7. Risks
Table of Contents

1 Introduction ............................................................................................................... 12
1.1 Legal framework .................................................................................................... 12
1.2 Definitions ............................................................................................................... 13

2 Hazard and Risk ........................................................................................................ 15
2.1 Risk Assessment Methodology ............................................................................. 15
2.1.1 The qualitative measure of consequences ....................................................... 16
2.1.2 The probability to occur measure ..................................................................... 16
2.1.2.1 Quantitative risk assessment .................................................................... 17
2.1.3 Short History of Accidents occurred in other projects ...................................... 17
2.1.3.1 Mining Incident at Aznalcómár (Spain) ....................................................... 20
2.1.3.2 The accident in Baia Mare ....................................................................... 21
2.2 Seismic Risk .......................................................................................................... 23
2.2.1 Seismicity in Romania ....................................................................................... 23
2.2.1.1 Determining seismic parameters for Roşia Montană area ............................ 24
2.2.2 Classification of Seismic Hazard and Design Specifications for Roşia Montană ............................................................................................................. 26
2.2.2.1 The Operating Basis Earthquake (OBE) ..................................................... 26
2.2.2.2 Maximum Design Earthquake (MDE) .......................................................... 27
2.3 The Risk of Meteorological Events ...................................................................... 27
2.3.1 Meteorological Events that Pose Risks to Hydrotechnical Structures ............ 27
2.3.1.1 Extreme Precipitation ............................................................................. 27
2.3.1.2 Probable Maximum Precipitation (PMP) .................................................... 28
2.3.1.3 Sudden Snowmelt ................................................................................... 29
2.3.2 Meteorological Events that Pose Risks to Transport Activities ..................... 30
2.3.2.1 Black Ice ................................................................................................. 30
2.3.2.2 Snow Cover ............................................................................................ 30
2.3.2.3 Blizzards .................................................................................................. 30
2.3.2.4 Fog .......................................................................................................... 30
2.3.3 Other Risk Events and Atmospheric Processes ............................................. 30
2.3.3.1 Hoary Frost ........................................................................................... 30
2.3.3.2 Storms ..................................................................................................... 31
2.3.3.3 Extreme Temperatures ............................................................................ 31
2.4 The Risk of Flooding and Inundation .................................................................. 31
2.4.1 Variables Involved in Generating Floods and Flash Floods ............................ 31
2.4.1.1 Triggering Factors ................................................................................ 31
2.4.1.2 Conditional Factors ............................................................................... 32
2.4.2 Analysis of the Multi-Annual Water Regime .................................................... 34
2.4.2.1 Multi-Annual Water Regime of Fluid Flow ............................................. 34
2.4.2.2 Frequency of Flash Floods and Floods .................................................... 35
2.4.2.3 Flood Wave Modeling ............................................................................ 37
2.4.3 Measures to Prevent, Reduce and Remediate the Effects of Floods and High Waters ................................................................. 38
2.4.3.1 Structural Measures ............................................................................... 38
2.4.3.2 Non-Structural Measures ...................................................................... 40
2.5 Fires ......................................................................................................................... 41
2.5.1 Natural and Anthropogenic Causes ................................................................. 41
2.5.2 Fire Impacts on the Natural and Built Environment ......................................... 42
2.6 Landslides ............................................................................................................. 42
2.6.1 Slope Inclination Analysis (Slope Map) ............................................................ 43
2.6.1.1 Hypsometry ........................................................................................... 43
2.6.1.2 Relief Fragmentation .............................................................................. 43
2.6.1.3 Depth of relief fragmentation (relief energy) .......................................... 43
2.6.1.4 Slope Inclination and Exposure Analysis ................................................. 43
2.6.2 Natural Slope Morpho-Dynamics ..................................................................... 44
2.6.3 Soil Stability Class Analysis ............................................................................. 45
2.6.4 Assessment of Landslide Risk Areas ................................................................ 46
2.6.5 Landslide Consequences on the Natural and Built Environment .......... 48
2.7 Risks Involved in the Depletion of Non-Renewable Natural Resources ..........48
3 Technological Hazards and Risks ....................................................................51
3.1 Identification and Presentation of the Hazardous Substances Used in the Project51
3.1.1 Hazardous substance inventory ..................................................................51
3.1.1.1 The ore ........................................................................................................51
3.1.1.2 The slurry ........................................................................................................51
3.1.1.3 Process water with cyanides ...........................................................................52
3.1.1.4 The rich solution .............................................................................................52
3.1.1.5 Acid runoff collected in the Cetate drainage pond ........................................52
3.1.2 Physico-Chemical Characteristics of the Main Hazardous Substances Present ..........................................................................................................................53
3.1.2.1 Hydrocyanic acid (HCN) ..................................................................................53
3.1.2.2 Sodium hypochlorite .......................................................................................54
3.1.2.3 Sodium hydroxide ..........................................................................................54
3.1.2.4 Hydrochloric acid ...........................................................................................54
3.1.2.5 Quicklime ......................................................................................................55
3.1.2.6 Metabisulfite ..................................................................................................55
3.1.2.7 Copper sulfate ...............................................................................................55
3.1.2.8 Ammonium nitrate ........................................................................................55
3.1.2.9 Mercury .........................................................................................................55
3.1.3 The physical and chemical behavior of the main hazardous substances, under normal operating conditions and in foreseeable accident conditions ........................................................................................................55
3.2 Identification of Relevant Safety Sections and Sources of Hazard .................58
3.2.1 Mining Operations Areas .............................................................................58
3.2.2 Site haul routes ...............................................................................................59
3.2.3 Process Plant ..................................................................................................60
3.2.3.1 Sodium Cyanide Solution Storage ..................................................................60
3.2.3.2 Hydrochloric acid storage ..............................................................................61
3.2.3.3 Carbon in Leach (CIL Circuit) .......................................................................61
3.2.3.4 Tailings Thickener ...........................................................................................62
3.2.3.5 DETOX Installation .........................................................................................62
3.2.3.6 Enriched Solution Storage ............................................................................63
3.2.3.7 DETOX Reagent Management .....................................................................63
3.2.3.8 Reagent Storage and Handling .....................................................................63
3.2.3.9 Sodium Hydroxide Storage ...........................................................................63
3.2.3.10 Lime Storage/Preparation ............................................................................63
3.2.3.11 Wet Ore Grinding ........................................................................................64
3.2.3.12 Gold Desorption/Processing Area .................................................................64
3.2.3.13 Process Water Tank .....................................................................................65
3.2.3.14 ARD Treatment Area ...................................................................................65
3.2.3.15 Compressed Air Plant ..................................................................................66
3.2.3.16 Oxygen Plant ...............................................................................................66
3.2.3.17 Transformer Station (110 kV) .....................................................................66
3.2.3.18 Explosives storage .......................................................................................66
3.2.3.19 Technological Lines .....................................................................................66
3.2.4 Pipeline Routes ..............................................................................................66
3.2.4.1 Tailings Delivery Pipeline ..............................................................................66
3.2.4.2 Clarified Water Pipeline ................................................................................67
3.2.4.3 Cetate Wastewater Pipeline .........................................................................67
3.2.4.4 Treated Water Discharge Conduits and Channels .........................................67
3.2.5 Tailings Management Facility .......................................................................67
3.2.5.1 Design Criteria ...............................................................................................68
3.2.5.2 Starter Dam .....................................................................................................69
3.2.5.3 Main Tailings Dam ..........................................................................................69
3.2.5.4 Secondary Containment System ....................................................................70
3.2.5.5 TMF Diversion Works ..................................................................................70
3.2.6 Cetate Water Catchment Dam ......................................................................71
3.2.7 Waste rock disposal sites .............................................................................71
3.2.8 Explosives storage .........................................................................................72
Table of Contents

4 Identification of Potential Accident Scenarios .................................................. 73
   4.1 Construction Phase ............................................................................. 73
      4.1.1 Mining Operations Areas ....................................................... 73
      4.1.2 Site haul routes ................................................................. 73
      4.1.3 Process Plant ........................................................................ 73
      4.1.4 Pipeline Routes ...................................................................... 73
      4.1.5 Tailings Management Facility ............................................. 74
      4.1.6 Cetate ARD Catchment Dam ............................................. 74
      4.1.7 Stockpiles ........................................................................... 74
      4.1.8 Explosives storage .............................................................. 74
   4.2 Operation Phase ............................................................................. 74
      4.2.1 Mining Operations Areas ....................................................... 74
      4.2.2 Site haul routes ................................................................. 75
      4.2.3 Process Plant ........................................................................ 75
      4.2.4 Pipeline Routes ...................................................................... 82
      4.2.5 Tailings Management Facility ............................................. 83
         4.2.5.1 Dam breach development ............................................... 83
         4.2.5.2 Damage of the final dam ............................................... 85
         4.2.5.3 Breakdowns in the Secondary Containment System .......... 86
         4.2.5.4 Breakdown of the decant water pumping station .......... 86
         4.2.5.5 Breakdown of the DETOX station .................................. 86
         4.2.5.6 Development of toxic aerosols and HCN on the pond surface .... 86
         4.2.5.7 Damage at the electricity supply and distribution system of the floating barge and SRS .... 86
         4.2.5.8 Power cuts caused by independent factors ....................... 87
         4.2.5.9 Suicidal attempts ......................................................... 87
         4.2.5.10 Occupational accidents ............................................... 87
      4.2.6 Cetate ARD Catchment Dam ............................................. 87
      4.2.7 Stockpiles Crumbling ........................................................... 87
      4.2.8 Explosives storage .............................................................. 88
   4.3 Closure Phase ............................................................................. 88
      4.3.1 Mining Operations Areas ....................................................... 88
      4.3.2 Site haul routes ................................................................. 88
      4.3.3 Process Plant ........................................................................ 88
      4.3.4 Pipeline Routes ...................................................................... 89
      4.3.5 Corna Tailings Management Facility .................................. 89
      4.3.6 Cetate Water Catchment Dam ........................................... 89
      4.3.7 Stockpiles ........................................................................... 89
      4.3.8 Explosives storage .............................................................. 89
   4.4 Qualitative Risk Analysis ................................................................... 89
5 Hazards and Risks Associated with Transport .............................................. 98
   5.1 Description of the Transport System ................................................. 98
      5.1.1 Quantities of Transported Materials and Substances ............. 98
      5.1.2 Sodium Cyanide Transport System ...................................... 99
      5.1.3 Transport of Explosives ....................................................... 99
      5.1.4 Hazardous Waste .............................................................. 99
      5.1.5 Metal Mercury Waste ......................................................... 99
      5.1.6 Municipal Waste ............................................................... 100
      5.1.7 Oversize Transport ............................................................. 100
      5.1.8 Doré Bullion Shipments ...................................................... 100
      5.1.9 Personnel Transport ............................................................ 100
   5.2 Selection of the Cyanide Delivery Route ............................................ 100
   5.3 Preliminary Risk Assessment ............................................................ 101
      5.3.1 Construction Phase ............................................................ 101
      5.3.2 Operation Phase ................................................................. 101
6.4.3 Tailings Management Facility ....................................................... 117
  6.4.3.1 Potential Failure Scenarios involving the Tailings Management Facility ................................................................. 117
  6.4.3.2 Propagation of the flood wave and cyanide transportation downstream ................................................................. 120
  6.4.3.3 Potential impacts on human settlements .................................................................................................................. 120
  6.4.3.4 Potential impacts on terrestrial and aquatic ecosystems ........................................................................................... 121
  6.4.3.5 Potential impacts on the physical environment ..................................................................................................... 121
  6.4.3.6 Potential transboundary effects ............................................................................................................................ 121
  6.4.3.7 Development of HCN on the pond surface .............................................................................................................. 121
6.4.4 Cetate ARD Catchment Dam ................................................................. 121
  6.4.4.1 Dam break and breach development ..................................................................................................................... 121
6.4.5 Explosives storage .............................................................................. 123
  6.4.5.1 Explosion or fire at the storage facility ................................................................................................................... 123
6.5 The blow effect and remote destruction .............................................. 126
6.6 Considerations on the explosion risk for ammonium nitrate and dynamite ................................................................. 127
6.6.1 Assessment of potential impacts ...................................................... 128
  6.6.1.1 Initiating detonation of the ammonium nitrate from a substance explosion in the work shed ................................. 128
  6.6.1.2 Initiation of ammonium nitrate by the buried dynamite ....................................................................................... 129
  6.6.1.3 Explosion of the ammonium nitrate storage facility .............................................................................................. 129
  6.6.1.4 Explosion of the work shed ...................................................................................................................................... 130
6.6.2 Road accident involving a vehicle providing on-site transportation of explosives ..................................................... 131
6.6.3 Offsite haulage routes ....................................................................... 132
  6.6.3.1 Potential release of sodium cyanide during transport to the RM Project site ............................................................ 132
6.7 Risk Assessment Methodology ............................................................. 134
  6.7.1 Toxicological and Eco-Toxicological Characteristics of the Main Hazardous Substances .................................................. 134
    6.7.1.1 The Effects of Cyanides on Public Health ............................................................................................................. 134
    6.7.1.2 The Effects of Cyanides on the Environment ........................................................................................................ 136
  6.7.2 Analysis of Health Risks in the Case of Accidental Emissions to the Air ........................................................................... 138
  6.7.3 Social Risk Analysis ..................................................................... 138
    6.7.3.1 Calculation of Individual Risk and Social Risk ..................................................................................................... 139
  6.7.4 Assessment of Cumulated Health and Environmental Risks ..................................................................................... 141
    6.7.4.1 Introduction to the Rapid Environmental and Health Risk Assessment (REHRA) Methodology ............................. 142
  6.7.5 Assessment of the Site Health and Environmental Risks and Ranking ........................................................................... 145
    6.7.5.1 Hazard Assessment .................................................................................................................................................. 145
    6.7.5.2 Health and Environmental Risk Assessment; ....................................................................................................... 145
    6.7.5.3 General Environment and Health Vulnerability Assessment .................................................................................. 146
7 Emergency Planning .............................................................................. 150
  7.1 Emergency Definition and Classification Based on Seriousness .......... 152
    7.1.1 Class A emergency (local emergency) ............................................. 152
    7.1.2 Class B Emergency (Site emergency) ............................................. 153
    7.1.3 Class C Emergency (emergency off site) ......................................... 153
  7.2 Organizing Emergency Response ...................................................... 153
  7.3 Specific Intervention Procedures ...................................................... 155
    7.3.1 Potential Hydrocyanic Acid Releases .......................................... 155
      7.3.1.1 Intervention: ......................................................................................................................................................... 155
    7.3.2 Potential Emissions of Cyanide Solutions from the Process Plant, after Tank, Pipe or Valve Failure ......................... 155
      7.3.2.1 Intervention: ......................................................................................................................................................... 155
    7.3.3 Leaks in the Mine Waste Piping Systems ...................................... 155
      7.3.3.1 Intervention: ......................................................................................................................................................... 155
    7.3.4 Break of Corna Tailings Dam or Secondary Containment Dam .... 156
      7.3.4.1 Intervention: ......................................................................................................................................................... 156
    7.3.5 Overload of the Tailings Management Facility and/or of the Secondary Containment System (without Dam Break) ...... 156
      7.3.5.1 Intervention: ......................................................................................................................................................... 156
    7.3.6 Rock/Mud Slide off the Waste Stockpiles ..................................... 157
7.3.6.1 Intervention: .................................................................................................................. 157
7.3.7 Pit Wall Failure .................................................................................................................. 157
7.3.7.1 Intervention: .................................................................................................................. 157
7.3.8 Explosion during ANFO Preparation ................................................................................ 157
7.3.8.1 Intervention: .................................................................................................................. 157
7.3.9 Explosion of Blasting Agents in the Explosive Storage .................................................. 157
7.3.9.1 Intervention: .................................................................................................................. 158
7.3.10 Premature/Unpredictable Explosion of Explosives at the Blasting Front ...................... 158
7.3.10.1 Intervention: .................................................................................................................. 158
7.3.11 Fires or Explosions of Occupied Buildings or Process Areas ....................................... 158
7.3.11.1 Intervention: .................................................................................................................. 158
7.3.12 Fires and Explosions Associated with Traffic/Transport Accidents .............................. 158
7.3.12.1 Intervention: .................................................................................................................. 159
7.3.13 Fires and Explosions Associated with Fuel Storage and/or Handling ........................... 159
7.3.13.1 Intervention: .................................................................................................................. 159
7.3.14 Chemical Spills on the Process/Storage Sites ............................................................ 159
7.3.14.1 Intervention: .................................................................................................................. 159
7.3.15 Chemical and/or Fuel Spills Associated with Traffic/Transport Accidents ................ 159
7.3.15.1 Intervention: .................................................................................................................. 159
7.3.16 Fuel Spills Associated with Fuel Storage and/or Handling .......................................... 160
7.3.16.1 Intervention: .................................................................................................................. 160
8 Alternative Options and Associated Risks ........................................................................... 161
8.1 Project Cancellation or Delay ........................................................................................... 161
8.2 The Use of Cyanide .......................................................................................................... 162
8.2.1 Alternative Technologies ............................................................................................... 162
8.2.2 Alternative Extraction Agents ....................................................................................... 162
8.2.2.1 Tiosulfate .................................................................................................................... 163
8.2.2.2 Thiourea....................................................................................................................... 163
8.2.2.3 Haloid Systems .............................................................................................................. 163
8.2.2.4 Bio-Leaching ............................................................................................................... 163
8.3 TMF Location .................................................................................................................... 164
8.3.1 Corna Valley ................................................................................................................... 164
8.3.2 The tailings pond at Roșia Poieni ................................................................................... 165
8.3.3 Seliște Valley .................................................................................................................. 165
8.3.4 Abruzel Valley ............................................................................................................... 165
8.3.5 Stefanca Valley .............................................................................................................. 165
8.3.6 Tailings backfilling into the excavation voids .................................................................. 165
9 Conclusions ......................................................................................................................... 166
10 Legal framework .................................................................................................................. 172
11 Bibliography ....................................................................................................................... 173
Annex no.1 List of hazardous substances on the site ............................................................... 177
Annex no.2 Relevant quantities of hazardous substances identified within the processing plant boundaries — according to Seveso Convention ........................................................................ 183
Annex no.3 The location of the safety areas within Roșia Montană Project site ...................... 185
Annex no.4 Hazard sources identified within the processing plant boundaries ..................... 186
Annex no.5  Simulated HCN emission dispersion at the processing plant total destruction 187
Annex no.6  Simulated HCN emission dispersion from the CIL tanks............................... 188
Annex no.7  Simulated HCN emission dispersion from the CIL tanks............................... 189
Annex no.8  Simulated HCN emission dispersion from the slurry thickener................................. 190
Annex no.9  Simulated HCN emission dispersion from the slurry thickener................................. 191
Annex no.10 Simulated HCN emission dispersion from the DETOX facility............................ 192
Annex no.11 Simulated HCN emission dispersion from the DETOX facility............................ 193
Annex no.12 Simulated fire in the diesel storage tank................................................................. 194
Annex no.13 Simulated diesel fire in the retention tank............................................................... 195
Annex no.14 Simulated diesel explosion in the storage tank...................................................... 196
Annex no.15 Simulated explosion of the LPG storage tank....................................................... 197
Annex no.16 Effects of an explosives storage facility explosion............................................. 198
Annex no.17 Modeling of risks associated to accidental exposure to HCN of employees working within impacted area and from the plant site......................................................... 199

List of Tables

Table 7-1. Differences between Hazop and Hazan......................................................................... 15
Table 7-2. Risk level..................................................................................................................... 16
Table 7-3. Risks probability to occur levels.................................................................................. 16
Table 7-4. Major accidents at gold mines, 1975 to 2005............................................................... 19
Table 7-5. Extreme precipitation values (Drobot, 2004)................................................................. 28
Table 7-6. Maximum estimated temperature for various return periods...................................... 29
Table 7-7. Flash flood generation – elements of frequency (1978-2002)......................................... 32
Table 7-8. The main watercourse characteristics of the river basins affected by the Roșia Montană Project.......................................................................................................................... 34
Table 7-9. Annual distribution of floods generated by flash floods and high waters in Roșia Montană and Abrud (1995-2005)........................................................................................................... 37
Table 7-10. Results of matrix assessment of landslide risk in ten locations of the mining site................................................................................................................................. 46
Table 7-11. The composition of the liquid phase of the slurry........................................................................ 52
Table 7-12 The estimated average chemical composition of the water stored into the TMF pond................................................................................................................................. 52
Table 7-13 The probable chemical composition of acid runoff collected in the Cetate drainage pond................................................................................................................................. 52
Table 7-14 the value of the dissociation constant ant the approximate concentration of fre cyanide for various initial concentrations...................................................................................... 56
Table 7-15 The stability factors used in designing TMF ........................................................................ 84
Table 7-16. Construction Phase...................................................................................................... 90
Table 7-17. Construction Phase...................................................................................................... 91
Table 7-18. Closure Phase.............................................................................................................. 95
### Table of Contents

- Table 7-19 The annual transported quantities on off site roads ........................................ 98
- Table 7-20 Construction Phase .................................................................................. 103
- Table 7-21 Operation Phase .................................................................................. 103
- Table 7-22 Closure Phase .................................................................................. 103
- Table 7-23 The reference thresholds considered at accidents simulations .............. 110
- Table 7-24 Calculated emission rate: ......................................................................... 113
- Table 7-25 Calculated emission rate: ......................................................................... 114
- Table 7-26 Calculated emission rate: ......................................................................... 115
- Table 7-27 Impact of tailings dam break on river water quality .................................. 120
- Table 7-28 The main results obtained in the Cetate Dambreak simulation ............... 122
- Table 7-29 Distances at which damage caused by the explosion are felt are: ............ 131
- Table 7-30 The minimum safety distance required in case of an explosion ............. 131
- Table 7-31 Vulnerable areas alongside Cluj-Napoca – Alba Iulia rode ..................... 133
- Table 7-32 Vulnerable areas alongside Alba Iulia – Zlatna rode ............................ 133
- Table 7-33 Vulnerable areas alongside Zlatna - Roșia Montană rode ..................... 133
- Table 7-34 Indicators of hazard assessment .................................................................. 145
- Table 7-35 Indicators of health and environmental risk assessment; ..................... 146
- Table 7-36 Indicators of general environment and health vulnerability assessment .... 147
- Table 7-37 Classification scale of environment and health vulnerability assessment ..... 147
- Table 7-38 Standard Operating Procedures (SOPs) for accident prevention and emergency management ................................................................. 151

### List of Figures

- Figure 7.1 Quantitative risk assessment and risk level matrix ..................................... 17
- Figure 7.2 Distribution of cyanide using mines world-wide ........................................ 18
- Figure 7.3 Environmental accidents associated to mining from 1975 to present .......... 20
- Figure 7.4 Environmental accidents associated to mining from 1975 to present in gold industry .......................................................... 20
- Figure 7.5 Regional seismicity (the Key shows the measured magnitude on the Richter Scale) ................................................................. 24
- Figure 7.6 Seismic Hazard Map of Romania ............................................................. 24
- Figure 7.7 Influence of the catchment shape on water concentration for catchments basins of equal area ....................................................... 33
- Figure 7.8 Flood on Roșia Valley ........................................................................... 36
- Figure 7.9 Slope Map ............................................................................................ 44
- Figure 7.10 Terrain Stability Class Map ................................................................... 46
- Figure 7.11 Map of the landslide susceptible areas ...................................................... 47
- Figure 7.12 pH and salinity dependence of the cyan ion hydrolysis ............................ 58
Figure 7.13  Qualitative risk analysis – Construction Phase ........................................... 96
Figure 7.14  Qualitative risk analysis – Operation Phase.............................................. 96
Figure 7.15  Qualitative risk analysis – Closure Phase ................................................ 96
Figure 7.16  The effects of the explosion of the LPG storage tank on people in the area116
Figure 7.17.  Pressures diagram ............................................................................. 124
Figure 7.18.  Shock wave profile ............................................................................. 124
Figure 7.19  Overpressure Chart at the explosion of the ammonium nitrate storage facility ................................................................................................................. 129
Figure 7.20  The effect on humans and goods at the explosion of the ammonium nitrate storage facility ........................................................................................................ 130
Figure 7.21  Overpressure Chart at the explosion of the work shed ..................................... 130
Figure 7.22  The effect on humans and goods at the explosion of the work shed............. 131
Figure 7.23.  The results of Zurich Hazard Analysis applied on the transport route........ 134
Figure 7.24.  Quantitative risk assessment (F-N diagram)........................................... 141
Figure 7.25.  Outline of the Global REHRA Approach ................................................ 144
Figure 7.26  Comparative situation of risks associated with the identified accidents.... 148
Figure 7.27  Comparative assessment of the main safety sections ................................ 149
Figure 7.28.  General organization of emergency response for the Roşia Montana Project ................................................................................................................. 154
Figure 7.29.  Socially acceptable Probability and Consequence Diagram for various industries or activities............................................................... 167
Figure 7.30  Probability and Consequence Diagram in dams and socially acceptable risk ................................................................................................................. 167

List of Exhibits

Exhibit 1 Site development - end of year 07 - Operations
Exhibit 2 Site development - end of year 14 - Operations
Exhibit 3 Site Development - End of Year 17 - Operations
Exhibit 4 Site Development - End of Year 19 - Operations
Exhibit 5 Tailings Management Facility - Final Dam
Exhibit 6 Tailings Management Facility (TMF) Schematic - Operations
Exhibit 7 TMF and SCD Cross - Sections
Exhibit 8 Estimated Limits of Tailings Deposition Under Starter Dam Break Scenario
Exhibit 9 Estimated Limits of Tailings Deposition Under Final Dam Break Scenario
Exhibit 10 Inundation Map for Maximum Peak Flow
1 Introduction

Risk assessment and management (RAM) is a control instrument in commissioning any major project. An Environmental Assessment Process (EIA) is designed to answer questions such as:

- Can the Project operate safely, without major accident risks or long term health impacts?
- Will the environment of the impacted area be able to cope with the waste and potential additional pollution that might be generated in the implementation of the Project?
- Will the Project site location create a conflict with surrounding land uses or prevent future development in the area?
- What human resources will be required or replaced and what social effects will it have in the community?
- What accidental damage might it cause to the ecosystems?

1.1 Legal framework

Emergency Governmental Ordinance No. 195 of 12/22/2005 on environmental protection stresses the prevention principle as strategically important in risk management. It is cited as a reference principle in the Yokohama Strategy and Action Plan (1994): "risk assessment is a necessary step in adopting adequate and successful policies and measures in preventing and mitigating disasters". It was evoked again in the Strategy of the World Conference in Kobe-Hyogo (2005). The main steps in risk management are hazard identification, qualitative and quantitative risk analysis, cost-benefit analysis in correlation with the management of change, and decision making. Hazard identification is typically the starting point for the risk assessment process. Methodologies have been developed and adopted in Europe that Romania has been implementing as part of the EU accession process. Thus, the specific EU regulation package is reflected on the national level and forms the basis of this Chapter and of the EIA study as a whole. Priorities in the theoretical legislative approaches to technological processes include potential major accident activities involving hazardous substances (Government Decision No.95/2003, transposing EU Seveso II Directive. Following recent industrial accidents (Baia Mare, Toulouse, and Enschede), the EU has developed a new Directive, 105/2003/EC, that includes some exceptions to the applicability of the Seveso II Directive, such as those concerning storage and processing activities in mining. The approaches considered in this Chapter include aspects dealt with by the new Directive. The key regulations referred to include: GD 918/2002 on the environmental impact assessment framework procedure and for approval of the public or private projects list subject to this procedure; MO no.860/2002 for approval of the environmental impact assessment and the issuance of environmental agreement procedures (with MO 210/2004); MO 863/2002 for approval of the methodological guidelines applicable to the stages of the environmental impact assessment framework procedure; EGO 34/2002 on integrated pollution prevention and control.

MO 863/2003 recommends the structure of the SEA report, which should include an outline of the "risk situations" that has been followed in structuring this Chapter. It requires the identification, review and assessment of natural and technological accident hazards and risks associated to the Project, and a description of the mitigation measures.

Therefore, this Chapter will review aspects related to the likelihood of potential accidents related to Roşia Montană Project, define the frequency with which such accidents might occur, based on the design data and proposed design or management controls of such risks. Mitigation measures for the general consequences of major accidents are also provided.
1.2 Definitions

The concepts of natural and technological hazards and risks are closely related and essentially form the contents of this Chapter. The following definitions are taken from EU Directive Seveso II (96/82/EC):

- **Hazard**: An intrinsic property of hazardous substances of physical situation with the potential to affect human health or the environment.
- **Risk**: The probability of a hazard-related specific effect to occur in a given period of time or under certain conditions leading to a technological incident/accident.

The term “safety” (security, safety in operation) has been preferentially used in work accident prevention strategies. The current concept of safety extends to loss prevention of products or goods and human accidents leading to disease, casualties or fatalities. Safety, hazard, and risk are frequently used terms in the field of industrial process security.

**Safety** or **loss prevention** means accident prevention by the use of adequate methods of identifying hazards in the chemical installation and removing them before an accident can occur.

**Hazard** is associated with any situation which could cause an accident.

**Risk** is the probability of an existing hazard to turn into an accident. Thus, risk in chemical industry is defined as probable annual loss of production or human accidents as a result of unforeseen technical events.

\[
R = F \times C
\]

where:

- \( R \) – risk, loss ; (tons/year)
- \( F \) – frequency, probability; (no. of events/year)
- \( C \) – consequence, seriousness, average loss; (tons/event)

Possibilities of the above relation to apply depend on the following factors:

- risk identification,
- determination of accident (incident) frequency,
- determination of average consequences per event.

**Risk identification** is the most difficult issue, due to the number and diversity of the events. Event possibility of occurrence may be established by statistical studies. Note that the chances of obtaining accurate results from the strict application of theoretical relations are very limited. Empirical methods for point situations combined with theoretical analyses will provide a higher degree of credibility. The following risk-related elements are included in risk assessments: chemical risk; carcinogenic risk, epidemiological risk, risk of nuclear contamination; risk of natural phenomena to occur.

In common terms, safety is defined as the state of being free of any danger, and the risk as the possibility of a potential danger to materialize. Note that the two abstract concepts are contrary to each other. In reality, they are limit situations that cannot be met in absolute terms.

**There is no sure system, free of any accident hazard. There is always some residual risk.**
It is important that these definitions be approached from the point of view of natural phenomena as well. Thus, Balteanu (2002) defines hazard as “a threatening event, and means the probability of a potentially harmful phenomenon for humans, the goods they produce and their environment, to occur during a given period of time. Hazard is not a new random or unpredictable event, but its materialization and consequences are difficult to predict and control. Hazards may be of diverse natural origin – geological, hydro-meteorological or biological. Multi-hazard assessments are difficult to conduct. Also, the computation of natural risks is laborious and there are few analytical approaches described in the literature.

Vulnerability is a key component of risk assessment. It is explicitly reflected in some relations. It was implicitly considered in this Chapter, especially under the quantitative approaches to technological risk. The main association of vulnerability with risk management may be done in the analysis of consequences. The relevant aspects are dealt with in sub-section 6.7. Vulnerability is sometimes defined as the capacity of a person or social group to anticipate, handle and recuperate following the impact of a hazard.
2 Hazard and Risk

2.1 Risk Assessment Methodology.

In developing risk assessment studies, the following questions are very important:
- What weaknesses might appear in the safety system?
- What could not work?
- What preventive actions might be undertaken to control the risk?
- How are these actions monitored?
- How to use the output values to assess the results and trends, in order to determine whether the company does the things right, does the things that need to be done and meets the objectives and targets?

