

Application of risk-based tailings management at Tüprag Efemçukuru Gold Mine

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Abstract

Eldorado Gold Corporation, and its subsidiary Tüprag Metal Madencilik San.Tic.A.S. (Tüprag), owns and operates the Efemçukuru Gold Mine (Efemçukuru) in Turkey. As part of their commitments to their Mining Association of Canada (MAC) membership, Efemçukuru joined MAC's Toward Sustainable Mining (MAC-TSM) initiative in 2015, followed by an evaluation of the site's tailings management system. The findings showed that the tailings management system at Efemçukuru had several well-established operational controls that were regularly and properly applied; however, opportunities for improvement and adoption of best available practices to the current tailings management system were identified (Norwest Corporation 2018). A program to meet or exceed all waste management protocols was started in 2016 with the mine achieving MAC AAA designation in 2021.

The tailings management system proposed by MAC follows a risk-based approach, meaning that the risk assessment process should be incorporated into the routine decision-making process, performance evaluation, and supported with documentation and records.

In risk-based management/approach, site-specific risk assessment, potential high-consequence events, critical controls, trigger-action-response-plan, emergency response plan, emergency preparedness plan, performance assessment and management assessment improvement have an important place. Consistent with systems such as the environmental management system ISO14001, the tailings management framework follows the plan-do-check-act cycle and ensures that a management model is established for control and continuous improvement.

In this article, Tüprag presents a case history of its practices in the management of the Efemçukuru tailings and mine rock storage facilities in accordance with MAC-TSM and its current efforts to align them to the Global Industry Standard on Tailings Management (GISTM). Although the results appear straightforward, significant effort and insight was required to update and implement the tailings management plan. This article is intended as a reference for mines that have not yet fully implemented MAC-TSM and GISTM standards and as an informative case history for mines that have already done so.

Keywords: *risk-based tailings management, risk assessment, potential high-consequence events, critical controls, trigger action response plan, emergency preparedness and response plan, Mining Association of Canada, towards sustainable mining, sustainable development goals, tailings management protocol, Global Industry Standard on Tailings Management*

1 Introduction

Eldorado Gold Corporation (Eldorado), and its subsidiary Tüprag Metal Madencilik San.Tic.A.S. (Tüprag), own and operate the Efemçukuru Gold Mine (Efemçukuru) located in western Turkey (Figure 1). As a member of the Mining Association of Canada (MAC), Efemçukuru committed to the MAC Toward Sustainable Mining (MAC-TSM) protocols in 2015 and completed an evaluation of the site's tailings management system. The findings showed that the tailings management system at Efemçukuru had several well-established operational controls that were regularly and properly applied; however, opportunities for improvement and adoption of best available practices (BAP) to the current tailings management system were identified (Norwest Corporation 2018; Ürkmez et al. 2022a, 2022b). A program to meet or exceed all waste management protocols was started in 2016 with the mine achieving MAC AAA designation in 2021 (Stantec 2022).

