potential erosive forces including snow avalanches and the river. This may also pose operating challenges during the cold winter months;
- Potentially higher maintenance requirements than (underground) alternatives, especially following closure due to long term degradation. These challenges however are significantly lower than those for a slurry tailing facility on surface;
- Management of the contact water to be pumped back to the Plant during the winter months may pose challenges, although the volume will be less than for on surface slurry tailings disposal; and
- Challenges with filter cake transportation and placement expected during the cold winter months.

2.7 Marine Tailings Deposition.

Marine tailings deposition was the final tailings deposition option considered.

The main environmental impacts of marine tailings disposal are the loss of benthic habitat on the footprint area where tailings are deposited at the bottom of the fjord, the impact on the diversity and abundance of species and the risk associated with the bio-accumulation of heavy metals in the food chain².

When considering international best practice guidelines e.g. the EU BREF³ document on mine waste disposal, marine disposal is usually only considered as an option when the waste is deemed to be inert and space is not

² Esin, E, Fresenius Environmental Bulletin. 2017

³ EU BREF = European Union Best Available Techniques reference documents

available for tailings deposition on land (e.g. in the case of the Hustadmarmor Calcium Carbonate Mine in Norway, used as an example in the BREF).

The World Bank's IFC issued sectoral EHS Guideline in 2007 stating that marine tailings disposal may be considered only in the absence of a socially and environmentally sound land-based alternative and based on an independent scientific assessment for mining. If this option is considered further it is recommended that it should be subject to a detailed feasibility study and Environmental and Social Impact Assessment (ESIA) including consideration of all tailings management alternatives, and only progress the option if it is shown that the discharge is not likely to have significant adverse effects on marine and coastal resources or on local communities. Any decision taken should further comply with international agreements such as the United Nations Convention on the Law of the Sea (UNCLOS), 1982.

Of the tailings deposition options considered, marine (or sub-aqueous) tailings deposition is probably the most controversial, primarily due to historical examples and the unknown long-term potential environmental impacts. In addition, due to the unbounded nature of the deposition, any remediation of the tailings should it ever become necessary would be impractical, difficult and extremely costly.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The ranking matrix is presented in Appendix A, with the main conclusions as follows:

Underground tailings slurry disposal - The assessment is that the risk to health and safety of underground workers is considered unacceptable and a successful permit application is considered unlikely. This option is therefore considered to be **fatally flawed** and should not be considered further.

Underground paste tailings backfill - The assessment indicates that this options has relatively high CAPEX and OPEX for the paste plant, which includes constructing a tailings thickener, filters, cement addition, high pressure pumps and pipeline. There are no significant technical risks and it is recommended that this option should be explored further during the next phase of the project.

Surface slurry tailings disposal - This option is considered unlikely to be successfully permitted acceptable due to perceived societal risks. This option is therefore deemed to be fatally flawed and it is recommended should not be considered further.

Surface filter cake (Dry Stack) disposal - This option has higher capex and OPEX than other options, but advantages include lower risks and likelihood of a successful permit application. There are no significant issues with this option which it is recommended should be taken forward into the next stage of the project.

Marine tailings disposal - This option is considered to have high potential environmental impacts, reputational risk to Nalunaq A/S and is considered unlikely to be successfully permitted. This option is therefore deemed to be **fatally flawed** and it is recommended that it should not be pursued further.

Golder recommends that the on-surface tailings filter cake disposal in a Dry Stack Facility (DSF) be developed as the base case for tailings disposal for the Nalunaq mine. Underground tailings paste backfill disposal should also be evaluated during the next phase of the project to determine the most advantageous options for the project.

