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ACACIA MINING OPERATIONS - GÖKIRMAK COPPER PROJECT

Risk Assessment for the Kepezkaya Tailings Storage Facility

Submitted to:
Acacia Mining Operations

REPORT

Report **Number** 1668788 Kepezkaya TSF Risk Assessment A.1

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1.0 INTRODUCTION

Golder Associates Turkey (Golder) was requested by Mr Uygar Saylam of Acacia Mining Operations (Acacia) to prepare a proposal to carry out Risk Assessments for the Kepezkaya Tailings Storage Facility (TSF) for the Gökirmak Copper Project, and prepare an Emergency Preparedness Plan for the tailings facility.

The Gökirmak Copper Project is located in the Kastamonu province of Northern Turkey. The Gökirmak deposit is a volcanogenic massive sulphide ("VMS") deposit located within Central Pontides metallogenic belt of Northern Turkey. The copper sulphide mineralization is characterized by pyrite and chalcopyrite which form thin, semi-massive to massive, layers that dip gently to the north at approximately 30º (roughly parallel to the regional Ekinveren thrust zone).

Hidro Dizayn, a Turkish consultancy firm, completed the design work for the Gökirmak TSFs. The total tailings storage requirement for the project has been estimated at 12.2 Mm^3, based upon the projected plant capacity over the 11 year Life of Mine (LoM) period. In order to meet the LoM tailing storage requirements, construction of two facilities are required, one at the Kepezkaya site (5.15 Mm^3) and a second at the Bağdere site (8.08 Mm^3). The Kepezkaya TSF will reach ultimate capacity during Q3 of Year 5 of operations. Tailings deposition would then switch to Bağdere for the remaining 6 years of operations.

The Kepezkaya TSF, will be built near Kepezkaya which is located approximately 1 km northeast of Hanönü. The project area, about 70 km from the city center of Kastamonu and about 1.0 km from the Hanönü, is located in the municipality of Hanönü.

2.0 SCOPE OF WORK

The scope of works carried out as part of the Risk Assessment for the Kepezkaya TSF is detailed below and is based on Golder's current understanding of the project requirements. The scope of work will be carried out to conform to legislation and regulations and/or to the most current and applicable European (including the current BREF document for Management of Tailings and Waste-Rock in Mining Activities) or International Standard, as well as international best practise guidelines.

The objective of the study is to assess the risk associated with the Kepezkaya TSF (including the annual probability of failure of the facility, but excluding the consequences of a failure), with the aim to identify any potential aspects which may require mitigating measures. In addition to this, Golder will prepared an Emergency Preparedness Plan (which does not form part of this report) for the TSF, according to international best practise guidelines.

2.1 Data Review

The data review carried out as part of the project included a review of all documents deemed relevant by Acacia Mining to the study. As part of the Risk Assessment carried out for the TSF, Golder requested copies of the following (TSF related) documents:

- TSF Design Report and Drawings;
- TSF Operating Manual;
- TSF As Built Drawings;
- TSF Geotechnical Report (foundation materials, wall construction materials and tailings);
- TSF Stability Review;
- Seismic Assessment Report;
- TSF Water Balance; and
- Any other documents deemed by the client to be relevant to the safety and stability of the TSF.

The documents provided to Golder were then reviewed and where applicable used to prepare the Risk Assessment for the TSF.

- AECOM-TR-R948-01-00_AMI_MineWaterManagementReport_Final (1).pdf
- Asya Maden Rev1 ESIA Report 17.03.2016 (1).pdf
- Asya Maden_ErosionPlan_Final.pdf
- GCP_MASTER_151021.pdf
- KEPEZKAYA_MALZEME_RAPORU_Kepezkaya WSF Natural Building Material Report.pdf
- SRKReport_UK06407_Gokirmak Copper Project_IER_Final3_ReviewedFGU.pdf

- G1 Project Report (Turkish)_Project Summary.pdf
- G1 Siting Study Turkish Hidromark Yer Seçimi.pdf
- G1 Tailing Dam Siting Study.pdf
- G3 Stability Analysis JEOTEKNIK_HESAP_RAPORU_ENG.pdf
- G4 Technical Specifications KPZ_C4_YAPI_VE_INSAAT_ISLERI_TEKNIK_SRTNM_151022.pdf
- G4_KPZ_C4_Construction_Works_Technical_Specifications-R2_December-2015.pdf
- G5.1 Hydrogeology KEPEZKAYA_ADT_HİDROJEOLOJİ_RAPORU.pdf
- G5.2 Hydrology KEPEZKAYA_ADT_HIDROLOJI_RAPORU.pdf
- G5.3.1 Geology KEPEZKAYA_MUH_JEO_RAPOR.pdf
- G6.3_Hydraulic_Calculations_Report_T.pdf
- G6.4_Structural_Calculations_Report_T.pdf
- G6.5_Roads_and_Infrastructures_Report_T.pdf
- G6.6_Illumination_Calculations_Report_T.pdf
- G6.7_Mechanical_Calculations_Report_T.pdf
- Upper_Drainage_Leachate_Management_Report_T.pdf

Dam Break Analysis

- rapor_ADT_March21_Hidrosaf.pdf
- Report_WSF_Hidrosaf_ENGLISH.pdf

Engineering Geology

- Appendices_of_Engineering_Geology_Rep_T.pdf
- Engineering_Geology_Rep_T.pdf
- G3 Stability Analysis JEOTEKNIK_HESAP_RAPORU_ENG.pdf
- G5.3.2 Geology KEPEZKAYA_MUH_JEO_EKLER.pdf

Geotechnical Calculations

- Geotechnical_Analyses_Report_E.pdf
- joint_stability_T.pdf
- SLOPE-NO1_JOINT25_T.pdf
- SLOPE-NO1-JOINT2_SLOPE-NO9-JOINT5_T.pdf
- SLOPE-NO3_JOINT25_T.pdf
- SLOPE-NO9_JOINT15_T.pdf

Seismic Risk Assessment Report

- Cover_T.pdf
- Seismic_Risk_Assessment_Report_T.pdf

Drawings for the following TSF Components

- BI_PAFTALARI_TSF Drawings
- DI_PAFTALARI_Concrete & Struct Details
- E_PAFTALARI_TSF
- J_PAFTALARI_Geology
- U_PAFTALARI_Figures
- YI_PAFTALARI_Storm Drainage

2.2 Risk Assessment for the Kepezkaya TSF

The risk assessment carried out for the Kepezkaya TSF is based on the data (including the design documents and drawings for the TSF) provided by Acacia. The risk assessment entailed the following:

- Evaluate the risks associated with possible failure modes for both the operating and closure stages;
- Determine operating parameters critical to these failure modes and possible impacts of failure; and
- Develop control strategies to reassess the design and/or manage the identified risks.

In this report Golder provide a short introduction to Risk Management, to highlight the primary failure mechanisms under consideration. This is followed by the development of Fault and Event Trees for each of the potential failure modes identified for the TSF, a discussion of the failure modes and identification of aspects critical to the long term safety of the facility, and the identification of potential mitigating measures.

3.0 DESIGN SUMMARY

Hidro Dizayn designed the Kepezkaya TSF as one of two facilities designed to store the Life of Mine (LoM) tailings for the Gökirmak Copper Project. The design of the facility has been carried out based on the requirements of the Turkish Regulations for the management of mine waste.

The total tailings storage requirement for the project is ~ 12.2 Mm^3, based on an average dry tailings density of ~ 1.65 t/m^3 (which relates to a specific gravity of 3.57), and the processing plant's capacity during the 11 year LoM.

The Kepezkaya TSF which has been designed to provide tailing storage for 5.15 Mm^3 (until Q3 of Year 5), is currently under construction approximately 1 km northeast of Hanönü. The rest of the LoM tailings will be deposited in the Bağdere TSF which has been designed for the storage of 8.08 Mm^3 (until the end of Year 11)

Based on factors including the height of the facility, the stored tailing volume, the facility's location in a seismic active zone and its proximity to Hanönü and Karayaprak, it is deemed that a 'HIGH' risk rating apply to the Kepezkaya TSF, in accordance to the Consequences of Failure (Risk) Classification System used by the Canadian Dam Association (CDA).

The TSF has in addition been assigned a Class 1 Hazard Rating in accordance with the current Turkish Legislation, due to the content of the tailings.

The Kepezkaya TSF to be constructed to full height before commissioning and will have a maximum height of approximately 53 m from its foundation. The upstream slope is benched with 2H:1V inter bench slopes and a bench width of approximately 4 m (at 10 m intervals down from the crest) resulting in an overall slope of approximately 2.4H:1V. The downstream slope is designed at 2.2H:1V.

The main embankment will be constructed from rockfill with a central interface drainage layer and a clay wedge on the upstream side, where the facility will be equipped with a composite liner.