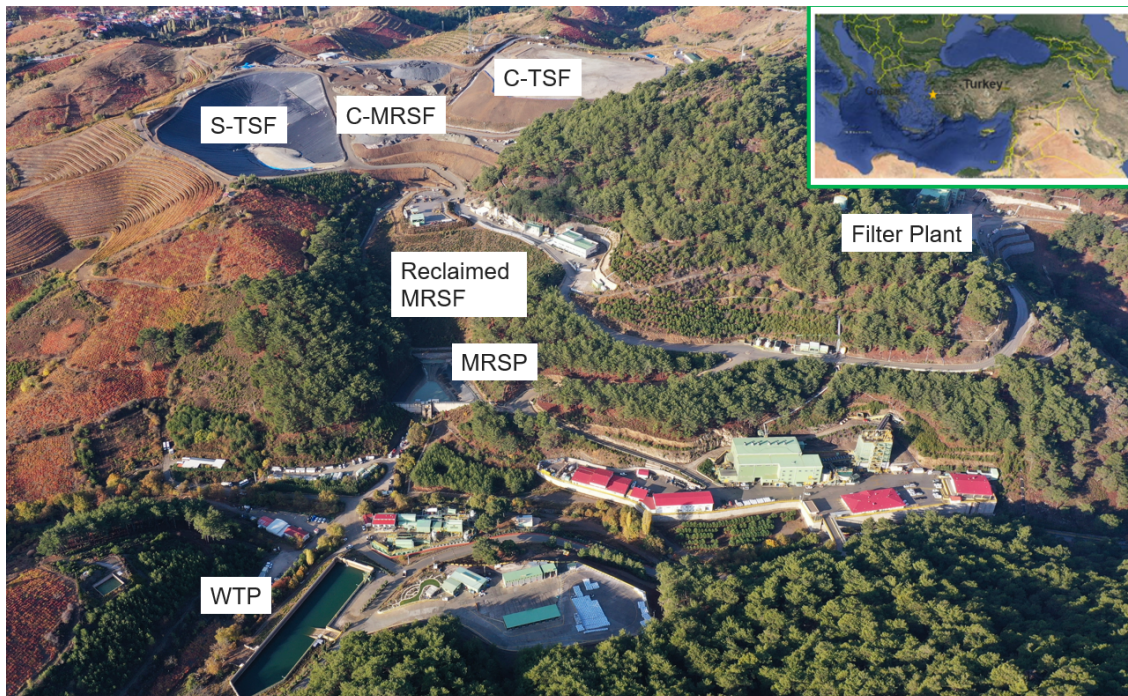


Figure 1 Efemçukuru Gold Mine location and general view

It is of great importance for the mining industry to develop waste management frameworks for the rapid development of the mining industry and for the mining industry to carry out sustainable and environmentally responsible mining activities. Current industry best practices recommend mine waste management systems that are risk-based (Mining Association of Canada [MAC] 2021a, 2021b, 2021c; Global Tailings Review 2020).

Management systems created with a risk-based approach can identify risks that may occur throughout the facility lifecycle (planning, construction, operation, closure and post-closure) and integrate them into company commitments and policies.

The risk-based management model implemented within the scope of the Eldorado Gold sustainability integrated management system (SIMS) at Efemçukuru includes systems that adopt international principles, approaches and standards. These systems are harmonised with each other and implemented within the scope of legal regulations.

Within the scope of sustainable mining at Efemçukuru, which started its operations in 2011, MAC-TSM protocols started to be integrated into the existing system in 2015.

2 Efemçukuru risk-based mine waste management framework

The risk-based management framework at Efemçukuru has been established on the basis of accountability and determination of responsibilities, documentation preparation, assessment of site-specific potential risks

and creation of action plans, use of best available technologies (BAT) and BAP, and regular internal and independent audits to evaluate systems and performance.

2.1 Tailings management policy and commitment

With the SIMS system developed by Eldorado, all key activities of the company are collected in one location. SIMS includes internationally accepted management systems and standards (UN global convention principles, world gold council responsible mining principles, ISO, MAC-TSM protocols, international cyanide institute management principles and GISTM). In addition, the commitments related to waste management have been integrated into the company policies and the tailings management system has been established based on these commitments:

- Health and safety policy.
- Environmental policy.
- Human rights policy.
- Social performance policy.
- Respectful workplace policy.

It is important to note that while this document uses the term tailings management as referred by MAC-TSM and GISTM, it is Eldorado's practice to apply similar policies to its mine rock storage facilities. Thus, throughout the document, the use of the terms tailings facilities and mine waste facilities are interchangeable.

2.2 Accountability and responsibilities

Accountability, responsibilities and authorities according to roles are defined within the framework of the health and safety policy, environmental policy, human rights policy, social performance policy, respectful workplace policy commitments and other policy provisions and within the MAC-TSM risk-based management system. Accountability, responsibilities and authorities for the following roles for waste storage facilities within the framework of MAC-TSM risk-based management should be specified separately.

