TECHNICAL MEMORANDUM

DATE 15/03/2022 **Reference No.** 21467213.C04.2.A.1

TO Joan Plant
Nalunaq A/S

CC Susan Digges La Touche, Ben Hodgetts

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FAILURE MODE AND EFFECTS ANALYSIS FOR NALUNAQ MINE

1.0 INTRODUCTION

Nalunaq A/S has engaged Golder a member of WSP (WSP UK Ltd) to provide support following comments and recommendations provided by DCE/GINR in relation to the Environmental Impact Assessment dated 1 October 2021 ('EIA draft 2') for the Nalunaq mine in southern Greenland prepared by WSP A/S, and the supporting technical background reports, prepared by Golder Associates (UK) Ltd, for the Nalunaq Gold Project. In relation to this, Golder submitted a proposal (reference CX21467213_Change Order 4, dated January 2022) which recommends a Failure Mode and Effects Analysis (FMEA) in relation to site operations. The FMEA is submitted as a requirement to satisfy DCE/GINR requirements for R1.1 and R1.2 as set out in Bach *et al* (2021).

2.0 METHODOLOGY

An FMEA is a process for assessing the various components of the dry stack tailings facility (DTSF) and associated mine facilities and systems to identify potential, realistic, failure modes. In this case the components include the DTSF, waste rock deposits, the underground mine and above ground infrastructure. Failure modes and their resulting effects on the system are thereafter examined and scored. Failure risk indicators to be examined include flooding, storm effects, mechanical weathering, landslide, climate change and earthquakes. The FMEA incorporates the potential failure modes, the environmental effects of failure, the current (or anticipated) controls or means of prevention of failure and the additional measures that may be put into place to further decrease the potential impact. The scoring system and further explanation for Severity, Probability and Detectability is presented in Table 1.

Table 1 : Scoring system for Severity, Probability and Detectability

Scoring category	Score	Criteria
Severity (SEV) How severe is the effect?	1	Lasting days or less; limited to small area (metres); receptor of low significance/ sensitivity (industrial area)
	2	Lasting weeks; reduced area (hundreds of metres); no environmentally sensitive species/ habitat)
	3	Lasting months; impact on an extended area (kilometres); area with some environmental sensitivity (scarce/ valuable environment).

Scoring category	Score	Criteria
	4	Lasting years; impact on sub-basin; environmentally sensitive environment/ receptor (endangered species/ habitats)
	5	Permanent impact; affects a whole basin or region; highly sensitive environment (endangered species, wetlands, protected habitats)
Probability (OCC) How frequently is the cause likely to occur?	1	The unwanted event has never been known to occur in the industry: or it is highly unlikely that it will occur within 20 years
	2	The unwanted event has happened in the business at some time: or could happen within 20 years
	3	The unwanted event has happened in the business at some time: or could happen within 10 years
	4	The unwanted event has occurred infrequently: occurs in order of less than once per year & is likely to reoccur within 5 years
	5	The unwanted event has occurred frequently: occurs in order of one or more times per year & is likely to reoccur within 1 year
Detectability (DET) How probable is it that the failure or cause of the failure will be detected? Is it practical to mitigate this failure?	1	The unwanted event will be detected and dealt with immediately
	2	The unwanted event is likely to be detected by the current controls in place
	3	The unwanted event could be detected
	4	The unwanted event is unlikely to be detected
	5	The unwanted event is extremely unlikely to be detected

The Risk Priority Number (RPN) represents the combined weighting of Severity (SEV), Probability (OCC) and Detectability (DET):

$$RPN = SEV \times OCC \times DET.$$

3.0 RESULTS

The FMEA is presented in Table 2.