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APPENDIX A

Tailings Disposal Options Assessment

Item	Description	Weighting factor			Option 1	Option 2	Option 3	Option 4	Option 5	Comment/ Explanation
					UG Slurry Tailings Disposal	UG Paste Backfill Tailings Disposal	On Surface Slurry Tailings Disposal	Dry Stack Tailings Disposal	Marine Tailings Disposal in Fjord	
A	Environmental Aspects									NOTE: FROM ENVIRONMENTAL AND SOCIAL PERSPECTIVES, OPTIONS 1, 3 & 5 ARE DEEMED TO BE FATALLY FLAWED. These options were however assessed in all categories for completeness
1	Permitting	33%								
1.1	Permitting - likelihood of obtaining permits		8%	3%	1	4	-100	4	-100	Permitting for UG disposal is deemed unlikely. On surface slurry tailings disposal, as well as marine disposal are deemed fatally flawd options due to potential environmental impacts.
1.2	Permitting timelines			3%	1	3	1	3	1	Permitting for UG disposal is deemed unlikely. On surface slurry tailings disposal, as well as marine disposal are deemed unlikely due to potential environmental impacts.
1.3	Different permits /ease of getting permits			2%	1	3	1	3	1	Permitting for UG disposal is deemed unlikely. On surface slurry tailings disposal, as well as marine disposal are deemed unlikely due to potential environmental impacts.
2	Land									
2.1	Concession boundary and/or land ownership		6%	2%	4	4	1	3	3	Underground disposal options are best in this regard, followed by the on surface Dry Stack Facility. Marine Tailings Disposal is considered poor due to impact on the Marine Environment.
2.1	Land use/Beneficial users of land not owned/possibility to purchase			2%	4	4	1	3	3	Underground disposal options are best in this regard, followed by the on surface Dry Stack Facility. From land ownership and use perspectives the Marine Tailings Disposal is the worst option, followed by on surface Slurry Tailings Disposal.
2.3	Beneficial users of adjacent land/other impact on owned land			2%	4	4	1	3	3	Underground disposal options are best in this regard, followed by the on surface Dry Stack Facility. From land ownership and use perspectives the Marine Tailings Disposal is the worst option, followed by on surface Slurry Tailings Disposal.
3	Water									
3.1	Discharge water quality/potential for re-use/reclaim water quality		8%	1%	2	2	2	2	1	No significant impact on water quality for re-use. On Surface facilities will need storage to contain water in a clarification pond, before re-use or discharge (after treatment if deemed necessary). Make-up water will be lost in the marine discharge option.
3.2	Discharge water quantities			3%	2	3	1	3	1	On Surface facilities will need storage to contain water in a clarification pond, before re-use or discharge (after treatment if deemed necessary). Make-up water will be lost in the marine discharge option.
3.3	Storm water storage			2%	2	2	2	2	3	From water balance results, the storm water storage requirements are also linked to the size of the catchment and the dewatering technology used for a particular option
3.4	Raw water abstraction quantities			2%	1	2	2	2	1	From the water balance results, raw water abstraction is linked to the degree of dewatering and assuming that the water quality from tailings recovery is sufficient for plant use, but also linked to the size of each catchment
4	Environmental Controls									
4.1	Seepage		6%	3%	2	3	2	3	3	Seepage will be much reduced for filter cake (Dry Stack Facility) options than for conventional tailings. Seepage also depends on the footprint area of the facilities, which will be smaller for the Dry Stack than for a conventional tailings facility
4.2	Dust			1%	5	5	2	2	5	Filter cake is potentially more prone to dusting, compared to conventional tailings, though filter cake deposition can work with a smaller exposed area and it is easier to spray and keep the deposition surface damp.
4.3	ARD/metal Leaching			2%	2	3	2	4	3	ARD and metal leaching are not expected to be issues.
5	Closure									
5.1	Potential for progressive closure		5%	3%	3	3	2	3	3	Downstream construction has lowest potential for progressive reclamation, with filter cake (dry stack) having the best potential for progressive closure.
5.2	Final land form/visual impact			1%	5	5	2	2	5	Based on current planned final height, overall land take
5.3	Potential requirement to change/update closure plan			1%	3	3	3	3	3	Options that deviate the most from current closure plan are most affected
B	Socio-Economic Aspects									
1	Current potential beneficial users	3%	3%	1%	3	3	3	3	3	Limited benefit to current potential users
2	Post closure use			1%	2	2	2	2	2	Post closure use is very similar for all options, although the filter cake option may be more flexible regarding number of post closure options.
3	Risk and Consequence of Facility Failure			1%	-100	3	2	4	4	Facility failure consequence is directly linked to the amount of tailings in the facility, the risk posed to personnel and the environment, the potential transport of tailings due to presence of water in the tailings, and how close to sensitive areas the option is located.

C	Project Economic Aspects									
1	Total Investments costs	32%	16%	16%	2	2	2.5	3	2	Based on estimated relative costs
2	Cost / m3 stored tailings at planned throughput		16%	16%	2	2	3	2	3	Based on estimated relative costs
D	Technical Aspects									
1	Life of the facility (current study)	32%	8%	8%	2	2	3	3	4	Based on estimated tailings volume and potential for future storage
2	Technical complexity									
2.1	Constructability and construction schedule		7%	3%	1	2	3	4	3	Filter cake is less dependent on scheduling and is not constrained by rate of rise but constructability can be impacted if working in small areas. For slurry tailings, options with the least area and highest rate of rise are the options that are most challenged with constructability and schedule (winter construction for instance)
2.2	Complexity of design			2%	1	2	3	3	3	Option 2 with the paste tailings is deemed to be the most complex to design. The filter cake and slurry tailings options are less complex than the UG deposition options which will also require the design of high pressure water proof plugs.
2.3	Complexity of operation			2%	1	2	3	3	4	UG backfill operations can be challenging. Dry stack tailings disposal is expected to be less challenging than slurry tailings disposal
3	Material requirement									
3.1	Construction material (waste rock/engineered fill) availability		8%	5%	5	5	3	4	5	Estimated based on the amount of engineered material required for construction, as well as the ratio of tailings vs fill
3.2	Closure material availability			2%	5	5	2	3	5	Estimate based on volume of material required for closure
3.3	Self build (tailings) availability			1%	3	3	3	3	3	Neutral, not deemed relevant for these options
4	Operational Flexibility									
4.1	Potential for storage capacity expansion in addition to life given by current study		9%	2%	1	1	3	4	4	Capacity for underground limited, space available for surface disposal options
4.2	Potential to accommodate increased throughput during operations			3%	1	1	3	4	4	Linked to rate of rise, scheduling difficulties, and total space available for the options (an increased throughput may shorten the life of the facility)
4.3	Flexibility to upset conditions			4%	1	1	3	4	3	Upset conditions may be defined as problems with water. Scheduling problems etc. Filter cake and marine are the most flexible options.
		100%	100%	100%						
	WEIGHTED SCORE (higher is more advantageous)				23.4	51.2	-12.8	59.8	-2.8	
	OPTION RANKINGS				3	2	5	1	4	Option 4 (Dry Stack Facility on surface) to be developed as the Base Case, Option 2 (UG Paste Disposal) to be assessed during the next Phase of the Project, Options 1, 3 & 4 are Fatally Flawed and will not be pursued.



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