- **Board of Directors or Governance Management:** Depending on the size of the company, it is the highest level of management. It is the approval mechanism of company policies and commitments.
- **Accountable Executive Officer:** An executive-level person (e.g. CEO, COO, vice president) designated by the Board of Directors or Governance Level, who is accountable for tailings management, and the development and implementation of the systems needed for responsible tailings management.
- **Responsible Person/s:** Person responsible for the implementation, development and performance evaluation of the tailings management system throughout the lifecycle of the waste storage facility (planning, construction, operation, closure and post-closure).
- **Engineer of Record (EoR):** The person responsible for ensuring facility safety, providing technical guidance, implementing, developing and evaluating and reporting the performance of waste management systems throughout the facility lifecycle for the enterprise.

2.3 Risk management

Within the framework of risk-based management, the identification, assessment, and management of risks at both the company and project levels is paramount. The risks at Efemçukuru are evaluated and updated annually within the framework of occupational safety and health, environment, engineering and operational, financial, legal, managerial and social aspects, especially for tailings storage facilities throughout the mine lifecycle.

2.3.1 Risk identification and assessment

At Efemçukuru, risks are identified and assessed using a probability-effect matrix with a failure mode effect analysis model. An example of Efemçukuru’s risk matrix table is presented in Figures 2 and 3. This matrix is also used to evaluate the risks of waste storage facilities. In this assessment, risks are defined as extremely high, high, medium and low (Stantec 2019). The potential consequences, severity and probability of the risks were determined by identifying the hazards with the risk assessment carried out, and thus the probability and severity of the hazards or risk were reduced or eliminated with the BATs and BAPs to be applied in mine waste management.

RISK ASSESSMENT of TSF and MRSF													
HAZARD CATEGORY	HAZARDS	Current Mitigation Measures	Current Risk Score					Additional Mitigation Measures	Remaining Risk Score				
			Consequence	Likelihood	Risk Rate	Risk Level	Result		Consequence	Likelihood	Risk Rate	Risk Level	Result
1 OHS	Lack of comprehensive occupational health and safety management system	- ISO 45001 - Company policies and commitments - Establishment of OHSE department - Company OHSE Department	Minor (2)	Unlikely (D)	5	L	2	- Dependent/Independent Internal and external audits. - MAC risk-based management systems * MAC-TSM audits * MAC Table of conformance * Critical controls * TARP applications * Determination of high level risks * Preparation of OMS guide	Minor (2)	Rare (E)	3	L	2
2 ENVIRONMENTAL	Lack of environmental management policy and system.	- Company policies and commitments. - EIA and waste management plan - ISO 45001 and ISO 14001 - MAC - TSM applications.	Moderate (3)	Rare (E)	6	M	3	- Dependent/Independent Internal and external audits. (MAC-TSM assessments, ISO 45001, ISO 14001, Ministry inspections, SIMS)	Minor (2)	Rare (E)	3	L	2
3 ENGINEERING AND OPERATIONAL	Failure to comply with the design criteria and projects.	- Independent QA / QC inspectors - Notification of construction reports and drawings to the ministry. - Performing tests (floor, mechanical, concrete) for the construction and reporting by accredited laboratories. - Ground tightness checks on site for ground. - Annual review reports and meeting	Minor (2)	Unlikely (D)	5	L	2	- MAC risk-based management systems * MAC-TSM Criteria audits * MAC Table of conformance * Critical controls * TARP applications * Determination of high level risks * Preparation of OMS (ISBIC) - Qualified EoR assignment	Minor (2)	Rare (E)	3	L	2
4 FINANCIAL													
5 LEGISLATION													
6 PROCESS MANAGEMENT													
7 SOCIAL													

Figure 2 Efemçukuru mine waste storage facilities risk identification/assessment example