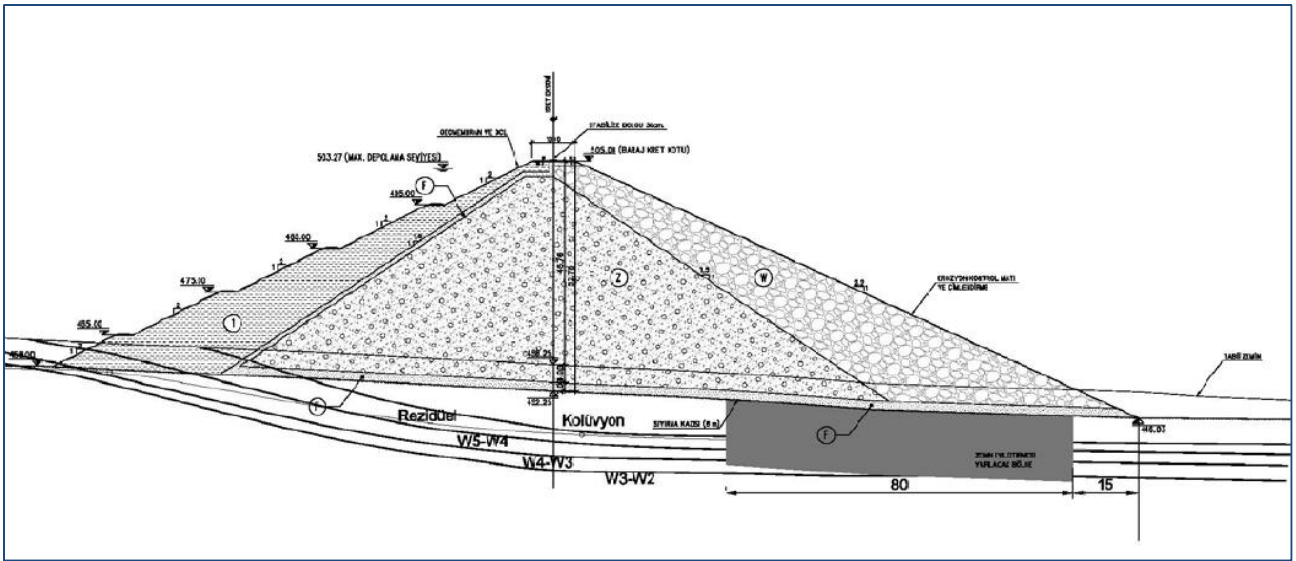

Figure 3-1 Section through the Embankment Wall

The upstream embankment and basin area of the TSF will be covered with a composite liner consisting of (from top to bottom):

- A drainage geocomposite;
- 2 mm HDPE geomembrane;
- Geosynthetic Clay Liner (GCL; and
- Drainage geocomposite.

The liner system will be installed on a minimum 500 mm thick protection layer of selected fill material.

An underdrainage system is installed beneath the lining system to remove clean groundwater and prevent the build-up of water pressure.

The facility will be equipped with a concrete lined storm water management system which has been designed to collect a 1:500 year 24 hour event.

Foundation improvement measures consisting of a series of Continuous Flight Auger (CFA) piles were installed below main TSF embankment.

Supernatant water on the TSF will be managed with a barge mounted decant system consisting of two duty, and one standby pump, with a maximum combined pumping capacity equal to 235 m^3/hr. The system can remove a 1:100 year storm event in approx. 72 hours.

The TSF has been designed with a freeboard for closure of 1.73 m which is based on retaining a 1:10,000 year storm event. The TSF will not be equipped with a closure spillway as per Turkish Regulations. This does not meet international best practice guidelines, or those of the International Commission on Large Dams (ICOLD).

A dam break analysis has been carried out for the facility by Hidrosaf Yazilim Bilisim.

Slope stability assessments were carried out for the TSF for the various cases, including normal operating conditions, as well as for the pseudo-static case of the Safety Evaluation Earthquake (SEE), which has a Peak Ground Acceleration (PGA) of 0.394 g for a 2,574 year return period. The PGA relating to the maximum credible earthquake (MCE) equating to a 10,000 year return period was not established.

It is important to note that although the European Union's BREF document for the disposal of mine waste recommends a minimum factor of safety (FoS) = 1.3 for the Operating Phase, many regulators and operators require/uses a minimum FoS = 1.5. Due to the hazard classification of the TSF, Golder would recommend using a FoS > 1.3, but preferably a FoS of about 1.5 or more.

A FoS of 1.44 was calculated by Hidro Dizygn for the downstream slope during normal operating conditions which is the minimum acceptable. Discussions on the engineering properties of the clay fill and weak rock fill has been undertaken with the designer and it is apparent that they have used conservative values in their stability analysis. The factors of safety for the OBE condition is satisfactory while for the SEE condition is below a value of 1 which would result in an increase in dynamic settlement which has been assessed by the designers and is acceptable.

It is recommended that for closure, the dynamic settlement is determined based on the maximum credible earthquake (MCE) which is the Long Term requirement for Closure (refer to Table 4.2, the CDA Guidelines for Dam Design).

The calculated FoS were taken into account as part of the Risk Assessment (using the Annual Probability of Failure for Factors of Safety relating to Construction Categories for Dams, Silva et al, 1998, please refer to Section 6.3.2)

Table 3-1 Calculated FoS for the Kepezkaya TSF (summary from SRK Independent Engineer's Review Report, January 2016):

	Calculated Factor of Safety	
Loading Case	Upstream Slope	Downstream Slope
End of construction	1.43	1.35
End of construction +OBE	1.23	1.17
Operation	4.70	1.44
Operation + OBE	3.66	1.25
Operation + SEE	2.34	0.94

Following closure of the Kepezkaya TSF, the facility will be capped with a system consisting of a geomembrane and a crest capping layer which will be equipped with a drainage collection system. The cap is some 1.8 m thick and would infill the majority of the operational freeboard. Therefore, at closure, there is only a limited capacity for the facility to retain water, however, if this water is not allowed to drain, it could overtop the dam resulting in erosion which if not dealt with could result in exposure and release of tailings.

4.0 RISK ASSESSMENT CRITERIA

4.1 Consequence Categories

Consequence categories are based on the incremental losses that a failure of the dam might inflict on downstream or upstream areas, or at the dam location. Incremental losses are those over and above losses that might have occurred in the same natural event or condition had the dam not failed. Incremental losses are evaluated in terms of:

- Loss of life;
- Economic losses or damage to property; and
- Other less quantifiable consequences related to social, cultural and environmental damage.

Table 3-1 presents an example of a widely-used classification system for dams (Canadian Dam Association, CDA) in terms of these loss categories. The highest consequence category of the three considerations is the governing rating for the dam.

Some very large dams whose failure includes potential damage of a nation-state level of concern are now classified with an additional "EXTREME" rating.

Table 4-1: Dam Classification in Terms of Consequences of Failure (CDA)

Dam Class	Population at Risk[(a)]	Incremental Losses		
		Loss of Life [(b)]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short term loss. No long term loss.	Low economic losses; area contains limited infrastructure or service.
Significant	Temporary Only	Unspecified	No significant loss or deterioration of fish or wildlife habitat. Loss of marginal habitat only. Restoration or compensation in kind highly possible.	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes.
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat. Restoration or compensation in kind highly possible.	High economic losses affecting infrastructure, public transport, and commercial facilities.
Very High	Permanent	100 or fewer	Significant loss or deterioration of critical fish or wildlife habitat. Restoration or compensation in kind possible but impractical.	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances).
Extreme	Permanent	More than 100	Major loss of critical fish or wildlife habitat. Restoration or compensation in kind impossible.	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances).

Source: CDA (2013, 2014)

(a) Definition for population at risk:

None – There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary – People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent – The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

(b) Implications for loss of life:

Unspecified – The appropriate level of safety required a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

4.2 Dam Consequence Rating

The Kepezkaya TSF is located approximately 1 km northeast of the town of Hanönü, which is located down gradient of the facility. The Yilanli stream flows past Hanönü on the eastern side of the town, where it joins the Gökirmak River, itself a tributary of the Kizilirmak River which eventually flows into the Black Sea.

Considering the hazard associated with potential failure of the facility relating to factors including the height of the facility, the volume of tailings stored, the location of the TSF in a seismic active zone and especially its proximity to Hanönü, it is deemed that a 'HIGH' risk rating might apply to the Kepezkaya TSF based on the Consequences of Failure (Risk) Classification System used by the CDA.

The release of tailings may potentially be a bigger concern should it enter the river system with at least the perception of widespread contamination. This could be a 'company threating' event due to loss of reputation. The TSF might then be appropriately regarded as a 'VERY HIGH CONSEQUENCE' dam.

4.3 Earthquake Hazard

According to ICOLD bulletin 98, (Reference 4.3) "damage of the dam is acceptable as long as the integrity and stability of the dam is maintained and the release of the impounded tailings is prevented", implying that some settlement of the dam is acceptable so long as this is less than the freeboard available on the facility.

ICOLD 98 (Reference 4.3) invokes a 10% probability of exceedance in a 50 year design life as reasonable for non-critical structures. This probability/exposure-period combination corresponds to a 475 year return period event. Dams, other than those in the 'LOW' consequence rating, are held to a higher standard with Table 4-2 illustrating the guidelines published by the Canadian Dam Association (Reference 4.2).

In the case of the TSF, a VERY HIGH consequence category implies that it is recommended that the design will meet the requirements associated with a seismic event with a return period 1/2 between a 1/2475 year and 1/10,000 year or MCE event, based on 'international best practice' standard of care.

Table 4-2: CDA Guidelines for Dam Design – Floods, Earthquakes and Minimum Static Factors of Safety (Operating Phase)

Consequence Category	Annual Exceedance Probability - Floods	Annual Exceedance Probability - Earthquakes	Minimum Static Factor of Safety			Downstream Slope No Steeper Than
			End of Construction	Long Term	Full or Partial Drawdown	
Low	1/3 between 1/975 and PMF	1/2475	1.3	1.5	1.5	2H:1V
Significant	1/3 between 1/975 and PMF	1/2475				

Consequence Category	Annual Exceedance Probability - Floods	Annual Exceedance Probability - Earthquakes	Minimum Static Factor of Safety			Downstream Slope No Steeper Than
			End of Construction	Long Term	Full or Partial Drawdown	
High	1/3 between 1/1000 and PMF	1/2475				
Very High	2/3 between 1/1000 and PMF	1/2 between 1/2475 and 1/10,000 or MCE				
Extreme	PMF	1/10,000 or MCE				

Based on this minimum design criteria, a Very High Risk TSF should be designed with an annual exceedance probability of ½ between 1/2475 and 1/10,000 or the MCE.

It is international best practice for closure of TSFs to design them to manage the PMF and MCE.

5.0 PROBABILISTIC RISK ASSESSMENT

The word 'risk' can confuse and be misleading, because common use of the word includes three separate ideas: hazard; chance of loss or injury; untoward outcome. These ideas are reflected in a risk assessment, in that it is directed towards answering three questions:

What can take place?	(hazard)
How likely is the occurrence?	(chance)
What will be the consequences if it happens?	(outcome)

Risk is taken to be the product of chance and outcome, added up over all possible hazards. Risk has the same units as the outcomes.

Risk assessments help make rational decisions, and this highlights two fundamental points, which are:

- A risk assessment is carried out in the context of a decision; and
- A risk assessment evaluates alternative outcomes, including both uncertainties and chance.