Thus reference measures are required (benchmarks or indicators) for use at all levels. It is evident that risk can not be reduced to zero therefore it becomes essential to set an affordable limit for everyday activities.

Accident prevention by risk assessment implies specific activities ever since the design stage, in the application of qualitative and quantitative methods and techniques based on existing data and systematic, creative, imaginative actions.

A qualitative analysis has for its main objective to establish the list of possible hazards, enable event ranking based on risk and is the first step in the quantitative risk assessment methodology.

Hazard identification techniques (qualitative analyses) – to identify hazards arising from the process – and hazard evaluation techniques (quantitative analyses) – to decide on how to act to eliminate or reduce them in order to protect the population and the environment are often mixed up. A summary of these two broad categories of techniques will distinguish the following two general components:
- For hazard identification: their intrinsic presence; observation of what goes on; checklist; Hazard and Operability Study (Hazop).
- For hazard evaluation: intrinsic presence; past experience; codes of practice; Hazard Analysis (Hazan).

The order of application is self-evident, from qualitative identification to quantitative analysis. What are the main differences between the two techniques?

Table 7-1. Differences between Hazop and Hazan

<table>
<thead>
<tr>
<th>HAZOP</th>
<th>HAZAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies hazards</td>
<td>Evaluates hazards</td>
</tr>
<tr>
<td>Preferred technique for use with each project</td>
<td>Selective technique: especially used for systems potentially exposed to major accidents</td>
</tr>
<tr>
<td>Qualitative</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Developed by a team</td>
<td>Developed by one or two experts</td>
</tr>
<tr>
<td>Also known as “What if?”</td>
<td>Also known as:</td>
</tr>
<tr>
<td></td>
<td>- Risk analysis</td>
</tr>
<tr>
<td></td>
<td>- Risk assessment</td>
</tr>
<tr>
<td></td>
<td>- Probabilistic Risk Assessment</td>
</tr>
<tr>
<td></td>
<td>- Quantitative Risk Assessment</td>
</tr>
</tbody>
</table>
In this Chapter:

2.1.1 The qualitative measure of consequences
It was classified into five levels of seriousness, an internationally accepted methodology used in risk assessment studies. The five levels have the following meanings (Table 7-2)

### Table 7-2. Risk level

<table>
<thead>
<tr>
<th>Crt. no</th>
<th>Qualitative measure</th>
<th>Meaning</th>
</tr>
</thead>
</table>
| 1       | Insignificant       | • For humans (population): insignificant harm  
           |                     | • Ecosystems: Some minor, short term and reversible adverse effects on a few species or parts of the ecosystem  
           |                     | • Socio-political: Insignificant social effects with no reason of concern for the community. |
| 2       | Minor               | • For humans (population): first aid is necessary;  
           |                     | • Emissions: emissions on the site that are immediately contained;  
           |                     | • Ecosystems: considerable fast and reversible damage for a few species or part of the ecosystem, animals forced to leave their usual habitat, plants unable to develop according to natural rules, air quality creates local nuisance, water pollution exceeds background levels for a short period of time;  
           |                     | • Socio-political: Social effects with little reason of concern for the community. |
| 3       | Moderate            | • For humans (population): medical treatment is necessary;  
           |                     | • Economy: reduced production capacity;  
           |                     | • Emissions: emissions on the site that are contained with outside help;  
           |                     | • Ecosystems: temporary reversible damage, damage to habitats and animal population migration, plants unable to survive, air quality impacted by potentially long term health risk compounds, potential damage to aquatic life, pollution requiring physical treatment, limited soil contamination that can be remediad quickly;  
           |                     | • Socio-political: Social effects of moderate concern for the community. |
| 4       | Major               | • For humans (population): serious harm;  
           |                     | • Economy: interruption of production activity;  
           |                     | • Emissions: off site emissions with no harmful effects;  
           |                     | • Ecosystems: death of some animals, large scale damage, damage to local species and loss of existing habitats, air quality requires “safe refuge” or evacuation decisions, soil remediation is only possible based on long-term programs;  
           |                     | • Socio-political: Social effects of serious concern for the community. |
| 5       | Catastrophic        | • For humans (population): fatalities;  
           |                     | • Economy: production stop;  
           |                     | • Emissions: off site toxic emissions with harmful effects;  
           |                     | • Ecosystems: death of large numbers of animals, loss of species of flora, air quality requires evacuation, extensive and permanent soil pollution;  
           |                     | • Socio-political: social effects of very high concern for the community. |

2.1.2 The probability to occur measure
Involves classification into five internationally accepted levels used in various alternatives, see Table 7-3.

### Table 7-3. Risks probability to occur levels

<table>
<thead>
<tr>
<th>Crt. no</th>
<th>Probability</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rare (improbable)</td>
<td>may only occur in exceptional situations – frequency of occurrence less than $10^{-4}$ (annual probability of occurrence in $10^{12}$ years)</td>
</tr>
<tr>
<td>2</td>
<td>Hardly likely to occur</td>
<td>Frequency of occurrence between $10^{-8}$ and $10^{-12}$</td>
</tr>
<tr>
<td>3</td>
<td>Possible</td>
<td>may occur some time - Frequency of occurrence between $10^{-6}$ and $10^{-8}$</td>
</tr>
<tr>
<td>4</td>
<td>Probable</td>
<td>may most likely occur – Frequency of occurrence between $10^{-4}$ and $10^{-6}$</td>
</tr>
<tr>
<td>5</td>
<td>Almost certain</td>
<td>may most likely occur I most cases - Frequency of occurrence more than $10^{-4}$ (possibly less than 10000 years).</td>
</tr>
</tbody>
</table>
2.1.2.1 Quantitative risk assessment
Is based on computing the level of risk as a product of the seriousness (consequence) and the probability of an event.

Using the information obtained from the analysis, an event’s risk is placed in a matrix like the following (Figure 7.1):

**Figure 7.1 Quantitative risk assessment and risk level matrix**

<table>
<thead>
<tr>
<th>Probability</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Insignificant</td>
</tr>
<tr>
<td>Improbable</td>
<td>&lt; 10⁻¹²</td>
</tr>
<tr>
<td>Hardly likely</td>
<td>10⁻³ to 10⁻¹²</td>
</tr>
<tr>
<td>Possible</td>
<td>10⁻³ to 10⁻⁶</td>
</tr>
<tr>
<td>Probable</td>
<td>10⁻⁶ to 10⁻⁴</td>
</tr>
<tr>
<td>Almost certain</td>
<td>&gt; 10⁻⁴</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Levels of risk</th>
<th>Definition</th>
<th>Action to be taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 4 Very low risk</td>
<td>Business as usual</td>
<td></td>
</tr>
<tr>
<td>5 – 9 Low risk</td>
<td></td>
<td>Specific standard operations procedures, with the involvement of workplace managers</td>
</tr>
<tr>
<td>10 – 14 Moderate risk</td>
<td></td>
<td>Prompt response action, as quick as the normal management system allows it, with the involvement of the top management</td>
</tr>
<tr>
<td>15 – 19 High risk</td>
<td></td>
<td>Emergency situation requiring immediate action and priority use of available resources</td>
</tr>
<tr>
<td>20 – 25 Extreme risk</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The extent of the risk assessment and the intensity of prevention and mitigation measures should be proportionate to the risk involved. Simple hazard identification models and quantitative risk analysis are not always sufficient and therefore detailed assessment is necessary. There are several methods used in quantitative risk assessment. Selection of a specific technique depends on the accident scenario analyzed.

More detailed analysis is conducted for accident scenarios that, based on the qualitative assessment, are found to be potentially major, of probability more than 10, i.e. may occur more frequently than 10000 years and major consequences, therefore a risk level higher than 15. Methods of estimating accidental atmospheric spills and dispersion modeling are used to assess the seriousness of the consequences. Specific simulation methods are applied for the assessment of consequences of potential explosions or fires. The results of simulations of breaches developing in the TMF or ARD catchment dam wall were used in assessing the consequences of such events.

The FN diagram frequency – consequence (loss of materials or number of fatalities) summarizes the results of such analyses and gives a graphical representation of the project specific social risk correlated with the socially affordable risk.

A global assessment of the risks associated with the Project is obtained by the quick environmental and health risk assessment methodology developed by the Italian Ministry of the Environment and the World Health Organization.

2.1.3 Short History of Accidents occurred in other projects
Technological accidents with environmental impacts from mining operations are generally associated with cyanide, whether these are involved on not. This situation is gaining ground due to the general population’s perception according to which mining and cyanides are
technologically related. Cyanide impacts generally have acute or short-term environmental effects, lasting between a few hours to a few days or weeks. Contrary to the above, the long-term environmental impacts of mining are associated with cyanide containing waste releases. Once disposed of on adjacent areas or waterside sites, sulfate containing mining waste may undergo oxidation followed by the slow release of acid rock drainage. The long-term environmental concern may evolve toward economic issues associated to the safety and stability of mining companies.

Considering the international use of cyanide treatment procedures (as presented in Figure 7.2.), a global cyanide management code of practice will be implemented based on the study of major environmental accidents from mining and an investigation of their causes. Table 7-4 presents a selective list of major accidents associated with all the types of mining activities that have occurred world-wide in the past 25 years.

**Figure 7.2. Distribution of cyanide using mines world-wide**

More than 30 major accidents have occurred during this interval, i.e. about one accident a year, involving small, medium and major mining companies. As mentioned in Figure 7.3, major accidents occurred all over the world, most frequently in transport, followed by pipe burst and dam break.

Breach of tailings dams caused 75% of all the accidents with an environmental impact, less than a third of which involved cyanides. This type of accident generally occurs due to tailings pond overflow, dam breach caused by design errors or earthquakes. The existing information related to such incidents suggest that cyanide spills have not caused loss of life. The major environmental impact was associated to the short term effects causing ecological damage and death of the aquatic environment.
Table 7-4. Major accidents at gold mines, 1975 to 2005

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Cause of spill</th>
<th>Description</th>
<th>Cyanide presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>Japan</td>
<td>Dam failure</td>
<td>Spill capacity: 80,000 m³ Deaths: 1</td>
<td>Not in the dam</td>
</tr>
<tr>
<td>1978</td>
<td>Zimbabwe</td>
<td>Dam overflow</td>
<td>Spill capacity: 30,000 tones Deaths: 1</td>
<td>Not in the dam</td>
</tr>
<tr>
<td>1985</td>
<td>USA</td>
<td>Dam failure</td>
<td>Spill capacity: 25,000 m³ Deaths: 0</td>
<td>Not in the dam</td>
</tr>
<tr>
<td>1988</td>
<td>USA</td>
<td>Pipe burst</td>
<td>Spill capacity: 250,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1991</td>
<td>USA</td>
<td>Dam overflow</td>
<td>Spill capacity: 39,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1994</td>
<td>South Africa</td>
<td>Dam overflow</td>
<td>Spill capacity: 600,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1995</td>
<td>Guyana</td>
<td>Dam failure</td>
<td>Spill capacity: 4,000,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1995</td>
<td>Australia</td>
<td>Dam failure</td>
<td>Spill capacity: 40,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1995</td>
<td>Australia</td>
<td>Dam overflow</td>
<td>Spill capacity: 5,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1995</td>
<td>Philippines</td>
<td>Dam failure</td>
<td>Spill capacity: 1,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1998</td>
<td>Kyrgyzstan</td>
<td>Transport accident</td>
<td>Spill capacity: 1,000 kg NaCN Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1998</td>
<td>USA</td>
<td>Pipe burst</td>
<td>Spill capacity: a few tons Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>1999</td>
<td>Philippines</td>
<td>Pipe burst</td>
<td>Spill capacity: 700,000 tones Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>2000</td>
<td>Romania</td>
<td>Dam failure</td>
<td>Spill capacity: 100,000 m³ Deaths: 0</td>
<td>✓</td>
</tr>
<tr>
<td>2000</td>
<td>Papua New Guinea</td>
<td>Transport accident</td>
<td>Spill capacity: 1,50 kg NaCN Deaths: 0</td>
<td>✓</td>
</tr>
</tbody>
</table>

Figure 7.4 shows a more detailed analysis of the process accidents at gold mines. Most technological accidents occurring on diverse sites globally are ultimately related to water management or the design of the decant ponds. The occurrence of transport-related accidents is generally higher in gold mining than in other types of mining, because of cyanide toxicity. Some accidents were caused by unconventional methods of carrying the cyanide to the site.

The emergence and implementation of numerous cyanide management codes and the existing regulations for the selection of site plans have determined a considerable reduction of such incidents. The codes do not contain a special specification of the maximum cyanide concentration in the decant pond. The lower the concentration, the lower the risk of a significant impact in aquatic life.
Two major accidents are described in relation to Roșia Montană Project.

2.1.3.1 Mining Incident at Aznalcóllar (Spain)
In April 1998, the tailings dam of the Apirsa mining operation in Southern Spain was partly breached due to the presence of organic soils in the foundation that had not been identified during the design stage. The event caused a big tailings and water flood wave, of very high metal concentrations. The tailings drained into the natural river system downstream (the Agrio River) and reached the Doñana National Park, 45 km to the south. The area impacted by the flood was assessed to be 4286 ha, along 65 km of river, of which 2600 ha were covered by the tailings and 98 ha were impacted in the Doñana National Park. The pond contained 15 m³ million tailings at the time of the accident. A few hours after the breach developed in the dam, about 5.5 m³ million fluids and 1.7 m³ million solids had been released. After the waters went down, the measured depth of tailings depositions ranged from 4m near the dam and a few millimeters 40 km downstream of it.
Short term effects were severe. The water and tailings affected more than 50 irrigation wells in the main river channel, and the aquatic fauna in it disappeared for a period of time. Three days after the accident, an ecological reconstruction plan was submitted to the authorities. The company objective was to restore the original uses to all the impacted lands. The tailings were physically removed and transported to the old Aznalcóllar pit for disposal. Prior to the incident, the relationships between the mining company and the authorities (Regional Government of Andalusia, the Guadalquivir Authorities and the Spanish Geological Inspectorate) had been good. Communication with the Doñana National Park administration had not been established before the incident, as the distance separating them (45 km) had been considered sufficient for the safety of the protected area. Also, there had been no legal requirements for the company representatives to implement an Emergency Response Plan during the incident. In 1997, Boliden had started developing Operation, Monitoring and Maintenance Plans for the tailings management facility of the company, which included Emergency Response Plans. At the time of the incident, the guidelines were not yet completed, as the safety audit had not been listed as a priority.

Three weeks after the incident, the company opened an information center near the village, providing information on the accident and what was going to be done during reconstruction. However, the center did not manage to attract enough visitors. In spite of the poor community response to the company’s initiative, the measure regarding information provision had a positive effect.

When news got round that Boliden was about to restart operation, the local community agreed to have the mine reopen, but under much stricter conditions.

Major deficiencies recorded in emergency management:

- lack of an Emergency Response Plan addressing this particular situation suggested that the responsibilities and objectives were set after the incident and under the subsequent media and political pressure;
- the absence of a good quality database made it difficult to evaluate the incident and take the best remediation measures;
- most of the information was circulated to the local community by the employees;

Lessons learnt

- the accident highlights the importance of relationships between the stakeholders in emergency management before accidents occur, based on mutual trust, adoption of roles and responsibilities, of action plans, etc.;
- developing relations with the media;
- decision of the company to be more proactive in providing information to the local communities, communicate risks;
- ecological restoration involves is on risks. Major logistic actions required for the remediation of major accident consequences involve a degree of risk.

2.1.3.2 The accident in Baia Mare

At 22:00 on January 30, the tailings dam of one of the facilities belonging to Aurul S.A. in Baia Mare began to crack. About 100,000 cubic meters of fluid and tailings containing some 50 to 100 tons of cyanide and heavy metals were released through the crack. The fissure was probably caused by a combination of design errors in the dam and process installations of Aurul SA, unusual operating conditions, and weather (heavy rains and snowmelt), that made the water level in the tailings pond rise very fast. There were no plans to cope with such extreme water level increases, nor for diversion of excess water. A fully
closed loop process, with no release into the environment was not possible under the circumstances.

The flow of pollutant fluid propagated through the downstream river system as follows: the rivers Sâsar, Lăpuș, Someș, Tisa and the Danube and ultimately the Black Sea, about four weeks after the accident. About 2000 km of the length of the Danube and its tributaries were affected by the discharge. Romanian sources declared that in Romania the spill caused interruption of 24 water supply systems in towns and additional costs or the wastewater treatment plants and some industries due to process interruption. Romania declared a very low quantity of dead fish in its waters. Hungary and Yugoslavia reported large quantities of dead fish along the Tisa. The report on fish mortality in the Danube indicated that the fish fauna was affected to a little extent.

Aurul SA was running its business in compliance with the governmental permits. According to the Romanian law, the plant and the ponds, classified under normal risk levels, did not require emergency plans or monitoring for the identification of hazardous situations. There were plans for accident situations, but they were not efficient enough.

Following subsequent analyses, it was found that both the company and the local authorities had inadequate emergency response plans and initiatives, failing to take into account the large quantities of high risk potential used in the vicinity of populated areas and the river system.

Nearly ten hours were lost between the time the Environmental Protection Agency in Baia Mare received the notification of the Aurul discharge and the time the Romanian Waters National Authority was informed. As a result, the local communities in riverside areas could not be informed about the accident in the shortest possible time. Once the Romanian Waters National Administration was informed, the local environmental and water authorities immediately checked the information to determine the level of pollution and asked the company to stop operations and remediate the problem. They also informed the Environmental and Water Protection Agency in Nyiregyhaza (Hungary) about the accident and alerted the downstream local governments about the spill and the hazards in using the river water for various activities.

The recommendations contained in the UNEP/OCHA Report mainly concern the mobilization and support of local authorities and the population of the impacted areas in their effort to reduce the negative environmental impacts from sources of pollution in the region. These include:

- the greater need for objective and accurate information, especially from the local authorities and the media. The events revealed the low level of knowledge and information of the population about hazardous substances and the risks posed by mining and related industries.
- communication among the local authorities, NGOs, and the local communities in regard to emergency plans and accident prevention measures is low. Communication channels have to be improved and NGOs and other interest groups need to contribute to public information;
- the short and long term effects of mining activities on public health, especially due to cyanide and heavy metals should be a major concern, especially for the communities of Bozânta Mare and Baia Mare
- a full risk assessment should be conducted, in order to improve safety in operations. An improved emergency plan needs to be developed and made known to the public and the local decision makers. Organizational responsibilities in the management of technological accidents must be made clear. Fast warning systems need to be set up, especially for the city of Baia Mare;
- further analysis of the concentrations of heavy metals in the river sediments is agreed by all the countries in the Somes-Tisa river basin, to enable an adequate long-term risk analysis. Sediment quality has already been identified as hazardous for many local aquatic systems;
- the development by the local authorities of studies to identify new sources of drinking water (in Baia Mare and along the Somes River) and the development of new monitoring systems for surface waters and private wells. Sources of drinking water need to be established for emergency situations, and a public health study in the impacted areas and a water-related disease monitoring process need to be put in place;
- international monitoring of the long term effects of the cyanide and heavy metals spill on biodiversity, especially on birds, mammals and aquatic vegetation;
- an intense and continuous dialog is necessary among the representatives of AURUL SA and the government in developing safer mining practices.

**Lessons learnt**

- opening the water circuit in the system;
- increasing the technological capacity for residual water detoxification;
- continuous monitoring of the pipe transport system and of TMF safety;
- implementing technological safety studies and emergency plans in accordance with international recommendations (UNEP – APELL, the Seveso Directives)
- application of the cyanide codes
- risk communication to the local communities and improved cooperation with the emergency management stakeholders.

In the following sections, hazard evaluation has also used comparison with the above-mentioned existing systems for reference, knowing that, a fundamental and credible stage of risk assessment is the analysis of case studies and the lessons learnt.

### 2.2 Seismic Risk

#### 2.2.1 Seismicity in Romania

Seismicity distribution in Romania and the surrounding regions is illustrated in Figure 7.5. An earthquake catalogue was developed, recording all the important seismic events for the past few centuries. Moreover, some older earthquake events, more than 1000 years old, are also mentioned.

Along most of the Carpathian Arch, the seismicity level is moderate, with low depth quakes, of maximum magnitude (M) 6 – 6.5 on the Richter scale. Apart from these seismic zones, of limited extent and effects, a special case is that of Vrancea, of intense activity, affecting more than 2/3 of Romania’s territory, as well as parts of Bulgaria, Moldova and the Ukraine. The region is about 275 km east of the Project area at the bending poit of the Carpathians. In the past few hundred years, several moderate and high magnitude earthquakes occurred in Vrancea. Among the more significant was the one in 1977, of M 7.5, at focal depth 109 km. The most powerful earthquake recorded in Vrancea Area was the one in 1940, of M 7.7. Another area of relatively significant seismic activity is located west of the Project site, in Timis County. Earthquakes recorded in this area and in the north of neighboring Yugoslavia are superficial shallow events of low or moderate magnitude (M 4-6). A major earthquake occurred in Timis area in 1887, with an estimated magnitude 7.0.
2.2.1.1 Determining seismic parameters for Roşia Montană area

Seismic parameters, especially land acceleration, for the Roşia Montană Project were determined by probabilistic and deterministic analytical methods. This information was used in choosing the design criteria for the Project.

Both methods need examining historic seismic data and regional tectonics in order to identify areas of seismic sources or fault lines and estimate the maximum magnitude for each seismic source. A relation that would define land movement attenuation is also necessary.

Probabilistic Analysis

A probabilistic analysis was conducted in order to determine the probability of various degrees of magnitude that might be expected on the Project site. This analysis relies on a review of all the records for the seismic areas.

The Global Seismic Hazard Assessment Program (GSHAP, 1999) published a map of Europe indicating seismic hazard, which has been incorporated into this analysis. The hazard map shows the maximum probable acceleration of the baserock (earthquake) with a 10% probability of exceedance in 50 years, corresponding to a 475 year period of return (one event in 475 years). This probabilistic analysis gives data regarding probable earthquake events based on historic records. The limitations of this approach are the relatively limited period for which data was collected.

Part of the seismic hazard map, including Romania, is illustrated in Figure 7.6. The maximum acceleration of the base rock determined from the map for the Roşia Montană Project locates the area within the interval that corresponds to low to moderate seismic hazard risk, of 0.8 m²/s to 1.0 m²/s (0.08 g to 0.10 g). This conclusion is closely related to the maximum acceleration of 0.082 g for a 475 year event, determined by the probabilistic analysis conducted under this Environmental Impact Assessment study.

Figure 7.6. Seismic Hazard Map of Romainia
Deterministic Analysis
A deterministic analysis was also conducted, and it identified and defined the seismic source zones, and the maximum earthquake magnitudes assigned to each seismic zone. Land acceleration determined for the investigated site, from each source, is considered to be the maximum acceleration (quake) that may occur, based on the available technical and geological information. The maximum acceleration produced by this procedure is referred to as the "maximum credible acceleration" and the corresponding earthquake as the Maximum Credible Earthquake.

Three case studies were considered in estimating the maximum credible acceleration for the Roşia Montană site. These studies are the worst cases, obtained based on review of the regional tectonics and the historic earthquake records.

- Two earthquake cases are related to superficial crust events, of maximum magnitude 6.5 and 7.0 and epicentral distances 75 and 130 km, respectively, from Roşia Montană.

- The third case relates to a sub-crustal earthquake of high magnitude in Vrancea seismic region.

Based on the results of the deterministic analysis, Roşia Montană was assigned a 8.0 magnitude MCE, generating a maximum 0.14 g acceleration of the base rock. Intensity on the Modified Mercalli Scale (IMM) corresponding to such an event was estimated at about level VII-VIII in stable land conditions.

For additional information on seismic issues, please refer to Chapter 4.5. of the Environmental Impact Assessment study.
2.2.2 Classification of Seismic Hazard and Design Specifications for Roșia Montană

Based on the collected seismic data, the design criteria for dam type facilities included in the Project. The main structures of this type include:

- Corna Dam and Tailings Management Facility;
- Cetate Water Catchment Dam.

Using the present-day philosophy of geotechnical works design (including dams), two earthquake level patterns have been considered:

- Operating Basis Earthquake - OBE for normal operations; and

In design terms, OBE and MDE are used with various functions.

- The basic design approach ensures that, should an OBE quake occur, structures (in this case the dam) will not be damaged, and business may continue as usual. At this stage of the design process, a high “safety factor” is applied, with insuring assumptions, aiming to maximize the sturdiness and hence the safety of the structures.

- The designed structure is then tested for the potential occurrence of an MDE event. Should such an event occur, the structure needs to remain stable (not give way), but may experience some damage requiring remedial action before the re-start of operations. The basic design ensures structural strength, even for a maximum design event (MDE).

Maximum ground acceleration and design magnitude were determined for both OBE and MDE.

- OBE is typically determined by the use of a probabilistic earthquake hazard analysis in order to select an acceptable level of hazard, based on the probability of exceedance over the Project lifetime. This is chosen with a 10% probability of exceedance in 50 years, corresponding to a 475 year period of return (one event in 475 years).

- MDE selection is based on a classification of decant ponds based on the criteria given in the Canadian Dam Association Guidelines “Dam Safety Principles” (1999). These criteria are given in Table 4.5.4 of Chapter 4.5.

Tailings dam classification is based on the potential consequences of dam failure, including human life safety and economic, social and environmental impacts. Immediately downstream of the proposed sites there are residential areas, and the characteristics of the landfilled tailings at the dam will compound the destructive physical impacts that might be caused by dam failure. Therefore, a “Very High” importance class of the consequences was assigned to the Corna dam at the TMF in Corna Valley. The adoption of such a classification requires an MDE specification for the designed facilities. Earthquakes considered in the design are given in Table 4.5.4 of Chapter 4.5. The selected Maximum Earthquake Event (MDS) was equal to the Maximum Credible Earthquake (MCE). The maximum acceleration corresponding to the base rock is 0.14g. The values considered for the design earthquake and the appropriate design parameters recommended for the TMF dam and the Cetate Water Catchment Dam are summarized below.

2.2.2.1 The Operating Basis Earthquake (OBE)

It was considered to have a 1 in 145 return period. This will correspond to a maximum acceleration in the base rock of 0.082 g. OBE was assumed to be M 8.0. This value is based on the historic earthquake record that indicates several high over 7M magnitude events in the last few hundred years, including the M 7.7 one in 1940 and the more than 7.5 estimated one of 1802. The probability of exceedance for an OBE event is about 0.035 (3.5%) for an
estimated lifetime of 17 years. It is expected that the TMF and Cetate Dam will continue to operate at normal standards after an OBE.

2.2.2.2 Maximum Design Earthquake (MDE)

It was considered equal to the Maximum credible Earthquake (MCE) Maximum acceleration of the base rock for an MCE is 0.14 g. The MDE event was assigned a magnitude of 8.0. For an MDE, damage of the dam structure is acceptable, provided stability and integrity are maintained and tailings or contained water are prevented to spill out.

Maximum accelerations determined for the OBE and MCE are established for movement of the base rock or stable ground, in which amplification is negligible.

In the development of this design process for Roşia Montană, the national and international standards and guidelines were taken into consideration. As a design philosophy, where standards varied, the most rigorous local and international standards were adopted.

In designing the Tailings Management Facility, the design parameters were chosen to fully cover the characteristic seismic risk for the respective area. Seismic activity is very limited in the Roşia Montană area. These seismic design parameters adopted for the TMF meet or exceed the 1.1 safety factor that was consider sufficient under the Romanian and European standards for tailings facility design.

2.3 The Risk of Meteorological Events

The different particularities of atmospheric circulation from one season to another determine the occurrence of various hazardous weather events and processes that might affect Project activities in certain circumstances. Thus, the warm season might be associated with heavy rains and storms, while in cold months frost and ice, blizzards and the snow cover may become problematic. Fog is another hazardous event that may occur in the region at any time of the year.

In this Section, we used consistent weather data from the met stations in the Eastern Apuseni Mountains (Câmpeni, 591 m ASL and Bâişoara – 1361 m ASL for 1961—2000; Roşia Montană – 1191 m ASL – for 1984—2000) as well as external weather data recorded for other periods.

2.3.1 Meteorological Events that Pose Risks to Hydrotechnical Structures

2.3.1.1 Extreme Precipitation

In the generation of large flash floods, an important role is that of torrential rains of high intensity and long duration, most frequently occurring in summer. Almost all the cases of dam failure involved extreme precipitation in the catchment area as a basic factor. Notable torrential, high intensity rains in the region include Poiana Vadului in 27.07.1964 (244 mm/24 hr), Arieşeni, at 104 mm/24 hr in 23.12.1995, Avram Iancu -102.4 mm/24 hr (on the same day) and Abrud -95 mm/24 hr in 21.17.1925. In the recorded period at Roşia Montană, the largest 24 hr event was 65.7 mm in July 1988.

Also notable, liquid precipitations in December 1995 involved 94.4 mm in 96 hours at Roşia Montană (plus a further 14.5 mm of snowmelt), 145.3 mm in the neighboring Abrud, q97.6 mm (261.9 mm in 168 hours, plus a further 27 mm of snowmelt) in Avram lancu and no less than 265.6 mm (315.5 in 168 hours) at Arieşeni. These precipitations fell over a frozen or supersaturated substrate and therefore the drainage coefficient was very high (more than 56% in the upper Aries basin and the Abrud catchment). The above quantities of precipitations were the largest recorded in the area within such a short period of time. To assess maximum 24 hour precipitation events and the maximum 24 hour snowmelt, several studies were conducted under the Project; Knight Piésold (2001), I.N.M.H./S.N.C. Lavalin (2002), I.N.M.H. (2003), Radu Drobot (2004). Of these, the most relevant results are
considered to have been obtained in the study of Radu Drobot (2004) “Assessment of Rainfall Intensity, Frequency and Runoff for the Roşia Montană Project”, the results of Probable Maximum Precipitation (PMP) obtained in the other studies being later considered highly underestimated.

Radu Drobot’s study was based on a vast collection of data regarding the largest 24 hr precipitations recorded for Romania (more than 100 years of measurements) and on the review of rain gauge datasets obtained from 21 weather stations/rain gauges in the vicinity of Roşia Montană (up to 57 km distant).

The analysis of the meteorological data was conducted for two separate periods: for the warm season (May-November) and for the cold season (December – April). The precipitations of the cold season were then correlated with the maximum water obtained from snowmelt, calculated using the degree-day method. Precipitation and snow melt values for 24 hours separately calculated for the two seasons were then converted for events of variable duration (between 15 minutes and 2 days), using regional conversion coefficients. A review of the datasets showed that the most important 24 hr precipitations were recorded at Deva (262 mm - July 1936), about 50 km south of the site, and at Poiana Vadului (244 mm - July 1964) only 30 km north-west of the site, these being close to the PMP values calculated for the Piésold and I.N.M.H (P.M.P. = 249 mm). In Romania, the most significant event of this kind was recorded at Curtea de Arges (206 mm in 20 minutes – July 1947), with the average precipitation intensity over 10 mm/min.

Of the 21 rain gauges considered, 10 were selected as the most representative (precipitation conditions similar to Roşia Montana), including Abrud, Albac, Avram Iancu, Baia de Aries, Bistra-Câmpeni, Mogoş, Țebea, Zlatna, Alba Iulia and Deva.

The most important results obtained in the study are presented in table 7-5.