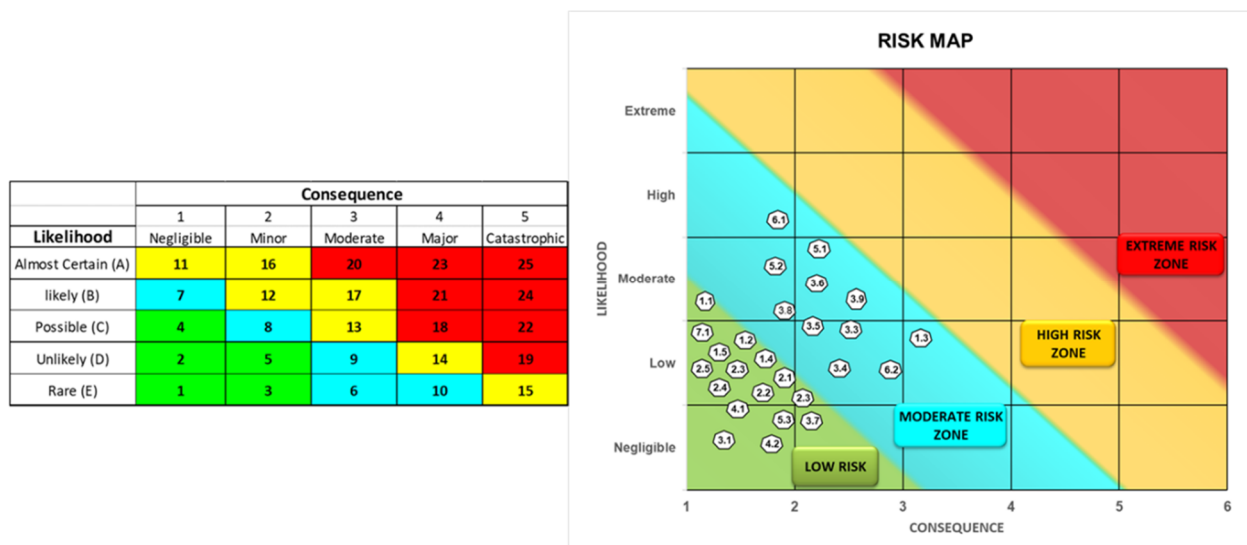


Figure 3 Efemçukuru mine waste storage facilities risk assessment and risk map example

2.3.2 Risk controls

2.3.2.1 Identification of critical control and hazards

At Efemçukuru, critical controls have been determined to prevent or mitigate the consequences of operational, technical or managerial events with high consequences. These critical controls may vary depending on the number of tailings storage facilities or storage characteristics (by site). An example of Efemçukuru's critical controls table is presented in Figure 4.

Hazards and Critical Controls				
Potential Failure Mode	Failure Mechanisms	Key Performance Indicators	Critical Controls	Performance Evaluation Criteria
Physical Stability failure of TSF and/or MRSF	<ul style="list-style-type: none"> Foundation failure Slope instability (tailings, toe berm or rock pile) Tailings Liquefaction (static / seismic) Mine rock degradation 	<ul style="list-style-type: none"> Groundwater levels (measured using VWP and standpipe piezometers) Density of stored wastes (compaction criteria) Visible slope movement (cracks, settlement, bulging, sloughing) Deformation measurements (prisms) 	<ul style="list-style-type: none"> Rock drains (used to control phreatic surface) Compaction criteria and QA/QC program (to mitigate risk of liquefaction or flow slide) Regular inspection by qualified personnel and EOR Independent reviews 	<ul style="list-style-type: none"> Design criteria considering extreme events Operational thresholds specified in the OMS manual (TARPs) Compliance with QA/QC construction program and specifications

Figure 4 Efemçukuru mine waste storage facilities critical controls and hazard example

2.3.2.2 Emergency response plan and preparedness plan

At Efemçukuru, an emergency response and preparedness plan has been developed in connection with the facility risk profile, specific to the mine waste storage facilities operating in accordance with the mine-wide emergency response and preparedness plans. The tailings storage facility emergency response and preparedness plan provides for the management of the mine waste storage facilities without requiring the site-wide emergency response and preparedness plan to be activated. Use of this two-stage emergency response plan (ERP) accelerates the response and reduces the severity of emergencies arising from the performance of the tailings storage facility or operational activities. Thus, emergency situations affecting the performance and operational activities of the tailings storage facility may be managed by the responsible person and team of the tailings storage facility, without the need to declare an emergency throughout the mine.