A risk assessment has some criterion against which the uncertain outcomes are to be compared, in arriving at the decision. A risk assessment then addresses the confidence that can be placed in the evidence, to determine if an outcome is greater or lesser than the decision criterion. This linking of the concept of risk to confidence is a common thread to all risk studies in all situations. However, it is usual to work with the opposite of confidence, namely uncertainty.

Uncertainty is the lack of knowledge. It is a neutral term and does not imply incompetence, lack of education, or lack of diligence. In a probabilistic risk assessment, uncertainty is quantified using a dimensionless number p within the range $0 \leq p \leq 1$. An assertion that $p = 0$ implies absolute confidence that the event will not occur; likewise an assertion that $p = 1$ implies absolute confidence that the event will occur. A judgement that there is an evens chance that the event may occur is simply $p = 0.5$. By considering a range of values and their corresponding probability, a probability distribution is obtained which expresses the uncertainty in the outcome based on our present knowledge. Expressing uncertainty in this way is called a Bayesian approach and does not need repeated occurrence data to be valid, although such data should be used in developing judgements where available and applicable.

It is this quantification of uncertainty through probability theory that has given the approach its name, Probabilistic Risk Assessment (PRA). It is also sometimes referred to as quantitative risk assessment.

Proof of adequacy depends on subsequent experience, but this is difficult because proof will depend on several, or perhaps many, replicate trials. This is largely impossible in civil or mining work where the failure rate tends to be very small. However, there have been a significant number of modern water retaining dams and tailings dams constructed and data related to dam failures have been produced and the outcomes discussed in this document. The probabilities of the various types of dam failure have been used, where appropriate in the PRA.

6.0 DAM FAILURES

6.1 General

There is considerable experience throughout the world relating to dam incidents and many experts have evaluated the nature and the causes of these incidents. Despite these efforts, the relative frequency of the various factors leading to dam incidents was not known until the last 15 to 20 years. It is important to understand the main causes for dam incidents and the likely probability of these incidents occurring and based on the historical records, this data has been used to assist in the risk assessment analyses.

6.2 Dam Failure Statistical Data

The source of dam failure data is from the International Commission on Large Dams' (ICOLD) Bulletin 99 dated 1995 (Reference 6.3), which collates data on dam failures for water retaining dams, tailings dam incidents by the US Committee on Large Dams (Reference 6.3) and ICOLD's Bulletin 121 (Reference 6.4) dated 2001 which assesses the risk of dangerous occurrences associated with tailings dams.

6.2.1 ICOLD Bulletin 99

The data in Bulletin 99 collates information from around the world but does not include data from China which were not considered to be reliable. For each dam, the failure mechanism was identified and the summary statistics plotted to give an indication of the type of dam, the age of the dam when failure occurred and the failure classification. Issues identified for the embankment dam category are:

- Foundation failure (land subsidence, shear strength, seepage, piping etc.);
- Construction materials (dispersive clays, silts and uniform sands, placing and compaction);
- Unforeseen actions (high pore water pressures due to silt accumulation or ice, precipitation, waves, earthquakes, overtopping, etc.);
- Structural behaviour of dam (impervious core, transition zones, slope protection, differential movement, unexpected settlement, seepage, liquefaction, rupture of upstream/downstream etc.);
- Maintenance (to prevent overtopping); and
- Appurtenant works (inadequate design, land subsidence, mechanical strength, spillways, canal/tunnel, blockage of pipes/culverts, operation, maintenance).

Each failure or incident was attributed to a particular cause with the main categories being subdivided into four main headings of Foundations, Materials, Unforeseen Actions or Loading, and Structural Behaviour of the Dam. Each main heading has been subdivided to allocate the particular cause of failure. Bulletin 99 concluded that with earth and rockfill dams, the most common cause of failure is overtopping (32% primary cause) followed by internal erosion in the body of the dam (16% primary cause) and internal erosion in the foundation (11% as primary cause). A table of the main categories and associated percentage occurrences is given below.

Table 6-1: Failure Categories

Foundations	Materials	Unforeseen Actions or Loading	Structural Behaviour
17%	4%	43%	36%

The main causes of failures are tabled below.

Table 6-2: Failure Modes

Overtopping	Internal erosion (dam)	Internal erosion (foundation)	Seepage (dam)	Seepage (foundation)	Rupture of upstream dam	Settlement	Conduit blockage
32%	16%	11%	5%	5%	4%	4%	4%

It is evident from the above statistics that for water retaining earth dams 59% of the failures are either from overtopping, or internal erosion either of the dam itself or its foundations.

6.2.2 ICOLD Bulletin 121

Bulletin 121 summarises the data from 221 tailings case records and the data categorised according to the following:

- Major failure during operation, resulting in complete abandonment;
- Major failure during operation that could be repaired;
- Accident to dam operating for some time that was rectified before failure occurred;
- Accident during initial filling;
- Accident before filling began;
- Accident in reservoir during operation that did not cause trouble to dam itself;
- Damage to partly constructed dam; and
- Major repair required due to deterioration or upgrade to comply with modern standards.

The study included incidents from 221 facilities and in summary those that could be attributed to be significant accidents are tabled below showing the relative percentages for active and inactive dams and the distribution between accidents and incidents that led to dam failure.

Table 6-3: Active and Inactive Dam Failure Modes

	Overtopping	Slope stability	Earthquake	Foundation	Seepage	Structural	Erosion	Mine subsidence	Unknown
Active dams*	15%	24%	18%	11%	11%	8%	3%	1%	9%
Inactive dams*	15%	11%	38%	12%	0%	8%	8%	0%	8%
All dams	15%	24%	18%	11%	11%	8%	3%	1%	9%

* For the above dam incidents, 87% for active dams and 13% for inactive dams.

The above table indicates that overtopping, slope stability and earthquakes are the most common causes of failure/accidents for tailings dams accounting for approximately 60% of the total incidents. For active dams, the incidents of slope stability incidents are more than double of the inactive phase. The converse is true for earthquake and erosion incidents where the incidents for inactive dams are double that of active dams. This is expected due to the longer time frame for inactive dams. Seepage incidents are significantly greater for active dams than inactive dams which are also expected.

For active dams, the breakdown of the tailings dam incident cause comparison with incident type is as tabled below.

Table 6-4: Active Failure Modes

	Overtopping	Slope stability	Earthquake	Foundation	Seepage	Structural	Erosion	Mine subsidence	Unknown
Accidents*	10%	33%	8%	17%	17%	10%	5%	0%	0%
Failures*	18%	22%	17%	9%	9%	7%	2%	3%	13%
All incidents	15%	26%	14%	11%	12%	8%	3%	2%	9%

*For the above dams, 35% were accidents and 65% led to failure of the dams

Similarly, the above data confirm that overtopping, slope stability and earthquakes are the most common causes of failure/accidents for tailings dams accounting for approximately 55% of the total incidents.

6.2.3 Discussion

For those failure mechanisms where there are no site specific data on which to base assessments of risk, the above data from Bulletin 121 and those included in Bulletin 99 have been used to provide an annual probability of failure of the TSF. Bulletin 99 shows that worldwide, excluding China, there were 59 dam failures of dams built in the period 1950-1986. Ignoring 7 of these dam failures, which occurred during construction and assuming a uniform rate of dam construction over this period, indicates that the rate of embankment dam category failure since 1950 has been approximately 1.65E-4 per annum. This annual probability has been used in the risk assessment together with the specific failure and accident cause data to provide annual probabilities for mechanisms that are considered possible at the TSF. These include:

- Overtopping;
- Internal erosion;
- Liquefaction;
- Spillway failure;
- Decant or culvert blockage; and
- Crest settlement.

6.3 Failure Modes

6.3.1 Overtopping

Of the cases reported in Bulletin 121, a significant proportion of the failures were due to overtopping, caused by a lack of control of the water balance within the impoundments. This could result from a number of reasons:

- Inadequate design to accommodate extreme hydrologic events up to the Probable Maximum Flood;
- Damage to vertical decants or culverts during operations due to loading; and

- Blockage due to poor maintenance.

Tailings facilities are not generally permitted to be discharged directly into the environment, therefore upstream flood waters should be fully diverted so as not to enter the impoundment. The TSF at Kepezkaya has a very small external catchment area and most of the storm water is diverted around the facility.

The TSF is designed to hold a limited volume of supernatant water, including rain water which falls directly on the TSF, and has been equipped with a barge mounted return water pump and pipeline to return supernatant water back to the processing plant. Tailings is placed using conventional spigot deposition along the northern, eastern and southern sides of the TSF, and the supernatant pond will be situated on the western side of the facility during the operating phase. At closure the return water pumping system will be decommissioned and the TSF will be capped with a liner to prevent the ingress of rainwater. In accordance with Turkish Regulations, the TSF will not be equipped with a closure spillway. Based on discussion with the designers, Hidro Dizayn, the lined facility has been designed to accommodate a maximum storm event with a 1:10,000 year return period, with a minimum freeboard of 1.73 m (during the Operating Phase). Rain water falling on the facility will be retained until it evaporates. Rain water from the surrounding catchment areas will be collected by the perimeter storm water channel, which will convey the water to the valley below via the concrete lined system. The return water system has been designed to manage a 1:100 year storm event. Any greater event could result in additional storm water entering the facility or if the storm water channel is not adequately maintained.

The Kepezkaya TSF will be constructed to its full height and will be equipped with an over drainage system, a composite liner, as well as an underdrainage system prior to commissioning of the facility.

Following closure of the TSF, the facility will be capped with a geomembrane and a crest capping layer which will be equipped with a drainage system although with no outlet. The cap thickness is 1.8 m and one placed will exceed the depth of the operating freeboard and the volume of water that could be retained by the facility to retain water would be significantly reduced.

It should be noted that international best practice is to design TSFs for closure to deal with a Probable Maximum Flood (PMF) event (which may exceed a 1:10,000 year event), and to equip facilities with a closure spillway. In no circumstances should a dam, that has the capacity to retain water, be without a spillway at closure.