Table 2 : FMEA for Nalunaq Mine and Associated Infrastructure

#	Phase within Life of Mine (LoM)	Area	Potential Failure Mode	Potential Failure Effect	SEVERITY (SEV)	Potential Causes	PROBABILITY (OCC)	Current process controls	DETECTABILITY (DET)	RISK PRIORITY NUMBER (RPN)	Action recommended
	Construction, Operation, Closure	*Example*	*What can go wrong?*	*What is the impact if the failure mode is not prevented or corrected?*	*1-5*	*What causes the step to go wrong?*	*1-5*	*What are the existing controls that prevent the failure mode occurring or detect it should it occur?*	*1-5*	*number (SEV x OCC x DET)*	
1	Construction / Operation / Closure	Jetty	Leaks and spills of hydrocarbons	Impact to surface waters and ecology, impact to marine life	4	Poor handling of fuels during refuelling, ruptured hoses, valve malfunctions. Damage to containers during transit.	3	All fuel transfer areas will be equipped with spill kits, including booms; the handling and managements of chemicals will be controlled to avoid adverse environmental impact. Only defined quantities of diesel will be unloaded to minimize potential impact. Further procedures will be outlined in an Environmental Management Plan (EMP).	2	24	Water quality will be monitored
2	Construction / operation	Jetty	Ballast water containing invasive non-indigenous species	Impact to marine life	4	Vessels berthing and discharging ballast water containing non-indigenous species	3	Ships must follow ballast management to a set standard and must implement a Ballast Water and Sediments Management Plan.	2	24	

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3	Construction / Operation / Closure	Beach landing area	Leaks and spills of hydrocarbons	Local impact to soils, impact to surface waters and ecology; potential impact to marine life	2	Poor handling of fuels during refuelling, ruptured hoses, valve malfunctions. Damage to containers during transit.	4	All fuel transit areas will be equipped with spill kits; the handling and managements of chemicals will be strictly controlled to avoid adverse environmental impact. Only defined quantities of diesel will be unloaded to minimize potential impact. Further procedures will be outlined in an Environmental Management Plan (EMP).	3	24	Water quality will be monitored
4	Construction / Operation / Decommissioning	Beach landing area	Supply chains and distribution	Unable to receive materials or personnel; monitoring, supplies or maintenance could be disrupted	4	High winds and sea conditions could make boat access and egress problematic; climate change / heavy rainfall could cause roads to washout	5	Weather monitoring and logistics planning.	1	20	Helipad to be constructed for use in emergencies, however due to high wind the risk of isolation cannot be completely mitigated.
5	Construction / Operation / Decommissioning	Camp / fuel storage facility	Leaks and spills of hydrocarbons	Local impact to soils, impact to surface waters and ecology	5	Poor handling of fuels during refuelling, leaks from containers within storage area. Damage to facility from rockfall, debris flow, avalanche.	2	All fuel storage areas to be bunded and transfer areas contained and equipped with spill kits. Tanks are expected to be of the double-wall type, with the primary containment tank surrounded by secondary containment consisting of HDPE membrane and rock filled berms.	1	10	

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6	Construction / Operation / Decommissioning	Camp	Rockfall	Fall of loose rock onto people, plant and or infrastructure	5	Rockfall, potentially due to increase in weathering due to climate change	1	Monitoring of slopes above for hazard. Active management and engineered rockfall protection.	1	5	
7	Construction / Operation / Decommissioning	Camp	Debris flow	Flow of debris slurry onto people, plant and or infrastructure	5	Flooding / Climate change	3	Location away from historic flow paths. Monitoring of slopes above. Active management and engineering as required	1	15	
8	Construction / Operation / Decommissioning	Camp	Avalanche	Fall of snow mass onto people, plant and or infrastructure	5	Heavy rain/snowfall	4	An avalanche terrain assessment has been carried out. Caution should be exercised when working in these areas following heavy snowfall. The mine camp should be protected by a berm between the hillside and the camp. Further procedures will be outlined in an Avalanche Management Plan (AMP).	2	40	Develop procedures in an Avalanche Management Plan (AMP).
9	Operation	Waste rock dump	Rockfall	Fall of loose rock onto people, plant and or infrastructure	5	Increased erosion due to climate change, vehicle movements	3	Monitoring of slopes above for hazard. Active management and engineered rockfall protection.	1	15	A detailed rock fall hazard assessment will be developed to inform the design of rockfall protection measures including berms or catch fences
10	Operation	Waste rock dump	Debris flow	Flow of debris slurry onto people, plant and or infrastructure	5	Heavy rain/snowfall	4	Location away from historic flow paths. Monitoring of slopes above. Active	2	40	