Table 7-5. Extreme precipitation values (Drobot, 2004)

<table>
<thead>
<tr>
<th>Average Return Period</th>
<th>Probability of Exceedance in 17 Years (%)</th>
<th>Precipitation in the warm season (mm)</th>
<th>Precipitation in the cold season (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>15,7</td>
<td>112</td>
<td>122</td>
</tr>
<tr>
<td>500</td>
<td>3,3</td>
<td>146</td>
<td>147</td>
</tr>
<tr>
<td>1000</td>
<td>1,7</td>
<td>161</td>
<td>158</td>
</tr>
<tr>
<td>10000</td>
<td>0,2</td>
<td>211</td>
<td>191</td>
</tr>
<tr>
<td>100000</td>
<td>0,0</td>
<td>450</td>
<td>440</td>
</tr>
<tr>
<td>PMP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A review of the tabled data will show that typical extreme precipitations in the warm season are much higher than those of the cold season, with a PMP value in summer comparable to the cold season PMP plus extreme amounts of water from snowmelt.

2.3.1.2 Probable Maximum Precipitation (PMP)

The statistical procedure in estimating PMP may be used wherever sufficient rain gauge data are available.

In considering precipitation records from neighboring stations, it was found that there is a long period of records, with 24 hr extreme precipitations available for more than 100 years. Of all the approaches in calculating the PMP, the most frequently used is the Hershfield procedure (WMO, 1986).

The Probable Maximum Precipitation (PMP) is defined as “theoretically the greatest depth of precipitation for a given duration (e.g. 24 hours) that is physically possible over a given size storm area at a particular geographical location at a certain time of the year” (WMO, 1986).
PMP was separately calculated for the cold and the warm season, respectively. Based on the precipitation data from Roșia Montană station, but using the PMP values for the 10 representative stations above, PMP was calculated separately for the two seasons (Table 7-5).

2.3.1.3 Sudden Snowmelt

The snow cover primarily develops during the cold months of the year, when air and substrate temperatures are negative. Snow is an important source of water that can be released fast in winter, in the case of tropical air advections, and trigger nival flood waves. More frequently, however, snow melts in spring when, in combination with fluid precipitation, it will result in very high flash floods of mixed origin.

The duration of the snow cover does not depend on substrate and air temperature staying below 0°C. but also on the amount of solid precipitation. Starting in October, there is a probability of snow cover to develop, and last until early spring.

At Roșia Montană, the maximum snow depth is recorded in January and February, with maximum monthly averages for 1983-2000 of 74.3 cm in January 2000, 60.2 cm in January 1987, and 51.4 cm in February 1999. For the same period, the maximum snow depth was recorded in late February 1999 (95cm), followed by 92 cm on January 22, 2000 and 80 cm on January 14, 1987.

In estimating the snow water content released in the thaw, we used the degree-day method based on the maximum daily temperature and a factor indicating the amount of water released for each Celsius degree per day (the values of this factor will vary from one month to another).

<table>
<thead>
<tr>
<th>Return Period (years)</th>
<th>1 day (°C)</th>
<th>2 day (°C)</th>
<th>3 day (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
<td>23</td>
<td>33</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>30</td>
<td>37</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td>25</td>
<td>21</td>
<td>38</td>
<td>43</td>
</tr>
<tr>
<td>50</td>
<td>21.5</td>
<td>40</td>
<td>44</td>
</tr>
<tr>
<td>100</td>
<td>22</td>
<td>41</td>
<td>45</td>
</tr>
<tr>
<td>500</td>
<td>24</td>
<td>44</td>
<td>47</td>
</tr>
<tr>
<td>1000</td>
<td>25</td>
<td>45</td>
<td>48</td>
</tr>
<tr>
<td>10000</td>
<td>26</td>
<td>47</td>
<td>50</td>
</tr>
<tr>
<td>MTP</td>
<td>30</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

By analysis of the snow cover at the Roșia Montană site (snow coverage, density) on correlation with the recorded temperatures, it was found that March and February are critical snowmelt periods.

The maximum estimated snowmelt was recorded in February 1999 (189 mm), for a maximum 95 cm deep snow. A frequency analyses for March indicate that the available water content in the snow is always higher than the potential value of the melted water computed with the degree-day method even for three days duration.

Both water management facilities on the Roșia Montană Project site are designed according to the Romanian specifications for hydrotechnical works. The TMF even exceeds the Romanian design standards, as it is built to contain waters generated in two consecutive PMP events.
2.3.2 Meteorological Events that Pose Risks to Transport Activities

The high gradient and winding roads typical for the Romanian mountains, corroborated with a given hazardous substance (e.g. fuel) in transport, may cause, when the roads are covered in ice or snow, to accidents with negative environmental or social impacts. The roads that will be used for transport to the site go up to about 1000 m, therefore characterization of the above indicators was conducted for the lower mountain reaches.

2.3.2.1 Black Ice

The reduced grip on ice covered roads makes this phenomenon a risk factor for road transport of goods and employee traffic. The average multi-annual number of black ice days in Apuseni Mountains is low, with an average 0.5-1 day a year (Câmpeni 1.1 days/year; Bâișoara – 0.3 days/year). Most frequently, ice develops in December (50% of the annual average) and less so in January. The maximum annual number of black ice days, however, may be 5-7 days/year in Apuseni Mountains. Therefore, the local vulnerability to such an event is low.

2.3.2.2 Snow Cover

Snow cover is another weather indicator that may influence the state of the roads, and hence, transport. In the eastern Apuseni Mountains, the snow cover appears, on average, in late November (November 23 – Câmpeni), and at the earliest in October (October 4 – Roșia Montană, October 24 – Câmpeni). This is intermittently maintained, on average, until late March (March 29 – Câmpeni) with the latest occurrence in May (May 9 – Roșia Montană). The average number of days with a snow cover (60-75 days/year) is higher in January and February (23 days, on average, in January, and 17 days in February, at Câmpeni) in the eastern Apuseni Mountains. The maximum monthly snow depth is recorded for February (12 cm at Roșia Montană station). The maximum snow depth in the region was 100 cm at Câmpeni and 95 cm at Roșia Montană. With good road maintenance during the winter months, and the use of specific snow removing equipment and snow control material, road accident risks due to snow cover on the road top may be reduced to a minimum.

2.3.2.3 Blizzards

Blizzard is an event that may cause production loss by the temporary traffic stop during snow drift blockage of the roads. Within the Carpathian Arch, however, the average multi-annual number of days with blizzards is low (1-2 days/year), due to the shelter effect of the mountains that protect this space from invasions of cold air from the east and north-east. Therefore, the local vulnerability to such an event is low.

2.3.2.4 Fog

Fog is a risk event that enhances accident occurrence, due to reduced visibility. The average multi-annual number of foggy days 48-55 days a year at less than 600 m elevations (53 days at Câmpeni) and increasing to more than 70 days for elevations over 1000 m (Bâișoara – 73 days). At lower elevation, the maximum frequency is attained during September-December (9 days in October at Câmpeni), and in December-March higher up.

2.3.3 Other Risk Events and Atmospheric Processes

2.3.3.1 Hoary Frost

Frost may become hazardous only if heavy enough to break aerial lines. Depositions may be as heavy as 5-7 kg per metre of cable in mountain regions. In such circumstances, operational activities on the site might be affected. The phenomenon is frequent in mountain regions, with a multi-annual average for Câmpeni of 44.3 days. Maximum frequency was recorded in October through March (42.6 days) with a maximum monthly value in November (9.8 days). Where possible, aerial cables should be regularly cleaned during frosty days, to avoid overloading and breakage.
2.3.3.2 Storms
The number of stormy days (thunderbolt, lightning) specific to the lower mountain regions is 35-40 days/year, with up to 80 storms recorded in some years. It is recommended that buildings and structures that dominate the surrounding areas should be equipped with specific electricity capturing and transfer devices for thunderbolt protection.

2.3.3.3 Extreme Temperatures
Mountains (except for depressions) act as a buffer to thermal variations, and therefore the absolute extreme temperatures recorded at Roşia Montană station ranged between moderate values (during 1984-1997). Thus, both the absolute minimum and the absolute maxima were reached in 1987 (-22.5 °C in January, and 28.7 °C in July, respectively). This parameter is, however, strongly influenced by elevation, and Roşia Montană weather station is located about 300-350 m higher than the average Project site elevation. Thus, at the station in Câmpeni, located about 200 m lower than the Project site, the absolute thermal range is much higher (71.8°C, compared to the 51.2°C at Roşia Montană), with temperature extremes of -32.7°C absolute minimum (January 1963), and 39.1°C absolute maximum, respectively (August 1896). Therefore, it is certain that temperature extremes will have lower/higher values on the RMGC site, but, because of the short recording time (since 1983) and in the absence of a weather station at this elevation (about 800 m), they were not captured.

In the eastern Apuseni Mountains, affected by foehn events, the overall multi-annual average number of frosty nights (t med ≤ -10°C) is low (26.9 at Câmpeni, with a maximum 10.6 days in January; 28.3 days at Băișoara, with 8.8 days in the same month). The average multi-annual number of tropical days (t max ≥ 30°C) is strongly influenced by elevations ranging between 7.2 days at Câmpeni station (August, 3.5 days) and 0.1 days at Băișoara station.

The risk posed by weather events is considered in the qualitative and quantitative assessments (Sections 4, 5 and 6) for specific industrial activities.

2.4 The Risk of Flooding and Inundation

2.4.1 Variables Involved in Generating Floods and Flash Floods
The driving role in the generation of flash floods if that of meteorological factors (e.g., high intensity torrential rain). They are part of the dynamic, causal factors, creating the triggering "input" of the flood.

Another group includes the conditional factors, which differ from one river basin to another for a similar triggering event. In their turn, conditional factors may be cumulative or preparatory factors (e.g., liquid and solid precipitations prior to the triggering factor, substrate humidity, the water level in the river channel and the groundwater table, the evaporation rate) and enhancing factors (some morphometric features of the catchment and the river system, substrate structure and texture, afforestation, activity and some consequences of anthropogenic activity).

2.4.1.1 Triggering Factors

Aero Synoptic Conditions Enabling Flash Floods
In analyzing these, were used the hydro-meteorological data (weather data from daily weather forecasts) for the periods in 25 years (1978-2002) when the 2 biggest flashfloods occurred.

Rain generated floods
They are predominant in the study area (over 60% - Table 7-7) primarily occur with advections of air masses from the western sector. In a situation of this kind, on the map representing the high altitude temperature-pressure fields, the isohyets are east-west.
oriented, and rather close together (high baric gradient), determining fast progress of the maritime-polar air masses from the Atlantic Ocean. Fast advection enhances the freshness of the air masses that release large amounts of precipitation in the Apuseni Mountains. High flash floods caused by rain are determined by such invasions of cold polar air conferring to the pre-existing warm, high vapor content air a very strong upwards movement that causes sudden condensation of the water vapors and the fall of high precipitation over a relatively short period of time.

Also frequent are the situations in which air masses from the south-west generate the heavy rains that participate in the formation of floods.

**Mixed origin floods**

South-western air mass circulation is dominant; however, an increase of the number of floods generated by southern and south/western circulation can also be noted. Especially at the onset of winter and spring, under favorable temperature and pressure situations, the warm air of the Mediterranean crosses the Mures Mountain chain through the lower pass between the Zarand and the Metaliferi Mountains, impacting the Abrud and Little Aries catchments (the frequency of warm air invasions has decreased in the past 10 years). The contribution of northern and eastern circulation to the generation of mixed origin floods is practically nil.

The aero-synoptic situation for Europe, often generating very intensive floods, consists of the existence of a deep depression over almost the whole continent (except the south), including several cyclonic nuclei generally moving west to east at high speed, as an effect of high altitude gradients (e.g. the flood of December 23-31, 1995).

**Strictly nival flash floods**

Strictly nival flash floods that would come up to the highest events of this kind (in one year) have not been identified in the area in the investigated time period.

In regard to the contribution of baric centers to flash flood generation, note that Mediterranean cyclones, following a predominantly south-western component, and the Icelandic cyclones, mainly from the north-west, participate in almost equal percentages.

**Table 7-7. Flash flood generation – elements of frequency (1978-2002)**

<table>
<thead>
<tr>
<th>No.</th>
<th>River/stream</th>
<th>Hydrometric station</th>
<th>Hmed (m)</th>
<th>Nivo-pluvial floods (%)</th>
<th>Pluvial-nival floods (%)</th>
<th>Pluvial floods (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Arieș</td>
<td>Câmpeni</td>
<td>999</td>
<td>6</td>
<td>34</td>
<td>60</td>
</tr>
<tr>
<td>2.</td>
<td>Abrud</td>
<td>Abrud</td>
<td>933</td>
<td>2</td>
<td>32</td>
<td>66</td>
</tr>
<tr>
<td>3.</td>
<td>Abrud</td>
<td>Câmpeni</td>
<td>931</td>
<td>6</td>
<td>32</td>
<td>62</td>
</tr>
</tbody>
</table>

**Extreme Precipitation**

This issue is discussed in detail in sub-section a. Extreme Precipitation of Section 2-3.1.1 Meteorological Risk Events.

**Sudden Snowmelt**

This issue is discussed in detail in sub-section b. Sudden Snowmelt of Section 2.3.1.3. Meteorological Risk Events.

**2.4.1.2 Conditional Factors**

**Morphometric factors of the catchments and watercourses**

The triggering weather event is not sufficient for a high intensity flash flood because, under similar triggering conditions, there may be great differences between one catchment and another, with physical factors boosting or reducing flood intensity. Such key factors include
the morphometric characteristics, with the shape and area of the catchment a determining first.

The Roșia and Corna catchments basins are of oblong shape, roughly east-west orientated in the first case, and north-east – south-west in Corna valley, respectively, and a relatively low degree of asymmetry. The above-mentioned shape attenuates the flood wave because, unlike almost circular basins, peak flows are not as high under the same environmental conditions and similar energy inputs, because in oblong basins water from rain and snowmelt collects gradually, without concentrating in certain areas (see Figure 7.7).

Figure 7.7. Influence of the catchment shape on water concentration for catchments basins of equal area

Also, the general orientation of the two main catchments (predominantly east-west), opposite to the main advection route of the air masses is included with the factors that contribute to a reduction of flash flood magnitude. Note, however, that for such small catchments convective rains are more significant than frontal rains.

Surface analysis, separate for the two catchments, reveals the higher value for Roșia catchment (14.7 km²) compared to the 9.7 km² of the Corna Basin. The extent of the catchment is very important for the formation of the flood waves. In smaller catchments, such as Roșia and Corna, that might be covered completely in a torrential rain, stream flow rates are very variable, directly related to the intensity and duration of the triggering storm. Conversely, in large catchments, flow regularization is found while rainstorms rarely cover the entire river basin.
### Table 7-8. The main watercourse characteristics of the river basins affected by the Roșia Montană Project

<table>
<thead>
<tr>
<th>No.</th>
<th>Watercourse</th>
<th>Stream length (km)</th>
<th>Average stream gradient (m/km)</th>
<th>Catchment Area (ha) (km²)</th>
<th>Average catchment elevation (m)</th>
<th>Forested area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Roșia</td>
<td>8</td>
<td>68</td>
<td>14.7</td>
<td>892</td>
<td>210</td>
</tr>
<tr>
<td>2.</td>
<td>Corna</td>
<td>5</td>
<td>38</td>
<td>9.7</td>
<td>833</td>
<td>236</td>
</tr>
</tbody>
</table>

**Values of the Runoff Coefficient in Locations with Different Substrate Characteristics**

The runoff coefficient may be defined as the ratio between the depth of runoff (effective or net rainfall) and the rainfall depth (global rainfall).

The study “Assessment of rainfall intensity, frequency and runoff for the Roșia Montană Project” - Radu Drobot gives the assessed values of runoff coefficients for the above extreme events. For the Roșia and Corna catchments, they generally range between 35 % and 80 %, a value conditioned by the catchment gradient, the catchment afforestation coefficient, the soil texture, and the anterior precipitation index (API), the depth of soil frost and the percentage of artificial impervious areas in the catchment.

Most of the river basin affected by the project have a less than 40% natural gradient. The percentage of forested areas in the Roșia and Corna catchments is estimated to be 20% and 30%, respectively, and the dominant soils are medium texture.

The winter PMP runoff could theoretically occur immediately after or concurrently with significant snowmelt, in which case a high API coefficient, and consequently a high runoff coefficient could be expected (nearly all the storm water and snowmelt will drain into surface watercourses). For that reason, the winter PMP runoff coefficient of 90% was proposed. A higher winter runoff coefficient could be expected in situations of frozen ground and frozen snow cover, but it would not be justified to combine this PMP scenario with the with the maximum snowmelt For the summer PMP, a maximum runoff coefficient of 80% was considered reasonable. In both cases, a 100% runoff coefficient could be used for water surface and over impervious areas (e.g. concrete paved areas). Summer maximum runoff coefficients range from 30% to 45% for 10-year return period, 35% to 60% for 100-yr and 50% to 70% for 1,000-yr or higher return period. The limits of the ranges correspond to the shortest and the longest rainfall duration, respectively. For the winter, all the above coefficients were raised by 10%, as loss of water through seepage and evaporation is lower.

2.4.2 Analysis of the Multi-Annual Water Regime

2.4.2.1 Multi-Annual Water Regime of Fluid Flow

**Flow distribution throughout the year**
Largely determines the economic value of waters – the more balanced the water regime, the better the water use. Typical periods of low flow may become risk events, and can affect the self-cleaning capacity of the watercourses, if contaminated effluents remain constant.

The studied site includes a few small catchments (Roșia, Corna, Abruzel, Seliste and Stefanca) the first two being noted for the larges overlap with the Project area (see Surface Water Catchment Basin Map). These two small watercourses are right hand side tributaries of the Abrud River which in its turn discharges into the Aries, immediately downstream of the town of Câmpeni.

In the absence of hydrometric stations of longer periods of records (stations Roșia-RW01 and Corna-CW01 have only been operational since the spring of 2001), average monthly flow rates were extrapolated for a period of 37 years, based on average daily flows measured at Abrud hydrometric station close by, which was installed in 1965. Based on
extrapolation, the multi-annual flow rate obtained was of 0.176 m³/s for the Roşia stream and 0.067 m³/s for the Corna Valley (see Table no. 5. Monthly Flow Parameters, in the report Biological Compensation Flows). Following transformations in the catchments of the two streams, average flow rates will decrease after year 7 of operation to 0.086 m³/s in Roşia Valley and 0.038 m³/s in Corna Valley, respectively.

**Flow distribution by season**

Is a consequence of how the main supply sources combine during the year. The water regime in the central area of Apuseni Mountains is distinguished by a balanced seasonal flow.

In winter, the outflow of the Roşia and Corna catchments is 23-23.5% of the annual flow, with a monthly average flow rate 0.162 m³/s, and 0.062 m³/s, respectively. The relatively high flow rate in winter is explained by the moderate temperature regime, with frequent invasions of sub-tropical arm air from Northern Africa.

Specific to the temperate-continental mountain regions, maximum flow is recorded in spring (40-45%) when it results from a combination of relatively heavy rain and snowmelt. In summer the percentage of the output flow in the two watercourses is maintained rather high (22.5%), as a consequence of torrential rains specific to the summer season and the relatively low evaporation, specific to the mountains.

Autumn is the season with the lowest seasonal flow (13.5%), as a consequence of reduced precipitation and lower groundwater reserves that feed into the river system.

**Flow distribution by month**

The monthly distribution of the flow highlights the month of April for the highest average flow (0.337 m³/s for the Roşia and 0.126 m³/s for the Corna stream, respectively), and September for the opposite situation (0.088 m³/s, and 0.032 m³/s, respectively). The maximum average monthly flow was estimated for March 1981 (1.29 m³/s, and 0.31 m³/s, respectively), an the minimum for November 2000 (0.016 m³/s, and 0.004 m³/s, respectively).

### 2.4.2.2 Frequency of Flash Floods and Floods

**Flash Floods**

With a limited set of hydrometrical measurement data (the automated hydrometric stations on the Roşia and Corna have only been operational since April 2001) interpretation and analysis of annual flow hydrographs will not provide pertinent results. At least 2—30 years of measured data would be necessary, and older data cannot be extrapolated with good results, as in the case of the average monthly flows, as in temperate-continental climates spatial and temporal variability of precipitation is very high, and the catchment response to rain is much faster than in the case of larger basins, often causing flash floods – figure 7.8.

An analysis of the hydrographs of the multi-annual evolution of average daily flows (lacking instant flow check data) between April 2001 and late 2004, will show the following:

- maximum average daily flows were recorded for the spring of 2004, both on the Roşia and the Corna (2.18 m³/s, and 1.64 m³/s, respectively);
- the annual flood frequency is high, with an average of 3 flash floods a year at 5 times the average flow and 2 floods a year at more than 10 times the average;
- most flash floods occur in summer, due to torrential rainstorms, quickly exceeding the soil seepage capacity, and in spring when rainstorms combine with snowmelt.

Valea Muşcanilor is located immediately to the north-east of the site, and has a 15 year measurement record and similar characteristics to the Roşia Valley (8 km long, 808 m
average elevation, 0.24 m³/s multi-annual average flow and 17 km² catchment area). An empirical extrapolation of the maximum flow data for the Roșia stream gave the following:

- maximum flow would have been recorded on 3/12/1981 (about 8 m³/s). Data on this flood could be extrapolated without great error, considering its nivo-pluvial origin and the frontal precipitations that affected the region.
- the 1/100 return period flow was established at 23 m³/s.

**Figure 7.8. Flood on Roșia Valley**

Another correlation may be made with the hydrometric station in Abrud, on the Abrud River. An analysis of the data related to the two largest floods during 1978—2002, we may find that:

- most flash floods occur in summer (44%) and in spring (36%);
- the months with the most flash floods were July (20% of all floods) and June (16 %);
- the highest three maximum floods were 84.5 m³/s-1995, 60 m³/s – 1980 and 51.3 m³/s-1982.

**Floods**

An analysis of the floods and damages caused by floods and flash floods during 1995-2004 in Roșia Montană and Abrud, the following may derive the following conclusions (Table 7-9):

- in both localities, the average ten-year frequency of floods is high, at 6/10: however, an analysis of older data (1978-2004) recorded at Abrud station suggested that by 1995 there had been no flood since 1982, therefore we might be witnessing an flood rate increase in the region.
- the most significant damage was caused by the flash flood of December 1995 (the most serious in the Abrud catchment) – loss estimated at MUS$ 1.6 in the town of Abrud and US$ 62,000 in Roșia Montană, followed by the event in June 1998 – MUS$ 1.15 Abrud, April 1997 – US$ 50,000 in Roșia Montană and April 2000 – US$ 29,000 in Roșia Montană.
- the greatest damage was caused to the hydrotechnical works in the Abrud River channel, in Abrud town (MUS $ 2.58);
- damage to individual households amounted to US$ 60,000;
Table 7-9. Annual distribution of floods generated by flash floods and high waters in Roșia Montană and Abrud (1995-2005)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abrud</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>2,74</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Roșia Montană</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0,152</td>
<td></td>
</tr>
</tbody>
</table>

In the physically impacted area, the risk of flood occurrence will be very low because of:

- the small comparative in catchment area of the Roșia and Corna streams that will be impacted and that will further reduce towards the end of the Project;
- the development of structures that will take up almost the receiving catchment of the two streams and contain most of the drainage (quarries, waste rock piles, tailings dams, etc.);
- the natural gradient of the terrain that does not allow water accumulation in the structure-free portions of the valley and the slope of the watercourses enabling fast drainage;
- the head of the draining hydrotechnical works (diversion channels) draining runoff from the site, some of them with discharge capacity 5-8 m³/s.

Moreover, any accumulation on the Corna or Roșia streams will lower the risk of flood downstream, by controlling some of the discharge into the Abrud River.

2.4.2.3 Flood Wave Modeling

Flood modeling is a mathematical procedure consisting of predicting and changing the intensity, speed and shape of the flood wave (i.e. the hydrograph) in one or several points along a watercourse. A flood may occur from storm or snowmelt flows, discharges from reservoirs (overflows), from a wave started by a reservoir slope or a combination of the above.

The objectives of modeling flood waves are to export flood hydrographs to relevant locations in the Project-impacted catchment areas, to assess design parameters (dam height, spillway capacity, diversion channel capacity, etc.) and provide input for the assessment of pollutant dilution for various sizes of design events.

The design of the Corna Valley Tailings Management Facility (TMF) was based on the Probable Maximum Flood (PMF) principle, which makes Roșia Montană the first project in Romania to consider PMF in the design. In the particular case of Roșia Montană Project, the TMF and Corna Dam are oversize, with the dam able to contain two PMF events. Flood modeling was based on the design parameters obtained from the hydro-meteorological study (Drobot, 2004) the natural features of the impacted area (topography, river network, etc.), and the design parameters of the Project structures (dam height, reservoir volume, spillway capacity, pumping flow, etc.). This was achieved by means of the rain-runoff type modeling software HEC-HMS (Hydrological Engineering Center – Hydrological Modeling System).

The Project site occupies two of the more important catchments: Roșia, and Corna. The flow regime of these two watercourses will be strongly influenced by the proposed geotechnical structures, primarily by the TMF and Corna Dam in the Corna Valley and the Cetate Water Catchment Dam in Roșia Valley.

In order to convert net precipitation into runoff, we used the Unitary Hydrograph (UH) method, and in modeling the flood wave the Muskingum-Cunge method.

An assessment of the results obtained from flood modeling suggests the following:
for the proposed Cetate dam height (737 m ASL), Cetate pond may safely contain floods of maximum return period 1/100 without discharge. For events of return rates 1/200, 1/500 and 1/1000, water will be released through the spillway at flow rates 1.7 m³/s, 5.8 m³/s, and 10.5 m³/s, respectively.

Cetate Dam spillway was designed for the safe transit of a 1/100000 event, when the peak flow through the spillway will be 30.5 m³/s. Dam capacity may still be exceeded for the probable maximum flood (329 m³/s – year 0 and 322 m³/s - year 7).

overflow from Cetate Dam for events exceeding a 1/100 return period would be of short duration, normally less than 24 hours.

the design parameters considered for the TMF in Corna Valley will ensure total containment of any flood event, including twice the PMF. Spill over the TMF emergency spillway due to a PMF could only be expected to occur during the last few months prior to the first raise of the tailings dam, which is planned for year 1.25 of the mine operation. This spill would be on the order of 1.6 m³/s and it would last for a few hours. The probability of a PMF event to occur during the few months prior to the first raise of the tailings dam is very low, and may be associated with a 1:12 million year event. Such a low risk was considered acceptable.

the TMF emergency spillway is sized to safely pass a 10-yr flood occurring immediately after the PMF. Discharge in the case of such an event would be 2.3 m³/s. Note, however, that this scenario is only possible for a short period during year 1.25 of Project operations.

during the remaining period of operations (years 2 to 17), the TMF will be able to cope with several PMF events. The volume of a Probable Maximum Flood (PMF) was assessed to be 2.8 Mm³, and between year 7 and the end of operations the flood mitigation available volume will be in excess of 11 Mm³.

After closure, the available flood containment capacity will be reduced by about 4.8 Mm³, as a consequence of ecological restoration. Seepage out of the decant pond will be provided by a diversion channel (built during year 14), starting from the lowest point in the pond (northern end) all the way through to Corna dam (828 m). Then the water will be directed to a stepped spillway on the right bank, downstream of Corna Dam. Flood modeling indicated that the diversion channel will be able to discharge any flood, including PMF. The maximum pond level during a PMF would remain 3 m below the top of the safety spillway.

the Secondary Containment Dam may safely retain all events of lower return periods up to 1/100. Discharge for return periods 1/500. 1/1000 and PMF would be 0.6 m³/s, 2.5 m³/s and 25 m³/s. Due to a very small catchment area, the Secondary Containment System could not be exceeded during a PMF.

Flood modeling results indicate that the proposed design parameters and criteria adopted for the structures would provide a very high level of safety in relation to hydrological risk events, dam overflow and accidental spills.

2.4.3 Measures to Prevent, Reduce and Remediate the Effects of Floods and High Waters

2.4.3.1 Structural Measures

Reservoirs

Cetate Water Catchment Dam and Pond

Design Flood. The Cetate Dam will collect current and future acid rock drainage as well as seepage water from the water containment structures in the Roșia catchment. The top of the
main dam will have a final rise of 737 m ASL, designed to impound a maximum 600 000 m³ at 728.3 m ASL.

Hydrogeological studies based on revised weather parameters (prof. Drobot, 2004) indicated that the pond will have the design capacity to contain flows associated with 24 hr. precipitation events of 1:100 return period (i.e. 324 000 m³) at maximum operating capacity before event occurrence (parameters to meet Romanian requirements). Higher intensity events (i.e. up to a 1:1000 years event and more) may be contained behind the dam when the reservoir is operated at normal operating levels. Any flow in excess of this will be discharged in order to protect the dam.

The spillway structure on the dam, located three meters below the dam crest (734 m), on the right hand side, will be constructed for a 100,000-year storm event in accordance with Romanian regulations. Any such discharge will occur during large storm events with a high capacity to dilute the contents of the pond. Permits will also be required to allow for the discharge of excess storm water from the Cetate Water Catchment Pond. For events of return rates 1/200, 1/500, 1/1000 and 1/10000, expected releases through the spillway would amount to 1.7 m³/s, 5.8 m³/s, 10.5 m³/s and 30.5 m³/s, respectively.

**Tailings Management Facility**

Design Flood. The final rise of the central dam will be about 840 m ASL, designed to contain 161 million tons of detoxified tailings. Before commencement of ore processing, the initial stage of the TMF embankment (main starter dam) will be constructed to an approximate elevation of 739 m above sea level (80m above ground surface). The initial rate of rise of the embankment will be 20 m in the first year, reducing to about 5 m in the final year. The final height of the embankment will be approximately 185 m. The elevation of each stage of the facility is will also consider water volumes resulting from a PMF.

National standards provide that the TMF must store a 1:10,000 year storm event, which corresponds to 227 mm of rainfall/snowmelt within a 24-hour period. For safety’s sake, the more stringent Probable Maximum Precipitation (PMP) event has been selected as the design criteria for the TMF: 450 mm for a summer event and 440 mm for a winter event with snowmelt.

In designing the TMF, the calculated flood wave exceeds the provisions of the Romanian regulations, as it represents the Probable Maximum Flood (PMF), a conservative approach, more in line with international practice. The maximum probable 24 hr volume of water was determined to be 2 500 000 m³, in the case of PMF in the warm season, and 2 750 000 m³ in the cold season. The design of the Corna Valley Tailings Management Facility (TMF) was therefore based on the PMF and PMP values, which makes Roșia Montană the first project in Romania to consider hydrogeological parameters as a design criterion.

Secondary Containment System The dam of the Secondary Containment System (11 m high) will be able to temporarily contain runoff from moderate intensity storms (designed for the safe containment of a 1/100 year 24 hr flood event – 43 000 m³) or TMF runoff and seepage. Under such exceptional circumstances, seepage out of the Secondary Containment System may increase for a short period of time. In addition, under extreme event a storm water release from the system will be required through a designed spillway. The spillway will be designed to control the discharges from a 1,000-year, 24-hour rainfall event. In both cases of increased seepage or a release associated with a storm event, the event will be short-term and mixing with unimpacted waters will result in a significant reduction in concentrations of any potential contaminants. Spills during lesser 1,000-yr 24hr floods would be 36 m³/h (1/500 yr), 150 m³/h (1/1000 yr) and 1500 m³/h for PMF.