Provided the pool elevation on the TSF is maintained at an acceptable level to allow a 1:10,000 year storm event to be safely accommodated during the operating period, overtopping of the TSF during the operating life of the facility is deemed unlikely. From the documents Golder reviewed and discussions with Hidro Dizayn, the facility has not been equipped with an emergency spillway (as per the Turkish Regulations for this type of materials containment), which means that overtopping of the TSF could pose a risk during the post closure period. Closure of the lined facility may also take some time as consolidation of the tailings in a lined facility can be slow, before the facility can be capped. The lack of an emergency spillway, together with poor maintenance during the post closure period could potentially lead to an overtopping failure of the TSF although the volumes of water are significantly reduced due to the thickness of capping once placed but could cause severe erosion of the dam wall face. These factors were therefore taken into consideration in this risk assessment.

6.3.2 Slope Failure

Slope failure is one of the more common modes of failure and is frequently associated with a rise in phreatic surface in the walls retaining the tailings. This could be due to a number of reasons including heavy precipitation or seepage through the TSF liner, or inadequate drainage provided by the underdrainage system installed below the TSF liner. Similarly, the assumed earthquake loading could be underestimated. As the Kepezkaya TSF is constructed using a conventional wall construction method, the main issue with slope stability will occur as a result of excessive pore pressures in the upstream clay liner of the TSF. The high pore pressures could be a result of:

- Seepage leaking through the liner and coming into contact with the clay layer; or

- Failure of the underdrainage system below the liner which could lead to a rise in the phreatic surface in the TSF wall, although this is deemed to be less likely than an increase of pore water pressure due to seepage through the lining which my occur due to liner failure.

The downstream slope of the dam wall (which will be approximately 53 m high) is constructed with rockfill at a slope of 2.2H:1 V. The upstream slope of the dam wall is constructed with 4 m wide benches at 10 m intervals, which will reduce the inter bench slope of 2H:1 V to and average slope of 2.4H:1 V. This section of the wall will be constructed of clay. It is understood that the lined slopes do not meet the 3H:1V slope requirement, as per the Turkish Regulations, although it is possible to successfully line slopes of 2H:1V.

Another factor that would influence the slope stability is the assumed earthquake data used in the design being exceeded. The SRK Independent Engineer's Review Report stated that the designers considered a Safety Evaluation Earthquake (SEE), with a Peak Ground Acceleration (PGA) of 0.394 and a recurrence interval of 2,574 years. For closure, the dynamic settlement for the MCE should be determined.

The Factors of Safety calculated by the designers for the outer slope of the TSF were converted to annual Probabilities of Failure using a relationship proposed by Silva et al (Reference 6.5), 1998 and Meyerhof (Reference 6.6), 1970. Probabilities for other modes of failure which may lead to a slope failure were based (where deemed relevant) on data extracted from the ICOLD bulletins, and was used in the overall assessment of risk of slope instability.

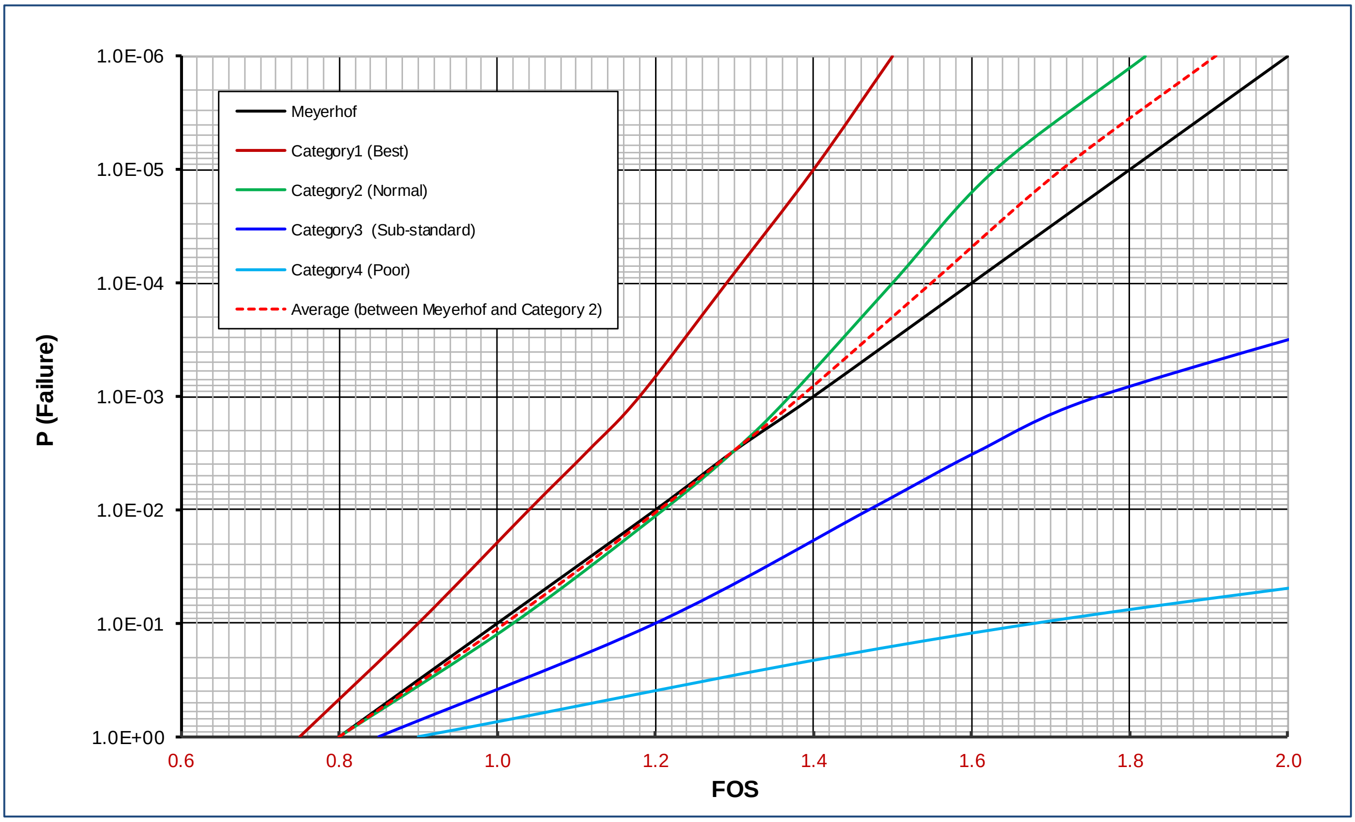

Figure 6-1: Relationship between Factor of Safety and Probability of Failure (after Silva et al and Meyerhof)

6.3.3 Earthquake

A Seismic Assessment has been prepared for the site by Gedik Tek Insaat.

Probabilistic and deterministic methods have been used to assess seismic design parameters for the project site, which is located approximately 55 km north of the Anatolian Fault, which is a highly seismic region. As the site straddles the border between the 3rd and 2nd Degree Seismic Zones (Turkish Standard) it has been decided to use the more stringent requirements associated with a 2nd Degree Seismic Zone, for design purposes.

- The Maximum Design Earthquake ("MDE") has been defined as 10% occurrence in 50 years (475 return period). The embankment has been classified as a high consequence structure with corresponding MDE of 2% in 50 years (2,474 return period).
- The Operating Basis Earthquake ("OBE") is defined as 50% occurrence in 100 Years (144 year return period). A Peak Ground Acceleration ("PGA") of 0.156 g was calculated using a deterministic approach. This compares with the following values calculated using a probabilistic approach:

  MDE = 0.209 g; and

  OBE = 0.117 g.
- The Safety Evaluation Earthquake (SEE) has a PGA of 0.394 g for a 2,574 year return event.
- The Maximum Credible Earthquake ("MCE") has been defined as a magnitude 8 event.

The designers should determine the PGA for the MCE to evaluate dynamic settlement of the dam wall at closure.

The International Commission on Large Dams (ICOLD) (Reference 6.1) states that the OBE equates to an earthquake event that usually has a return period equal to between 250 years and 1,000 years and when occurring will not affect the performance of the structure. The MCE has a return period of some 10,000 years and when occurring will not cause total failure of the embankment wall but will result in severe damage i.e., slumping of the crest. The MCE is particularly applicable for facilities classified as an extreme hazard based on the CDA and for the long term situation such as the close out phase of the facility. The following summary of loading assumptions and allowable damage for earthquakes has been proposed by J.A.Studer, (Reference 6.7).

Table 6-5 Loading Assumptions and Allowable Damage (from J.A.Studer, 2004)

Loading Assumption	Recurrence Period	Allowable Damage
Safety Earthquake (MCE)	10'000 years in most countries	No uncontrolled outflow, major damage is allowable.
Design Earthquake (DE)	3'000 to 10'000 years	No uncontrolled outflow, major damage is allowable.
Operating Basic Earthquake (OBE)	125 to 475 years	Serviceability of the dam has to be guaranteed, only minor damage allowable.

It should be noted that the lined TSF has been designed to retain a 1:10,000 year flood event following closure, but has not been equipped with a closure spillway (as per Turkish Regulations).

Generally, an earthquake has the potential to liquefy tailings materials (i.e. catastrophic loss of strength induced by rapid shaking) or cause settlement of the dam crest resulting in a reduction in freeboard and overtopping of the dam. Although this could potentially happen to the tailings in the Kepezkaya TSF, as a lined facility, tailings liquefaction is not deemed to pose more than a minor risk to the facility, as the TSF wall will be constructed to final height before deposition commences, and wall stability doesn't depend on the strength of the impounded tailings. Crest settlement of the wall is however possible should a large seismic event occur, although the minimum freeboard of 1.73 m on the TSF means that the risk associated with the settlement of the embankment of the facility leading to a release of water from the facility is much reduced.

It is important to note that most dams do not tend to fail catastrophically particularly constructed from rockfill following large seismic events, but experience crest settlement and sometimes other damage such as surface sloughing. The pseudo static method of stability analysis as used by the designers (which applies the PGA as a horizontal load to the analysis) is a conservative approach to use when evaluating slope stability for the adverse condition of a seismic event occurring. For this case, crest settlement calculation e.g. using the approaches proposed by or Bray and Travasarou (Reference 6.8) or Makdisi & Seed (Reference 6.9) may be more appropriate.