The mine waste storage facilities emergency preparedness (EPP) and ERP include the purpose, scope, key definitions, roles and responsibilities, emergencies, emergency response, emergency response resources, contact list and hierarchy, plan management, ERP-EPP updates, training, and ERP-EPP testing topics such as testing plans. Identified emergencies are as follows.

- Extreme weather (heavy rain).
- Standpipe water levels for tailings storage facility and mine rock storage facility.
- High piezometric (water level) conditions.
- Significant slope movements/instability.
- Earthquakes.

Tabletop and full-scale exercises are regularly performed every year within the scope of the waste storage facilities emergency action plan and performances are evaluated.

2.3.2.3 TARPs

TARPs are a tool used to help identify and manage risk. The first step in development is to identify potentially adverse conditions that could occur at the waste storage facility. An example from Efemçukuru is shown in Figure 5, which presents the TARP for the extreme weather condition. Once the adverse condition is identified, trigger levels must be defined for each alert level. Efemçukuru uses four alert levels: normal risk

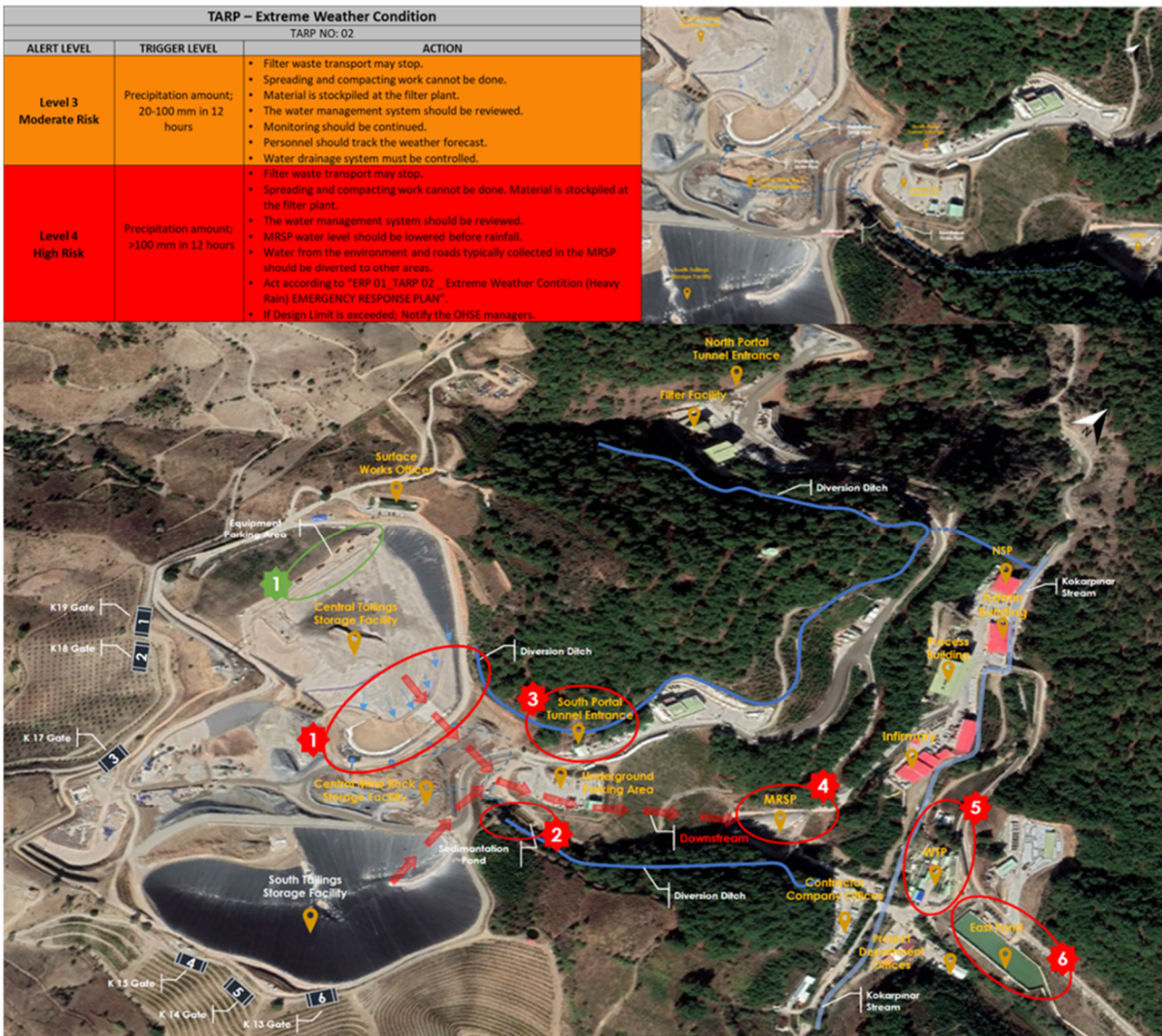
(normal operating condition), low risk, moderate risk and high risk. A set of actions/controls is then developed for each alert level in order to manage the risk associated with each increasing alert level. The adverse conditions were identified and TARPs developed collaboratively between the site responsible person, the EoR, and their respective teams. Seven TARPs have been developed for the Efemçukuru tailings storage facilities and are reviewed annually or after a significant event or design change.