**Cârnic Contaminated Water Catchment Dam**

The Cârnic reservoir will be built immediately downstream of the Cârnic waste rock stockpile. The facility will be designed to collect possible acidic runoff from the waste rock and pump it to the wastewater treatment plant. The dam of the catchment pond will have a rise of 852 m
ASL and a constructed height of 22 m. The dam as designed to contain 1:50 yr flood events. In the case of larger floods, water will be allowed to overflow into the Corna TMF, through a 10 m wide spillway built outside the dam body.

Flow Control, Containment and Diversion Works
Wherever practicable, diversion ditches will be constructed to minimize the volume of surface water that were not severely impacted by historic mine workings or associated to the Roșia Montană Project. The ditches will reduce the volume of clean water mixing with water requiring treatment, thus reducing the wastewater storage and treatment requirements. In addition, the diversion ditch water will help maintain the biological base flows in the creeks downstream of the Project.

Another function of the diversion ditches is to reduce the potential flooding of site facilities. The Project is located within hilly terrain and the proposed ditches around the pits, stockpiles, plant, and waste disposal areas will provide control of surface runoff except under extreme events. For the plant site, surface runoff will be directed to the plant storm water pond that will also act as a secondary containment system for the plant facilities. In order to be able to operate at design capacity, the diversion ditches will have to be periodically cleared of silt, whenever necessary. The location of the diversion ditches at various stages of Project implementation is shown in Exhibits 1 – 4.

TMF Diversion Works
In order to minimize the volume of water entering the TMF on Corna Valley, diversion channels will be constructed to collect and route clean runoff water before it drains to the TMF and discharge it downstream of the SCS.

The left bank Corna Diversion Channel will be constructed on the south hillside of the TMF to collect and route surface water to the downstream toe of the SCS. The South Diversion Channel collects runoff from a smaller drainage area of about 0.24 km² and 0.35 km long. A similar channel will be constructed on the northern side, along the main waste rock haulage road, at a higher elevation that the final TMF level. The ditch will collect runoff from a catchment of about 1.15 km². The total length of the ditch will be about 3.5 km, at 0.5% to 8% gradients, depending on the terrain. Its cross-section will be trapeze shaped and on high gradient sections, cobbled. The design flood is 5 m³/s, according to a 65 mm storm (1/23 yr 24 hr event probability) Should larger floods occur, in excess of these ditches containment capacity, the excess water will drain into the TMF. This water volume was also included in the calculation of the extreme runoff containment capacity of the TMF.

Water Diversion Works in Roșia Catchment
These Roșia diversion works will divert the Roșia Stream and unaffected runoff water from the north slope of the Roșia Valley to downstream of the Cetate dam. The channel will be about 1.7 km long. The diversion channel was designed as a fixed, linear, concrete structure, with a number of lateral spillways allowing excess water to overflow into the Cetate dam during events exceeding the design capacity of the channel. The Roșia diversion channel was first designed for a 5 m³/s flow in the internal section of the channel, and 8 m³/s in the flow discharge channel. To minimize erosion, the spillways will be located on existing gulleys and tributaries on the right hand side of the Roșia Stream. The North diversion channel, extending around the Jig and Orlea Pits after year 7, is designed for a drainage capacity of 2 m³/s.

2.4.3.2 Non-Structural Measures

The National Strategy for Flood Risk Management, published in 2005, aims to reduce the impact of floods on the population and goods, by adequate planning and a policy in line with the standards and expectations of the human communities, with environmental protection.
The Flood Management Strategy is the framework document for preparedness and the adoption of specific measures to: know flood risks, monitor flood events, inform the public, consider flood risks in all land use development activities, adopt preventive measures, prepare for emergency situations, reconstruct and learn from past experience. This is also a basis for the central and local governments to choose specific flood protection and regional development measures. The strategy also defines the specific operational responsibilities of the central and local government authorities, of the public and businesses and of individuals.

The Forecast and Warning System for Hazardous Meteorological and Hydrological Events
The development of meteorological and hydrological forecasts of the best possible utility and the best use thereof by the risk managers are important ways of preventing and reducing the negative effects associated with hazardous hydro-meteorological events. Very short-term forecasts (nowcasting) concern an anticipation time of maximum 12 hours. They concern hazardous weather events of great space-time variability: rainstorms, electrical discharge, windstorms, etc. Therefore, this type of prognosis materializes as a warning, alert, or red meteor message, depending on the intensity of the hazard, broadcast by the regional weather service. In Romania, these activities are included in a National Integrated Meteorological System (SIMIN) equipped with state-of-the-art devices (e.g. Doppler radars installed at Bobohalma and Oradea and covering the Roșia Montană area) that may improve the flow of weather data and hence help develop very short term forecasts (3-12 hours) with more than 90% accuracy. For very small catchments, like the Roșia and Comă Valleys, this is the very type of necessary equipment, as floods will occur immediately after a rainstorm. The flows of the two watercourses are permanently monitored by automated hydrometers located at the outflow into the Abrud. Rain gauges have also been installed in the region to record precipitation (at Roșia Montană meteorological station and at the RMGC station).

Flood Risk Map
In the Project footprint, the risk of fluvial floods during operations is low, with minimizing factors described in item b of section Analysis of the Multi-Annual Water Regime. Temporary stagnation of water on limited, undrained areas, is, however, possible. Downstream of the two important dams within the Project site (Corna and Cetate Dams), in the unlikely event of breaching or collapse, the resulting flood wave might easily expand out of the river channel, flooding the adjacent land and facilities up to a level proportionate to the size of the dam breach, reservoir levels, and the time during the Project life where they might occur. Flood wave propagation scenarios along the Corna and Roșia streams and their receiver, the Abrud River (in the form of flood risk maps) considering various parameters are given in Figure 4 - TMF Dam break scenarios for use in Roșia Montană EIA, February 2006 and Drawing - Cetate Dambreak Repor. The identification and analysis of these hazards is necessary for the assessments in Sections 4, 5 and 6. Emergency response planning (section 7) also contains elements of this Section.

2.5 Fires

2.5.1 Natural and Anthropogenic Causes
Research indicates that there are no records of forest fires in the mining site area. Therefore, although no formal fire risk assessment was conducted for the meteorological and topo-climatic conditions of the site it may be stated that fire risks will be insignificant, even during extended periods of drought. As the Project area is subject to relatively abundant precipitations all year round, the risk of severe fires is considered low. However, due to the potential consequences of a forest (or any other) fire, the required prevention and management measures will be implemented by the application of the Accidental Pollution Prevention and Control Plan.
An outburst of fire in the surrounding forests as a result of a thunderbolt strike or any other cause is a natural hazard which has been considered in the Project design and management.

Particular aspects that need considering include protection of the process plant structures and offices against fire (due to human health risks and potential damage to reagent and process fluid storage and potential release into the environment) and protection of the tailings transport pipelines (due to the risk of breakage and spills). Protection against exposure of the vulnerable Project components (such as the plant and the pipelines) to fire will be facilitated by the creation and maintenance of clear spaces around such structures, to prevent the spread of fire, and the establishment of fire control procedures. The area and location of the clear spaces will be specified in the final engineering design.

Procedures related to such tree free spaces are included in the “Accidental Pollution Prevention and control Plan”, including the following:

- fire prevention and preparedness/planning for fire control;
- links to the local emergency response services;
- provisions for emergency shut down of the operations and pipelines;
- links with the community and education about such issues.

### 2.5.2 Fire Impacts on the Natural and Built Environment

Potential fire impacts will be prevented and managed by the application of the “Accidental Pollution Prevention and control Plan”. Thus, no individual, community or human settlement will be affected by fires on the Project site. A system of fresh water supply and management will be implemented also covering the needs of fire prevention and control.

The structural components of the Fresh Water System will be located on the Aries River, about 10 km north of the mining site at Roşia Montană. Therefore, the plant manager will also be in charge of the Fresh Water Supply System will also manage the fire fighting system. Moreover, a mobile tanker holding 80000 liters of water will always be available on the mining site and will be able to respond to any fire emergency due to natural or accidental causes.

In such circumstances, the risk generated by potential fires (with natural or anthropogenic causes) will be low and managed accordingly under the Romanian legislation in force.

### 2.6 Landslides

A landslide is defined under the Romanian legislation as a “movement of rocks and/or masses of earth that form the slopes of mountains or hills, the embankments of geotechnical or other land improvement works, that may cause human casualties and material damage! (Law No. 575/2001).

Slide risk assessment on the investigated site is based on an analysis of the inclination of natural slopes and other go-morphological indicators (hypsometry, fragmentation and relief energy, slope orientation) the analysis of current slope morphology and dynamics (in relation to geology, vegetation, soils, and land use).

Based on this approach, areas of land susceptible to landslides or other geo-morphological processes (creep, collapse, wind or water erosion, gulleys, etc.) may then be identified.
The results of risk assessment include the slope maps, the map of the critical slope inclination, the land stability class map and the summary landslide risk map (map of the landslide probability areas fig 2).

2.6.1 **Slope Inclination Analysis (Slope Map)**
From a geo-morphological perspective, medium geo-morphometrical indicators are predominant, reflective of a morpho-dynamically balanced forms of relief and medium intensity geo-morphological processes. A morphometric analysis was conducted, based on the following geo-morphometrical indicators (Gligor, 2005):

2.6.1.1 **Hypsometry.**
Hypsometrically, the relief of the investigated site ranges between 400 m and 1130 m, with an elevation gradient of 730 m, which classifies the investigated unit into three hypsometric steps and the medium mountain category (high degree of morphological fragmentation):

- the 800-1000 m step includes leveled tops and long slopes, intrusive structures and volcanic delluvial areas generated by the eruptive massifs.
- the 600-800 m step includes the valley corridors, depression areas within the mountains and marginal erosion basins (Roșia Montană Depression, Abrud-Bucium corridor);
- the 400-600 m step covers a limited area, only including developed valley corridors (Abrud Valley), with flood plain sectors, stepped terraces, glacis, accumulation cones.

2.6.1.2 **Relief Fragmentation**
The density of relief fragmentation ranges between 2-4 km/km², and characterizes natural slopes, intersection ridges and hydrographic convergence areas.

2.6.1.3 **Depth of relief fragmentation (relief energy)**
Has average values ranging from 200 to 300m, specific to secondary inter-rivers and glaciated, morpho-dynamically balanced slopes.

2.6.1.4 **Slope Inclination and Exposure Analysis**
Slope inclination values are conditioned by the specifics of denudation processes, the rock structure typology, relief evolution and the current morpho-dynamics.
The morphometric analysis based on the inclination index indicates the presence of the following slope categories: **0-3°; 3-6°; 6-15°; 15-35°; over 35°** (Figure 7.9.).
Figure 7.9. Slope Map

Quasi-horizontal areas (0-3°)
Take up limited areas, including inter-rivers, river flood plains and terrace, landfill and tailings ponds steps.

Slightly inclined slopes (3-6°)
Are typical to the connections between level ground, slopes and depression basins, confluence areas and the landfill bottom sectors.

Medium inclined slopes (6-15°)
They cover extensive areas of the glaciated slopes, terrace fronts and secondary inter-rivers.

Slopes of inclinations ranging between 15-35° and over 35°
Are typical of limited areas of the investigated site, on slopes developed over Neogene eruptive morpho-structures (structural erosion controls) on the pit cornices (Cetate) and the embankments of slope landfills (Muntean et al., 1998).

In conclusion, the 12-15° slope is the critical point in soil generation, creep initiation and the origin of landslides (Gligor, 2005). Denudation intensity increases for the slopes developed over friable lithologies (sandstone, marl, clay, conglomerate) and on weathered delluvial covers.

2.6.2 Natural Slope Morpho-Dynamics
The current morphology of the structural denudation relief is marked by the Neogene volcanism and tectonism. The volcanic necks on the investigated site (Cârnic, Cetate), cut off by erosion at roughly the same level (1060-1080 m), classify in the medium erosion area (1000-1100 m).
The morphology of the investigated site is characterized by the limited change of the longitudinal and transversal profiles of the valleys and the slopes (e.g. Roşia Valley), and by the differentiated intensity of the geo-morphological processes. The high susceptibility to erosion of the pyroclasts explains land degradation in the Roşia Montană-Bucium area, where linear erosion (gutters, ravines, ruts, gulleys) are dominant in the current morpho-dynamic processes. In the northern and north-eastern portion of the Roşia Montană depression, lithology consists of grey marl with intermissions of sandstone, gypsum, black shale, which explains the suitability, intensity, and diversity of the shaping processes.

These are compounded by landslide over old delluvial deposits, reactivated by the deeper and regressive erosion of the ravines (right flank of Roşia Valley) Susceptibility to erosion of the molasse deposits is also expressed by the high values of the drainage system density (3.5-4 km/km²).

The density and depth of fragmentation are characteristic of a strongly erosion-dissected relief, consisting of segmented profile slopes, developed over a heterogeneous lithostructural substrate of different slopes and exposures. Therefore, the current morphodynamics is generated by area erosion (weathering, storm runoff, pellicular denudation, superficial landslides, solifluxion and creep) and by linear erosion (rilling and gulleying).

In conclusion, the current geo-morphological processes (superficial landslides, ravination and gulleying) affect the natural slopes in the vicinity of Roşia Montană, Bâlmoşeni, Bildeşti, Corna, Gura Roşiei and Abrud. For the investigated site, the onset and re-activation of geo-morphological processes (superficial landslides, rolling and gulleying) induced by road development (along Roşia and Corna Valley). The size and intensity of landslides are relatively reduced on the natural slopes on the site and are typical of natural slope morphodynamics in the region.

2.6.3 Soil Stability Class Analysis
A comparative analysis of the relevant topical maps in preceding studies (land use map, geological map, morphometric map, vegetation map, soil map, aerial photograms) helped define the soil stability classes (stable, potentially unstable and unstable). The definition of these classes was mainly developed based on the criterion of slope inclination versus vegetation cover, soils and land use.

Analysis of the geo-morphometric indicators and overlay of the above topical maps helped define three categories of stability class (Carson, Kirkby, 1972; Mapping and Assessing Terrain Stability Guidebook, 1999):

- **stable land** – characterized by 0-6° slopes, on deep soils, tree or meadow vegetation and low intensity geo-morphological processes;
- **potentially unstable land** – characterized by 6-15° slopes, on truncated (partly eroded) soils, poorly consolidated vegetation and active or reactivated geo-morphological processes (superficial slides, crumbling, ravination and gulleying);
- **unstable land** – characterized by slopes over 15° (15°-35° and over), typical of inclined slopes with young soils, fragmented vegetation and steep slope geo-morphological processes (crumbling, collapse, stepped landslides, rolling, rain wash);

The three stability class categories of the land are represented on the topical map of terrain stability (Figure 7.10.), developed in ArcView 3.2.A, ArcGIS 9 and the overlay method.
2.6.4 Assessment of Landslide Risk Areas

For a more suggestive presentation of the findings of the specific risk analysis related to the Roşia Montană Project, the following risk quantification matrix was developed based on potential landslide scenarios. Risk assessment is qualitative in nature.

In the assessment matrix, based on the existing information and the interpretation of the above maps, ten relevant locations of the site were selected for applying the proposed methodology. The results of matrix evaluation were then represented on the map of landslide probability areas (susceptibility to landslides).

In setting the values associated with the probability and seriousness levels, consideration is given to the existence of technical safety structures and equipment provided in the design, to the results of studies and relevant risk scenarios (Table 7-10).

Table 7-10. Results of matrix assessment of landslide risk in ten locations of the mining site

<table>
<thead>
<tr>
<th>No.</th>
<th>Site and scenario</th>
<th>Probability (P)</th>
<th>Seriousness (G)</th>
<th>Risk (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Process Plant</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Minor soil disturbance with no effect on the structures or ecosystems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Site haul routes</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Superficial soil disturbance with no effect on the ecosystems and structures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pipeline routes</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Superficial soil disturbance with no effect on the ecosystems and structures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Roşia Valley (access road and railroad)</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Superficial slides generated by vibrations and heavy rain, with potential fissuring of the transport infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Waste rock piles</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Superficial slides associated with material rolls with no disturbance to the structures and ecosystems</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The map of landslide risk susceptible areas was developed based on the GIS generated topical maps in ArcView 3.2.A, ArcGIS 9 and the overlay technique. Thus, three categories of landslide risk susceptible areas were defined:

- Insignificant Landslide Risk Areas
- Low Landslide Risk Areas
- Moderate Landslide Risk Areas

The three categories of land stability categories are represented on the topical map of landslide risk susceptible areas (Figure 7.11.).

**Figure 7.11. Map of the landslide susceptible areas**
2.6.5 Landslide Consequences on the Natural and Built Environment

The natural slopes that support the foundation of anthropogenic structures may show signs of instability due to the nature of the material or variations in its structure. Such instability may cause collapse of structures developed on such land, due to the weight of the structure and/or external forces (such as earthquakes). Therefore, the general layout plan and the design of the aboveground structures must consider the terrain conditions in order to reduce the risks resulting from geotechnical hazards. This may be achieved by adequate foundation design, the selection of a suitable site from the point of view of natural conditions, including with avoidance of land presenting signs of mass slide (landslides).

The Feasibility Study and the structural design have considered the specific foundation conditions, and the geo-morphological and geotechnical condition of the site. The data was obtained from geological and soil maps, and from a detailed investigation of the building area characteristics, including investigation of intrusions by the use of boreholes and test sampling. The level of investigation is in keeping with the Romanian requirements and recommendations and the international engineering codes, including those mentioned in the dam design.

The probability of overflow due to landslide into the TMF, which might reduce the safety area between the Corna pond and dam, was examined in the Environmental Impact Assessment Study. In taking account of this possibility, the Corna TMF dam and pond were designed to contain up to two PMP events, defined as an event of 1:100 000 000 probability of occurrence. The successive rises of the dam crest will be managed so as to provide the storage capacity and safety margin at all times. Moreover, emergency measures are included in the Tailings Management Facility Operations Plan. The Corna dam and pond design also includes a safety spillway for exceptional situations other than the probable maximum precipitation.

More details regarding this scenario may be found in the Environmental Impact Assessment Study (ESG et al., 2005), and Section 6.

In conclusion, the analysis of morphometrical parameters and their correlation with other sets of information on the natural slopes on and near the site shows that the (qualitatively estimated) landslide occurrence risk is low to moderate and its consequences will not cause major impacts on the structural components of the Project.

2.7 Risks Involved in the Depletion of Non-Renewable Natural Resources

The main Project objective is the extraction of ore from the Roșia Montană deposit in order to recover gold and silver. The definition of the areas that may be operated in economically profitable conditions was developed based on an extensive geological exploration program. The resulting data were used in the geometrization and calculation of various types of geological resources, and in selecting the extraction method.

Based on the data obtained in the exploration stage and by means of specific calculation approaches that take account of both technological and economic factors, the existing quantity of resources in the deposit was then calculated (Figure 4.5.6 in Section 4.5. Geology). Starting from a minimum exploitable content (contour limit) of 0.6 g/t for gold, the total, including measured, indicated and possible resources will add up to an approximate 400 million tons of ore. Of these, 214.905 million tons are demonstrated and probable resources with a content of 1.46 g/t of gold and 6.9 g/ton of silver, distributed into four mineralized zones, as follows:

- Cetate – 57.292 million tons;
- Cârnic – 112.376 million tons;
- Orlea – 39.829 million tons;
In some zones, the resources were not fully defined, with potential extension in the future. Also, based on gold and silver price fluctuations on the international market, the reserve base may be extended or diminished, by the establishment of a different minimum exploitable limit.

Taking account of the characteristics of the Roșia Montană deposit (the shape of the ore bodies, quality of reserve, silver and gold content) the best extraction method involves open face pit mining. Exploitation will be directed by the drilling of gold and silver control boreholes, in advance of operations. The results of detailed geological research work were used for a detailed characterization of the ore and the conduct of efficient extraction work. Some of the reserves planned for extraction in the first six years of operation will be so-called low grade ore. For economic reasons, only high grade ore will be processed in the first six years. Low grade ore will be stored in a 5.5 million tonnes stockpile and processed in the last three years of operations, when pit operations will be closed.

The balance of waste rock will be deposited in two waste rock disposal sites. Cetate waste rock pile will contain 21,289 million tons and Cârnic pile, containing 109,391 million tons. Once the mining operations are closed, 46,051, 11,941, 20,418 and 40,011 million tons will be backfilled into Cârnic, Jig, Orlea and respectively Cetate Pits. The tailings resulting from ore processing and the extraction of gold and silver will be stored into a tailings management facility. The total amount of tailings deposited in the TMF is 214,905 million tons.

A number of activities conducted during various Project phases, especially during construction, will require the use of construction materials. Such materials are especially needed for the construction of the TMF and other starter dams, but also in the building of roads, for aggregate and concrete, etc. The studies conducted in the mining concession area showed that there are two types of resources that might be used for this purpose: La Pârâul Porcului Sandstone Pit and Șulei Andesite Pit.

Sandstone will be used for the buildings of areas 1, 2, 3, and 5 of the dams and dikes, and andesites in building area 4. Apart for these rocks, waste rock from pit and other stripping operations (especially alluvial deposits) removed from the pond, process plant, waste rock piles, low grade ore pile and other sites will also be used in building the dams and dikes. Due to compositional features, sandstone is the best suitable rock used as aggregate in concrete mixing. The drainage layer designed to be built under the waste rock piles will consist of andesites and waste rock.

Sandstone and andesite will be quarried on two sites: Piriul Porcului and Sulei, respectively. The volume of resources estimated for the two quarries is: 933 thousand m$^3$ sandstone and 3.5 million m$^3$ andesite.

Ground preparation for catchment ponds, waste rock and tailings disposal and the process plant sites will require soil stripping. This material will be stockpiled and used in the rehabilitation phase.

The mining activities were planned so as to limit geological resource exploitation to the areas where such an activity would be profitable, with the use of the best technologies, and in consideration of a minimum exploitable content (contour limit) of 0.6 g/t for gold. The mining activities conducted during the Project will not deplete the geological resources of gold and silver. In the future, the unexplored areas of the deposit will make the object of further extraction, based on the economic conditions and/or technological progress. Selection of the waste rock stockpile, dams, and process plant locations involves areas that contain no geological resources, where the gold content is around 0.1 g/t or lower. Some of the resources will be immobilized by the fact that they lie under the protected area. Because
of extraction methods and economic factors, some of the resource bodies in the immediate vicinity of the pits will not be capitalized, and will be classified as loss. Building materials will only be quarried to the extent that they meet the Project needs. Mining and rehabilitation works will be conducted so as to allow further extraction of the remaining resources in the future.

Some of the waste rock will be used as construction material. The quantities of stripped soil during construction and operations will be used in rehabilitation. Also, the waste rock piles and TMF pond may become a future geological resource, either for residual amounts of gold and silver the may not be extracted by means of current technologies or economic context, or for other metals or industrial minerals.

In conclusion, there is no significant risk associated with resource depletion. Mining activities will be planned so as to extract only the profitable gold and silver resources and only the necessary construction rock for the Project. Land management on the mining site will minimize reserve “serilization” (limitation of future access to the reserve) and the selection of major facility sites (waste rock piles, tailings ponds or water catchment structures, etc.) was reasonably made, based on an assessment of technical alternatives that would prevent limitation of access to potential mineral reserves. Some of the waste rock will be used as construction material. Depending on the economic conditions and technological progress, the waste rock and tailings might become a mineable resource for the future.
3 Technological Hazards and Risks

3.1 Identification and Presentation of the Hazardous Substances Used in the Project

3.1.1 Hazardous substance inventory

3.1.1.1 The ore

The ore that will be mined at Roșia Montană contains, apart from Au and Ag, a number of metals including: Ca, Mg, Na, Cu, Hg, As, Pb, Zn, Fe, Mn etc. in the form of: apatite, mixed Fe and Mn carbonate, muscovite, orthoclase, pyrite, quartz and rutile. The specifics of the metal extraction process involves the existence of the following hazardous substances and materials on the site:

- Solid Sodium Cyanide and in 20% solution;
- Hydrochloric Acid 32 %
- Solid Sodium Hydroxide and in 20% solution;
- Cyanide containing slurry;
- Cyanide rich solution;
- Process water with cyanides;
- Technical Ammonium Nitrate;
- Sodium Hypochlorite solution;
- Lime (quicklime, slaked lime and lime wash);
- Liquefied Petroleum Gas (LPG);
- Gasoline
- Diesel;
- Compressed Oxygen;
- Sodium metabisulphite;
- Copper Sulfate
- Mercury;
- ARD

3.1.1.2 The slurry

It results from cyanide leaching retains in its composition the substances contained in the raw materials plus calcium hydroxide, sodium cyanide, and low levels of chlorides with a reduced gold and silver content. It is notable that following the chemical processes, the form in which these substances are present is radically changed, with the presence of (soluble and insoluble cyanides) a defining factor of their hazardousness. It should also be noted that in recirculation, clarified water becomes gradually enriched with soluble forms, the trend being toward reaching the solubility limit. Slurry is a mix of solids and water, with approximately 48% solids (mass ratio) The composition of the liquid phase ranges on a broad scale (Table 7-11.)
Table 7-11. The composition of the liquid phase of the slurry

<table>
<thead>
<tr>
<th>Indicator</th>
<th>UM</th>
<th>Water in slurry (CIL)</th>
<th>Water in slurry (after detox)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CN</td>
<td>mg/l</td>
<td>193-210</td>
<td>5.8-19.3</td>
</tr>
<tr>
<td>WAD CN</td>
<td>mg/l</td>
<td>180-199</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/l</td>
<td>8.7-10.4</td>
<td>9-17</td>
</tr>
<tr>
<td>Zn</td>
<td>mg/l</td>
<td>5.2-6.2</td>
<td>0-0.6</td>
</tr>
<tr>
<td>OCN</td>
<td>mg/l</td>
<td>110-120</td>
<td>205-210</td>
</tr>
<tr>
<td>Co</td>
<td>mg/l</td>
<td>0.3-0.5</td>
<td>0.4-0.7</td>
</tr>
<tr>
<td>Ni</td>
<td>mg/l</td>
<td>0.1-5.3</td>
<td>0.3-3.1</td>
</tr>
<tr>
<td>Fe</td>
<td>mg/l</td>
<td>1.9-3.4</td>
<td>2.2-2.7</td>
</tr>
<tr>
<td>PH</td>
<td></td>
<td>10.5-11</td>
<td>8.1-8.4</td>
</tr>
</tbody>
</table>

3.1.1.3 Process water with cyanides
Process water with cyanides mainly consists of recycled clarified water from the decant pond and variable amounts of ARD treated wastewater and fresh water. The estimated average chemical composition of the water stored into the TMF pond is presented in table 7-12.

Table 7-12 The estimated average chemical composition of the water stored into the TMF pond

<table>
<thead>
<tr>
<th>Indicator</th>
<th>UM</th>
<th>Decant Water (from the TMF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CN</td>
<td>mg/l</td>
<td>1.13-5.09</td>
</tr>
<tr>
<td>WAD CN</td>
<td>mg/l</td>
<td>0.22-0.77</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/l</td>
<td>0.1-0.15</td>
</tr>
<tr>
<td>Zn</td>
<td>mg/l</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>OCN</td>
<td>mg/l</td>
<td>350-390</td>
</tr>
<tr>
<td>Co</td>
<td>mg/l</td>
<td>0.1-0.5</td>
</tr>
<tr>
<td>Ni</td>
<td>mg/l</td>
<td>0.2-0.4</td>
</tr>
<tr>
<td>Fe</td>
<td>mg/l</td>
<td>0.2-1.4</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>8-11</td>
</tr>
</tbody>
</table>

3.1.1.4 The rich solution
The rich solution resulting from elution contains about 3 % NaCN (excess sodium cyanide and complex gold and silver cyanides and others (e.g. Mercury) plus 2% NaOH and impurities. Besides extraction of the gold and silver, electrolysis involves a number of other chemical and electrochemical processes that gradually reduce the cyanide content, which can become 50% or less of the initial amount.

3.1.1.5 Acid runoff collected in the Cetate drainage pond
Acid runoff collected in the Cetate drainage pond will come from drainage of historical mining works (including the Adit 714 runoff) and the new mine. The probable composition of such waters would be very similar to that determined by analysis (see table 7-13).

Table 7-13 The probable chemical composition of acid runoff collected in the Cetate drainage pond

<table>
<thead>
<tr>
<th>Indicator</th>
<th>UM</th>
<th>Roşia Stream</th>
<th>714 Adit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>2.9 – 5.0</td>
<td>2.7 – 3.4</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/l</td>
<td>0.006 – 0.047</td>
<td>0.079 – 1.74</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/l</td>
<td>0.014 – 0.038</td>
<td>0.097 – 0.351</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/l</td>
<td>86 – 152</td>
<td>104 - 400</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/l</td>
<td>0 – 0.04</td>
<td>0.077 – 1.175</td>
</tr>
<tr>
<td>Cobalt</td>
<td>mg/l</td>
<td>0.011 – 0.188</td>
<td>0.240 – 0.947</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/l</td>
<td>0.263 – 0.933</td>
<td>0.341 – 3.16</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/l</td>
<td>3.41 – 57.2</td>
<td>225 - 578</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/l</td>
<td>15 – 51</td>
<td>86.5 - 116</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/l</td>
<td>16.1 – 62.5</td>
<td>19.5 - 475</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>mg/l</td>
<td>0.0063 – 0.009</td>
<td>0.0004 – 0.03</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/l</td>
<td>0.031 – 0.139</td>
<td>0.483 – 0.732</td>
</tr>
</tbody>
</table>
3.1.2 Physico-Chemical Characteristics of the Main Hazardous Substances Present
The term 'cyanide' refers to a singular charged anion made of one carbon and one nitrogen atom connected by a triple link, CN. The most toxic form of is free cyanide, which includes the anion itself and hydrocyanic acid, HCN, in gas or liquid form. At pH 9.3-9.5, CN ad HCN are in equilibrium, present in equal amounts. At pH over 11, more than 99% of the cyanide will remain in the solution as CN, while at pH 7, more than 99% of the cyanide will be in the form of HCN. Although cyanide is very soluble in water, its solubility decreases with an increase in temperature and in high salinity. Both HCN gas and solution are colorless and smell of almonds, although not everybody can detect the smell.

3.1.2.1 Hydrocyanic acid (HCN)
HCN (CAS 74-90-8) is a colorless toxic liquid with a characteristic almond smell. At 25° C it is a low viscosity fluid boiling at 25.79° C. HCN is miscible with water in any proportion, and soluble in ether. HCN spontaneously polymerizes if not absolutely pure or stabilized. HCN is a very weak acid, with an ionization constant in the same order of magnitude as natural amino-acids.
Synonyms: hydrocyanic acid, prussic acid, formo-nitrile

Molecular mass: 27,03
Melting temperature: -13,24 °C
Boiling temperature: 25,70 °C
Density, liquid, g/ml: 0 °C 0.7150;
10 °C 0.7017;
20 °C 0.6884
Solubility in water (log Ks) 9.2
Threshold of perception: in water 0.17 ppm
in air 0.58 ppm
Self-ignition temperature: 538
Flammability point, °C -17.8
Flammability limits, % 5.6 – 40
Explosion limits upper, 40%, lower 5.6%
Toxicity for fish LC50, mg/l 0.05 to 0.18

Ionic cyanides:
Sodium Cyanide (CAS 143-33-9), NaCN is a white, cubic crystalline solid, very soluble in liquid ammonia. It is odorless when dry, but releases an almond smell when moist.
Molecular mass: 49,01
Melting temperature: (100%) 563,7 °C; (98%) 560 °C
Boiling temperature (extrapolated): 1500 °C
Density, g/cm³: Cubic 1.6; Orthorhombic 1.62-1.624
Solubility in water 48 g/100 ml at 10°C
It is not flammable, explosive or combustible.
Toxicity for fish LC50, mg/l 0.23 to 0.4

Calcium Cyanide Ca(CN)₂ is easily soluble in water, water solution slowly releasing HCN. It is one of the free cyanides.