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								management and engineering as required			
11	Operation	Waste rock dump	Avalanche	Fall of snow mass onto people, plant and or infrastructure	4	Avalanche	3	Procedures will be outlined in an Avalanche Management Plan (AMP).	2	24	Develop procedures in an Avalanche Management Plan (AMP).
12	Operation	Waste rock dump	Spills and leaks from fuel storage and handling	Local impact to soils, impact to surface waters and ecology	4	Poor handling of fuels during refuelling, leaks from containers within storage area.	3	All fuel storage to be bunded and transfer areas contained and equipped with spill kits	2	24	Water quality will be monitored
13	Construction	DTSF Area	Erosion, sediment transport	Impact to surface waters	4	Movement of vehicles and materials during construction of DTSF foundations	4	Berms will be constructed to divert any runoff into collection channels (EIA, 2021)	2	32	
14	Operation	DTSF Area	Dry stack weak zones in areas critical to dry stack stability	Potential failure of slopes of dry stacked tailings that could affect people and the environment	4	Insufficient compaction of tailings, wet or frozen conditions	2	Compaction procedures, identified area for out of spec material included in detailed design	1	8	Monitor for potential slope failure

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15	Construction / Operation	DTSF Area	Foundation material is unsuitable	Failure of slopes of dry stacked tailings that could affect people and the environment	4	Insufficient geotechnical data	1	Good construction management; adequate geotechnical data	2	8	
16	Construction / Operation	DTSF Area	Inadequate or defective foundation system	Seepage of tailings leachate and contamination of soil and groundwater	4	Insufficient geotechnical data,	2	Risk assessment	2	16	Continued monitoring of leachate and surface water quality
17	Construction / Operation	DTSF Area	Inadequate or defective drainage	Insufficient dry stack drainage leading to a rise in the phreatic surface resulting in failure of slopes of dry stacked tailings that could affect people and the environment	4	Insufficient dry stack drainage	2	A hydrological assessment of the system indicates that the proposed design operates effectively	2	16	Continued monitoring of phreatic surface
18	Operation (Water Management)	DTSF Area	Inflows to sediment pond exceed design capacity of system	Sediment laden water is discharged to the environment	4	High rainfall and/or snowmelt events	2	Water from the sediment pond is discharged by a weir system, with a discharge only proceeding once the water has reached a predetermined level. A water management plan (WMP) has been developed. Further flow and hydrometric monitoring (rainfall, snowfall and pan evaporation) will be undertaken to improve understanding of flows.	2	16	This is a consideration for extreme event planning. Routine maintenance to ensure that sediment build-up does not occur, and operating capacity maintained. As stated, further flow and hydrometric monitoring (rainfall, snowfall and pan evaporation) will be

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											undertaken to improve understanding of flows.
19	Construction / Operation	DTSF Area	Fall of loose rock onto people, plant and or infrastructure	Local impact to soils and impact to downstream receptors, including the river	2	Rock fall	2	Careful site choice; good design; spot areas of rock fall potential	3	12	A detailed rock fall hazard assessment will be developed to inform the design of rockfall protection measures including berms or catch fences
20	Construction / Operation	DTSF Area	Fall of snow mass onto people, plant and or infrastructure	Local impact to soils and impact to downstream receptors, including the river	5	Snow avalanche	4	Careful site choice; good design; carry out slope assessment following heavy snowfall. Further procedures will be outlined in an Avalanche Management Plan (AMP).	2	40	Develop procedures in an Avalanche Management Plan (AMP).
21	Construction / Operation	DTSF Area	Dust emission	Potentially contaminative dust released to atmosphere	3	Surface desiccation leading to uncontrolled dust emissions particularly during strong wind events	4	Appropriate compaction and materials management; surface is unlikely to become dry enough for dust emissions to arise and, if unusually dry, surface can be sprayed with water	2	24	Procedures to be specified in an Environmental Management Plan

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22	Construction / Operation	DTSF Area	Inundation of DTSF resulting in contaminants entering flood water	Contaminants enter flood waters. Impact to soils and impact to downstream receptors, including the river	2	Flooding / Climate change	1	DTSF raised above 1:1000 flood level. Minimise contact water by intercepting flows upgradient of the DTSF and processing plant and divert them away; DSF is protected from the maximum flood event by an outer berm; flood armouring.	2	4	Surface runoff from catchment areas upgradient of the proposed DTSF and Process Plant facilities will be intercepted by a series of diversion channels and drains, and then conveyed to the Kirkespir river. “Contact” water from the top surface of the DTSF stack will be discharged to a proposed settling basin (“Sediment Pond”). Water in the Sediment Pond will then be allowed to discharge through a weir to a receiving channel, which in turn discharges to the Kirkespir river. All these measures should mitigate risk of contamination of the river. Environmental monitoring procedures to be specified in an Environmental Management Plan