6.3.4 Foundation Stability

The geotechnical site investigation adequately characterises the foundations beneath the TSF Kepezkaya site.

Golder consider that foundation failure of the TSF is highly improbable due to the dam wall foundation improvement measures installed (Continuous Flight Auger piles).

7.0 RISK ASSESSMENT METHODOLOGY

7.1 General

The risk assessment for the TSF is based on the assumption that the facility will be operated in accordance with the design intent of the facility in a safe and responsible manner, and the performance will be monitored monthly and quarterly and the data evaluated by a competent person.

Information for input to the fault tree analysis has been collated from both precedent information of previous facility failures discussed in Section 7, and from site specific or site generated data such as material properties, rainfall and seismicity. Also, in the absence of any of the above information, probabilities have been assigned to the likelihood of an event occurring based on professional judgement which is a subjective consideration. Assigning a probability this way is termed the Bayesian approach and does not depend upon repeated experiences i.e. precedent. The adequacy of the Bayesian approach to probability assessment depends on two important factors:

- Consistency and care applied to developing the probabilities; and
- The current state of knowledge.

The first factor is dealt with by adopting systematic procedures to derive the probability estimates (Reference 6.1). The second factor is dealt with by describing the confidence range for the estimate and with more knowledge the range should be able to be extended with more confidence.

7.2 Probabilistic Risk Assessment

The analysis draws upon a fault/event analysis to systematically combine all potential faults in the system and evaluate the possible consequences of failure. Such an approach is very disciplined and also allows for incorporation of human interactions and physical phenomena.

The approach that was followed involved the identification of all system faults that could potentially result in a dam failure and the consequential release of liquefied tailings and/or water. The consideration of the interaction of two or more failure events that could combine to result in a flow failure is particularly relevant, and hence the technique draws upon:

- A fault tree to represent the potential combination of possible causes of a failure; and
- An event tree to represent the consequences of failure.

7.3 Development of Cause/Consequence and Fault/Event Trees

For a dam failure a “fault” (or “failure event”) is defined as any possible contributory cause of a failure of the TSF, such that there could be an associated release of residue and/or water from the facility in sufficient quantity to induce a flow failure. An “event” is defined as any consequence of such a flow failure.

Faults are combined in the fault tree using AND gates and OR gates as follows:

- “AND” gates are used where two or more faults are statistically dependent upon each other; and

- "OR" gates are used where two or more faults are statistically independent of each other.

Probabilities of faults in the fault tree are calculated according to the respective formulae:

- For AND gates: Pt = P1 x P2 x........x Pn; and
- For OR gates: Pt = 1 - (1 - P1) x (1 - P2) x ......x (1 - Pn).

Where P1, P2 etc. are contributory components to Pt.

The event tree is developed as a series of questions that progressively eliminate consequences of lesser significance, culminating in the identification of the top event. This may be defined as, "discharge occurs beyond the TSF".

Probabilities (value between 0 and 1) are assigned to an affirmative answer to each question in the event tree, the probability of a negative answer (Pno) being calculated as 1 – (Pyes).

For this level of analysis, all probabilities in the fault/event tree are assigned through professional judgement, augmented where necessary by some basic calculations and rigorous calculations. A guide used in the assignment of probabilities to the lowermost faults in the fault tree included in the basic calculations is as follows:

Table 7-1: Description of Probabilities

Annual Probability of Occurrence	Description
1E-6 (1 in 1 million)	Almost impossible or negligible (no published information on a similar case exists)
1E-5 (1 in 100,000)	Highly improbable (published information exists, but in a slightly different context)
1E-4 (1 in 10,000)	Very Unlikely (it has happened elsewhere, but some time ago)
1E-3 (1 in 1,000)	Unlikely (recorded recently elsewhere)
1E-2 (1 in 100)	Possible (could have occurred already without intervention)
1E-1(1 in 10)	Highly probable (a previous incident of a similar nature has occurred already)
0.2 – 0.5 (1 in 5 to 1 in 2)	Uncertain (nearly equal chance of occurring to that of not occurring)
0.5 - 0.9 (>1 in 2)	Nearly certain (one or more incidents of a similar nature have occurred recently)
1 (or 0.999)	Certain (or as near to, as makes no significant difference)

8.0 FAULT/EVENT ANALYSIS FOR TSF

As part of the Risk Assessment, Golder identified and evaluated the most likely failure modes for the Kepezkaya TSF during the Operating and Post Closure Phases.

As risk is often is defined as "Risk = Probability of Occurrence X Consequences", the probabilities of occurrence for the events under consideration could be compared directly, as the consequences of the occurrence (i.e. release of tailings) has been taken as a constant factor. Based on this approach, Golder compared the likelihood of occurrence of the following three events which could lead to the release of tailings from the TSF:

- Embankment Failure of the TSF; OR
- Overtopping Failure of the TSF.

8.1 General

The probabilistic risk assessment has been undertaken for two scenarios, the TSF during operations and closure.

The probability of tailings release varies with time, primarily from the variation in essentially the three phases of the life of the facility (Construction, Operation and Closure).

During the initial construction phase of the main embankment wall and wall raises, there is the possibility of construction error, although in the case of the Kepezkaya TSF, this is less likely as the lined facility will be constructed to its final height prior to commissioning.

Operating error is greatest during commissioning of the facility as it is brought into use and then decreases steadily reflecting the effect of the operators moving up the learning curve. As the lined facility will not be raised and the TSF will only impound the tailings, any operating errors relate more closely to the water management on the facility, rather than the tailings deposition. There is however a residual risk relating to water management on the TSF (and the lack of a closure spillway) after tailings deposition ceases, is it may take some time until the tailings has consolidated sufficiently to allow the facility to be capped.

Maintenance error exists during the operating period, as maintenance of the completed structures and facilities will be required. However, there will be a group of experienced and trained people who have a commitment to operating the facility, so the chance of maintenance error is small during this period. This pattern changes markedly once the impoundment enters the close-out phase. At that time, there is likely to be a loss of trained operators and the motivation from the commercial interest is diminished. Correspondingly, there is an increase in maintenance risk at the start of the closure period, and this chance of maintenance error increases progressively throughout the close-out period. In particular, the long term risk includes the risk of institutional failure, when there is a deliberate but untoward policy change.

The probability of tailings release at later times has been computed for the operational and closure phases, and is presented for each case as an average annual probability of failure. Presentation of the results in this way allows easy comparison with the worldwide statistical failure rate for dams, from which the standard of care of the proposed raise can be judged.

8.2 Overview of Event Tree

The fault trees for the Kapezkaya TSF (refer to Appendix B) represents the conditions during tailings disposal during the Operating as well as the Closure Phases for the TSF. Referring to the drawings, the top event of concern is release of tailings from the TSF. This could result from two alternative events:

- Embankment Failure of the TSF; OR
- Overtopping Failure of the TSF.

These events in themselves each require the concurrent occurrence of other causative events. In the case of the Embankment Failure, the perimeter embankment wall must be breached and the retained tailings must be in a mobile state such that they can move away from the impoundment.

In the case of the Overtopping Event, the facility must have inadequate freeboard and a significant amount of water needs to have accumulated on top of the facility which would also mobilise the tailings.

Specific elements of the event tree shown are discussed in detail in the sections below. In developing an understanding of the specific hazards to be considered, guidance has been sought from precedent of the most likely causes.

8.3 Embankment Failure

Embankment Failure can occur due to a number of factors including static or dynamic failure, internal failure as well as foundation failure below the TSF embankment.

The mechanisms that could initiate an embankment wall failure have been identified and are discussed below. These include:

- Static and earthquake failure of the main embankment walls;
- Slope failure due to internal erosion of the embankment slope or the embankment foundations; and

- Foundation failure.

8.3.1 Static Slope Failure

Static Slope Failure of the TSF embankment can be caused by a number of factors, including (but not limited to) sub-standard construction (which may include the foundation of the wall), design or construction errors, use of unsuitable or sub-standard construction materials, raised phreatic surface and inadequate drainage to deal with the situation, and over loading. Often a number of these factor combined can lead to a situation where the Factor of Safety (FOS) of the embankment can reduce to < 1 which may lead to a static slope failure under normal operating conditions.

8.3.2 Dynamic Slope Failure

A Dynamic Slope Failure may be triggered by a seismic event (earthquake) in a slope which may, under normal operating conditions, have a FOS >1. The likelihood of such an occurrence depends however on a number of factors including (but not limited to) the construction of the wall (including the material), the magnitude of the seismic event as well as the design parameters of, and the FOS/Allowable Settlement the wall has been designed for (generally the higher the FOS, the lower the likelihood of failure).

8.3.3 Foundation Failure

Golder consider that foundation failure of the TSF is highly improbable and this is reflected in the probability of 1.40 E-5 selected for foundation failure of the facility (reduced from the ICOLD values stated for foundation failure).

8.3.4 Internal Erosion

Internal erosion in the body of an embankment and internal erosion in the foundations are the second and third most frequent causes of embankment failure recorded by References 4.1 and 4.3. Approximately 27% of dam failures are accounted for by these two mechanisms. These reports indicate that worldwide, excluding China, there were 59 failures of dams built in the period 1950-1986. Ignoring 7 of these dam failures, which occurred during construction and assuming a uniform rate of dam construction over this period, indicates that the rate of embankment dam failure since 1950 has been approximately 1.65E-4 per annum. This suggests that the failure rate for internal erosion failures of embankment dams is on average around 4.5E-5 per annum.

The Kapezkaya TSF embankment is unlikely to experience seepage pressures as high as those experienced by water-retaining dams. However, due to the presence of the supernatant pond on the facility during the operating phase, piping failure may still cause internal erosion, although the presence of the TSF liner and the low permeability of the deposited tailings should assist in reducing any seepage pressures. Allowance has therefore been made with respect to erosion induced failures for the TSF. This mechanism is considered highly improbable (2.0E-5 per annum) during operations and unlikely (1.0E-3 per annum) at closure as the lining system and filters deteriorate.