Cuprous Cyanide, CuCN, is relatively insoluble in water (log Ks = -15.9) and is one of the total WAD cyanides.
Zinc Cyanide, ZnCN, is relatively insoluble in water (log Ks = -19.5) and is one of the total WAD cyanides.

Nickel Cyanide, Ni\((CN)\_2\) is relatively insoluble in water (9.1 x 10\(^{-4}\) g/ 100 water at 25\(^\circ\) C) and is one of the total WAD cyanides.

**Complex cyanides**

**Weak Complex Cyanides:** \([Cd(CN)\_4]^{2-}\) is a weak complex (log Ke = 17.9) and is one of the total WAD cyanides.

\([Zn(CN)\_4]^{2-}\) is a weak complex (log Ke = 19.6) and is one of the total WAD cyanides, fish toxicity LC\(_{50}\) = 0.18 mg/l.

**Moderate Complex Cyanides:**

\([Ni(CN)\_4]^{2-}\) is a moderately strong complex (log Ke = 30.2) and is one of the total WAD cyanides, fish toxicity LC\(_{50}\) = 0.42 mg/l.

\([Cu(CN)\_3]^{2-}\) is a moderately strong complex (log Ke = 16.3) and is one of the total WAD cyanides.

\([Cu(CN)\_2]^{+}\) is a moderately strong complex (log Ke = 21.6) and is one of the total WAD cyanides, fish toxicity LC\(_{50}\) = 0.71 mg/l for 24 hour exposure.

\([Cu(CN)\_4]^{3-}\) is a moderately strong complex (log Ke = 23.1) and is one of the total WAD cyanides.

\([Ag(CN)\_2]^{+}\) is a moderately strong complex (log Ke = 20.5) and is one of the total WAD cyanides.

**Strong Complex Cyanides:**

\([Fe(CN)\_6]^{4-}\) is a strong complex (log Ke = 35.4) and is one of the total cyanides, fish toxicity in the light LC\(_{50}\) = 35 mg/l and in darkness LC\(_{50}\) = 860-940 mg/l.

\([Fe(CN)\_6]^{3-}\) is a strong complex (log Ke = 43.6) and is one of the total cyanides, fish toxicity in the light LC\(_{50}\) = 35.2 mg/l and in darkness LC\(_{50}\) = 860-1210 mg/l.

\([Au(CN)\_2]^{+}\) is a strong complex (log Ke = 38.3) and is one of the total cyanides.

\([Co(CN)\_6]^{3-}\) is a strong complex.

3.1.2.2 Sodium hypochlorite

Sodium hypochlorite is a water soluble complex, with melting point -60\(^\circ\)C and boiling point (with break down) in the range of 48-76 \(^\circ\)C, and vapor pressure at 20 \(^\circ\)C 17.5 mmHg. It is normally an aqueous solution, of a slight greenish yellow, with characteristic chlorine smell, rather stable in adequate storage. Sodium hypochlorite is unstable, the breakdown speed of the aqueous solution increasing with the concentration, exposure to solar radiation or sources of heat, pH decrease and metal contamination (Nickel, Cobalt, Copper, Iron). It is incompatible with acids, ammonia, urea, ammonium nitrate, cellulose and other oxidizable substances. Thermal oxidizing break down will release toxic gases containing sodium oxide and chlorine. The solutions are neither flammable nor explosive.

3.1.2.3 Sodium hydroxide

Sodium hydroxide (NaOH) is a white, hygroscopic, odorless solid. It is fully soluble in water, soluble in alcohol, methanol and glycerin, insoluble in acetone and ether. When dissolved in water, it releases an important amount of heat. It is normally an aqueous solution, of a slight greenish yellow, with characteristic chlorine smell, rather stable in adequate storage. Sodium hypochlorite is unstable, the breakdown speed of the aqueous solution increasing with the concentration, exposure to solar radiation or sources of heat, pH decrease and metal contamination (Nickel, Cobalt, Copper, Iron). It is incompatible with acids, ammonia, urea, ammonium nitrate, cellulose and other oxidizable substances. Thermal oxidizing break down will release toxic gases containing sodium oxide and chlorine. The solutions are neither flammable nor explosive.

3.1.2.4 Hydrochloric acid

Hydrochloric acid (HCl) is a pale yellowish liquid, with strong pungent smell (odor threshold 0.1 in 5 ppm), with boiling point -84 \(^\circ\)C and melting point -112 \(^\circ\)C, and vapor pressure is 4
Chapter 7 Risks

atm at 17.8 °C. It is easily soluble in water (0.823 g/l at 0 °C ad 0.561 g/l at 60 °C). Freezing points are -17.17°C for a 10.81 % solution and −46.2 °C for the 10.81 % solution. It has good chemical and thermal stability (breaks down at more than 1782 °C). It reacts with water generating thick vapor HCl fog, attacks most metals with Hydrogen release and reacts violently with alcohols, hydrocyanic acid and potassium permanganate. It is non-combustible, but at high temperature releases hydrogen and chlorine.

3.1.2.5 Quicklime
Quicklime (CaO) is a white, hygroscopic solid, easily soluble in water, forming slaked lime, Ca(OH)₂. CaO reacts violently with acids, halogens and metals.

3.1.2.6 Metabisulfite
Metabisulfite (Na₂S₂O₅) is a sulfur smelling white powder, thermally decomposing at 150 °C into sulfur oxides. It is a strong reducing agent and reacts with oxidants. It reacts violently with sodium nitrite, NaNO₂, and in the presence of acids, metabsulfite releases sulfur oxides. It is an irritant and a toxicant by inhalation, toxic for the aquatic environment.

3.1.2.7 Copper sulfate
Copper sulfate (CuSO₄·5H₂O) is a blue solid, thermally decomposing at 110 °C releasing toxic and corrosive sulfur oxides vapors. The aqueous solution is slightly acidic. It is an irritant and a toxicant by inhalation.

3.1.2.8 Ammonium nitrate
Ammonium nitrate (NH₄NO₃) is a white, hygroscopic substance, a strong oxidant, explosive in the presence of combustible substances or reducing agents. An irritant and toxicant when it explodes, as it decomposes thermally at 140°C forming nitrogen oxides and ammoniac. Sensitive to mechanical shock if mixed with organic substances.

3.1.2.9 Mercury
Mercury is a heavy metal (molecular weight 200.61) liquid at normal temperatures, releasing vapors at 20° (vapor pressure 0.012 mmHg), boils at 365.58° and melts at -38.87°. In contact with moist air it oxidizes easily forming a layer of mercurous oxide (Hg₂O). Found in nature in the form of mercury sulfide (HgS), an ore known as cinnabar, from which it is extracted at 500-600°. The resulting mercury vapors condensate and release a collateral product —SO₂. In some mines – as in Almaden (Spain), it is found in geodes as liquid mercury, and in Yugoslavian mines it is found impregnated in the shale. It is widespread in soil and water in low concentrations ranging between 0.005-0.25 ppm. Investigations conducted in various industrialized countries show that 25 % of the mercury is used in the industry of alkaline chlorine compounds, 20 % in electrical material, 15 % in dyes, 10 % in measuring and control devices (thermometers, barometers, etc.), 3 % in dentistry, 2 % in laboratories, 20 % in other uses (catalysts, ingredients for pharmaceutical preparations and cosmetics, amalgamation processes, preservative agents for paper paste, etc.). In its metallic form, it is used in the manufacturing of various laboratory equipment, thermometers, barometers, mercury lamps, the manufacturing, repair or maintenance of electric meters, in the chemical industry for the preparation of chlorine, alkalis, acetic acid and acetaldehyde.

3.1.3 The physical and chemical behavior of the main hazardous substances, under normal operating conditions and in foreseeable accident conditions
Cyanide is highly reactive, forming simple salts with the cations of alkaline metals and ion complexes of various strengths with several metal cations. The solubility of these salts is influenced by the cation and the pH. Alkaline sodium, potassium and calcium cyanides are toxic, as they are highly soluble in water, therefore dissolve quickly to form free cyanide. Conversely, the cyanides of heavy metals are generally insoluble, with the exception of mercuric cyanide, Hg(CN)₂, which is a covalent, soluble combination. Given the weak acid
character of the Hydrocyanic acid, cyanides in aqueous solutions are only stable in the alkaline pH range.

Cyanide forms ionic complexes of diverse stability with various metals. The weak or moderately stable compounds, such as cadmium, copper and zinc compounds, are classified as weak acid dissociable (WAD). Although metal-cyanide compounds, they are less toxic in themselves than free cyanide, in their breakdown releasing both free cyanide and the cation that may be equally toxic. Even in the neuter pH range of most surface waters, the cyanide-metal WAD compounds may break down sufficiently to become environmentally hazardous if present in large quantities. The table 7-14 shows the value of the dissociation constant ant the approximate concentration of free cyanide for various initial concentrations of the cyanide complex:

Table 7-14 the value of the dissociation constant ant the approximate concentration of free cyanide for various initial concentrations

<table>
<thead>
<tr>
<th>No.</th>
<th>Complex</th>
<th>Dissociation constant</th>
<th>Initial complex concentration [mg/l]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Free CN- concentration [mg/l]</td>
</tr>
<tr>
<td>1</td>
<td>Ag(CN) -2</td>
<td>1x10 -21</td>
<td>1.23x10-6</td>
</tr>
<tr>
<td>2</td>
<td>Cu(CN)2-3</td>
<td>5x10 -28</td>
<td>2.65 x10-4</td>
</tr>
<tr>
<td>3</td>
<td>Cd(CN)2-4</td>
<td>1.4x10 -12</td>
<td>1.6</td>
</tr>
<tr>
<td>4</td>
<td>Zn(CN)2-4</td>
<td>1.3x10 -17</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Cyanide forms compounds with Gold, Mercury, Cobalt, Iron, that are very stable in low acidity conditions. Ferrous cyanide complexes are very important due to the abundance of iron in the soil and the extreme stability of this complex in a variety of environmental conditions. However, ferrous cyanides are photochemically decomposed and release cyanides if exposed to ultraviolet light.

Metal-cyanide complexes also form salt-type compounds with the metal cations such as potassium ferro-cyanide (K₄Fe(CN)₆) or copper ferrocyanide (Cu₂[Fe(CN)₆]₃), the solubility of which varies with the metal cyanide and the cation. Almost all the alkaline salts of metal cyanides are very soluble, after dissolving, these double salts decompose and the released metal cyanide compound may produce free cyanide. Iron cyanide complexes will form insoluble precipitates with Iron, Copper, Nickel, Manganese, Lead, Zinc, Cadmium, Tin, and Silver. These non-toxic salts remain stable on a pH range of 2 to 11. Complex Iron cyanides are generally very stable. Although the ion hexacyanoferrate (III) also known as ferricyanide [Fe(CN)₆]³⁻, is more stable than the hexacyanoferrate (II) also known as ferrocyanide [Fe(CN)₆]⁴⁻, their stability constants being 10⁴⁴ and 10³⁷, respectively, the equilibrium: [Fe(CN)₆]n⁻ < → Feₙ⁺ + 6CN⁻ is reached much faster in the first case than in the latter. Thus, ion [Fe(CN)₆]⁴⁻ is more inert, and therefore non-toxic, unlike ion [Fe(CN)₆]³⁻, although the value of the stability constant would indicate the reverse.

Cyanide reacts with some species of sulfur to form the less toxic thiocyanate. Potential sulfur sources include sulfur containing minerals and sulfates such as calcipyrite, calcosine and pyrite or marcasite pseudomorphosis after pyrrhotine, and their oxidation products, such as polysulfides and tio-sulfates. SCN decomposes in low acidity conditions, but normally it is not considered a WAD cyanide as it has similar properties to cyanide complexes. HSCN is
about 7 times less toxic than HCN, but a strong lung irritant, as SCN chemically and biologically oxidizes into carbonate, sulfate and ammonia.

Cyanide oxidization, either by a natural process or by the treatment of cyanide containing effluents, may produce the OCN⁻ cyanate anion. Cyanate is less toxic than HCN and quickly hydrolyzes into ammoniac and carbon dioxide. Cyanide oxidization into cyanate, which is less toxic, typically requires a strong oxidizing agent such as ozone, oxygenated water, SO₂/air or hypochlorite. However, cyanide absorption into organic and inorganic substances in the soil appears to foster oxidation under natural conditions. Cyanides and metal cyanide complexes are absorbed by the organic and inorganic constituents of the soil, including aluminum, iron and manganese oxides, some types of clay and organic carbon. Although the cyanide retention power of some inorganic materials is uncertain, cyanides are strongly linked to organic matter.

Under aerobic conditions, microbial acivity amy degrade cyanide into ammoniac, then oxidizing into nitrate. This process was proven effective at cyanide concentrations of up to 200 ppm. Although biological degradation also occurs in anaerobic conditions, cyanide concentrations of more than 2ppm are toxic for these microorganisms. Biological oxidation breaks down free cyanides into HCO₃⁻ and NH₃, and by subsequent nitrification NO₂⁻ and NO₃⁻. Other degradation products such as SCN⁻ are also subjected to biological degradation, with HCO₃⁻, HSO₄⁻ and NH₃ generation.

As pH decreases, HCN may be subjected to hydrolysis, with the generation of formic acid or ammonium formiate. Although the reaction is not fast, it may be significant for groundwater, in anaerobic conditions.

One of the most important reactions affecting free cyanide concentration is HCN volatilization, of key importance in regard of accident hazard. Free cyanide does not resist in most surface waters because the pH of such waters is usually less than 8, therefore HCN will volatilize and disperse. The amount of cyanide lost in this way will increase with the decrease of pH and the temperature increase.

Gas HCN release from the free cyanide containing solution will very much depend on their salinity. The figure 7.12 shows pH and salinity dependence of the cyan ion hydrolysis.
The meaning of the “I” symbol is ion strength, or salinity. Note that there will be the more gas HCN the lower the solution pH is than the pKa. The correlation between pKa and salinity is:

<table>
<thead>
<tr>
<th>I</th>
<th>0</th>
<th>0.1</th>
<th>0.5</th>
<th>1</th>
<th>3</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>pKa</td>
<td>9.22</td>
<td>9.05</td>
<td>8.95</td>
<td>8.95</td>
<td>9.22</td>
<td>9.66</td>
</tr>
</tbody>
</table>

Gas HCN release will be at first diminished by salinity increase, but at salinity more than 3 it will be fostered. Therefore, in very saline solutions gas HCN will form even at higher pH values. 0.5 to 1 salinity will allow work with slightly lower pH values, with the same amount of HCN volatilizing, therefore safer operating conditions.

### 3.2 Identification of Relevant Safety Sections and Sources of Hazard

Project activities are very complex and cover an extensive area. Various areas of the site will have particularities that will allow the definition of several safety sections. Their locations are given in Annex no.3 and they are described in the following, focusing on a description of the operations that are important for safety and may become sources of accidents for Roşia Montană Project.

#### 3.2.1 Mining Operations Areas

Following detailed geotechnical investigation the following base parameters have been adopted for the design of the four pits extending to depths ranging between 220 and 260 m bellow the current topographical level:

- Ramp width of 27 m, including berms and ditches;
- Ramp gradient of 8% with occasional use of 10%, where this would not create a hazard;
- Bench height of 10 m;
- inter-ramp slope angles less than 42° overall; lower angles may apply within vent breccias.
Mining operations at Roșia Montană will employ conventional open-pit mining techniques for drilling and blasting, loading and haulage operations, using blast-hole drills, hydraulic shovels, front-end-loaders and off-road dump trucks. The pits will be deepened throughout the operations phase by the mining of a series of benches using drilling, blasting, and heavy excavation equipment. A general description follows:

- Production drilling will be performed by two drills capable of drilling 10 m benches in a single pass;
- A blast-hole pattern of approximately 8 m by 8 m will be used to produce blasted material meeting the required material size specifications for the primary crusher;
- ANFO (Ammonium Nitrate-Fuel Oil mixture) will be the primary blasting agent;
- Charges will be detonated with millisecond delays, in such a manner as to minimize noise and vibration and maintain economic parameters related to rock fragmentation.

It is estimated that 0.25 kg of explosives will be consumed for each tonne of rock blasted. Due to the numerous underground adits and workings below the pit footprint, added precautions will be taken to prevent unexpected cave-ins and ensure that worker safety is maximised, and also that any archaeological remains are recorded and recovered. The AMFO explosive mix (NH₄NO₃ + diesel) will be prepared at the pit, by means of special mobile equipment, and packed in protective foil to protect against bad weather (ammonium nitrate loses its specific properties in contact with water). Explosive priming will involve a Nonel type starter with a wick to ensure blasting even in bad weather and facilitate location of misses (unblasted holes) if they occur.

Ground vibrations are an integral part of the rock blasting process. Sudden acceleration of the rock around the hole wall, due to the action of blasting gas pressure will induce dynamic tensions into the surrounding rock mass. These tensions will generate an ondulatory movement in the ground that will spread in concentric waves from the blasting point mainly along the soil surface. The ondulatory movement will dampen as it moves away from the point of origin and will attenuate with the distance.

The explosive rock blasting operation in the pits will always cause vibrations or seismic waves, the purpose of blasting being that of fracturing the rock mass for processing. This operation requires enough energy to exceed rock resistance and elasticity limit. The remaining energy will pass through the rock mass distorting, but unable to fracture it, which what causes the seismic waves.

Upon concluding the works, perimeter berms around the pits will be built for the purpose of public safety, and to control vehicle access to the pits. The berms will be built of waste rock as an ongoing process during operations.

### 3.2.2 Site haul routes

Primary surface haul roads will be constructed from the mining locations to all waste or ore destinations (crusher, process plant, low grade ore and waste rock stockpiles). These haul roads will be constructed to a minimum of 27 m wide to allow for safe dual lane operation for the open-pit haul trucks. The roads will be surfaced with crushed gravel and maintained by watering and grading to a high standard to reduce rolling resistance, increase tire life, maximise haul truck productivity, and control dust.

In general, the on-site access roads will be retained during the early years of closure to continue access to work areas undergoing reclamation activities. Lockable gates and appropriate signage will restrict use of the roads. Once most of the major closure work has been completed, the culverts from the access roads will be removed and the roads will be ripped or scarified and revegetated. Certain access roads will be retained to allow for monitoring activities or, as required, for the planned post-mining land use.
3.2.3 Process Plant

Annex no.4 shows the location of the sources of hazard identified on the Process Plant site. The process plant will be located on the watershed between the Salistei Valley and the Roşia Valley. This location was chosen for its proximity to the Cârnic and Cetate pits, which provide the majority of the proven and probable reserves, as well as its proximity to the TMF to be situated in the Corna Valley. The process plant will be air conditioned to enable continuous operation throughout the year.

After the ore is transported to the processing plant, it will be reduced to the appropriate size for the chemical-based gold and silver recovery process. The general technology and ore processing methods incorporate the following, principal elements:

- Single stage crushing of Run of Mine (ROM) ore by means of a gyratory crusher;
- Stockpiling of crushed ore;
- Reclalm of crushed ore and wet grinding using a semi-autogenous grinding (SAG) mill followed by two ball mills in parallel;
- Cyanide leaching, commencing in the grinding circuit, from which a classified fine product passes to the CIL tanks to undergo agitation and continued cyanide leach;
- Adsorption of extracted gold and silver onto activated carbon within the CIL tanks followed by separation of the loaded carbon and elution of the gold and silver from the activated carbon in pressure vessels;
- Electro-winning to recover gold and silver stripped from the activated carbon, as a precious metals sludge, and smelting of this sludge to produce gold and silver ingots (doré);
- Thickening of the tailings;
- Residual cyanide detoxification before the tailings leave the process plant containment zone;
- Placing of treated tailings into the TMF;
- Water reclamation from the TMF for recycling and re-use;
- Fresh water abstraction from Aries River.

The crushed ore stockpile, carbon-in-leach (CIL) cyanidation tanks, cyanide detoxification tanks and thickener will be located outdoors, while most other facilities will be located inside specially designed buildings.

The following is a summary description of the identified sources of hazard.

3.2.3.1 Sodium Cyanide Solution Storage

Cyanide will be delivered in ISO compliant 16 t bulk containers (especially designed and constructed), as a dry flake solid. The cyanide will be dissolved in the transport containers with a caustic solution (process water and sodium hydroxide) recirculated at a flow rate of approximately 40 m³/h from a agitator mix tank.

The mix tank is designed to take on the entire contents of the transport container. It is a vertical cylinder open at the top, with a flat bottom flush with the ground. It is 5 m in diameter 5.5 m high and with a total volume of 87 m³. Once the contents of a container is dissolved, the cyanide solution is brought to a concentration of about 20% (or 10.6% CN ions), with a density of about 1.12 and pH at least 11, then transferred into a cylindrical covered storage vessel with flat bottom, 6 m n diameter, 7 m high and capacity 216 m³. The two storage tanks are located in a specially designed and built structure, with a containment vat of 110% the capacity of the storage tank equipped with a sump and submersible pump.
for the capturing and recirculation of any leak and spill into the process. From the storage tank, the cyanide solution is passed into the CIL leaching circuit (at a flow rate of about 7.3 m³/hr) and into the elution circuit at a flow rate of about 0.54 m³/hr.

3.2.3.2 Hydrochloric acid storage

It will involve a 20 m³ storage tank made of corrosion resistant material located in a specially designed and built structure with a containment vat of at least 22 m³ capacity.

3.2.3.3 Carbon in Leach (CIL) Circuit

The CIL feed slurry is mixed with cyanide solution and suspended slake lime (needed for pH regulation at 10-11) and leached in two parallel trains into each of seven agitated and oxygenated tanks (leaching tanks). The slurry contains 40-45% solids, has specific weight 1.37-1.45 and flows at a rate of 1565-1836 m³/hr, which gives it a 3.4 hour time in each tank. Each leaching tank is 18.7 m in diameter 19 m high and with a total volume of 5000 m³. For the achievement of the slightly oxidizing environment required for the extraction process, oxygen is blown into the reaction mass at a rate of 30-50 kg/hr in the first tanks and 20-40 kg/hr in the next two. No oxygen is added in the last three tanks of each set.

During the reaction that occurs in this circuit, the gold and silver form cyanide complexes in alkaline solution. To ensure a high efficiency of extraction, excess free cyanide ions are required. Dilute sodium cyanide solution is added as required to the first four tanks of each train of CIL tanks in order to provide the minimum free cyanide concentration required in the circuit (at first 500 mg/L and a sustained 300 mg/L in the following tanks). This is equivalent to a cyanide dosage rate of 0.7 kg/t of slurry.

As CN⁻ is the active ion in the gold and silver complexation process, it is important that the cyanide is stabilized by the maintenance of a sufficiently high pH (more than 10). This is achieved through the addition of hydrated lime slurry to the CIL feed (as required) to CIL tanks.

The CIL tanks are fed with activated carbon particles that adsorb the precious metals leached by the cyanide. The concentration of activated carbon in the slurry will be 7-15 g/L. Each tank will have internal screens to prevent the activated carbon particles from discharging from the tank with the residue. Fresh carbon is placed in the last CIL tank where it starts to scavenge precious metal values from the leach residue slurry. The carbon loads with these precious metals it will be periodically pumped counter-current to the leached residue flow to the next upstream tank. The most highly loaded carbon in the first cyanidation tank will be pumped with the residue to one of two loaded carbon recovery screens, and together, the screened slurry will be directed to the next leaching tank, while the carbon will discharge gravitationally into one of the two acid rinsing columns.

Chemical reactions with the ore, carbon and air will turn the cyanide into other chemical species, such as cyanates and thiocyanates. Oxidation will form ammoniac and ammonium ions, as well as carbon dioxide. Cyanide will also be lost from the leaching system by absorption of metal complexes (gold, silver, iron, copper, nickel and zinc) on the activated carbon. Cyanide loss will also be caused by the formation of insoluble ferro-cyanide metal compounds.

Volatilization is another potential cause of cyanide loss, but it is minimized by ining pH 10.5, when cyanide is at its most reactive and is not volatile. However, for concentrations of 300 mg/L and pH 10.5, about 5% of the cyanide will be in the form of hydrocyanic acid and it is expected that it volatilize, especially as the tanks are agitated and some have oxygen blown into them. The experience of similar circuits has shown that about 2% of the HCN will volatilize but without impacting on personnel health and the environment, due to the poor stability of the acid, the small percentage that will volatilize, dispersion, and the fact that the reaction vessels are open. Moreover, a study of the effects of HCN volatilization was conducted by TRANSGOLD S.A. BAIA MARE and its conclusions could not demonstrate any adverse effect of this volatilization.

It may be estimated that a little over 50% of the cyanide will be used in the leaching process.
3.2.3.4 Tailings Thickener
From the last tank in each set, the slurry will gravitationally flow into the feeding tank of the tailings thickener at a rate of about 3.600 m³/hr, with a solid content of about 45% and pH 9-11, to be mixed with flocculation agents that help settle the solid fraction. The thickener provides a method to increase the solids content of the underflow slurry and will generate a relatively clear overflow. The thickener overflow will discharge (at a rate of about 985 m³/hr, with an estimated content of total cyanide 219 mg/L and pH 9-11) into the grinding circuit for reuse and cyanide recovery and the thickened tailings (at flow rate about 2708 m³/hr and estimated total cyanide content of 181-189 mg/L or WAD cyanide 177-187 mg/L and pH 9-11) will be pumped into the cyanide detoxification circuit.

The thickener is 42 m in diameter and has a volume of about 3700 m³; it is placed outside, in an impervious concrete containment vat (together with the feeding tank and the two DETOX reactors) of containment capacity 110% of its volume.

Some of the cyanide is expected to volatilize. (about 13 t/yr). The decant process will provide recirculation of about 3.2 t/hr cyanide in the process water, while about 1.9 t/hr will pass into the detoxified, tailings sent to the TMF.

3.2.3.5 DETOX Installation
The Project will use the INCO SO₂/air on tailings procedure for the detoxification of cyanides contained in the tailings. This is a proven technology that has been adopted in more than 90 mines, worldwide is the BAT in the field, and ensures compliance with the Draft Directive on cyanide concentrations in tailings slurry sent to the TMF. WAD Cyanide concentrations will be reduced to less than 10 mg/L before the treated tailings leave the confines of the process plant. The cyanide detoxification facilities will consist of two tanks operating in parallel. Treated water or freshwater will be added to the cyanide detoxification feed header to dilute the underflow of tailings thickener from normally 60% solids to 50% solids.

Each leaching tank is 13 m in diameter 14.5 m high and with capacity 1688 m³.

The estimated residence time of the suspension in each of the reactors is 1.5 hours. The suspension goes down to ambient temperature at a rate of approximately 1125 m³/hr, has relative density 1.45, and pH is maintained at 8-10.

Air will be bubbled into each reactor. Airflow will be about 9 Nm³/hr and controlled at each tank through a rotameter.

The source of SO₂ is sodium metabisulphite – (Na₂S₂O₅) a solution that will be metered into each tank depending on the WAD cyanide concentration in the tailings circuit. The control system then adjusts the flow of the SO₂ to effect detoxification.

A copper sulphate (CuSO₄) solution will be metered into each tank to maintain a required concentration of copper ion in solution to catalyse the detoxification reaction. Copper sulphate control is managed by the control system adjusting the dose rate based on the measures flow of solution into the detoxification reactors.

Lime slurry will be added to each tank via a ring main system to control the pH in the tanks at 8.5.

The pH control system includes duplicated meters that will ensure accurate control of this parameter. pH alarms will signal the potential triggering of the stop operation procedures by operating staff in case of lost control over the pH. An ion selective oxidation-reduction probe will be used in each reactor to evaluate the oxidation potential of the detoxified slurry and ensure no free cyanide remains. This same probe can be used as a control element in the basic automated control system employed. Reagent dosing will be controlled using ratio dosing based on the mass flow of both thickener underflow and the contained cyanide to ensure consistent discharge quality. Analytical procedures will provide the operators with quick and accurate cyanide measurements, which will allow for set-point adjustment as required to maintain process control.
Section 3: Technological Hazards and Risks

3.2.3.6 Enriched Solution Storage
Elution (desorption) of precious metals from the activated carbon gives a gold and silver rich solution containing about 3% sodium cyanide and 2% NaOH, which is stored in special containers, four of about 280 m³ capacity each and one of 180 m³. These are located in an impervious concrete containment vat provided with a sump and a submersible pump.

3.2.3.7 DETOX Reagent Management
The reagent management facility of the DETOX installation will consist of the following main equipment:

- a. The metabisulfite preparation reactor is 4 m in diameter, 4.48 m high and has a capacity of 46.2 m³. The preparation contains about 20% metabisulfite, has relative density about 1.48 and pH 4. Solution consumption is about 60 m³/hr and supply will involve 1000 kg boxes.
- b. The copper sulfate preparation reactor is 3.5 m in diameter, 3.4 m high and has a capacity of 31.5 m³. The preparation contains about 15% copper sulfate, has relative density about 2.28 and pH 4. Solution consumption is about 60 m³/hr and supply will involve 1000 kg boxes.
- c. The flocculant preparation reactor (Ciba Magnafloc 5250) is 4.5 m in diameter, 4.3 m high and has a capacity of 68 m³. The preparation contains about 0.25% flocculant, has relative density about 1 and pH 7. Solution consumption is about 75 m³/hr and supply will involve 1000 kg boxes.

3.2.3.8 Reagent Storage and Handling
There will be a number of chemicals and reagents required for the project. Each of these chemicals and reagents will be stored on site in minimal quantities. The storage and handling areas will be designed and constructed in compliance with the norms and standards in force to prevent and minimize the risks and account for incompatibilities. The necessary reagents and chemical compounds include:

- Flocculant;
- Sodium metabisulphite;
- Copper sulphate;
- Smelting fluxes: silica, potassium nitrate, soda ash and borax;
- Activated carbon;
- Carbon dioxide.

3.2.3.9 Sodium Hydroxide Storage
It will involve a 40 m³ storage tank made of stainless steel, located in a specially designed and built structure together with a solid NaOH dissolving vessel (fed in 1000 kg batches) which is 3 m in diameter, 3.26 m high and has a capacity of 20 m³ both placed in an impervious containment vat of at least 44 m³ capacity. The NaOH solution is prepared at concentration 20% density about 1.2 and pH 12.

3.2.3.10 Lime Storage/Preparation
Dry lime will be added to the SAG mill feed conveyor and lime wash will be added to the agitated CIL tanks for pH control. Slaked lime is also dosed to the detoxification reactors to maintain pH control and treat acidic waters.

Raw quicklime in the form of clots is stored in a facility of 860 t capacity, then ground in the SAG, the capacity of which is 12 t/hr, with lime powder stored in a 600 t silo. The entire lime storage, grinding and handling system is connected to a dust control installation with a scrubber that guaranteed particulate emission levels below 2 mg/m³. The rinsing water used in the scrubber is recycled from a lime wash preparation reactor, 9.5 m in diameter, 11.4 m
high and a nominal volume of 738 m³. The resulting suspension is about 15%, with density 1.09 and pH 12.