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23	Operation	DTSF Area	Scour damage to DTSF Embankment Face	Damage to DTSF leading to potential release of tailings with environmental damage, high capital costs and potential mine shut down	4	Periods of high river flow/ flooding / climate change	4	Conservative assessment for rip-rap requirements. Riprap will be placed upon a geofabric filter material, between toe and crest of embankment to a minimum height of 300 mm above the peak design flood level	1	16	Inspection following high flow events
24	Operation	DTSF Area	Scour damage to DTSF Embankment Toe	Damage to DTSF leading to potential release of tailings with environmental damage, high capital costs and potential mine shut down	5	Periods of high river flow/ flooding / climate change	4	Assessment of scour depth, incorporating a Factor of Safety of 1.5 carried out. Assessment indicates that the installation of a Scour Apron will represent a suitable option to protect the toe of the embankment.	1	20	Installation of a scour apron is required to protect the toe of the DTSF. Routine inspection / maintenance
25	Operation	DTSF Area	Leachate seepage from the DTSF is of a poorer quality than predicted	Concentrations of potential contaminants of concern (PCOCs)may exceed Greenland water quality guidelines, with the potential to adversely impact the ecosystem of the river	5	The source term for the DTSF leachate may be incorrect; flow in the Kirkespir River may be lower than predicted.	4	An assessment has been undertaken that suggests that downgradient concentrations of PCOCs in groundwater without any low permeability engineered liner are within Greenland limits for water quality even at low flow conditions. Source terms have been derived from the most recently available geochemical test data (SGS, 2020) and therefore the source term is unlikely to be significantly different to that presented. Source term is more likely to represent a conservative estimate, as leachate values are calculated using mass	1	20	Current process controls (geochemical analysis and assessment) are likely to be sufficient to prevent failure. Environmental monitoring procedures to be specified in an Environmental Management Plan

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								concentrations and partition coefficients.			
26	Operation	DTSF Area	Damage to haul road, DTSF untrafficable due to rainfall	Damage is likely to vary between minor, to extensive, leading to lack of mine access and egress for workers and equipment.	4	Long period of heavy rainfall	2	Installation of diversion channels designed to carry flows generated by 1 in 1000 year event prior to spilling	1	8	Consider access road design optimisation as design progresses.
27	Operation	DTSF Area	Damage to haul road, DTSF untrafficable due to rock fall	Minor damage to road, minor access issues	2	Rock fall	2	Careful site choice; good design; spot areas of rock fall potential	3	12	Consider access road design optimisation as design progresses.
28	Operation	DTSF Area	Damage to haul road, DTSF untrafficable due to avalanche	Disruption to supply chains and distribution routes. Damage is likely to vary between minor, to extensive, leading to lack of mine access and egress for workers and equipment.	2	Snow avalanche	1	Procedures will be outlined in an Avalanche Management Plan (AMP).	3	6	
29	Operation	DTSF Area	Damage to bridges, erosion of road	Minor damage to road, minor access issues	1	Climate change leading to more extreme rainfall, snow and strong winds	4	Road and bridges to be regularly checked and maintained	3	12	
30	Operation	DTSF Area	Spills and leaks from fuel storage and handling	Local impact to soils, impact to surface waters and ecology	1	Poor handling of fuels during refuelling, leaks from containers	4	All fuel storage to be bunded and transfer areas contained and equipped with spill kits	2	8	Environmental monitoring procedures to be specified in an

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						within storage area.					Environmental Management Plan
31	Operation	Process plant	Escape of process water into the environment	Local impact to soils, impact to surface waters and ecology	4	Damage to plant by flooding, rockfall, debris flow, avalanche	3	The process water is designated as non-lethal and unlikely to impact adversely upon the recipient surface water receptors. The concentration of reagents in the effluent is low.	1	12	All potential causes of damage will be mitigated, but are still possible; process water is designed as non-lethal. Environmental monitoring procedures to be specified in an Environmental Management Plan
32	Operation	Process plant	Process Plant is flooded	Damage to process plant; potential impact upon operational capability; potential escape of process water; potential injury to workers	3	Flooding	3	Flood risk assessment. Process building is constructed on an engineered platform built above the 1:1000 year event flood line. A diversion channel will intercept water from the hillside and channel it along the western edge of the process plant; the channel has been designed to convey the 1 in 1000 year event.	2	18	There will be an ongoing assessment of potential risk; although all potential causes of damage will be mitigated, ongoing monitoring of water levels and quality will be specified as part of an Environmental Management Plan.