8.4 Tailings Mobilization

For tailings to be released from the impoundment in the event of a breach in the containment system the tailings must be in a mobile state. The main mechanism causing mobility would be the accumulation of a significant volume of impounded water and/or either dynamic or static liquefaction of the tailings.

8.4.1 Water Accumulation

Water accumulation of the TSF can be the result of a number of factors, including a large storm event, failure or blockage of the return water pumping system on the TSF, water in the supernatant pond on the TSF displaced by landslide debris, or failure of the storm water diversion system leading to water from the outside catchment accumulating on top of the TSF. This Accumulation of Water on top of the TSF together with Failure of the Embankment may lead to a situation where a Release of Tailings may occur.

8.4.2 Liquefaction of Tailings (Static or Dynamic)

Loose saturated materials having a contractive structure can potentially develop very high pore pressures and lose virtually all their resistance to deformation when they are subjected to cyclic shear stress, a phenomenon called liquefaction. A sudden loss of horizontal support caused by a slope failure of the embankment may be enough to trigger this behaviour. The susceptibility of the tailings to liquefaction due to a loss in horizontal support, reduces as the density increases and as the saturation reduces. The density of the tailings and its saturation is dependent on how it is deposited and the drainage conditions. Due to the conventional spigot deposition of the tailings, the consolidation/densification of the tailings will take time.

As the Kepezkaya TSF is a lined facility and doesn't rely on either centreline or upstream wall raising, tailings liquefaction is not considered to be a serious consideration. The potential for the tailings to liquefy under dynamic conditions, is possible to highly probable during operations during a modest seismic event (5.05 E-2 per annum).

For static liquefaction, the likelihood of occurrence is closely related to static slope failure which has a probability of 4.80 E-4 per annum. The probability of the event occurring is equivalent to between very unlikely and highly improbable.

The potential for the tailings to liquefy post closure will decrease significantly as the material consolidates and densifies and this has been taken into account in the risk assessment.

8.5 Inadequate Freeboard

An important factor that may contribute to an overtopping failure of a TSF is if the facility does not have adequate vertical (beach) freeboard to safely store a storm event or supernatant water accumulated on the facility. Inadequate freeboard on the TSF can be the result of the following factors.

8.5.1 Poor TSF Management

Poor TSF Management may lead to a situation where the facility has been operated in such a way that it doesn't have adequate vertical freeboard to safely accommodate water accumulated on top of the facility, resulting in raising water encroaching on the outer perimeter of the facility until it starts overtopping. Management of the facility significantly decreases post closure and the need for maintenance should therefore be minimised.

8.5.2 Static Settlement

Static settlement of the outer perimeter wall could also led to a situation where the crest settles to a point where it is so low that tailings are mobilised and are released, or where the crest is at the same elevation as the pool on the TSF or slightly lower, resulting in a failure to contain the tailings and water.

Crest settlement is most likely to be caused by ground settlement, through ground loss although crest settlement as a result of a seismic event is still possible. Crest settlement through ground loss would be by internal erosion (piping). The ICOLD data for water-retaining dams (Reference 3.1) indicate that approximately 11% of the dam failures have been caused by piping which with an annual probability of dam failure of 1.64E-4 encompassing all failure modes, is equivalent to an annual probability of failure due to crest settlement of 1.80E-5 per annum.

For the Kepezkaya TSF a probability of static settlement of 5.00 E-5 has been selected as this mode is deemed very unlikely to highly improbable based on the operating freeboard the facility is designed for, the modest height of the dam wall and foundation improvements. The same probability has been selected for closure, as it was deemed that the risk associated with the mode will be similar.

8.5.3 Dynamic Settlement

Dynamic settlement of the TSF's crest is similar to static settlement with the important difference that a seismic event acts as the driving force for the containment failure to occur. Again such an event, if large enough, may result in the release of tailings and water from the TSF.

The issue of seismicity and its effect on an embankment has been assessed and, because of the earthquake activity in this part of Turkey, the impact of a MCE has been included as representing the risk to the facility, equivalent to a 1 in 10,000 year event, 1.0E-4.

8.6 Water Accumulation

Water accumulation of the TSF can be the result of a number of factors, including a large storm event, failure of the return water pumping system on the TSF, water in the supernatant pond on the TSF displaced by landslide debris, or failure of the storm water diversion system leading to water from the outside catchment accumulating on top of the TSF. This Accumulation of Water on top of the TSF together with Failure of the Embankment may lead to a situation where a Release of Tailings may occur.

8.6.1 Storm Event

A large storm event in the vicinity of the TSF may lead to the accumulation of a large volume of water consisting of rainfall which fell on top of the TSF and its immediate catchment area.

8.6.2 Decant (Return Water) Failure

Failure of a return water pump barge may lead to an inability to remove supernatant water off the TSF leading to an accumulation of water on top of the facility.

Blockage of decants/spillways is one of the most common causes of failure for water-retaining dams, equivalent to approximately 10% of dam failures. Similarly blockage of pipes and culverts account for approximately 4% of dam failures (References 6.1, 6.2 and 6.3). As previously stated the rate of embankment dam failure since 1950 has been approximately 1.65E-4 per annum. Given the proportion of failures attributed to these causes, it has been suggested that the failure rate for spillways and pipes culverts is 2.31E-5 per annum.

Lack of maintenance, trees being washed down into the spillway or culverts, and vandalism are situations that have occurred at other sites and are included in the statistics reported above by ICOLD.

The TSF has not been designed to operate without a decant system and surplus supernatant water on the facility is decanted via a barge mounted pumping system to the pump station situated below the facility, from where water is returned to the Plant. If the barge pumping system fails, water could accumulate on the TSF and overtop the facility. Such an event could cause catastrophic failure of the facility. Through the use of storm water diversion channels, the external catchment area to the TSF is small and the amount of water that recharges the facility consists primarily of rainfall falling on the surface. The time frame that this event can occur is also limited. Thus, the probability of failure of the barge pumping system is considered to be an unlikely occurrence.

During the Post Closure Phase, the TSF will not be equipped with a closure spillway (as per Turkish Regulations) to decant any water accumulated on the facility safely to the valley below. Overtopping failure of the TSF during this period depends on maintenance, which if poor, could lead to the accumulation of water on top of the TSF. Due to the lack of a closure spillway, this eventuality is deemed to be possible to highly probable (5.0E-02).

8.6.3 Water Displaced by Landslide

The interstitial pool on the TSF may also be displaced and the level of the water on the facility increased should debris from the cut slope failure above the TSF occur, and slide into the TSF. The likelihood of such an event occurring is however deemed to be negligible (3.89E-6).

8.6.4 Storm Water Diversion Failure

Failure of the storm water diversion system could lead to an accumulation of storm water on the TSF, which could ultimately lead to an overtopping failure of the facility. The associated probability is considered unlikely with a probability of 1.0 E-3 during the Operating Phase, but unlikely to possible during the Post Closure Phases (5.0 E-3) because of the issues of long term maintenance.

8.7 Summary

A summary of the probabilities of failure for the TSF during the Operating and the Post Closure Phases is provided in Table 8.1.

From the Fault Event Trees it becomes clear that a number of factors play important roles in determining the likelihood of the main failure modes which could lead to the occurrence of the top fault (i.e. tailings release from the facility).

These factors include:

- The likelihood of Water Accumulation on top of the TSF. This could assist in the mobilisation of tailings which, when combined with an Embankment Failure, could lead to failure of the TSF Embankment. Water Accumulation on top of the TSF, when combined with Inadequate Freeboard on the facility, could also lead to an Overtopping Failure. An additional factor (when relevant) which could also lead to water accumulation on the TSF, is failure of the Storm Water Diversion Channel which could lead to water flowing onto the TSF; and
- The lack of a spillway to the TSF during both the Operating and the Post Closure phases (as these are not allowed based on Turkish regulations), pose a risk to the TSF, especially during the early phases of closure prior to placement of the cap, as no return water pumping system is available to remove any water accumulating on top of the facility and if there were, this water would have to be treated or tinkered away as it would be contaminated. As this could potentially lead to an overtopping failure, the risk profile of the TSF significantly increases during the early phases of the Post Closure Phase. .The risk reduces significantly once the cap is fully installed as the facility cannot contain a large volume of water and further reduces if a drainage system with an outlet is provided.

To illustrate the importance of capping the TSF and then equipping the TSF during the Post Closure Phase with an Emergency Drainage System (EDS) installed in the abutment next to the facility is constructed. An EDS is an alternative term for a spillway, Golder developed an additional Fault and Event Trees for Closure scenarios.

Following discussions with Hidro Dizayn, Golder evaluated the following three Post Closure scenarios for the TSF:

- Immediately following closure of the TSF, and prior to installation of the capping layer; and
- The closed TSF once the capping layer has been installed.

The closed TSF with the capping layer installed, but also equipped with and Emergency Drainage System to allow the cap to drain and remove surface water. The main differences between the risks relating the Operating and Closure Phases are the following:

- During the Operating Phase many risks relate to the operating activities carried out on and around the TSF, including tailings deposition, water management and maintenance. Careful management, training and experience can play important parts in lowering the risk associated with these activities, and to an extent (provided the facility is operated with care) this can be a relatively “controlled” environment and stage of the TSF’s life cycle; and
- During the Post Closure Phase some risks associated with the TSF are still present but many change due to changes in the facility (e.g. tailings consolidation, removal of the freeboard by the installation of a closure capping layer, equipping the facility with an EDS), or due to other factors which may be difficult to quantify including e.g. lack of maintenance and the effect thereof on the TSF and associated infrastructure e.g. the storm water diversion channel, etc. Due to the length of this phase and the fact that it may be to a large extent an “uncontrolled” environment, ongoing maintenance of the facility will be required, but through careful closure planning and the use of a robust closure design, the need for maintenance can be minimised.

The lack of an EDS for the TSF during the Post Closure Phase, is however deemed to pose the greatest risk to the TSF. This could lead to a situation (prior to capping of the facility) where, if the TSF's freeboard is compromised and water accumulates on top of the facility, an overtopping failure could occur. The associated risk is deemed to be less once the TSF has been capped, although water accumulating on top of the TSF could overtop the dam wall causing erosion which in time could expose and possible release of tailings. In addition to these two Post Closure scenarios, Golder developed a Fault and Event Tree to highlight the importance of equipping the capped TSF with an EDS for the Post Closure Phase.