3.2.3.11 Wet Ore Grinding
The ore grinding circuit will consist of a single SAG mill followed by two ball mills, operating continuously and in parallel.
Prior to grinding, dry lime will be added to the crushed ore ahead of grinding in order to ensure a protective alkalinity in the milling circuit and to create an appropriate pH in the CIL circuit. The overall grinding circuit will have an average throughput rate of 1,625 t/h new feed.

Crushed ore from the stockpile will be fed at a constant rate to the SAG mill. Feed into the mill from the conveyor will be mixed with aqueous mill solution, containing cyanide, which has been recovered as overflow from the CIL tailings thickener. The SAG mill discharge will be classified with a trommel, from which the undersize will be directed into a cyclone feed pump box.

The trommel undersize flows by gravity to the cyclone feed pump box from where it is then pumped to the two sets of classifying cyclone clusters. This separates the slurry into two streams:
- Cyclone overflow, which is the fine material suitable for processing in the CIL;
- Cyclone underflow, which is the coarse material that reports as feed to the two ball mills for further grinding.

Two ball mills operating continuously will be controlled remotely from the central control room. The ball mills discharge over trommel screens designed to scalp out remnant balls and unground material. The refuse discharged into a concrete bunker (and may be taken over by a front loader) and the overflow is mixed with the cyclone discharge of the SAG and transferred to the feeding pump of the CIL circuit.

3.2.3.12 Gold Desorption/Processing Area
The most highly loaded carbon in the first cyanidation tank will be pumped with the residue to one of two loaded carbon recovery screens. Then, the carbon, rinsed in a weak acid solution (to remove calcium deposits on the grain surface), will be neutralized by rinsing in diluted alkaline solution and then transferred to one of two parallel elution columns where a hot cyanide-caustic solution will be used to strip the precious metals from the carbon at a rate of 7.1 m³/hr (about 2% NaOH and 3% NaCN). The process is discontinuous and happens in three steps:
- lasting 90 min and involving heating the elution solution to 100°C by circulation through the first heat exchanger (hot oil – preheated elution solution);
- lasting 240 min and involving maintaining the elution solution at 127°C by circulation through a heat exchanger (hot oil – hot elution solution);
- lasting 30 min and involving cooling the elution solution to about 60°C by circulation through the first heat exchanger (hot oil elution solution – cold elution solution).

The heat exchangers will use thermal Mobiltherm 603 oil (heated by LPG combustion) and will be periodically rinsed (automatically) with sulfuric acid.

Stripped carbon from each elution column will be dried, reactivated in the reactivation oven (using LPG), reclassified according to size and reintroduced into the last tank of the cyanidation process. Carbon will be continuously reactivated.
The enriched solution will be pumped to the electrolytic cells, where gold and silver will be deposited on stainless steel cathodes. Electro-winning will operate in batch mode and will be started and stopped one to two times per day depending on the quantities of the metal to be processed. The working temperature of the solution in the cells is 60°C, the nominal cell
volume is 32 m³ and the total batch volume 303 m³, with solution flow into the cell 25 m³/hr. The necessary electric current will be supplied by a 4500 A transformer, and the technological parameters of the cells are: current density 6-20 A/mp, voltage 4+10 V and intensity 1300+4330A.

The gold and silver deposited on the stainless steel cathodes will be removed under a pressurized water jet, obtaining a sludge that will then be dehydrated in a batch press filter, the process being operated once or several times a day. Precious metals sludge from the filter press will then be loaded into charge containers (boats) on mobile carts. The boats will be inserted into the mercury retorts where the mercury would volatilize and be recovered into containers by means of vacuum pumps. Mercury vapors will be ducted to a condensation facility and a column filled with activated carbon impregnated with sulfur to capture any trace of residual non-condensed mercury vapors. Condensed mercury will be captured in the charge tank and stored. The retorted precious metal sludge is then fluxed (with silica, borax, nitrite) and melted in an induction furnace. The electric induction furnace will operate on a batch campaign basis in association with emptying and filtering of electro-winning cells and retorting. Doré will be cast into 25 kg ingots in a cascade mould. Anticipated operation is three batches per shift to the furnace, with five to 12 shifts per week. Off-gases from the induction furnaces will be drawn through a 5000 Nm³/hr extractor and passed through a scrubber to capture any precious metal or other dusts by rinsing with 5% diluted NaOH solution.

A general ventilation system captures the gases from electrolysis, carbon regeneration columns and other sources, providing a gas extraction rate of 46280 Nm³/hr at about 290 °C, sending them to a scrubber, where they are rinsed in water at an approximate rate of 5000 m³/h.

Of the eluted cyanide, about 50% will be lost in reactions occurring in the process, and the rest will be recycled in the process.

3.2.3.13 Process Water Tank
Treated water is stored in a tank of approximate capacity 12000 m³, 40 m diameter, 10 high located in the wastewater plant area with the fresh water tank, in a containment vat provided with drainage channels leading to the water catchment dam.

3.2.3.14 ARD Treatment Area
The wastewater plant is designed specifically to reduce dissolved metal concentrations and to meet the required quality parameters. The plant design capacity is 400 m³/hr has with the option for upgrading for additional capacity, if needed in the future. The plant will use a treatment process based on the lime neutralisation/precipitation method, which includes the following unit operations:
- Air oxidation;
- Lime neutralization/precipitation and pH control;
- pH adjustment with carbon dioxide (CO₂);
- Flocculation with solids recycle; and,
- Solids / liquid separation by settling in a clarifier.

Following the neutralisation and oxidation/precipitation steps, the solution will be discharged by gravity to the clarifier for solids - liquid separation. The clarifier capacity is about 2000 m³, 28 m diameter, and is designed for an average flow rate of 505 m³/h treated water, of pH 8.5. A flocculant will be added to the clarifier feed tank to aid the settling characteristics of the sludge in the clarifier.

When the wastewater plant is operating, discharges from the plant will be used primarily for dust suppression and in the process plant for dilution in the cyanide detoxification process.
Clarification underflow excess residue will report to the Tailings Tank for placement with the tailings in the TMF. Some discharge water of adequate quality standards will be used to maintain biological base flows in the Roşia and Corna Valleys during dry seasons; during wet periods, excess quantities of treated water, that are in compliance with water quality requirements, will be discharged to the Roşia Valley stream.

3.2.3.15 Compressed Air Plant
It includes 4 compressors (three in operation and one in reserve) that provide 950 kPa pressure and a flow rate of 6000 Nm³/hr. It is located within a sound insulated structure, on vibration dampening supports.

3.2.3.16 Oxygen Plant
It provides 90% pure oxygen at a maximum flow rate 250 kg/hr at pressure 40 kPa. The installation is placed indoors, and the buffer vessel outdoors.

3.2.3.17 Transformer Station (110 kV)
Its capacity is 10 MVA and it is equipped with protective and safety devices according to the specific norms.

3.2.3.18 Explosives storage
The fuel storage facility on the plant site will include a double wall aboveground storage tank for diesel (~ 800.000 liters) and a double wall underground tank for gasoline (~ 20.000 liters) located in an impervious containment watt.

3.2.3.19 Technological Lines
The management of water in the process plant is designed to maximise recycling of process water and to minimise process water effluent beyond the plant boundary with an aim to minimise demand for fresh water. There will be a demand for fresh water for:

- Reagent mixing;
- Gland seal water of process pumps;
- The elution circuit;
- Electro-winning;
- drinking water and water for fire protection;

Process solution and suspension circuits include pipelines and casings of various sizes, made of corrosion resistant material. Circulation through them will be both gravitational and by pumping.

3.2.4 Pipeline Routes
The proposed Roşia Montană processing plant will require a constant and reliable water supply. Processing and delivery of the tailings to the TMF will require approximately 1 tones of water per tones of ore. The requirement per tones of ore processed could be expected to vary in practice due to the variation in the hardness of ore, the moisture content, and ore mineralogy through the course of operations. There is a need to help ensure that there is never less than a minimum acceptable volume in the decant pond to ensure that there is sufficient still clear water to float the pump barge and keep the pump intakes clear of sediment, at the same time ensuring that the volume of water in the pond is within safety limits.

3.2.4.1 Tailings Delivery Pipeline
Detoxified tailings from the processing plant will be pumped from the tailings pump box located at the processing plant to several discharge points at the TMF at a rate of 2.349 m³/hr. The 5.2 km-long pipeline will be 800-900 mm in diameter and will generally follow the mine roads leading to the TMF. Suitable containment will be provided to control any
occurrences of spillage. The solids content of the tailings being transferred to the TMF will be approximately 48%, and the WAD cyanide content below 10 mg/L.

3.2.4.2 Clarified Water Pipeline
About half of the process water will go into the TMF pond and will be reclaimed by means of vertical turbine pumps mounted on a barge located on the TMF decant pond. Reclaim water will be pumped at a rate of about 1516 m³/hr through a combination steel (with liner) and HDPE pipeline to the Process Water Tank, located within the processing plant. The estimated initial pipeline length will be 5.1 km but it will gradually reduce as the tailings impoundment fills and the decant pond moves closer to the plant. The pipeline between the secondary containment dam and the TMF is 1200 m long and ensures the recirculation of TMF seepage at a rate of 114 m³/hr. The WAD cyanide content of these waters will be below 5 mg/L.

3.2.4.3 Cetate Wastewater Pipeline
The acid water captured in the pond will be pumped at a rate of about 378 m³/hr to the wastewater treatment plant, located in the processing plant. Due to the expected oscillations in the pond levels, the pumping station is anticipated to be located on a floating barge. The 300-mm pipeline will be buried along the access road to the plant, parallel with the fresh water supply pipeline, and it will be 1805 m long.

3.2.4.4 Treated Water Discharge Conduits and Channels
Baseflow in Roşia and Corna Streams will be supplemented by release of treated water from the wastewater treatment plant or from the fresh water supply system when necessary. The release points will be downstream of the Cetate Dam and the TMF Secondary Containment System. Minimal baseflows will be maintained by the diversion channels, release of treated water from the wastewater treatment plant, or from the fresh water supply system. The releases from the wastewater treatment plant will be increased as required to dispose of the project surplus water and the design capacity of the conduits leading to the Roşia Stream will be increased accordingly. Pipelines will be constructed to feed treated water discharge into graded conduits, which will be maintained by gravity flow from the discharge point from the wastewater treatment plant. Under extreme dry conditions, fresh water may be used to supplement the Roşia and Corna stream flow to maintain the biological baseflow. The treated water discharge into Roşia Valley will have a flow rate about 314 m³/hr (2080 m long pipeline or open channel from the industrial WWTP) and 20 m³/hr into the Corna (4900 m from the industrial WWTP to the secondary containment system).

3.2.5 Tailings Management Facility
The quantity of tailings disposed of annually will be about 13 million tons, the final amount at the end of the operations phase being about 218 million tons. Ore procession operation will generate detoxified tailings at a rate of approximately 13 Mt/year for approximately 17 years, producing a total of approximately 218 Mt. For the settling and disposal of this waste a decant pond was designed, after several sites were investigated, for the Corna Valley, not far from the process plant and south of it. The design containment capacity is sufficient for the lifetime of the Project, plus a safety volume for the case where larger amounts of ore might be processed.

The following main components have been included in the TMF:

- A containment structure (Coma Dam) made of rock to provide containment of the treated tailings;
- Coffer dam and runoff diversion channels;
- A basin for treated tailings, upstream of the embankment;
- A treated tailings delivery and water reclaim system;
• Seepage secondary containment and repumping system, and in later stages of the Project, a wastewater treatment facility for the contaminated pond water, proposed to be located downstream of the dam;
• A waterproofing system for the decant pond bottom;
• A complex geotechnical monitoring system;
• Service roads.

Exhibit 5 shows the final configuration of the Tailings Management Facility. Exhibits 6 and 7 show the design concept and cross-sections of the TMF dam and secondary retention dam. The substrate of the TMF consists of Cretaceous detrital sedimentary deposits, in an Apatian-Albian-Maastrichtian flysch sequence that incorporates sandstone, shale, breccias, of general north to south inclination. These deposits are of low general permeability. The previous succession is covered by a Quaternary sediment layer, consisting of colluvial materials on the slopes and alluvium on the valley bottom. The alluvial soils of higher permeability than the subjacent formations, will be largely excavated and removed as part of the construction of the TMF dams.

The building of the TMF dam will consist of two main steps: construction of the starter dam, and construction of the main dam (Corna Dam), respectively. The starter dam will be completed at the end of year 1 of the Project, and will be about 99 m above ground level. The so created 2,500,000 m³ capacity will provide containment for the first 15 months of operations. Later, the (main) Corna Dam will be built over the starter dam gradually, as the Project advances, by methods of centerline construction, at annual rise rates of 20 m in the first year to 5m in the final year. The final elevation of the dam crest will be 185 m.

3.2.5.1 Design Criteria
In order to avoid major accident occurrence from natural or anthropogenic reasons, or a combination of the two, design criteria were selected in compliance with Romanian and international standards, in order to provide a maximum level of safety during construction, operation and post-closure. The chosen design criteria are summarily presented in the following:

Flood Control Criteria
Romanian guidelines dictate that the TMF must store a 1:10,000 year storm event, which corresponds to 227 mm of rainfall/snowmelt within a 24-hour period. This compares with the Probable Maximum Precipitation (PMP) event of 450 mm for a summer event and 440 mm for a winter event with snowmelt. To be conservative, the more stringent PMP event has been selected as the design criteria for the TMF. An emergency spillway for the dam will be constructed near the top for emergency situations, in the unlikely event that pumps fail due to malfunction or power interruption at the same time as the PMP event. The volume of water in the decant pond, under normal operating conditions, is about 1,000,000 m³. The minimum considered level is 500,000 m³ and the maximum 2,500,000 m³. The probable maximum flood (PMF) is 2,500,000 m³ in summer and 2,750,000 m³ in winter, respectively. The TMF was so designed as to be able to contain 2 consecutive PMFs. If necessary, some of the pond water may be pumped into the WWTP downstream of the secondary containment system, where it may be treated down to TN001 standards, and discharged into the Corna Stream.

Safety Factors for Slope Stabilization
For static loading conditions the main tailings embankment (Corna Dam) will be designed with a minimum factor of safety of 1.3 during starter dam construction, 1.5 during subsequent dam raising construction and another 1.5 for closure. A factor of safety of 1.3 is used during construction, since no tailings or water are behind the dam. Once tailings are impounded, a factor of safety of 1.5 will be achieved. A minimum factor of 1.1 will be used for consideration of seismic loadings.
Seismic Design Criteria
Although the Roșia Montană mine is located in an area of very low seismic activity, the seismic design parameters have been considered (as presented in Section 4.5 Geology), calculated for the following parameters:

- **Operating Basis Earthquake** - taken as the 1 in 475 year return period event corresponding to a maximum bedrock acceleration of 0.082 g for a magnitude 8.0 earthquake; and;

- **Maximum Design Earthquake** - taken as equal to the Maximum Credible Earthquake with a maximum bedrock acceleration of 0.14 g, and an earthquake magnitude of 8.0 degrees.

These seismic design parameters of the TMF meet or exceed Romanian and European safety standards for tailings facility design.

The TMF is a complex structure, with several components:

### 3.2.5.2 Starter Dam
The initial starter dam cross-section, as shown in Exhibit 7, is typical of the majority of zoned earth water dams used throughout the world. The final starter dam elevation will be 739 m ASL, and the final height will be 99 m. The starter dam will be made up of six separate zones of different material types, which are as follows:

- **Zone 1** - This zone is the low permeability core of the dam, which will minimise seepage through the embankment. The construction material will be obtained from excavated clay overburden on the dam site, along access roads, or on the pit site stripping operations.

- **Zone 2** - This material will be placed as a filter downstream of the low permeability core and above and below the blanket drain over the downstream footprint of the embankment;

- **Zone 3** - This material will be installed upstream of Zone 1 in the upstream half of the embankment. In addition, it will be placed downstream and on top of the Zone 2 material in the downstream half of the embankment. This material will act as a transition/filter layer between the Zone 2 and Zone 4 materials. It will be produced from crushed rock obtained either from the open pits or from an off-site pit;

- **Zone 4** - This zone will comprise the majority of the downstream portions of the embankment and a limited portion of the upstream slope. The material will be made up of durable dacite run-of-mine waste rock or run-of-mine pit rock;

- **Zone 4B** – This zone will comprise the majority of the upstream portions of the embankment. Since this zone of the embankment is not critical for stability, it will consist of substandard dacite or mixed breccia mine rock or pit rock.

- **Zone 5** - This zone will be installed as a coarse blanket drain over the downstream half of the embankment footprint. This coarse blanket drain will be sandwiched in between Zone 2 material, which acts as a drain material and filter layer for the coarse Zone 5 drain. This material will be manufactured by crushing andesite or sandstone rock from the identified quarries.

### 3.2.5.3 Main Tailings Dam
The main Corna dam will be built using the centerline method of construction, with the downstream shell made of rockfill. The main embankment will be constructed in a series of raises over the course of the mine life. Exhibits 5 and 6 show the cross-section of the embankment. Similar materials and construction installation methods will be used for the main embankment as those described previously for the starter dam.
Corna dam will be constructed in stages with the starter dam being the first stage. As noted previously, the central low permeability zone will act as a water retention structure for the initial construction of the starter dam. Subsequently, the dam crest elevation will be raised based on storage requirements, while at all times respecting the pervious dam concept to ensure dam safety and minimise environmental risk. The dam downstream slope will be designed with benched slopes approximately every 40 metres to permit access, and to provide erosion control. The extension of the tailings dam will consist of constructing two downstream raises above the starter dam and then heightening the dam solely with centreline raises. The downstream method of construction will be used to construct the initial two raises. This method provides for increased dam safety during early operating years, as the beach development along the embankment to support centreline construction will not be well established due to the rapid rate of raise requirements.

3.2.5.4 Secondary Containment System

Minor seepage through the main dam is expected, is normal for any dam, and is a design feature that contributes to progressive dewatering of tailings within and behind the dam structure, which results in increases in stability with time. Seepage through the dam will be collected directly in the secondary containment system (SCS), located at the final downstream toe of the embankment (Exhibit 7). For design purposes, seepage is estimated at approximately 9 m³/hr to 45 m³/hr for the starter dam and final tailings dam, respectively. The SCS will consist of a 10 to 15 m deep sump excavated into weathered rock in conjunction with a zoned rockfill dam and pumping system to pump water over the TMF embankment and back into the tailings impoundment.

The secondary containment dam will be approximately 24.06 yd high and will be a zoned rockfill dam, similar to the starter dam. The material types and methods used for construction of the SCS are virtually identical to those of the tailings embankment. The biggest difference between the materials is that the material used to construct the SCS will be chemically inert, and non-acid generating.

The seismic design inputs used for the SCS are identical to those used for the TMF. For static loading conditions, the main tailings embankment will be designed with a minimum factor of 1.5. A minimum factor of 1.1 will be used for consideration of seismic loading.

3.2.5.5 TMF Diversion Works

In order to minimise the volume of water entering the TMF, two diversion channels will be constructed to collect and route clean runoff water before it drains to the TMF and discharge it downstream of the SCS (Exhibits 1, 2, 3, and 4). Both channels are sized to pass the 24-hour, 25-year storm event. Additional diversion channels may be employed for the management of surface runoff.

The designed TMF is extremely robust, containing several safety measures in addition to most structures of the type that exist in Romania and worldwide. The design particulars include:

- containment capacity for 2 consecutive PMFs;
- with each dam rise, a spillway will be constructed to discharge excess water from potential extreme events in a controlled way. This will help prevent bank erosion downstream of the dam;
- the starter dam will be a zoned rockfill dam built with slopes of 2H:1V and 1.75O:1V for the downstream and upstream face, respectively;
- the main Corna TMF dam will be a tailings dam built using the centerline method of construction, with the downstream shell made or rockfill. Typically, the slopes for such hydrotechnical structures range between 1.5H:1V and 1.75H:1V; Corna dam will have an overall downstream slope of 3H:1V for increased safety;
Section 3: Technological Hazards and Risks

- a drainage system at the bottom of the waste rock pile and a filter layer between the rock beds, to reduce moisture and stabilized the stored material;
- a monitoring system installed on and near the dam, to provide implementation of a strict Quality Assurance program, in all the dam building phases.
- implementation of a strict monitoring program of TMF stored water volumes

3.2.6  
**Cetate Water Catchment Dam**

Acid runoff from historical operation (including the Adit 714 runoff) and the new mine will be captured in the Cetate drainage pond. This Dam belongs in Class II importance and Category B according to Romanian standards. The dam will be 31 m high measured from the crest to the initial ground level (39 m in all, measured from foundation level) and the total containment area is 4.9 km². The maximum operating capacity of the pond is 600,000 m³, with 25000m³ stored sediment.

An estimated 231 to 371 m³/h ARD will be contained. The base flow in the Roșia stream will be maintained primarily by constructing a diversion canal that will collect and divert water not impacted by the new mining operations around the Cetate dam and discharge it into Roșia Creek. Initially, the 3.9 km diversion canal will drain an area of about 7.5 km², which has not been impacted by recent mining, the collected volume of water representing about 70 % of the Cetate pond catchment. Hence, initially the base flows of the Roșia Stream downstream of the Cetate dam will only be affected to a minor extent by the construction of the dam. The dam will be breached as soon as it is found that the water quality parameters collected in the pond meet the regulated discharge norms for direct discharge into the Roșia Valley. All the exposed areas will be re-profiled to reduce residual effects of ponding and, to the extent possible, to restore the natural flow in the respective area. Strategic revegetation will be pursued, aiming to restore the natural local vegetation species. The wastewater treatment lagoon system that will be built downstream of the dam will be maintained after closure to provide ongoing semi-passive treatment of runoff waters.

3.2.7  
**Waste rock disposal sites**

The pit design includes about 256.926 million tons waste rocks. Quarried rock and pre-stripped waste rock will be utilised as appropriate for construction of the Corna Valley TMF embankments and other impoundments. If not required for construction, waste rock will be hauled to the Cetate and/or Cîrnic stockpiles. Starting in Year 10, the Cîrnic pit will be backfilled with mine waste from the late pushbacks of the Cetate, Orlea, and Jig pits. Prior to the placement of any waste in the designated waste rock areas, the surface area to be covered will be stripped of topsoil; scarification and compaction of the exposed colluvial and/or weathered bedrock materials will provide a semi-impervious layer under the waste rock disposal sites. Diversion channels around the waste rock piles will capture potential surface waste run-on and divert it around the piles. Run-off from the waste rock piles reports to the water management system and will be collected within the TMF or one of the water management dams, which will allow pumping to the wastewater treatment plant or the process plant.

Waste rock will be selectively stockpiled, with potentially ARD generating rocks placed at the core of the pile, and non-ARD generating rock on the outside. The stockpiles will be provided with a storm water drainage system that will provide stability over time and collect potential acidic waters generated by the stockpiled rock, directing them to the Cetate dam and pond and/or the industrial WWTP.

The waste rock stockpiles will be regraded to facilitate the installation of topsoil during and after closure. The final slope grades will be 2.5 horizontally and 1 vertically (2,5H:1V) with steps approximately 5 m wide. Once the final rise will be completed, the embankments and steps will be regarded and covered with topsoil to reduce seepage and provide a durable
substrate for vegetation development. The Cetate Waste Rock drainage will be directed to the Cetate pond and/or the wastewater treatment system.

The stability of the stockpiles, their foundations and adjacent areas will be checked for local and overall stability. Local instability is caused by a collapse of some of the earth mass. There are cases where a local instability event may be extinguished by a redevelopment of the local hydrometric range. However, the process may become active, even take violent aspects, making any intervention useless. The most dangerous form of local instability is caused by the forces of the infiltration flow.

The cause of the overall instability of the stockpiles is given by the low strength of the stored material, foundation ground or strata thereof, the situation being compounded by the existence of an infiltration flow and accidental factors such as, for example, earthquakes or explosions.

The stockpile stability calculations must consider a check of the safety coefficient for all the forms of instability. An analysis of stockpile break indicates the following causes:

- Foundation failure – exceedance of the bearing capacity of the natural ground by fast loading or overloading, uneven compaction of the foundation, activation of creep in the basic layers, slow flow of the foundation material, poor circulation of seepage water, rock weathering, etc.
- Risk of exceedance of the stockpile water drainage capacity;
- Break of stockpiled material due to stress under exceptional situations (earthquakes, pressure, etc.)

3.2.8 Explosives storage

The location of the explosive storage must take account of the distance to the pits, where explosive blasting will occur; this should not be affected by the seismic waves produced during blasting.

The existing data show that the explosive storage facility is located in a construction free area, except for the access road. The closest structure to the explosives warehouse, located about 1200 m is the TMF dam (the warehouse is north-west thereof).

Under Romanian law, explosives may only be stored in specially built and controlled structures, based on well documented designs approved by the labor inspectorates. The explosives will be separately stored in two structures, one for ammonium nitrate and one for the dynamite. Thus, ammonium nitrate will be stored in an aboveground building, and dynamite and other starter devices in an underground facility, located about 110 m NE of the ammonium nitrate facility, to which it is linked via an underground passage. Each of the storage facilities will be equipped with the storage space proper and a working shed, containing a smaller amount of explosive, for easier handling. Thus, the explosives facilities will currently store 80 tons of ammonium nitrate, and 5 t dynamite, respectively, and the work sheds 20 t of ammonium nitrate and 1 t of dynamite, respectively.

The two facilities partly communicate via the underground tunnel that starts from one of the above ground facility safety area limits.

The dynamite will be stored in its original package. The ammonium nitrate will be stored in bulk, in bags, and as a grainy, porous form, that will help retain the added fuel oil for the preparation of ANFO.
4 Identification of Potential Accident Scenarios

This Section describes potential accident scenarios, circumstances in which they may occur and a qualitative assessment of the probability of occurrence, as well as of the size/seriousness of the consequences, for each Project phase and each of the safety sections identified above.

4.1 Construction Phase

4.1.1 Mining Operations Areas
Road and occupational accidents occurring in the preparation of the mining areas are assigned medium probability, due to the rigorous organizations of all these works, of ongoing training of the operational staff, and the provision of adequate safety equipment and measures. Such accidents may cause more or less serious injuries to one or several workers.

4.1.2 Site haul routes
Road and occupational accidents occurring in the on-site transportation of rock and overburden materials or of materials to the work sites are assigned medium probability, due to the rigorous organizations of all these works, of ongoing training of the operational staff, and the provision of adequate safety equipment and measures. Such accidents may cause more or less serious injuries to one or several workers.

4.1.3 Process Plant
Fire at the fuel storage facilities may occur due to terrorist attacks or failure to observe operational rules and are assigned low probability of occurrence due to the relatively small amounts of fuel used during this phase. Such accidents may cause more or less serious injuries to one or several workers and minor material damage.

Local fires during construction and assembly works may occur due to open fire activities (welding, etc.) and have low probability of occurrence on the one hand due to the rigorous organization of all these works, to the ongoing training of the workforce and the provision of adequate protection equipment, and on the other hand due to the absence or presence in low quantities of combustible materials. Such accidents may cause more or less serious injuries to one or several workers and minor material damage.

Fuel spills from storage facilities may occur due to technical dysfunctions or to failure to observe the operational rules and have low probability of occurrence. The consequences would be minor, consisting of potential impact on the areas adjacent to the spill.

Road and occupational accidents occurring in the on-site transportation of construction materials to the work sites and/or during construction and assembly works are assigned medium probability, due to the rigorous organizations of all these works, of ongoing training of the operational staff, and the provision of adequate safety and working equipment and measures. Such accidents may cause more or less serious injuries to one or several workers and potential minor material damage.

4.1.4 Pipeline Routes
Not applicable
4.1.5 **Tailings Management Facility**
Not applicable (the scenarios are dealt with under Phase II: Operations)

4.1.6 **Cetate ARD Catchment Dam**
Not applicable (the scenarios are dealt with under Phase II: Operations)

4.1.7 **Stockpiles**
Not applicable

4.1.8 **Explosives storage**
The risks associated to the explosives storage facility are discussed in Part II. Operation Phase

4.2 **Operation Phase**

4.2.1 **Mining Operations Areas**
Explosions during in-pit mixing of ANFO. The ammonium nitrate and fuel oil mix (ANFO) is an explosive mix (under the legislation on explosive materials) and will be subject to the same general safety requirements as all civil use explosives. The probability of the explosive mix to self-ignite is low, as this mix is rather impervious and involving special devices with all the safety measures in place. Under certain conditions of storage or use, such as long exposure to a heat source or even to the sunlight, it may detonate accidentally due to an increased ignition sensitivity. However, such cases are extremely rare. The seriousness of such an accident occurring is rather high, as it may result in loss of life.

The explosion of undetonated holes after blasting is low probability. Although misses are possible, they can be detected during the mandatory blasting front check conducted by the blaster after each blasting operation. The probability of not detecting the potential misses during the front check is medium. If detected, a plan will be developed to liquidate such unspent explosives, either by drilling blasting holes next to them, causing their destruction in subsequent detonation, or by applying additional loads on top, in the secondary blasting of oversize rocks. On the other hand, the shotmen will be carefully selected upon recruitment, and provided with special training for explosives operation, and will be regularly subjected to psychological checks. Should blasting holes still remain undetonated and explode in an uncontrolled manner, the resulting accident may be serious, causing loss of life and material damage.

Vibrations due to the use of explosives for mining purposes. The use of explosives is a source of noise, vibrations and seismic waves, they may generate health risks and risks to the local buildings. Pit blasting operations are conducted based on well defined schemes, with explosive amounts carefully calculated for the mining purpose, so that the generated seismic wave should not affect the local structures. The potential of explosive blasting to generate destructive effects on constructions is low.

Collapse of the work front at the open pit may occur in the following situations:
- The use of too much explosive is less likely, as pit blasting is conducted based on well established schemes and according to the terrain conditions.
- The existence of an underground void below the pit bench is possible, as the historic mining works locations on the site are not all known.
- The occurrence of cracks in the massif or of friable interspersions that would cause the “break” of more rock than initially predicted is low probability, as the massif rock has been investigated and its geo-mechanical characteristics are known, and the topographers and geologists will conduct daily inspections of the work front to identify any potential crack.
• The appearance of an aquifer in the operations area and failure to capture it ranks as low probability. The probability of caving in to occur is low if the operating technologies are properly complied with and exploration precedes any opening of a new work front, and if the blasting technologies are correctly applied. The consequences may be of moderate seriousness and include:
  • human casualties involving the workers at the work front;
  • damage to the pit equipment and potential spill of fuel onto the soil;
  • damage to pipelines or electrical cables located on or near the affected site;
  • collapse of access roads, hence impossibility to continue operations before the roads are repaired.

4.2.2 Site haul routes
Road and occupational accidents occurring in the on-site ore haulage from the pit to the process plant are assigned medium probability, due to the rigorous organizations of all these works, to proper road development, to ongoing training of the operational staff, and the provision of adequate safety equipment and measures. Such accidents may cause more or less serious injuries to one or several workers and potential minor material damage.