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33	Operation	Process plant	Rockfall above process plant	Process plant is damaged; workers may be injured or killed; potential escape of process water; chemicals may be released into the environment	3	Rockfall	3	Careful site choice; good design; spot areas of rock fall potential. Beneficiation process relies on a flotation process. Major process area will be surrounded by containment.	2	18	A detailed rock fall hazard assessment will be developed to inform the design of rockfall protection measures including berms or catch fences.
34	Operation	Process plant	Avalanche above process plant	Process plant is damaged; workers may be injured or killed; chemicals may be released into the environment	5	Snow avalanche/ high snowfall	3	Careful site choice; good design. Further procedures will be outlined in an Avalanche Management Plan (AMP).	2	30	Develop procedures in an Avalanche Management Plan (AMP).
35	Operation	Process plant	Debris flow above process plant	Process plant is damaged; workers may be injured or killed by flow of slurry; chemicals may be released into the environment	5	Flow of debris slurry above plant	2	Careful site choice; good design; spot areas of debris flow paths	2	20	
36	Operation	Process plant	Spills and leaks from fuel and chemical storage and handling	Local impact to soils, impact to surface waters and ecology	5	Poor handling of fuels during refuelling, leaks from containers within storage area.	2	All fuel storage areas to be bunded and transfer areas contained and equipped with spill kits; the handling and managements of chemicals will be strictly controlled to avoid adverse environmental impact, Fuel will be stored in double-walled tanks. Mixed reagents will be located in containment areas in the process plant.	2	20	Environmental monitoring procedures to be specified in an Environmental Management Plan.

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37	Operation	Process plant	Release of dust	Local impact from dust to surrounding soils, ecology and surface waters	4	Release of dust from stockpiles external to mill and from the processing facility	3	The processing facility is to be covered by a dome building and will be equipped with a dust suppression system.	1	12	
38	Operation	Process plant	Escape of waste to the environment	Potential release of waste into the environment with impact to surface waters and ecology	1	Damage to waste containment area by flooding, rockfall, debris flow, avalanche or high winds	3	Waste to be kept in contained facility; tailings from process will be transported to DTSF	1	3	Environmental monitoring procedures to be specified in an Environmental Management Plan.
39	Operation	Process plant	Fire	Potential release of waste/chemicals/process water into the environment with impact to surface waters and ecology	1	Electrical malfunction; ignition of flammable reagents/fuel	3	Process building is constructed of non-combustible material; fire protection system consists of fire hose stations and fire water tanks.	1	3	
40	Operation	Mine underground workings	Groundwater Inrush to Mine	A sudden incursion of water and/or non cemented backfill and tailings into the mine, endangering workers and equipment.	3	The presence of weak ground or fractures / faults between two areas of working	2	A groundwater inrush assessment has been carried out due to the proximity of the Valley Block to the flooded South Block. Assessment indicates risk is low. Geotechnical mapping and ongoing monitoring to mitigate risk during operations.	1	6	During development of Valley Block water levels in existing workings will be monitored as will geotechnical ground conditions during development.

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41	Operation	Mine underground workings	Groundwater inflows to mine are greater than expected	Higher groundwater inflows could give rise to higher than estimated water management requirements downstream from the mine. May need increased pumping capacity within the mine. Increase in water treatment capacity may be needed.	4	Conceptual hydrogeological model may be incorrect; may intercept preferential flow paths; climate change	1	Groundwater inflows have been calculated, via a variety of methods, to inform water management requirements. Monitoring is recommended upon restart of operations such that inflow estimates and our understanding of the response of the mine to rainfall events is refined.	1	4	Monitoring points and v-notch weirs to be installed to refine estimates.
42	Operation	Mine underground workings	Groundwater flows to mine are less than expected	Water is insufficient for mine water demands; supplementary supply wells may be required	2	Conceptual hydrogeological model and calculations may contain inaccuracies	2	An assessment of supplementary water requirements was undertaken.	3	12	
43	Operation (Water Management)	Mine underground workings	Mine floods due to failure of management controls and or equipment	Causes sediment and/or holding pond to become inundated, resulting in high sediment laden water being discharged to Kirkespir River.	2	High rainfall and/or snowmelt events	2	A water management plan (WMP) has been developed	3	12	This is a consideration for extreme event planning. Routine maintenance to ensure that sediment build-up does not occur, and operating capacity maintained