TARP – Extreme Weather Condition		
TARP NO: 02		
ALERT LEVEL	TRIGGER LEVEL	ACTION
Level 1 Normal Risk	Precipitation amount; 1-5 mm in 12 hours	<ul style="list-style-type: none"> Filter waste transport, spreading and compacting can be continued in a controlled manner. Monitoring should be continued. Water drainage system must be controlled.
Level 2 Low Risk	Precipitation amount; 6-20 mm in 12 hours	<ul style="list-style-type: none"> Filter waste transport can be continued in a controlled manner. Spreading and compacting work cannot be done. Material may be stockpiled in the area. Monitoring should be continued. Personnel should track the weather forecast. Water drainage system must be controlled.
Level 3 Moderate Risk	Precipitation amount; 20-100 mm in 12 hours	<ul style="list-style-type: none"> Filter waste transport may stop. Spreading and compacting work cannot be done. Material is stockpiled at the filter plant. The water management system should be reviewed. Monitoring should be continued. Personnel should track the weather forecast. Water drainage system must be controlled.
Level 4 High Risk	Precipitation amount; >100 mm in 12 hours	<ul style="list-style-type: none"> Filter waste transport may stop. Spreading and compacting work cannot be done. Material is stockpiled at the filter plant. The water management system should be reviewed. MRSP water level should be lowered before rainfall. Water from the environment and roads typically collected in the MRSP should be diverted to other areas. Act according to "ERP 01_TARP 02 _ Extreme Weather Contition (Heavy Rain) EMERGENCY RESPONSE PLAN". If Design Limit is exceeded; Notify the OHSE managers.

Figure 5 Efemçukuru mine waste storage facilities TARPs example

2.3.2.4 TARPs connected ERP scenarios

Specific ERP scenarios have been developed for critical TARPs. An example from Efemçukuru is shown in Figure 6 for the extreme weather condition TARP. These ERP scenarios define the alert level when the facility ERP should be activated, and specific actions to be taken in the field prior to declaring a site-wide emergency. The number of TARPs and ERP scenarios developed should be based on site-specific conditions, performance criteria and the facility risk profile. Efemçukuru has developed four ERP scenarios connected to TARPs for the mine waste storage facilities. As part of the ERP these can be included in annual tabletop and full-scale field exercises.



TARP 02_ Extreme Weather Contition (Heavy Rain) EMERGENCY RESPONSE PLAN

Emergency Action Plan in this scenario should be started when TARP 02 Level 4 trigger level is reached.