The main probability factors for the release of tailings from the Kapezkaya TSF during the Operating and Post Closure Phases are as tabled below.

Table 8-1: Summary of Probabilities of Failure for the Operating and Post Closure Phases

Kepezkaya TSF	Annual Probability of Tailings Release
Operating Phase	**3.95E-05**
	1 in 25,313
Immediately Post Closure Prior to Capping	**1.09E-04**
	1 in 9,197
Post Closure TSF Capped	**5.17E-05**
	1 in 19,342
Post Closure TSF Capped plus Emergency Drainage System	**2.13E-05**
	1 in 46,866

The probability associated with the potential release of tailings from the Existing Kapezkaya TSF in its current condition, meets International best practice guidelines for the management of tailings management facilities during the Operating Phase, but is below standards during the Post Closure Phase.

The lack of a spillway for the TSF during the Post Closure Phase, is however deemed to pose a risk to the long term stability of the facility, especially due to the close proximity of the TSF to the town of Hanönü.

As can be seen from the table above, the probability of failure of the TSF is significantly higher during the Post Closure Phase directly after closure of the TSF (prior to capping but also after capping of the facility) than during the Operating Phase, which is contrary to the reduction in Probability of Failure one would normally expect when moving from the Operating to the Post Closure Phase. This is due to the lack of a closure spillway which is not allowed according to current Turkish Regulations.

Equipping the capped TSF with an Emergency Drainage System located in the abutment next to the facility, should however assist in reducing the annual probability of failure of the TSF during the Post Closure Phase from between 1.09E-04 (no cap) and 5.17E-05 (cap but no EDS), to approximately 2.13E-05 (cap with EDS). This reduction in the probability of failure from the Operating to the Post Closure Phase, demonstrates the importance of equipping the TSF with an Emergency Drainage System, and is more in line with that one would typically expect for facilities of this type during these phases.

Provided this risk mitigating measure is implemented, the TSF is deemed to meet international best practise guidelines for closure.

8.8 Mitigating Measures

Following preparation of the Risk Assessment for the Kepezkaya TSF and evaluation of the failure modes identified for the facility and their causative events, Golder identified a number of risk mitigating measures to reduce the probability of failure and tailings release from the Kapezkaya TSF although the operational phase is satisfactory as it stands. The measures include:

- Equipping the TSF with an Emergency Drainage System in preparation for the Post Closure Phase, as demonstrated by the second Post Closure scenario considered, should reduce the Probability of Failure of the facility by almost half the probability during the Operating Phase. Equipping the TSF with an Emergency Drainage System would also be in accordance with the ICOLD guidelines for TSF closure. The supernatant pond on the TSF during the Operating Phase can be managed with the return water pumping system; or

- Doming the TSF capping system at closure thereby negating the issue of any retention of water on the facility.

Although ultimately from a Risk Management perspective it is much better to prevent a TSF failure and Release of Tailings from occurring in the first place, a number of additional risk mitigation measures can also be implemented, which may include the following:

- Preparation and use of an Operating Manual for the TSF;
- Training of Staff in correct operating of the facility;
- Preparation of an Emergency Preparedness Plan and training staff in the correct response should an emergency occur; and
- Adequate monitoring and reporting of the condition of the dam wall and operations.

9.0 CONCLUSION AND RECOMMENDATIONS

Following the Risk Assessment and Cost Estimates prepared for the Overall Upgrade Options for the Kapezkaya TSF, the following conclusions can be made:

- The TSF has a sufficient factor of safety based on the conservative geotechnical parameters used in the stability analysis and the risk assessment for the operational phase is satisfactory;
- Although the TSF has been designed for the pseudo-static slope stability case of the Safety Evaluation Earthquake, international best practise is to also carry out an assessment based on the Maximum Credible Earthquake, especially for the Post Closure Phase;
- The annual probability of failure of the TSF during the Operating Phase is approximately 3.95E-5;
- The annual probability of failure of the TSF during the Post Closure Phase is approximately:
  - Prior to capping 1.09E-4;
  - After capping but no EDS 5.17E-5;
  - After capping with EDS 2.13E-5;
- These probabilities are less for the operational phase and greater for the post closure phase compared to the annual probability of dam failure of approximately 1.65 E-4 (or 1 in 6,061) calculated by ICOLD from their dam failure database;
- During both phases the probability of an Overtopping Failure is greater than that of an Embankment Failure; and
- The lack of an Emergency Drainage System for the TSF during the Post Closure Phase, is considered problematic particularly prior to capping. Golder therefore recommends equipping the TSF with either an Emergency Drainage System or a facility to pump surplus water from the facility as the cap is being installed and an EDS once the cap has been installed to allow the cap to drain and remove clean runoff from the cap surface.

10.0 REFERENCES

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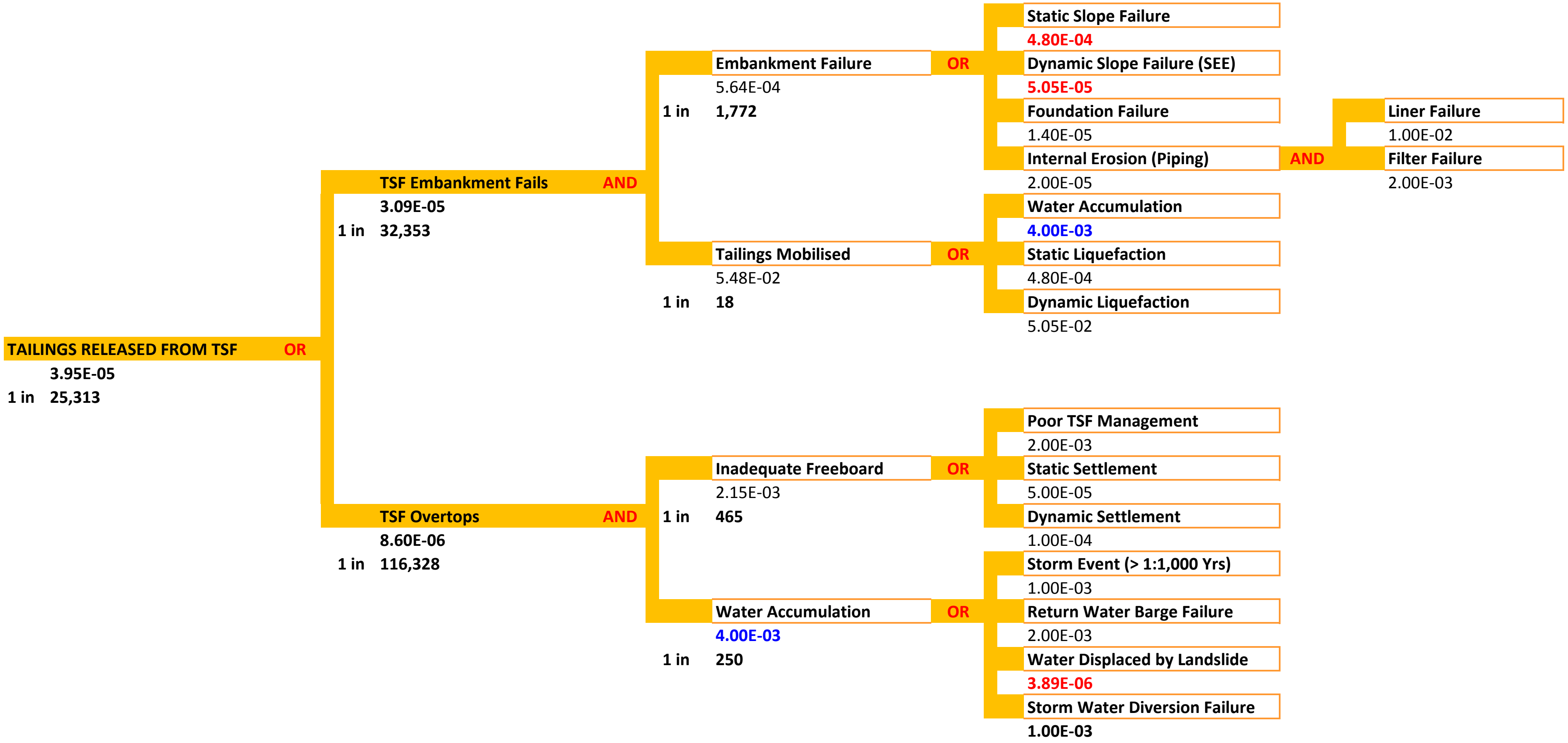
20 December 2016