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44	Operation (Water Management)	Mine underground workings	Groundwater inflows of poor quality discharged to the environment	Concentrations of potential contaminants of concern (PCOCs)may exceed Greenland water quality guidelines, with the potential to adversely impact the ecosystem of the river	4	Lack of monitoring; groundwater of different quality to that previously assessed is encountered; spillage of chemicals / hydrocarbons has occurred	1	Water quality monitoring data (four spot measurements) for the Kirkespir River has been assessed; further water quality monitoring will be undertaken	3	12	Water quality monitoring will be ongoing. Environmental monitoring procedures to be specified in an Environmental Management Plan.
45	Operation	Mine underground workings	Rock rockfall	Risk to workers, impact to operations	4	Changing precipitation patterns (periods of increased rainfall due to climate change) causing increased degradation in workings.	2	Geotechnical assessment; previous experience	2	16	
46	Operation	Mine underground workings	Collapse of drives, adits or stopes	Complete collapse impacting resources and production rates; fall of loose rock onto people, plant and or infrastructure	4	Breakdown in process (i.e. ground support installations or checking and replacing old ground support). Poorer and/or deterioration of ground conditions than expected/identified leads to application of	2	Rehab and installation of adequate support	3	24	

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						inadequate ground support in some areas of the mine					
47	Operation	Mine underground workings	Water inrush	Contaminated water lost to the environment; inundation of workings or part of workings	4	Potentially caused by instability / deterioration of bulkhead or encountering preferential flow feature	2	Assessment of geology, hydrogeology and bulkhead; monitoring of South Block water levels and surface water quality	1	8	Ongoing monitoring of water levels and bulkhead is recommended
48	Operation	Mine underground workings	Collapse of mine bulkhead on 300 level	Release of unconsolidated tailings within the block mining area; flooding of lower sections of mine and out of 300m portal affecting people, plant and infrastructure	5	Punching shear failure along the rock/concrete contact or through the rock mass, deep beam flexural failure, hydraulic jacking of the rock surrounding the plug, excessive downstream seepage around the plug and possible downstream erosion, long-term disintegration of concrete, such as acid or sulphate attack, and/or	2	An investigation into the integrity of the bulkhead did not find excessive seepage and demonstrated that the water was unlikely to attack the concrete (it was not acidic).	2	20	Ongoing monitoring of bulkhead is recommended

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						alkali aggregate reactivity					
49	Operation	Mine underground workings	Acid generation from mine waste disposed of within mine	Acid mine drainage and leachate impacting surface waters and ecology	4	Mine waste has a different geochemical composition from that tested	2	Historical water quality testing carried out annually since 2004, as well as more recent geochemical testing and assessment, has determined that the mine waste at Nalunaq is not acid generating. It is therefore unlikely that the mine waste generated would be of a different composition and acid mine drainage generated.	2	16	Environmental monitoring procedures to be specified in an Environmental Management Plan.
50	Operation	Mine underground workings	Escape of chemicals used in blasting activities	Groundwater contamination by nitrates	5	Damage to explosives storage, spillage of emulsion	1	Emulsion will be used for blasting activities and this is surrounded by a film of oil which will minimise contact with water sources and also has a low capacity to release nitrogen to the water sources. Spillage kits will be available, and any spillage will be cleaned up using cat litter, bentonite or similar and disposed of in accordance with available guidance.	1	5	