4.2.3 Process Plant
Total destruction of the plant installations by terrorist attack, with standard or nuclear weapons, involving simultaneous damage to the HCl tank (including containment) and to the NaCN solution tank, the tanks containing enriched solution, to one or more leaching tanks, leading to spillage of their entire content. The probability of occurrence is very low for armed attack, as the facility is not of strategic significance, and such an attack would assume the existence of a previous conflict, and hence anticipation of such an event, which would provide enough time to stop operations and remove all sources of contamination (sodium cyanide and cyanide solutions, hydrochloric acid). A terrorist attack is a low probability event (even if higher than for an armed attack) and, as it may not be anticipated, its effects would certainly be very serious. Even if the event involves the simultaneous explosion of the cyanide tank or a leaching tank and the hydrochloric acid tank, the probability for the hydrochloric acid solution and the cyanide to come into contact is very low, due to their respective location in different areas and at a sufficiently safe distance from each other (more than 50 m). Also, the land adjacent to the acid and cyanide solution storage facilities, respectively, will be graded to drain in different directions, which will make the mix of acid and cyanide solutions practically impossible.

If, however, acid comes into contact with the cyanide containing solutions, large amounts of hydrocyanic acid will be generated and volatilized into the ambient air around the process plant, in concentrations exceeding the fatal dose. Depending on the atmospheric conditions, the area affected by fatal doses of HCN may extend to long distances, even off site, and affect residential areas, with the potential to kill people caught into the toxic cloud without a gas mask.

Serious damage to the sodium cyanide solution tank, resulting in the spillage of the entire content thereof (180 m3 solution containing about 40 t NaCN) It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (important contraction of the building material at abnormally low temperatures compounded by freezing of the entire contents, especially of the screws that fasten the manhole cover). The probability of occurrence is rather low, considering that the tank is located in a close building and the tank is designed to meet the strength requirements established for static, dynamic, and seismic loads.
Even if the whole sodium cyanide solution contained in the storage tank spills out, the amount will be contained in the impervious collection tank which is designed to collect the entire content of the storage tank and the cyanide blending vessel. The containment tank is also provided with a sump and a submersible pump able to return all the spills into the process. Should the spilled volume nonetheless exceed the containment capacity of the secondary containment system, the excess solution will be directed to the collection tank of the DETOX plant, where it can be collected, treated and pumped into the TMF. Such a spill may generate (especially in high temperature conditions) a release of HCN in toxic ambient concentrations in the immediate vicinity of the impacted area. People present on the impacted site may also get sprinkled by the spill.

Breakage of a solid cyanide container, followed by spillage of its content (max. 16t) May occur during on-site transport or handling. The probability is low, as the container is specially designed and built.

Breakage of a solid cyanide storage tank is not a very serious occurrence, but may affect the people in its immediate vicinity and, in certain circumstances (rain, etc) may cause relatively small spills of cyanide on adjacent areas.

Serious damage to the HCl solution storage tank, resulting in the spillage of the entire content thereof (20 m³) It may occur under terrorist attack, as a fissure in the tank due to high mechanical stress (seism, accidental hitting, accidental break of the bottom nozzles, of the discharge piping, faulty material).

Although the probability of occurrence is medium, the containment tank will ensure collection of the maximum content of the vessel, and the probability of the containment system to fail at the same time is extremely low. It is possible, however, for a small part of the acid to spill out of the collection tank if the fault occurs high enough for the liquid jet to fall beyond the tank border.

Spillage of hydrochloric acid from the storage tank into the containment system will release corrosive HCl vapors into the impacted area, and may cause harm to the people in its close vicinity, but such intoxications are not typically very serious, as the fog aspect and pungent smell will ward people off. A more serious concern would be spray getting into the eyes of the people on the very site of the accident.

Breakage of a tanker carrying hydrochloric acid solution, followed by spillage of its content (max. 20 m³) May occur during on-site transport or unloading. The probability is medium, as the materials used in building the container are relatively frail (plastic material) ad involves road transport.

Spillage of hydrochloric acid will release corrosive HCl vapors into the impacted area, and may cause harm to the people in its close vicinity, but such intoxications are not typically very serious, as the fog aspect and pungent smell will ward people off. A more serious concern is for the acid to come into contact with the cyanide potentially present in the impacted area, which may release HCN, with potential harm to the people nearby. A very serious occurrence involves the spill getting into the containment system of the cyanide containing tanks, already (potentially) holding cyanide bearing water or cyanide leaks, when massive release of HCN might even exceed he lethal concentration. Depending on the atmospheric conditions, the area affected by toxic concentrations of HCN may extend off site, and affect people caught into the toxic cloud without a gas mask.

Serious damage to a leaching tank, resulting in the spillage of the entire content thereof (5000 m³ and max. 14 x 5000 m³ = 70000 m³). It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/ high temperatures, break of the screws that fasten the manhole cover, etc.).

The probability of occurrence is rather low, considering that the tanks are placed in a concrete containment tank, relatively far from the site roads and are designed to meet the strength and stability requirement established for static, dynamic, and seismic loads.
Spillage of the whole amount of cyanide slurry contained in the leaching tank(s), if very fast, may cause a discharge over the secondary containment border and passage into the DETOX plant collection tank, where it can be collected, treated and pumped into the TMF. Such a spill may generate (especially in high temperature conditions) a release of HCN in toxic ambient concentrations in the immediate vicinity of the impacted area. People present on the impacted site may also get sprinkled by the spill.

Serious damage to the thickener, resulting in the spillage of the entire content thereof (max. 3700 m³). It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/high temperatures, break of discharge nozzle). The probability of occurrence is rather low, considering that it is designed to meet the strength and stability requirements establish for static, dynamic, and seismic loads. The thickener is placed in an impervious containment tank (together with the DETOX reactors) which is designed to contain the entire content of the facility. The containment tank is also provided with a sump and a submersible pump able to return all the spills into the process. Should the spilled volume nonetheless exceed the containment capacity of the secondary containment system, the excess solution will be directed to the collection tank of the DETOX plant, where it can be collected, treated and pumped into the TMF. Such a spill may generate (especially in high temperature conditions) a release of HCN in toxic ambient concentrations in the immediate vicinity of the impacted area. People present on the impacted site may also get sprinkled by the spill.

Serious damage to the access platform or railings thereof over the leaching tanks, resulting in people accidentally falling into the slurry mass. It is hardly likely both due to the constructive system and to the fact that any important fault may be easily detected by visual inspection. The seriousness of such an event is high, with the injured person suffering from chemical burns over the whole body, or even dying from drowning or ingesting a solution of cyanides and toxic metals.

Serious damage to the DETOX water treatment facility, resulting in the spillage of the entire content of one or both reaction vessels (max 2 x 1600 m³). It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/high temperatures, break of the screws that fasten the manhole cover, break of the discharge nozzles). The probability of occurrence is low, considering that the equipment is designed and built to meet the strength and stability requirements establish for static, dynamic, and seismic loads. Spillage of the entire cyanide loaded water contained in the DETOX facility will cause its discharge onto the concrete pad on which the facility is mounted, into the containment system, which has sufficient capacity to cope with the maximum potential spill. The containment tank is also provided with a sump and a submersible pump able to return all the spills into the process or directly into the TMF. Such a spill may generate (especially in high temperature conditions) a release of HCN in toxic ambient concentrations in the immediate vicinity of the impacted area, but the level of the release will not involve toxic concentrations (due to the high alkalinity and low concentration of free cyanide). People present on the impacted site may get sprinkled by the spill.

Operating errors/failure of the DETOX facility Probability of occurrence is medium, due to ongoing and regular checks (involving redox sensors and laboratory analyses) of the physical and chemical parameters of the tailings slurry prior to discharge into the decant pond.
Inadequate treatment of the discharge (too high cyanide content) will not generate serious effects due to dilution of the relatively low amount of liquid (over a short time) into the very large amount of clarified water in the pond. Anyway, the water collected in the pond will not discharge into the natural receiver, but will be recycled in the process instead.

Operating errors and/or failures in the measurement and control devices, resulting in a lower pH in the leaching tank, thickener and/or DETOX slurry. Hardly likely, due to automated control and regular laboratory checks of the physical and chemical parameters of the slurry and the continuous monitoring of ambient HCN levels. The effects of such failure may be rather serious, due to the increased concentrations of HCN above the leaching tanks (especially at higher ambient temperatures) that would affect the workers on the operations platform. pH reduction will be very slow (even with total absence of lime wash input) due to the large amount of fluid in each tank, hazardous pH levels may only be attained within hours in the first leaching tank, by which time the failure cannot fail to be identified and remedied, therefore the effects will be medium and short term.

Serious damage to the rich solution storage tank(s), resulting in the spillage of the entire content thereof (max. 420 m³). It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction of the tank building material at abnormally low temperatures). The probability of occurrence is rather low, considering that the tanks are designed to meet the strength and stability requirements established for static, dynamic, and seismic loads. The 5 storage tanks for enriched solution are placed within an impervious containment system designed to contain the entire content of the storage tanks. The containment tank is also provided with a sump and a submersible pump able to return all the spills into the process. Should the spilled volume nonetheless exceed the containment capacity of the secondary containment system, the excess solution will be directed to the collection tank of the DETOX plant, where it can be collected, treated and pumped into the TMF. Such a spill may generate (especially in high temperature conditions) a release of HCN in toxic ambient concentrations in the immediate vicinity of the impacted area. People present on the impacted site may also get sprinkled by the spill.

Damage to the 15% CuSO₄ solution storage tank, resulting in the spillage of the entire content thereof. It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction of the tank building material at abnormally low temperatures). The probability of occurrence is rather low, considering that the tank is designed to meet the strength and stability requirements established for static, dynamic, and seismic loads. The consequences of such an incident would be minor, as the tank is placed within an impervious containment tank provided with a sump and a submersible pump able to return all the spills into the process. The acidity of the copper sulfate solution may determine a release of HCN in the air in the immediate vicinity of the spill, should it occur at the same time as leaks of cyanide containing suspensions. People present on the impacted site may also get sprinkled by the spill.

Damage to the 20% Na₂S₂O₅ solution storage tank, resulting in the spillage of the entire content thereof. It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction of the tank building material at abnormally low temperatures). The probability of occurrence is rather low, considering that the tank is designed to meet the strength and stability requirements established for static, dynamic, and seismic loads. The consequences of such an incident would be minor, as the tank is placed within an impervious containment tank provided with a sump and a submersible pump able to return all the spills into the process. The acidity of the sodium metabisulfite solution may determine a release of HCN and/or SO₂ in the air in the immediate vicinity of the spill, should it occur at
the same time as cyanide containing suspensions. People present on the impacted site may also get sprinkled by the spill.

Accidents in the reagent storage area. Reagent storage involves specially designed warehouses equipped with prevention and response systems, in the original packaging, and observance of the incompatibility rules, therefore accidents of this kind have a low probability of occurrence and the potential consequences are minor.

Serious damage to the sodium hydroxide solution tank, resulting in the spillage of the entire content thereof (40 m³) and/or the blending vessel (20 m³). It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction of the building material at abnormally low temperatures compounded by freezing of the entire contents, especially of the screws that fasten the manhole cover). The probability of occurrence is rather low, considering that the tank is located in a close building and is designed to meet the strength requirements establish for static, dynamic, and seismic loads.

Even if the whole sodium hydroxide solution contained in the storage tank spills out, the amount will be contained in the impervious collection tank which is designed to collect the entire content of the storage tank and the blending vessel. The containment tank is also provided with a sump and a submersible pump able to return all the spills into the process. People present on the impacted site may also get sprinkled by the spill.

Serious damage to the lime wash storage tanks, resulting in the spillage of the entire content of the lime wash preparation vessel (max. 700 m³). It may occur under terrorist attack, or a crack developing in the tank wall due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/ high temperatures, break of discharge nozzle).

The probability of occurrence is low, considering that the facility is designed and built to meet the strength and stability requirements establish for static, dynamic, and seismic loads.

Spillage of the lime wash contained in the tank will cause its discharge onto the concrete pad on which the facility is mounted, and then, through the drainage system, it may be carried into the storm water tank. People present on the impacted site may get sprinkled by the spill.

Operating errors - acid wash of activated carbon. They have medium probability. Insufficient rinsing of the activated carbon may cause release of higher amounts of HCN upon contact with the rinsing acid, but this will occur within the elution column, which is equipped with a ventilation system discharging through the dispersion stack. Potential residual cyanide amounts on the carbon will not be very high, and even in the event of the ventilation system malfunctioning, the effects cannot be too serious.

Operating errors in electrolysis. They are less probable due to the periodical check of the physical and chemical parameters conducted by means of laboratory analysis and monitoring.

Too low a content of NaOH in the rich solution subject to electrolysis may enhance releases of toxic gases (including HCN) in the cell area during the process. As the ventilation system will ensure the capturing and stack discharge of such releases, they may only affect potential operators present in the electrolysis area unless the ventilation system is malfunctioning.

Damage to the LPG storage tank and distribution system, resulting in tank explosion and ignition of the released gas. Probability is relatively low, due to the special regime applied in the tank design, execution and control. Explosion of the LPG storage tank may be very serious in the short term, causing material damage, and even personal injury.

Serious damage to the process water storage tank, resulting in the spillage of the entire content thereof (max. 12300 m³) It may occur under terrorist attack, or a crack developing in
the tank wall due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/ high temperatures, break of the screws that fasten the manhole cover, break of the discharge nozzles). The probability of occurrence is rather low, considering that the tank is designed to meet the strength and stability requirements established for static, dynamic, and seismic loads. Spillage of the entire amount of (cyanide bearing) process water in the storage tank will cause its discharge into the containment system. The impact area may not exceed the impervious pad around the tank. Such a spill may generate (especially in high temperature conditions) a release of HCN in toxic ambient concentrations in the immediate vicinity of the impacted area, but the level of the release will not involve toxic concentrations (due to the high alkalinity and low concentration of free cyanide). People present on the impacted site may also get sprinkled by the spill.

Damage to the sodium hypochlorite used in water disinfection for treatment. These are medium probability events and may occur if the plastic barrels are knocked during handling. Due to the oxidizing effect and high alkalinity of the hypochlorite solutions, potential spills may cause chemical burns to the exposed persons but effects are generally less severe. Such events may result in more serious consequences in case of contact with acids, when it will break down and release chlorine gas into the air, but the only potentially injured will be the persons close to the spill and only in the short term.

Damage to the lime wash-ARD reactor, resulting in the spillage of the entire content thereof. It may occur under terrorist attack, or a crack developing in the vessel walls due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/ high temperatures, break of discharge nozzle). The probability of occurrence is low, considering that the facility is designed and built to meet the strength and stability requirements establish for static, dynamic, and seismic loads. Spillage of lime wash contained in the storage tank will cause its discharge into the containment system, whence it will be pumped back into the process. Only the people present on the impacted site may get sprinkled by the spill, therefore the consequences will be minor.

Damage to the flocculant -ARD reactor, resulting in the spillage of the entire content thereof. It may occur under terrorist attack, or a crack developing in the vessel walls due to very high mechanical stress (seism, important contraction/expansion of the tank building material at abnormally low/ high temperatures, break of discharge nozzle). The probability of occurrence is low, considering that the facility is designed and built to meet the strength and stability requirements establish for static, dynamic, and seismic loads. Spillage of solution contained in the storage tank will cause its discharge into the containment system, whence it will be pumped back into the process. Only the people present on the impacted site may get sprinkled by the spill, therefore the consequences will be minor.

Damage to the ARD clarifier, resulting in the spillage of the entire content thereof. It may occur during a terrorist or armed attack due to very high mechanical stress (seism). The probability of occurrence is low, considering that the facility is designed and built to meet the strength and stability requirements establish for static, dynamic, and seismic loads. Spillage of the solution contained in the tank will cause its discharge onto the containment system and pumped back into the process, or possibly, through the drainage system, it may be carried into the storm water tank. Only the people present on the impacted site may get hurt in the accident, therefore the consequences will be moderate.

Damage to the compressed air facility, consisting of explosion of the buffer vessels and/or pressurized handling pipes, may only occur if the safety valves get jammed or malfunction, and the probability of occurrence is low due to the special equipment involved and to the special, ISCIR-compliant design, execution and control.
This kind of failure may cause serious injuries but only to the people on the impacted site.

Damage to the oxygen production and distribution facility, consisting of explosion of the buffer vessels and/or pressurized handling pipes, may only occur if the safety valves get jammed or malfunction, or upon contact with oils or lubricants and the probability of occurrence is low due to the special equipment involved and to the special, ISCI-compliant design, execution and control. This kind of failure may cause serious injuries but only to the people on the impacted site, or generate local fires if the oxygen comes into contact with organic substances.

Damage to the electricity supply and distribution system, consisting of shorts and/or overheating followed by ignition of the conductor insulation and even of the power transformer. Such events are of medium probability of occurrence as the design and execution of the system is based on the regulated safety standards, the materials are high quality, there are automated safety and control devices that will provide (partial or total) supply cuts as soon as the normal operating parameters of the system are exceeded. The only event of this kind that might have serious consequences consisting of important material damage to the owner is fire at the transformer station that might also involve personal injury for the response teams. An indirect effect of more serious consequences would be a site-wide power cut. Break down and fire in the fuel tanks (diesel and gasoline).

Power cuts caused by factors beyond the control of the company are low probability events, and may only occur in exceptional situations in the national power supply system. Reserve power generators have been provided. Contingent power cuts may have rather serious, but short-term consequences, consisting of solution spills (no pumping into the TMF) and, for a longer-term cut during very low temperature spells, solution freezing in the piping systems with an increased potential for break down upon restarting the facility.

Break down and/or fire in the fuel storage facilities may occur due to terrorist attack or incompliance with the operating rules and have low probability of occurrence. Such accidents may cause more or less serious injuries to one or several workers and minor material damage.

Breakdown in the cyanide handling systems (pipes, casings, pumps) resulting in spills, that may occur with medium probability throughout the operation phase (slightly higher at pump start and in the areas provided with sealing flanges). Breakdown of the cyanide solution handling systems have relatively low seriousness (spill amounts are typically very small) but people may get sprayed. Of more concern are the cases where the spilt solutions come into contact with acid solutions and HCN may be released.

Breakdown in the cyanide slurry handling and/or pre-treatment systems (pipes, casings, pumps) resulting in spills, that may occur with medium probability throughout the operation phase (slightly higher at pump start and in the areas provided with sealing flanges). Such spills only involve very low hazard, as the amounts are low and will be collected onto concrete areas and directed to the emergency tank. Potential sprinkling of the operators in the impacted area may only have minor effects.

Breakdown in the handling systems of cyanide containing solutions/suspensions (pipes, casings, pumps) resulting in spills, that may occur with medium probability throughout the operation phase (slightly higher at pump start and in the areas provided with sealing flanges). Such spills involve relatively small amounts of material and may only occur on impervious areas on which they will be collected and directed to the emergency tank. Due to the
relatively low cyanide content and high pH, HCN releases are practically impossible (except in accidental contact with hydrochloric acid). Due to high alkalinity, sprinkling of the operators in the impacted area may have rather serious consequences.

Breakdown in the hydrochloric acid handling systems (pipes, casings, pumps) resulting in spills, that may occur with medium probability throughout the operation phase (slightly higher at pump start and in the areas provided with sealing flanges). Spillage of hydrochloric acid will release corrosive HCl vapors into the impacted area, but in this type of failure the spills involve very small amounts, therefore potential harm to the people in its close vicinity is hardly likely, and such intoxications are not typically very serious, as the fog aspect and pungent smell will ward people off. A more serious concern is for the acid to come into contact with the cyanide potentially present in the impacted area, which may release HCN (in very small amounts), with potential harm to the people in close vicinity.

Breakdown in the sodium hydroxide handling systems (pipes, casings, pumps) resulting in spills, that may occur with medium probability throughout the operation phase (slightly higher at pump start and in the areas provided with sealing flanges). The spill of NaOH solution on floors only involves the risk of sprinkling the operators in the area, while potential personal injury might be serious if the corrosive drops reach the eyes and immediate rinsing and first aid measures are not taken.

Suicidal attempts by ingestion of cyanide solution. It is rather unlikely, due to limited access to the premises, especially in the operational areas, and the fact that the cyanide handling system is a closed loop one and the company personnel are subject to psychiatric controls during recruitment and regularly afterwards. The consequences of such an event would be very serious, almost certainly resulting in death.

Occupational accidents occurring during the on-site maintenance and repairs activities or response action are assigned medium probability, due to the rigorous organization of all these works, conducted under the direct supervision of the specialist middle management, to ongoing training of the operational staff, and the provision of personal protective equipment and adequate and high quality tools and devices. Occupational accidents occurring during maintenance and repairs work or response action may cause more or less serious injuries or intoxication to several workers.

4.2.4 Pipeline Routes
Fissure in the tailings pipe due to wear or other causes. The probability is rather low, due to erosion, especially in sensitive areas (elbows, flanges, compensators, valves). The use of polyethylene as a construction material will substantially reduce its probability. Such breakdowns will cause spill of material containing hazardous substances in small amounts, that will affect limited areas, and will be typically collected entirely into the impervious drainage system, therefore the effects will be minor. The most serious situation would involve breakdown in the dam crossing areas.

Fissure in the decant water pipeline due to wear. The probability is low due to the absence of solids that might cause erosion. However, the risk is slightly higher in the flexible area (between the barge and the fixed pipe on the ground) also due to the fast and sizeable oscillations of the free liquid levels in the pond. Such breakdowns will cause spill of material containing hazardous substances in small amounts, that will affect limited areas, and will be typically collected entirely into the drainage system and the TMF, therefore the effects will be minor.

Break, crack, or failure of a joint in the slurry or decant water pipeline systems. They may be caused by faults in the material, malfunction of the guiding systems or expansion...
compensators, or by water hammer effect at pump start. They have low probability, but increasing with extreme temperature events. Such breakdowns will have moderate short-term effects, as they will involve spill of rather large amounts of material containing hazardous substances that the drainage system will not be able to handle entirely, so that relatively extensive areas of land might be affected. In such circumstances, the effects might be significant, but short-term, as the safety systems will allow fast detection and trigger immediate pump stop.

Breakdown in the ARD piping system from the Cetate Dam to the ARD wastewater treatment plant may be caused by faults in the material, malfunction of the guiding systems or expansion compensators, or by water hammer effect at pump start. They have low probability, but increasing with extreme temperature events. Such breakdowns may cause minor short-term effects, as the safety systems will allow fast detection and trigger immediate pump stop.

Occupational accidents occurring during the on-site maintenance and repairs activities or response action are assigned medium probability, due to the rigorous organization of all these works, conducted under the direct supervision of the specialist middle management, to ongoing training of the operational staff, and the provision of personal protective equipment and adequate and high quality tools and devices. Occupational accidents occurring during maintenance and repairs work or response action may cause more or less injuries to one or several workers and may be considered events with minor consequences.

4.2.5 Tailings Management Facility

4.2.5.1 Dam breach development

Dam breach development may be hypothetically caused by extreme natural events, such as very strong earthquakes or overloading. A potential threat might also include terrorist or armed attack.

The tailings dam (Corna Dam) will be constructed in stages. In Stage I: Construction Phase, the starter dam will be built as an integral part of the Corna Dam structure. This starter dam will provide containment of the process water, and will be gradually filled by the process plant slurry. To prevent spills, the initial storage capacity of the dam will be about 2,500,000 m³, corresponding to a summer PMF. A spillway will be built at elevation 738 m, which will allow controlled discharge of water should overloading become hazardous. The starter dam will continue during Stage II: Operation Phase, in the same geometry. A dam break scenario was studied for this geometry of the starter dam, involving breach development. The breach was conservatively assessed to be 285 m long (about 1/3 of the crown length) and 40 m high (about 40% of the total starter dam rise). The scenario also conservatively considered that about 30% of the tailings stored behind the dam would flow through this breach. The dam rise rate was set so as to allow sufficient free volume available for the storage of additional quantities of water that may result from extreme weather events or the slide of rock and soil amounts into the TMF.

Breach development was also considered for the final dam (crown elevation 840 m asl), due to overload in combination with a dam engineering deficiency. The total volume available for tailings deposition is 161,468,148 m³. The maximum useful decant pond volume is about 171.6 Mm³, of which about 161.5 Mm³ available for the tailings, 4.5 Mm³ for decant water, and about 5.5 Mm³ for storm water. The latter means a volume of water equivalent to two PMFs, which makes Corna dam and pond of oversized design. Corna Dam will be provided with a spillway at an elevation of 839 m. Corna Dam will be built by the centerline method of construction, with the downstream face built of very gently sloping rockfill material at a 3H:1V slope, which greatly enhances dam stability.

A dam break scenario was also assessed for Corna Dam, involving a breach 285 m long (about 1/3 of the crest length) and 60 m high (about 35% of the total starter dam height). The
scenario also conservatively considered that about 20% of the tailings stored behind the dam would flow through this breach. The dam break causes considered in the studies for the two scenarios of starter and final dam break included:

**Overloading**
Overloading may occur in the case of accumulation of water in excess of the dam containment capacity, or in the case of transfer of considerable quantities of solids into the TMF, following a landslide event.
To prevent such an event occurring, the available volume of water in the pond will be automatically controlled. Moreover, the available volume of the TMF was oversized to hold about 5.5 Mm³, i.e. the volume of twice the PMF event. This makes the occurrence of such an event very unlikely.

**Seismic Events**
In designing the Tailings Management Facility, the design parameters were chosen to fully cover the characteristic seismic risk for the respective area. Seismic activity is very limited in the Roșia Montană area. The design parameters used included:

- Operating Basis Earthquake - taken as the 1 in 475 year return period event corresponding to a maximum bedrock acceleration of 0.082 g for a magnitude 8.0 earthquake; and;
- Maximum Design Earthquake - taken as equal to the Maximum Credible Earthquake with a maximum bedrock acceleration of 0.14 g, and an earthquake magnitude of 8.0 degrees.

These seismic design parameters adopted for the TMF meet or exceed the 1.1 safety factor that was consider sufficient under the Romanian and European standards for tailings facility design.

**Structural Defects, Foundation Failure**
Foundation building and the dam design will provide very good stability, making foundation failure or structural faults a very unlikely event. From a safety perspective, the construction approach, involving a zoned rockfill dam and filters and a downstream face of 3H:1V slope is better than the techniques adopted for most tailings management facilities worldwide. The stability factors used in designing the system will ensure failure risk reduction to very low levels (table 7-15)

<table>
<thead>
<tr>
<th>Table 7-15</th>
<th>The stability factors used in designing TMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating conditions</td>
<td>Stability factor</td>
</tr>
<tr>
<td>During construction</td>
<td>1.3</td>
</tr>
<tr>
<td>During operation</td>
<td>1.5</td>
</tr>
<tr>
<td>Seismic Events</td>
<td>1.1</td>
</tr>
<tr>
<td>Fast emptying (starter dam and Cetate Dam)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

The structure of the terrain in the dam site area was researched by detailed geotechnical studies, based on the interpretation of data from 23 boreholes. Samples were taken and tested in the laboratory. On-site hydrogeological investigations conducted in parallel also identified the permeability distribution. Piezometers were installed to help characterize the groundwater regime in Corna Valley.

**Piping**
Piping may occur due to water moving through a permeable medium and mobilizing fine particulates. Over time, cavities of various sizes may develop and cause an undermining of the structure. This phenomenon occurs mainly in the contact zone between contrasting grain media, where fine particles may easily be carried in between larger ones. Special piping
prevention measures have been incorporated in the Corna Dam design. Filters and transition areas on the contact zone between the tailings and the andesite fragments in the dam body have been provided. Such filters and transition areas will be made of sandstone quarried th La Pârâul Porcului, crushed and sorted for optimum size, with rigorous quality control during construction.

The TMF pond in Corna Valley might be subject to piping only due to construction faults, associated to human error, and resulting in the creation of inadequate portions in the filters. Considering the construction particulars of the dam, and specially the use of a rock fill, and monitoring systems, such an event may only lead to minor incidents. The appearance of preferential pathways for water carrying fine particulates in the pervious portions of the dam may be detected by visual observation and by means of the dam monitoring system in the Corna Dam.

**Erosion and slope Instability**

Erosion may occur either under the influence of storm water / runoff falling/ washing the dam embankment, or in the case of water overflowing the dam. The dam design greatly reduces the probability of such events to occur. The rock fill dam involving large size fragments, erosion from precipitation/ runoff is practically nil.

The TMF pond in Corna Valley might be subject to piping only due to construction faults, associated to human error, and resulting in the creation of inadequate portions in the filters. The appearance of preferential pathways for water carrying fine particulates in the pervious portions of the dam may be detected by visual observation and by means of the dam monitoring system in the Corna Dam.

**Liquefaction**

In the design stage, it was assumed that liquefaction may cause a reduction of the shear strength in the tailings, under seismic load, of up to 20% of the normal value. The design approach adopted for the TMF will reduce liquefaction opportunities, due to some specific features:

- The water area of the decant pond will be maintained as far from the dam as possible, toward the upstream end of the facility, hundreds of meters away from the crown;
- The upstream facing slope of the deposited tailings will be maintained 0.5%;
- The tailings will be sorted based on size, with the coarser grained deposited in the dam area and the finer upstream;
- The water in the tailings will be partly eliminated through the pervious dam and the drains built at the base of the TMF.
- The downstream prism will be built of rockfill, which will increase the strength in case of partial liquefaction upstream of the dam.

**Armed or Terrorist Attack**

The probability of an armed attack occurring is very low, as the facility is not of strategic significance, and such an attack would assume the existence of a previous conflict, and hence anticipation of such an event, which would provide enough time to stop operations and take steps to minimize the amount of water contained. A terrorist attack is a low probability event (even if higher than for an armed attack) and, as it may not be anticipated, its effects would certainly be very serious.

**4.2.5.2 damage of the final dam**

Considering the containment capacity of the TMF pond, designed for two consecutive PMFs, damage resulting in overflow of the final dam has a very low probability of occurrence. It may only occur if the operating parameters (beach width and freeboard allowance) fail to be
complied with systematically and over the long term and/or if the drainage or decant water discharge systems become damaged for long periods of time. Extreme weather events (abundant precipitation, extremely low temperatures) increase the probability of such breakdowns to occur.

Even if such failures have less serious consequences that the previous event, they are worth considering, as the discharge of hazardous liquids may significantly impact water quality downstream.

4.2.5.3 Breakdowns in the Secondary Containment System
Breakdowns in the Secondary Containment System Designed to collect seepage through the Corna dam and storm waters washing the downstream area thereof, a breakdown in this system may result in exceeded containment capacity and discharge into the recipient water (Corna Valley) of excess water, which is an unlikely event.

The potential consequences are of moderate seriousness and relatively short-term, as the predicted toxic content (cyanides, heavy metals) of this water is low, mainly due to dilution.

4.2.5.4 Breakdown of the decant water pumping station
Breakdown of the decant water pumping station (floating barge) resulting in discontinued water recycling at the process plant and due to pump failure or power cuts.

The probability is medium, but the presence of back up pumps supplied with power from two independent sources (electric and the Diesel generator set) will limit the effects to the short term.

Even if it is an unwanted event, that might affect normal business at the TMF and even at the plant, the seriousness is moderate and short term.

4.2.5.5 Breakdown of the DETOX station
Serious failures or incidents that make treatment of the cyanidated slurry impossible before discharge into the TMF, due to malfunctioning reagent dosage systems or discontinued reagent supply.

Even if faults in the dosage system are probable enough, the presence of the monitoring systems and the parallel operation of two DETOX facilities will considerably reduce this risk.

Difficulties in reagent supply may occur due to the remoteness of the supply sources and to access difficulty to the plant site (caused by floods, snow, access road deterioration, etc.), but such an incident is predictable and therefore allows for the adoption of the necessary measures.

Failure to treat the water (loaded with cyanide) may generate moderate short term effects as they will be reduced by dilution and therefore may not impact significantly on the receiving water quality.