TARP 02 - In case of starting Emergency Action Plan for Extreme Meteorological Conditions (Excessive Rainfall), ongoing operational activities should be stopped. Personnel and Equipment should be sent to critical areas. OHSE Manager should be contacted and informed. EOR should be contacted. The red arrows indicate the direction of flow, and the red areas indicate critical areas in case of excessive precipitation.

Personnel should be sent to the heel, where the surface waters of the C-TSF storage area are collected and discharged, and continuous monitoring should be made during precipitation.

In the event that the discharge pipes are insufficient and overflow through the toeberm, the inundation drain pipes placed on the Central EOK Storage Area (C-TSF Toeberm) will be activated and direct the surface water to the sediment catchment pond.

In such a case, additional one personnel and excavator or backhoe-loader should be directed to the area and the inundation drain pipes should be checked.

Personnel should be sent to the front sedimentation pond, where the surface waters of all storage areas are collected, and the pond level should be monitored at the time of precipitation. Also, the condition of the pond water drain cap and drain pipes should be checked. In case of overflow of water in the pond, inundation drain pipes (sluices) placed at the edge of the pond will be activated in and direct the pond water to MRSP.

Personnel should be directed to this part in order to monitor the water coming from the transportation ramp on the Central MRSP area to the south portal tunnel entrance.

The pond and pump opposite the tunnel should be checked. In case of increased water density, a loader or backhoe-loader should be directed to the tunnel entrance, and the waters should be directed to MRSP or NSP through the roadside channels.

The authorized supervisor should be contacted to get information on issues such as MRSP, WTP, east pond water level and working performance and to provide information about the current situation.

In addition, storage areas, roads, canals, small ponds and ditches and pipe inlets in these sections should be checked.

If necessary, mobile water discharge pumps in the container depot should be activated.

In the event that it is difficult to manage the current situation with TARP 02 - Emergency Action Plan for Extreme Meteorological Conditions (Excessive Rainfall) or if the conditions are severe, EMERGENCY should be started and the Mine-wide ERP and EPP protocol should be followed.

Figure 6 Efemçukuru mine waste storage facilities TARPs connected ERPs example

2.4 Operation, maintenance and surveillance manual

The operation, maintenance and surveillance (OMS) manual has been prepared as a guiding document for mine waste storage at Efemçukuru. Its implementation improves the safety and efficiency of the mine waste storage facilities and provides for high quality and sustainable management practices. The Efemçukuru OMS is based on *A Guide to the Management of Tailings Facilities* (MAC 2019a) and *Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities* (MAC 2019b).

The OMS manual is site specific and assists in the assessment, improvement, and standardisation of the performance of the existing tailings management system at Efemçukuru. Key components of this manual are as follows:

- OMS governance, including organisational roles, and corresponding responsibilities as well as the management of safety, quality system of the management organisation personnel and their corresponding activities.
- The description of the facility, including facility conditions, main components, and design criteria.
- The description of the facility's operations including transportation and storage of tailings, building and capacity improvement of storage facilities, water management, environmental conservation, and documentation and reporting.
- The description of routine and condition-based maintenance of the facility and documentation and reporting.
- The description of routine, condition-based and annual comprehensive surveillance including inspections and documentation and reporting.
- The description of an EPP and ERP.

This OMS manual comprises the commissioning, operating and closure processes of the tailings storage facilities and mine rock storage facilities and summarises the procedures, instructions and emergency responses with respect to their operations, maintenance and surveillance. Further detail regarding operational requirements and design criteria are presented in related appended modules. The activities included in this manual emphasise that performance objectives, risk management plan and critical controls should be planned, designed and implemented in a manner consistent with operational objectives and waste storage facility closing targets.

This guide should also include the following topics:

- OMS scope and purpose/activity tracking
 - Quality management.
 - Resources and planning.
 - Reporting.
- Roles, responsibilities and authority
 - Education and qualification.
- Occupational health and safety
- Tailings storage facility description
- Surveillance
 - Performance targets.
 - Operating procedures.
 - Tailings transport and placement.