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51	Operation	Mine underground workings	Spills and leaks from fuel storage and handling	Local impact to soils, impact to surface waters and ecology	2	Poor handling of fuels during refuelling, leaks from containers within storage area.	3	All fuel storage areas to be bunded and transfer areas contained and equipped with spill kits; the handling and managements of chemicals will be strictly controlled to avoid adverse environmental impact. Tanks will be of the double-walled type.	1	6	
52	Operation	Mine Portal	Rockfall	Fall of loose rock onto people, plant and or infrastructure	5	Rockfall; potential increase in weathering due to climate change	3	Monitoring of slopes above for hazard. Active management and engineered rockfall protection.	2	30	Alternative emergency egress to be mainatained.
53	Operation	Mine Portal	Debris flow	Flow of debris slurry onto people, plant and or infrastructure	5	Debris flow above plant; climate change	1	Location away from historic flow paths. Monitoring of slopes above. Active management and engineering as required	2	10	Alternative emergency egress to be maintained.
54	Operation	Mine Portal	Avalanche	Fall of snow mass onto people, plant and or infrastructure. Loss of production	5	High snowfall	3	Avalanche hazard monitoring and management programme	2	30	Develop procedures in an Avalanche Management Plan (AMP). Alternative emergency egress to be maintained
55	Operation	Mine Portal	Spills and leaks from fuel storage and handling	Local impact to soils, impact to surface waters and ecology	4	Poor handling of fuels during refuelling, leaks from containers within storage area.	3	All fuel storage areas to be bunded and transfer areas contained and equipped with spill kits; the handling and managements of chemicals will be strictly controlled to	1	12	Environmental monitoring procedures to be specified in an Environmental Management Plan.

#	Phase within Life of Mine (LoM)	Area	Potential Failure Mode	Potential Failure Effect	SEVERITY (SEV)	Potential Causes	PROBABILITY (OCC)	Current process controls	DETECTABILITY (DET)	RISK PRIORITY NUMBER (RPN)	Action recommended
								avoid adverse environmental impact			
56	Operation	Mine Portal /underground workings	Avalanche on southern and eastern side of Nalunaq Mountain, above access tracks and 350, 400 and 450 Levels	Could potentially bury, kill, or injure workers. Could bury or damage equipment including vehicles	5	Snow avalanche/ high snowfall	3	Slope assessment following heavy snowfall; appropriate route choice and operational controls when working in the area	3	45	Further procedures will be outlined in an Avalanche Management Plan (AMP).
57	Operation (Water Management)	Mine underground workings	Blockage within mine water distribution system	Release of potentially contaminated water	4	Damage through rockfall, freezing or ice build-up, pump failure	2	Regular checks, redundancy in system	2	16	Water distribution systems will be monitored and maintained to avoid build-up of ice or other obstructions. Redundancy in pumping system
58	Operation	Whole site	Sudden Closure	Dependent upon cause	4	Financial pressures, environmental incidents, social incidents, regulatory changes, structural failures	3	All environmental controls will remain active (e.g., monitoring and maintenance). Closure planning to incorporate planning for sudden or temporary closure	2	24	Closure plan to include stated measures in case of temporary suspension of mining or state of inactivity.
59	Operation	Whole site	Loss of power to operations	Potential sudden or temporary cessation of groundwater dewatering (pumping from mine);	4	Generator damaged by extreme winds, ice and/or snow	3	All environmental controls will remain active (e.g., monitoring and maintenance). Closure planning to incorporate	2	24	

#	Phase within Life of Mine (LoM)	Area	Potential Failure Mode	Potential Failure Effect	SEVERITY (SEV)	Potential Causes	PROBABILITY (OCC)	Current process controls	DETECTABILITY (DET)	RISK PRIORITY NUMBER (RPN)	Action recommended
				could cause release of contaminated water				planning for sudden or temporary closure			
60	Decommissioning and Closure	Mine underground workings	Instability of underground workings	Risk of ground surface becoming unstable; rockfall	1	Physical (stress) effects, deterioration processes, potentially exacerbated by climate change	3	Suitable closure planning	2	6	Integrated closure plan will ensure environmentally secure closure; monitoring results will be incorporated
61	Closure	DTSF and rock dumps	Instability of surface landforms, particularly DTSF	Risk of ground surface becoming unstable; rockfall	1	Inadequate protection, failure of rip rap or scour protection, avalanche, flooding, erosion.	3	Mine Closure Plan. Mine closure planning includes limited final height, berm and batter walls constructed at specified angle for closure, revegetation of walls, rock armouring, capping if specified, revegetation to prevent erosion.	2	6	Mine closure planning to be an integral part of life of mine. The mine closure plan will be periodically reviewed, amended and updated over the life of mine as necessary.