HO/RW/es

APPENDIX A

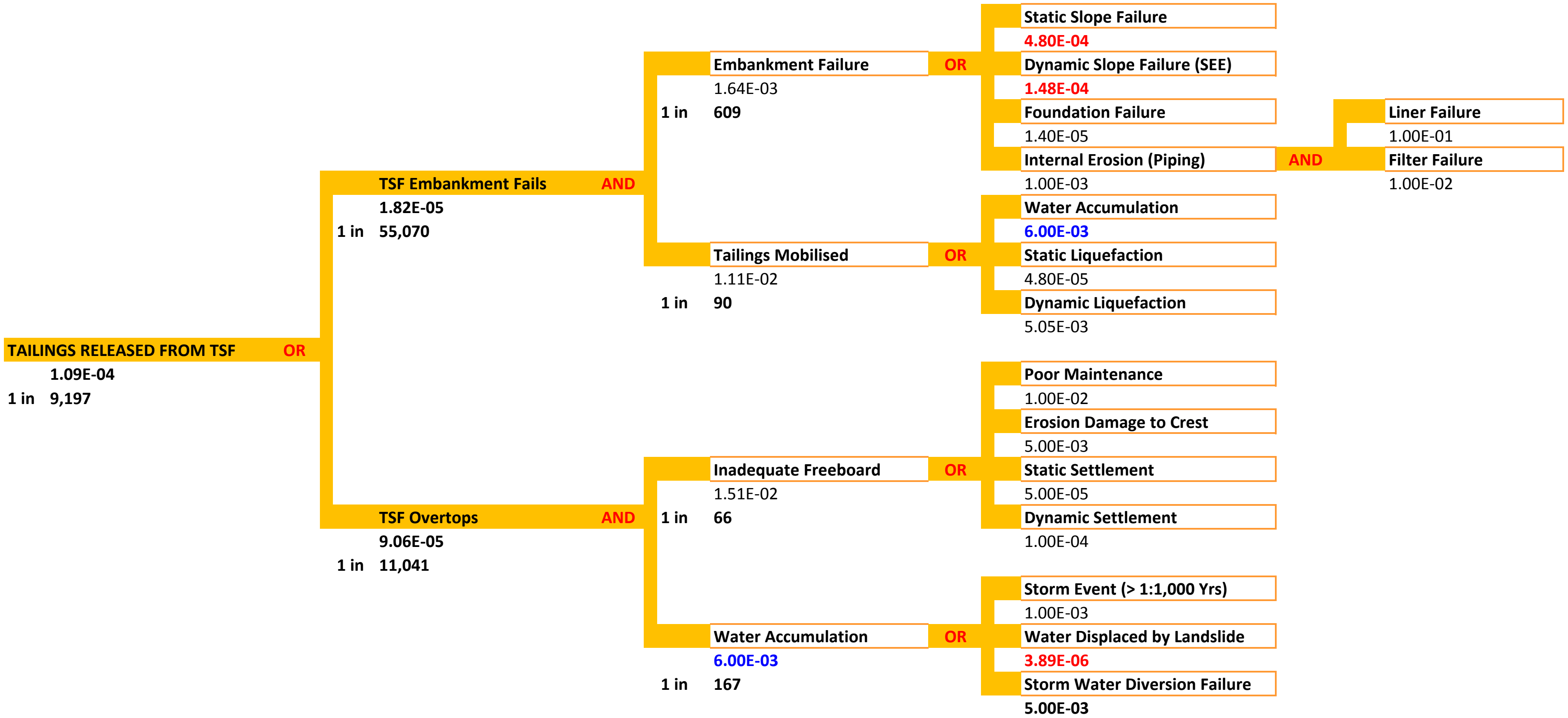
Fault Event Trees

ACACIA MINING - KEPEZKAYA TSF
OPERATING PHASE



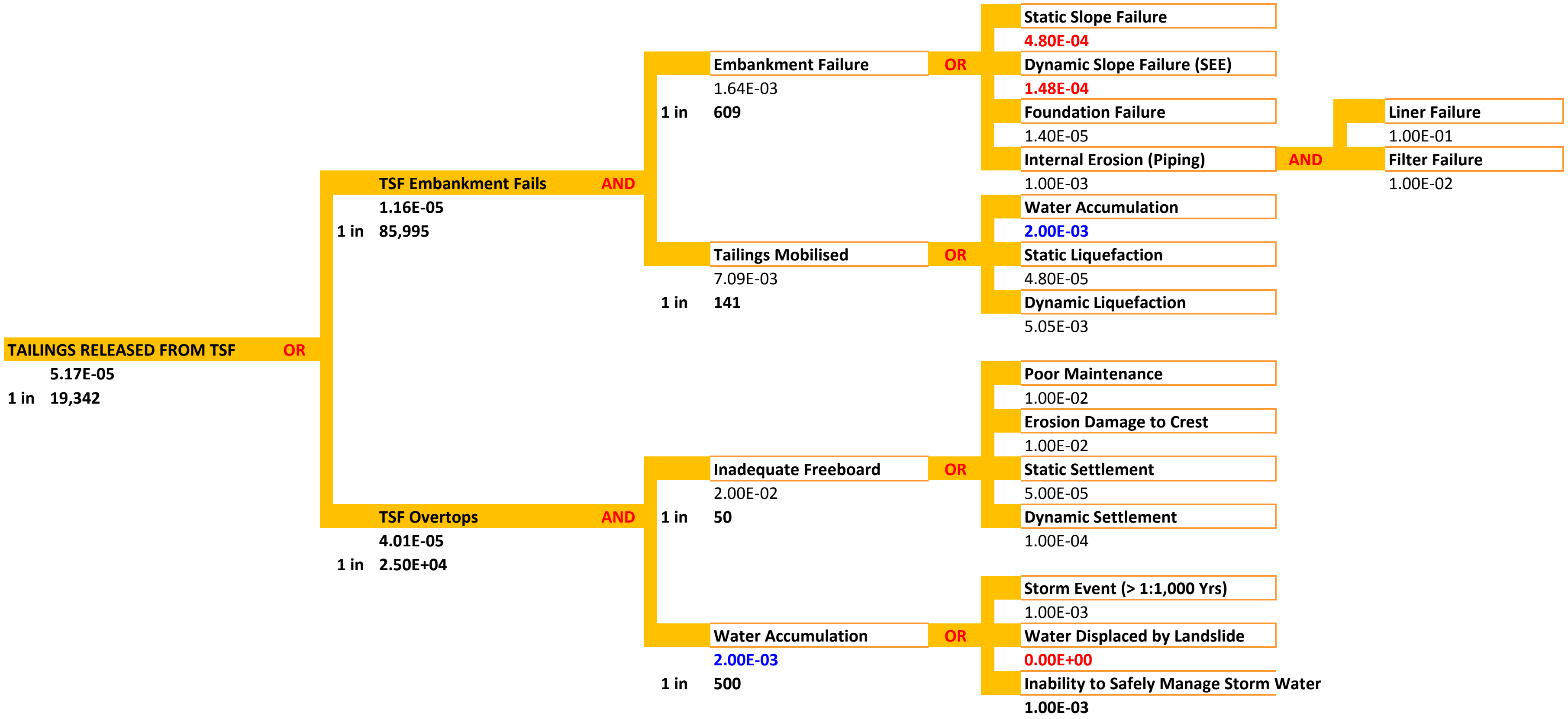
ICOLD AVERAGE ANNUAL POF ~ 1 in 6061

ACACIA MINING - KEPEZKAYA TSF
IMMEDIATELY POST CLOSURE PRIOR TO CAPPING



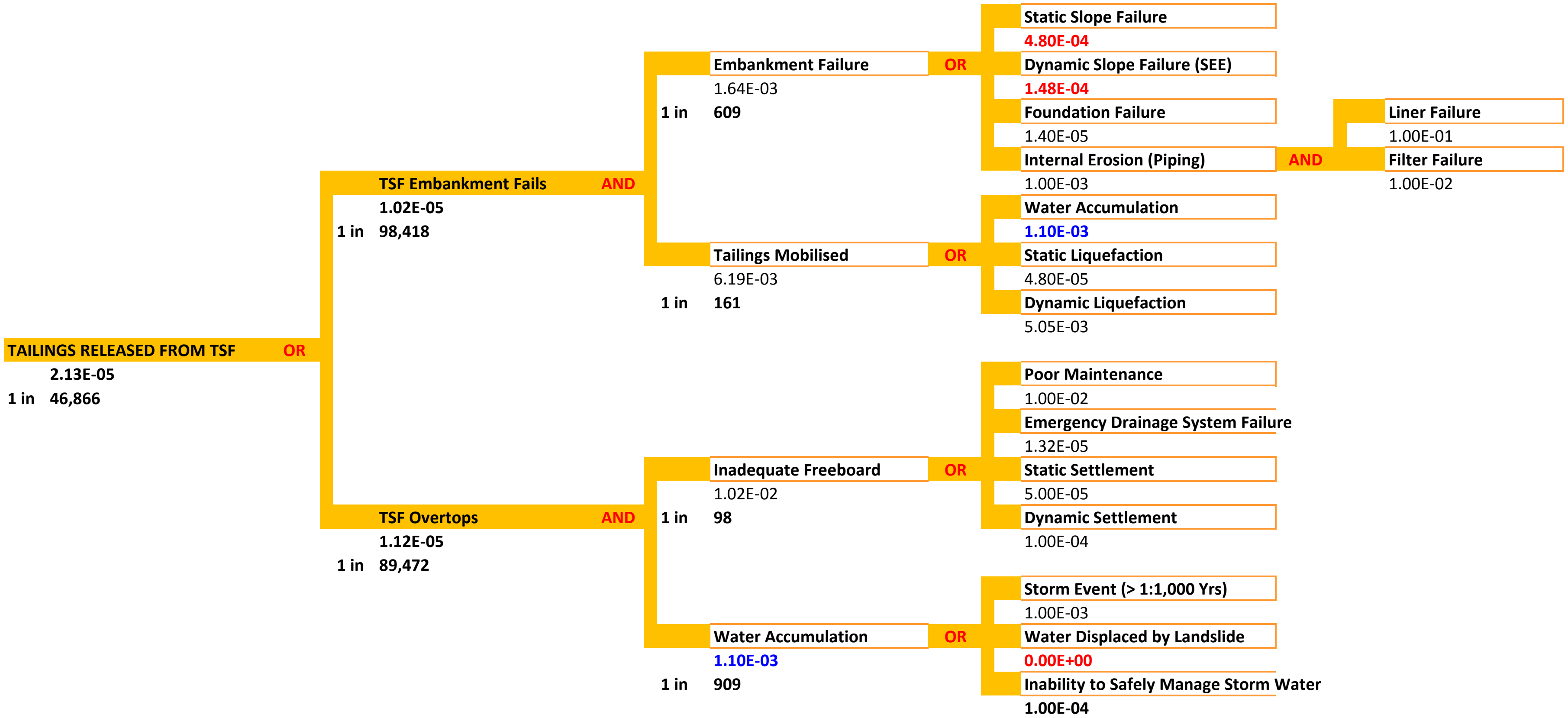
ICOLD AVERAGE ANNUAL POF ~ 1 in 6061

ACACIA MINING - KEPEZKAYA TSF
POST CLOSURE AFTER CAPPING



ICOLD AVERAGE ANNUAL POF ~ 1 in 6061

ACACIA MINING - KEPEZKAYA TSF
POST CLOSURE AFTER CAPPING WITH EMERGENCY DRAINAGE SYSTEM



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