- Ongoing tailings plant construction.
- Classification of tailings storage facilities.
- Water management.
- Shutdown.
- Site access.
- Maintenance.
 - Definition of maintenance activities.
 - Maintenance-related documents.
- Monitoring.
 - Design considerations for a monitoring program.
 - Monitoring activities.
 - Field monitoring and inspections.
 - Monitoring equipment.
 - Analysis of monitoring results, communications and decision making.
 - Emergency response plans.
 - Critical controls and TARPs.
 - Assessment of performance.
 - ERP and EPP.
 - Management review.

2.5 Assessment of performance

With the help of SIMS, which supports effective risk management decisions and includes all systems, it has been determined how the performance of the facility and systems will be periodically audited and evaluated. A series of internal and independent audits are carried out based on UN Global Compact Principles, World Gold Council Responsible Mining Principles, ISO, MAC-TSM protocols (MAC 2019a), International Cyanide Management Code principles and law compliance.

2.5.1 *Annual review of tailings management*

The tailings management system at Efemçukuru has been reviewed annually since 2017 in order to evaluate the annual performance within the scope of MAC-TSM waste management protocols (İnci et al. 2019). A report covering the performance and operational activities of the tailings storage facilities is prepared, and the report is presented at a meeting attended by the relevant and responsible managers and EoR.

The annual review report and meeting generally cover the following topics:

- Operational activities (stability, water management, storage capacity, personnel, equipment, monitoring, maintenance, documentation, other activities).
- Environment.
- Financial.
- Occupational health and safety.
- Social.

- Legal requirements.
- Administrative evaluation.
- New projects (future plans).

2.5.2 *Internal audits*

Audit requirements for Efemçukuru are specified in Eldorado's SIMS program. Within the scope of SIMS-specific compliance assurance, corporate sustainability audits and reviews include internal sustainability assessments of facilities (ISO, MAC-TSM, etc.) and internal audits and reviews required by institutions.

In particular, the MAC-TSM tailings management protocols are evaluated annually by the responsible and authorised person(s) and EoR. These evaluations are carried out with the following documents.

- Waste management protocol document and each indicator of the protocol comprehensively reviewed with its own grading system in detail.
- *Table of Conformance* (MAC 2019b).
- Tailings Guide implementation checklist.

2.5.3 *Independent review*

Independent (external) audit requirements for Efemçukuru are specified in Eldorado's SIMS program. These audits consist of corporate sustainability audits and reviews, facility assessments and audits by government agencies (MAC-TSM, ISO, Independent Tailings Review Board [ITRB], ministry audits, etc.).

In order to ensure that the management and risks of tailings storage facilities are defined and understood, and to support sustainability and continuous development, international practices applied in the field are regularly audited by third party expert/s or organisation/s. These audits for tailings storage facilities and management are carried out by the individuals determined by MAC within the scope of MAC-TSM tailings management protocol compliance and by the ITRB within the scope of company planning.

- The independent review focuses on a broad framework such as the following topics.
- Risk assessment and risk management plans.
- Description of the facility, including design and construction information.
- Key personnel and OMS manual.
- Results of internal and external audits, performance evaluations and management reviews.
- Previous independent review results and recommendations and implementation status.
- Medium and long-term plans of the facility.
- Implementation of current best practices and BAT.
- Whether the waste storage facility is managed based on current best practice and BAT.
- Whether the waste storage facility is consistent with methodologies that comply with the design criteria, legal requirements and risk profile.

3 **Conclusion**

With the development and growth in the mining industry, its social and environmental effects are also increasing. The mining industry needs to be supported within the framework of responsible mining with the BAT and BAP. In this context, Tüprağ's Efemçukuru Gold Mine is the first mining operation in Turkey to apply the filtered tailings storage method, which is considered to be best practice for this site. In addition, it is the

first and only mining operation in Turkey that implements the internationally accepted MAC-TSM protocols, reaching and striving to maintain a level of AAA.

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