#	Phase within Life of Mine (LoM)	Area	Potential Failure Mode	Potential Failure Effect	SEVERITY (SEV)	Potential Causes	PROBABILITY (OCC)	Current process controls	DETECTABILITY (DET)	RISK PRIORITY NUMBER (RPN)	Action recommended
62	Closure	DTSF / Mine	Contamination of ground and surface waters	Concentrations of potential contaminants of concern (PCOCs)may exceed Greenland water quality guidelines, with the potential to adversely impact the ecosystem of the river	5	Acid Mine drainage	4	An environmental monitoring programme has been in place on site and no detrimental impacts from the historical mining have been identified to date. Materials are classed as inert with respect to ARD potential, and there is a low concentration of the only identified potential contaminant of concern (PCOC).	2	40	With current process controls damage is considered unlikely. Environmental monitoring procedures to be specified in an Environmental Management Plan.
63	Decommissioning and Closure	Whole site	Spillage of oils and chemicals	Contamination of groundwater and surface waters and potential ecological impact	5	Spillage or remobilisation of contaminants during decommissioning of storage tanks and oil / chemical storage facilities.	4	Careful management during decommissioning of storage facilities	2	40	Integrated closure planning and managed decommissioning of hydrocarbon and chemical storage facilities to mitigate risks to environment
64	Decommissioning and Closure	Site access	Haul road and bridges damaged or blocked	Access removed or restricted, potential injury to workers during decommissioning phase. Could disrupt monitoring activities.	2	Flooding, rockfall, debris flow, avalanche	3	Site is in a suitable location to avoid risk as far as possible	3	18	

4.0 CONCLUSIONS AND DISCUSSION

The highest value of RPN is 40. The RPN provides a tool for prioritising additional actions and or implementing or updating current process controls (e.g., ongoing monitoring). The RPN should be used in the prioritisation of risks, and addressing these, rather that identifying risks as ‘high’, ‘medium’ etc. By this methodology, areas that represent an elevated risk to the environment have been identified as follows:

- The accidental spillage of hydrocarbons may occur at various positions on the site, at all stages through the LoM, from refuelling, transit and storage. Where spillage occurs in the vicinity of the jetty or beach there is the potential for the hydrocarbons to impact a wider area. It is recommended that refuelling is carried out within fully contained areas and that appropriate spill kits are available.
- Damage to the DTSF through flooding / periods of high river flow leading to the release of tailings into surface waters is mitigated via engineering, which includes raising it above the 1:1000 year flood level, diverting runoff from upslope, by installation of a scour apron to protect the toe of the embankment and installation of armouring to the embankment face.
- Upon closure, the highest potential for environmental impact arises from mine drainage and the decommissioning or removal of hydrocarbon storage tanks and related equipment. The potential for contamination from mine drainage will be mitigated by an environmental monitoring programme for the site as set out in an Environmental Management Plan. Previous monitoring has demonstrated that no significant detrimental impacts from the historical mining have been identified. Geochemical testing carried out to date has demonstrated that materials can be classed as inert with respect to ARD potential, and there is a low concentration of the only identified PCOC. Closure planning will be undertaken as an integrated process and monitoring during site operations together with the results of scheduled kinetic testing will further inform the closure plan. Decommissioning of fuel storage should be undertaken in accordance with a suitable method statement to be protective of the environment.

The most significant risks to the project arise from natural hazards such as rockfall, avalanche, debris flow and flooding / high rainfall. Much of the risk from these hazards is mitigated by careful site selection, but ongoing monitoring and management of these hazards will be required throughout the LoM to ensure the safe functioning of the site with no detriment to the environment.

5.0 REFERENCES

- Bach, L, Juncher Jørgensen, C, Bomholt Dyrholm Jacobsen, I, Jia, Y and Nymand, J. 2021. DCE/GINR – Review of “Nalunaq Gold Project. Environmental Impact Assessment 2021. Version 01-10-2021” – draft 2. Aarhus University, DCE - Danish Centre for Environment and Energy. – Scientific note. 26 November 2021

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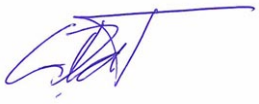

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