4.2.5.6 Development of toxic aerosols and HCN on the pond surface
Development of toxic aerosols and HCN on the pond surface will occur permanently, the amount of water released into the air depending on both the physical and chemical characteristics of the pumped and impounded water and on the weather conditions.

With strong insolation and high temperature, the amount of HCN released into the air on the pond surface will increase, but if the pH is maintained within normal process limits, HCN ambient concentrations will remain below the toxic threshold, even in close proximity to the water surface.

4.2.5.7 Damage at the electricity supply and distribution system of the floating barge and SRS
Damage to the electricity supply and distribution system of the floating barge and secondary dam, consisting of shorts and/or overheating followed by ignition of the conductor insulation. Such events are of medium probability of occurrence as the design and execution of the system is based on the regulated safety standards, the materials are high quality, there are automated safety and control devices that will provide (partial or total) supply cuts as soon as the normal operating parameters of the system are exceeded.
Such events are of low seriousness and short duration, the consequences being material damage and interrupted pump back of solutions (normally not causing a stop of operations at the plant). Of slightly more concern is the interruption of pump back from the secondary containment system which might result in the discharge of the contained solutions into the receiving water, and the discharge rate exceeds the capacity of the treatment system. To remove this possibility, the pump back station will be supplied from two independent power sources (generator and grid supply).

4.2.5.8 Power cuts caused by independent factors
Power cuts caused by factors beyond the control of the company are low probability events, and may only occur in exceptional situations in the national power supply system. Contingent discontinuation of power supply may have moderate consequences consisting of short-term interruption of decant water pumping.

4.2.5.9 Suicidal attempts
Suicidal attempts by ingestion of cyanide containing solution. It is very unlikely, due to limited access to the TMF premises, and the company personnel are subject to psychiatric controls during recruitment and regularly afterwards. The consequences of such an event would be very serious, almost certainly resulting in death.

4.2.5.10 Occupational accidents
Occupational accidents occurring during the on-site maintenance and repairs activities or response action are assigned medium probability, due to the rigorous organization of all these works, conducted under the direct supervision of the specialist middle management, to ongoing training of the operational staff, and the provision of personal protective equipment and adequate and high quality tools and devices. Occupational accidents occurring during maintenance and repairs work or response action may cause more or less injuries to one or several workers and may be considered events with minor consequences.

4.2.6 Cetate ARD Catchment Dam
Dam break resulting in the development of breaches may occur in case of terrorist attacks or a classic or nuclear attack, an earthquake, etc. The probability of occurrence is very low for a terrorist or armed attack. The pond location is exposed to minor seismic risk and the dam was designed to withstand an earthquake of magnitude greater than 8. Such an accident may have serious consequences including impact on extensive land areas, impact on downstream water quality, plus material damage and potential human injuries.

Breaks resulting in overflow are low probability of occurrence, as they may only occur in the case of failure to observe the operating parameters. Extreme weather events (abundant precipitation, extremely low temperatures) increase the probability of such breakdowns to occur. Such breakdowns have relative low seriousness, resulting in short-term impact on downstream water quality.

Damage to the pumping station, consisting of pump malfunction or power cuts and resulting in the interruption of ARD pumping to the wastewater treatment facility have a medium probability of occurrence. Under normal operating conditions, the consequences would be minor and short-term.

4.2.7 Stockpiles Crumbling
Risk of waste rock pile crumbling. Loss of stability in the waste rock stockpiles is determined by the configuration and physical and mechanical characteristics of the foundation ground,
the hydrodynamic particularities of the local waters and their interaction with the stockpiled materials, the geotechnical features of the waste rock (porosity, internal friction angle, cohesion, specific weight, humidity, degree of compaction, etc.). The probability of occurrence is medium, with the observance of the technical design criteria for pile stability, established for the specific conditions of the site and the characteristics of the material. The stockpiles will be monitored by visual inspection, manual and automatic topographical measurements and the deposition will be made in raises, with leveling and compaction of the stockpiled material.

The seriousness of the accident may be major, due to the massif amounts of stockpiled waste rock and to the fact that a landslide may cause damage to buildings or access roads on the site.

4.2.8 Explosives storage
Explosion or fire at the storage facility. Ammonium nitrate is not an explosive substance, but may explode in the presence of fuel oil or detonators. The dynamite storage facility is built according to the regulations in force, and located underground. This location provides additional protection and limits the consequences of a potential explosion. As specific security and protection must be provided for such a facility, the probability of explosion on this site is relatively low.

An explosion of the whole amount of material at the storage facility will be very strong, and may cause the death of persons nearby, but will not affect buildings or structures, all located more than 1 km away.

Road accident involving a vehicle providing on-site transportation of explosives. The probability of occurrence of such an accident is low, as transport speed on site is regulated and on-site transport vehicles are specially assigned to this purpose. The seriousness is rather high as, in the case of accident, ammonium nitrate may come into contact and mix with fuel oil and, in the case of fire or overheating, will cause a very strong explosion. This might trigger a chain effect, if other facilities in the area may be affected and in their turn cause further accidents.

4.3 Closure Phase

4.3.1 Mining Operations Areas
Not applicable

4.3.2 Site haul routes
Road and occupational accidents occurring in the on-site haulage of materials during decommissioning are assigned medium probability, due to the rigorous organizations of all these works, of ongoing training of the operational staff, and the provision of adequate transport and safety equipment and measures. Such accidents may cause more or less serious injuries to one or several workers.

4.3.3 Process Plant
Local fires during decommissioning works may occur due to open fire activities (welding, etc.) and have low probability of occurrence on the one hand due to the rigorous organization of all these works, to the ongoing training of the workforce and the provision of adequate protection equipment, and on the other hand due to the absence or minimal presence of hazardous or combustible materials. Such accidents may cause more or less serious injuries to one or several workers and minor material damage.

Occupational accidents occurring during the decommissioning of equipment and structures are assigned medium probability, due to the rigorous organization of all these works, of ongoing training of the operational staff, and the provision of adequate working and safety equipment and measures.
Such accidents may cause more or less serious injuries to one or several workers and potential minor material damage.

4.3.4 Pipeline Routes
Not applicable

4.3.5 Corna Tailings Management Facility
Inadequate wastewater treatment in the lagoon system downstream of the Secondary Containment System is hardly likely because this system will have been tested during the operations phase and improved based on the actual characteristics and flow rates of the collected water.
The potential consequences are of moderate seriousness and relatively short-term, as the predicted discharge rate and toxic substance loads of this water is low.

4.3.6 Cetate Water Catchment Dam
Not applicable (Cetate Dam will have a permanent breach constructed to allow the passage of flood water)

4.3.7 Stockpiles
Crumbling of the waste rock stockpiles after closure and rehabilitation works are carried out is of low probability and moderate seriousness, with the associated risk much lower than during the operations phase.

4.3.8 Explosives storage
Not applicable
With the completion of closure and rehabilitation works, no Project specific accident scenario may be identified.

4.4 Qualitative Risk Analysis
For a more suggestive presentation of the findings of the specific accident risk analysis related to the Roșia Montană Project, the following risk quantification matrix was developed based on potential accident scenarios (Tables 7-16, 7-17 and 7-18). This involved assigning numerical values for each level of seriousness of the consequences and probability of occurrence. The risk associated to each scenario is the product of the two assigned values. In setting the values associated with the probability and seriousness levels, consideration is given to the existence of technical safety structures and equipment provided in the design and to the results of former studies.
### Table 7-16. Construction Phase

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Mining Operations Areas</strong></td>
</tr>
<tr>
<td>1</td>
<td>Occupational accidents</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate personnel training, compliance with the parameters and requirements of the pit opening</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Site haul routes</strong></td>
</tr>
<tr>
<td>1</td>
<td>Road and occupational accidents</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate training and equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Process Plant</strong></td>
</tr>
<tr>
<td>1</td>
<td>Fires in the fuel storage</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate training and equipment, special design and construction of the storage facility, fire prevention and control measures</td>
</tr>
<tr>
<td></td>
<td>facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 Local fires due to construction and assembly works</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Process Plant</strong></td>
</tr>
<tr>
<td>2</td>
<td>Fires in the fuel storage</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Workforce injury, material damage</td>
<td>Adequate training and equipment, fire prevention and control measures</td>
</tr>
<tr>
<td></td>
<td>facilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 Fuel leaks from storage tanks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Process Plant</strong></td>
</tr>
<tr>
<td>3</td>
<td>Road and occupational accidents</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate training and equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Pipeline Routes</strong></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Tailings Management Facility</strong></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Cetate ARD Catchment Dam</strong></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Stockpiles</strong></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Explosives storage</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dealt with in Table 4-2.</td>
</tr>
</tbody>
</table>
Table 7-17. Construction Phase

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Explosions during in-pit mixing of ANFO.</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Loss of life or serious injury of the operator of the blending device</td>
<td>Avoidance of heat or sources of fire (sparks) near the blending device</td>
</tr>
<tr>
<td>2</td>
<td>Misfired blasting holes (misses) left after blasting</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Loss of life or serious injury of the personnel in the area, material damage</td>
<td>Work front check by the blaster after each blasting and misfires will be detonated in the next blast</td>
</tr>
<tr>
<td>3</td>
<td>Vibrations due to the use of explosives for mining purposes</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>May be badly perceived by the human factor and cause structural damage to buildings</td>
<td>Precise calculation of explosive quantities, for efficient blasting and to prevent impacts from vibrations</td>
</tr>
<tr>
<td>4</td>
<td>Collapse of the work front at the pit</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Material damage and human accidents</td>
<td>Observance of process parameters required by the operating method and daily check of the work front by the surveyors, geologists and foremen</td>
</tr>
<tr>
<td>5</td>
<td>Road and occupational accidents</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Material damage and human accidents</td>
<td>Adjusting travel speed at the pit to weather conditions, the state of roads and traffic requirements under the health and safety norms</td>
</tr>
<tr>
<td>6</td>
<td>Total destruction of plant facilities</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>Impact on the local soils from massive toxic discharges, potential toxic air emissions</td>
<td>Adequate location of risk sources at the plant (cyanide fluids drainage separate from acidic drainage)</td>
</tr>
<tr>
<td>7</td>
<td>Serious damage to the sodium cyanide storage tank</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>8</td>
<td>Breakage of a solid NaCN container</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Local spills on soil</td>
<td>Special container design, on-site traffic management, special training of the drivers, decontamination measures</td>
</tr>
<tr>
<td>9</td>
<td>Serious damage to the HCl solution holding tank</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Toxic spills, sprinkling, local toxic HCl vapor emissions</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>10</td>
<td>Breakage of the hydrochloric acid hauling road tanker</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>Local spills on soil</td>
<td>Special tanker design, on-site traffic management, special training of the drivers, decontamination measures</td>
</tr>
<tr>
<td>11</td>
<td>Serious damage to a leaching tank</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>12</td>
<td>Serious damage to the thickener</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>13</td>
<td>Serious damage to the access platform or railings above the leaching tank</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>Operator injury</td>
<td>Adequate design and construction, visual inspection</td>
</tr>
<tr>
<td>14</td>
<td>Serious damage to the DETOX facility</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Toxic spills, local HCN emissions</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>15</td>
<td>Operating errors and/or failure of the DETOX</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Excess CN content of the slurry pumped into the</td>
<td>Automated and laboratory monitoring, operator</td>
</tr>
</tbody>
</table>

Section 4: Identification of Potential Accident Scenarios

Page 91 of 205
### Section 4: Identification of Potential Accident Scenarios

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Operating errors and/or failures in the measurement and control devices, resulting in a lower pH in the leaching tank, thickener and/or DETOX slurry.</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>Local HCN emissions to the ambient air</td>
<td>Automated and laboratory monitoring, operator training, automated detection and warning systems</td>
</tr>
<tr>
<td>12</td>
<td>Serious damage to the rich solution holding tanks</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>13</td>
<td>Damage to the 15% CuSO4 solution tank</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Damage to the 20% Na2S2O5 solution tank</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Damage to the reagent storage facilities (copper sulfate, sodium metabisulfite, etc.)</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Local spills on soil</td>
<td>Special storage facility design, on-site traffic management, special training of the drivers and handlers, decontamination measures</td>
</tr>
<tr>
<td>16</td>
<td>Serious damage to the sodium hydroxide solution tank</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Corrosive spills, operator sprinkling and chemical burns</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>17</td>
<td>Serious damage to the lime wash holding tank</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>Corrosive spills, operator sprinkling and light chemical burns</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>18</td>
<td>Operating errors - acid wash of activated carbon.</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Local HCN emissions</td>
<td>Ventilation system and gas scrubber</td>
</tr>
<tr>
<td>19</td>
<td>Operating errors in electrolysis</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>Local HCN emissions</td>
<td>Ventilation system and gas scrubber</td>
</tr>
<tr>
<td>20</td>
<td>Explosion of the LPG storage tank</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Workforce injury, material damage</td>
<td>Special tank design and construction, special operator training, special regular checks</td>
</tr>
<tr>
<td>21</td>
<td>Serious damage to the process water holding tank</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Spills of hazardous content liquids on soil</td>
<td>Leak detection systems, visual inspections, containment tank</td>
</tr>
<tr>
<td>22</td>
<td>Damage to the sodium hypochlorite bottles</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Spills of hazardous content liquids on soil and potential toxic chlorine emissions to the local ambient</td>
<td>Dedicated storage and transport containers, special operator training, separate storage, away from heat and sources of acids</td>
</tr>
<tr>
<td>23</td>
<td>Damage to the ARD lime wash reactor</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>- if action is not taken to prevent the discharge of inadequately treated effluent, acidic nature and high levels of Zn, Fe, Ca, etc. will compromise the facilities it will come into contact with - in nature: contamination of watercourses and ground water, impact on the local quality of life</td>
<td>- presence of pH sensors in the neutralization tanks will signal any failure of the ARD-lime wash reactor - an automated monitoring and control system is required for the ARDWWTP</td>
</tr>
<tr>
<td>24</td>
<td>Damage to the ARD-flocculant reactor</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Sludge will not settle, the resulting water will not meet quality requirements</td>
<td>- supervision of the flocculant input system by means of a monitoring system - backup pumps required</td>
</tr>
<tr>
<td>25</td>
<td>ARD clarified breakdown</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>- area flooded with a considerable volume of water, hence risk of damage to the adjacent structures - process water supply from the WWTP no longer possible</td>
<td>- availability of suction pumps for such incidents process water needs supplied form other sources (enough pumping capacity per unit of time available to the process plant from the TMF or fresh water sources)</td>
</tr>
<tr>
<td>26</td>
<td>Damage of the compressed air facility</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Workforce injury, material damage</td>
<td>Special facility design and construction, special operator training, special regular checks</td>
</tr>
</tbody>
</table>
## Section 4: Identification of Potential Accident Scenarios

### Chapter 7 Risks

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Damage of the oxygen production and distribution facility</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Special facility design and construction, special operator training, special regular checks</td>
</tr>
<tr>
<td>28</td>
<td>Failures of the electricity supply and distribution system, involving fire</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Local production stop, workforce injury, material damage</td>
<td>Special facility design and construction, special operator training, special regular checks</td>
</tr>
<tr>
<td>29</td>
<td>Temporary power supply cut</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Interruption of production activity</td>
<td>Special operator training, power generator, special regular checks</td>
</tr>
<tr>
<td>30</td>
<td>Damage and/or fire at the fuel tanks</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>Workforce injury, material damage, local air contamination with combustion products and VOCs</td>
<td>Adequate training and equipment, special design and construction of the storage facility, fire prevention and control measures</td>
</tr>
<tr>
<td>31</td>
<td>Damage of the cyanide solution handling systems</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Special design and construction, ongoing visual inspection, special regular inspections</td>
</tr>
<tr>
<td>32</td>
<td>Damage of the cyanidated slurry handling systems</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Special design and construction, ongoing visual inspection, special regular inspections</td>
</tr>
<tr>
<td>33</td>
<td>Damage of the cyanide containing solutions/suspensions handling systems</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Toxic spills, local HCN emissions</td>
<td>Special design and construction, ongoing visual inspection, special regular inspections</td>
</tr>
<tr>
<td>34</td>
<td>Damage of the hydrochloric acid solution handling systems</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>Corrosive spills, sprinkling, local toxic HCl vapor emissions</td>
<td>Special design and construction, ongoing visual inspection, special regular inspections</td>
</tr>
<tr>
<td>35</td>
<td>Damage of the sodium hydroxide solution handling systems</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>Corrosive spills, operator sprinkling and chemical burns</td>
<td>Special design and construction, ongoing visual inspection, special regular inspections</td>
</tr>
<tr>
<td>36</td>
<td>Suicidal attempt</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>Death</td>
<td>Access restrictions to the hazardous areas, psychological check on recruitment and regularly afterwards</td>
</tr>
<tr>
<td>37</td>
<td>Occupational accidents during maintenance and repair works</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate workforce training and equipment</td>
</tr>
</tbody>
</table>

#### d. Pipeline Routes

<table>
<thead>
<tr>
<th>No.</th>
<th>Pipeline Routes</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fissure in the tailings pipe</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Toxic spills on adjacent soils, sprinkling, local HCN emissions</td>
<td>Special design and construction, leak detection system, ongoing visual inspection, special regular inspections, decontamination measures</td>
</tr>
<tr>
<td>2</td>
<td>Fissure in the decant water pipe</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Spills of hazardous content liquids on adjacent soils</td>
<td>Special design and construction, leak detection system, ongoing visual inspection, special regular inspections, decontamination measures</td>
</tr>
<tr>
<td>3</td>
<td>Break of the tailings pipe or decant water handling pipe</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Toxic spills on adjacent soils, sprinkling, local HCN emissions</td>
<td>Special design and construction, leak detection system, ongoing visual inspection, special regular inspections, decontamination measures</td>
</tr>
<tr>
<td>4</td>
<td>Damage of the pipelines carrying ARD from Cetate pond to the WWTP</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Spills of hazardous content liquids on adjacent soils</td>
<td>Special design and construction, leak detection system, ongoing visual inspection, special regular inspections, decontamination measures</td>
</tr>
<tr>
<td>5</td>
<td>Occupational accidents during maintenance and repair works</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate workforce training and equipment</td>
</tr>
</tbody>
</table>

#### e. Tailings Management Facility

<table>
<thead>
<tr>
<th>No.</th>
<th>Accident</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dam break and breach development</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>Material damage, property damage, potential deaths, soil, surface and ground water</td>
<td>Observance of design methodologies in construction, continuous dam monitoring</td>
</tr>
<tr>
<td>No.</td>
<td>Hazard</td>
<td>Probability</td>
<td>Seriousness</td>
<td>Risk</td>
<td>Potential Impact</td>
<td>Preventive Measures</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------------------------------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>Dam overflow</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>Flooding of downstream land, soil, surface and ground water contamination</td>
<td>Adequate water management in the TMF, correct operation of the pumping systems</td>
</tr>
<tr>
<td>3</td>
<td>Breakdowns in the Secondary Containment System</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Discharge of contaminated water into the receiving watercourse</td>
<td>Operator and maintenance workers’ training, backup equipment available</td>
</tr>
<tr>
<td>4</td>
<td>Damage of the decant water pumping station</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Rise of water levels in the pond</td>
<td>Operator training, production stop if necessary</td>
</tr>
<tr>
<td>5</td>
<td>Incidents preventing wastewater treatment discharged into the DETOX system</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Increased CN concentration in the pond</td>
<td>Automated and analytical monitoring of the DETOX facility, operator training, production stop if necessary</td>
</tr>
<tr>
<td>6</td>
<td>Development of toxic and HCN aerosols on the pond surface</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>Permanent HCN emissions to the ambient air</td>
<td>Maintaining low CN concentrations by providing slurry treatment prior to TMF discharge, capturing of upstream ARD and diversion channels</td>
</tr>
<tr>
<td>7</td>
<td>Failures of the electricity supply and distribution system</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Temporary stop of pumping into and out of the pond</td>
<td>Special facility design and construction, special operator training, special regular checks</td>
</tr>
<tr>
<td>8</td>
<td>Temporary power supply cut</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Interruption of production activity</td>
<td>Special operator training</td>
</tr>
<tr>
<td>9</td>
<td>Suicidal attempt</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>Death</td>
<td>Access restrictions to the hazardous areas, psychological check on recruitment and regularly afterwards</td>
</tr>
<tr>
<td>10</td>
<td>Occupational accidents</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Workforce injury, material damage</td>
<td>Adequate workforce training and equipment</td>
</tr>
<tr>
<td>f.</td>
<td>Cetate ARD Catchment Dam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Dam break and breach development</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Acidic water floods, population injuries, material damage, impact on aquatic fauna</td>
<td>Dam design and building according to the norms, continuous monitoring, spillway</td>
</tr>
<tr>
<td>2</td>
<td>Dam overflow</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>ARD discharge with impact on aquatic life</td>
<td>Dam design and building according to the norms, continuous monitoring, spillway</td>
</tr>
<tr>
<td>3</td>
<td>Damage of the dam -ARDWWTP pumping station</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Rise of pond water level and potential spill of acidic water downstream of the dam</td>
<td>Operator and maintenance workers’ training, backup equipment available</td>
</tr>
<tr>
<td>g.</td>
<td>Stockpiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Risk of waste rock pile crumbling</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Damage to the site roads and industrial facilities in the impacted area</td>
<td>Observance of the deposition technology, stockpile compacting and grading, daily monitoring by means of topographical measurements</td>
</tr>
<tr>
<td>h.</td>
<td>Explosives storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Explosion or fire at the storage facility.</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>- human casualties (security guard and workers in the impact area)</td>
<td>Observance of explosive storage facility construction conditions under the norms in force - Restricted access to the storage facility area to the security personnel and shotmen</td>
</tr>
<tr>
<td>2</td>
<td>Road accident involving a vehicle providing on-site transportation of explosives.</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Material damage in the impact area, human casualties (driver, shotman and potential workers in the impact area)</td>
<td>Conducting technical inspections of the vehicles, use of safe transportation, adjusting speed to weather conditions and the state of pit roads</td>
</tr>
</tbody>
</table>
## Table 7-18. Closure Phase

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a. Mining Operations Areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Site haul routes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Road and occupational accidents</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Process Plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Local fires due to decommissioning works</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Workforce injury, local air contamination</td>
<td>Adequate training and equipment, fire prevention and control measures</td>
</tr>
<tr>
<td></td>
<td>2 Road and occupational accidents</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Workforce injury, material damage</td>
<td>Adequate workforce training and equipment</td>
</tr>
<tr>
<td></td>
<td>d. Pipeline Routes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>e. Tailings Management Facility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Inadequate water treatment</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Discharge of contaminated water into the receiving watercourse</td>
<td>Semi-passive wastewater treatment system with lagoons, ongoing analytical monitoring of the discharge</td>
</tr>
<tr>
<td></td>
<td>f. Cetate ARD Catchment Dam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>g. Stockpiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Waste rock stockpile crumbling</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Material damage, potential impact on local roads</td>
<td>Periodical stockpile stability monitoring, especially after heavy rain.</td>
</tr>
<tr>
<td></td>
<td>h. Explosives storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The figures 7.13, 7.14 and 7.15 are presenting a summary of the qualitative risk analysis. The cells show the index of the safety zone and the corresponding scenario number:

**Figure 7.13 Qualitative risk analysis – Construction Phase**

<table>
<thead>
<tr>
<th>Probability</th>
<th>10^{-4}</th>
<th>10^{-6}</th>
<th>10^{-8}</th>
<th>10^{-12}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a.1, b.1, c.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7.14 Qualitative risk analysis – Operation Phase**

<table>
<thead>
<tr>
<th>Probability</th>
<th>10^{-4}</th>
<th>10^{-6}</th>
<th>10^{-8}</th>
<th>10^{-12}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a.3, 5, b.1, c.10, 22, 23, 24, 31, 32, 33, 37, d.1, 4, e.4, 10, f.2, 3</td>
<td>c.5, 11, 30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7.15 Qualitative risk analysis – Closure Phase**

<table>
<thead>
<tr>
<th>Probability</th>
<th>10^{-4}</th>
<th>10^{-6}</th>
<th>10^{-8}</th>
<th>10^{-12}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b.1, c.1, 2</td>
<td></td>
<td>e.1, g.1</td>
<td></td>
</tr>
</tbody>
</table>
The results of qualitative risk analysis show that all the accident scenarios considered involve low or very low risks. However, it was considered useful and necessary to provide a more detailed analysis, based on a quantitative risk assessment for all the scenarios entailing major consequences, of probability greater than $10^{-6}$ and/or involving a risk index greater than 9, which are considered potentially major accidents.
5 Hazards and Risks Associated with Transport

Transport of materials, personnel and equipment to and from the Roșia Montană Project site involves a specific set of environmental and social risks associated with the use of the railroad, and especially the national, regional, and local road systems. The diversity and quantity of transported materials and equipment may contribute, in the diversity and size of the potential accidents, to the generation of specific risks in this activity. RMGC will, to the extent possible, adopt its own precautionary measures, additional to the observance of international and national legal provisions in order to minimize risks from transport. It will also continuously cooperate with the authorities in order to select the best route alternatives to minimize risks. However, some additional risk factors (such as the state of the road or the weather conditions, or the skills and behavior of other road users) will remain beyond RMGC’s control and influence. It is essential to recognize such potential risks and develop the necessary mitigation measures in order to reduce the potential occurrence of accidents and incidents related to transport and to develop and improve fast response procedures for transport-related emergency situations should they occur.

Access to the project location is provided by the existing road system. There is still need for a connecting road, about 3.4 km long, to be built on the actual site. Site roads will also be built to connect the various facilities and provide access for inspection and service. A new access road to Roșia Poieni will also be built. Two alternatives have been reviewed for this road, both involving a similar length (5.9 and 6.6 km, respectively).

5.1 Description of the Transport System

5.1.1 Quantities of Transported Materials and Substances

The conduct of mining, processing and construction/closure activities will require a broad range of consumables (additional to sodium cyanide delivery) involving environmental and health hazards. Fuel, gasoline, and liquefied petroleum gas (LPG) will be delivered by commercial carriers and stored on site. Process chemicals and reagents will also be delivered by certified carriers in bulk or in various types of containers, generally involving 20 ton trucks. Specific transport risk mitigation measures for this kind of substances will apply, based on the type of transport.

The table 7-19 shows the annual transported quantities on off site roads, for the main supplied or generated materials:

<table>
<thead>
<tr>
<th>Name</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated Carbon</td>
<td>410 tons</td>
</tr>
<tr>
<td>Flocculant</td>
<td>510 tons</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>2,300 tons</td>
</tr>
<tr>
<td>Quicklime</td>
<td>54,000 tons</td>
</tr>
<tr>
<td>Sodium cyanide</td>
<td>12,000 tons</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>2,000 tons</td>
</tr>
<tr>
<td>Copper Sulphate</td>
<td>860 tons</td>
</tr>
<tr>
<td>Sodium metabisulphite</td>
<td>13,000 tons</td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>8700 tons</td>
</tr>
<tr>
<td>Mineral oils</td>
<td>518 tons</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>16,500 tons</td>
</tr>
<tr>
<td>Gasoline</td>
<td>820 tons</td>
</tr>
<tr>
<td>Mercury</td>
<td>162.5 kg</td>
</tr>
<tr>
<td>Used hydraulic oil</td>
<td>35040 liters</td>
</tr>
<tr>
<td>Used lubricant oil</td>
<td>70080 liters</td>
</tr>
<tr>
<td>Used Vaseline</td>
<td>17520 liters</td>
</tr>
<tr>
<td>Used tires, batteries, electronic equipment</td>
<td>300 to</td>
</tr>
<tr>
<td>Domestic WWTP sludge</td>
<td>2059 kg</td>
</tr>
</tbody>
</table>
## Sodium Cyanide Transport System

Cyanide transport will exclusively involve special, ISO certified SLS containers, 16 tons each, with the following constructive specifications:

- two filling caps at the top
- internal sprinkler system used in dissolving the product upon delivery
- bottom discharge opening

An SLS (Solid to Liquid System) container allows the transport of cyanide in solid state. At destination, water is added via the integrated sprinkler system, then the cyanide solution is unloaded with no loss, using compressed air blown through a dedicated coupling, into the process plant storage containers.

The container size is ISO compliant, allowing for (road and railroad) transport and the use of standard container handling devices.

The container has a protective frame. For ease of handling, the protective framework is provided with legs, which allows separation from the transport trailer for temporary storage. The collar is 5.17 mm thick, which, together with the protective framework, provides additional protection to the load in case of accident.

An SLS container allows the transport of cyanide in solid state. At destination, water is added via the integrated sprinkler system, then the cyanide solution is unloaded with no loss, using compressed air blown through a dedicated coupling, into the process plant storage containers.

Cyanide transportation will cover the operational phase of the Project, i.e. about 17 years.

### Transport of Explosives

Annually, this will involve about 8700 tons of ammonium nitrate and considerable amounts of additional materials. Transport and use of explosives requires special precautions, under the legal regulations in force. The materials used in producing the ANFO explosive mix (ammonium nitrate and fuel oil), starters, blasting caps, wicks and other materials will be delivered to the Project location by specialist contractors. The selected transportation will be by road, in special vehicles, at a rate of several times a month. The implemented mitigation measures are largely similar to those implemented in fuel, LPG, and hazardous reagent transport. Deliveries of highly hazardous loads will be accompanied by fire and police escorts. In addition, the following risk mitigation measures will apply:

Ammonium nitrate deliveries will involve Romanian suppliers, the most probable being the fertilizer plants in Târgu Mureș and Turnu Magurele. High risk areas, due to potential consequences, will include the urban and rural areas driven through.

### Hazardous Waste

RMGC will collect and deliver in special vehicles any hazardous waste generated in its activities. After accumulation at the Temporary Hazardous Waste Storage Facility, hazardous waste will be taken, with an appropriate frequency, based on the rate of accumulation, to permitted disposal sites. Specific measures will be implemented in order to reduce the risks involved in the transport of hazardous waste, based on the quantities and hazardous characteristics of the waste.

### Metal Mercury Waste

Mercury is a by-product of ore processing. Mercury will be generated in the gold recovery stages and in the carbon reactivation circuit, by distillation followed by retort condensation. The recovered mercury will be temporarily stored in sealed containers at the Temporary...
Hazardous Waste Storage Facility. Production rate is estimated at 0.5 kg mercury per day. Accumulated amounts will be regularly carried off site for recycling. Due to the toxicity of the mercury, special safety measures are provided during transport, in order to minimize the risk of mercury spills in case of accident. Precautions during transport and the selection of adequate haulage containers will reduce the risks of mercury transportation.

5.1.6 Municipal Waste
Municipal waste will be segregated and transported on a regular basis, in special vehicles, to the permitted landfill in Sibiu. Exhibit 3.3-7 (from Chapter 3 – “Waste”) shows the selected waste transportation route. The disposal site and transportation route will be changed if permitted municipal landfill sites will open in the Project area to provide safe disposal to the site-generated municipal waste. The risks associated to municipal waste transportation are low, given the low hazardousness of the waste and to the implementation of adequate minimization measures.

5.1.7 Oversize Transport
As with any mining project, heavy equipment is necessary to support all phases of mine life. Heavy equipment deliveries will be required in the construction and operation phases of the Project. Decommissioned equipment will be removed from the Project site for reuse or resale during decommissioning and closure.

Assessment of SHLO (slow heavy load or oversize vehicle) transport alternatives was conducted in a study commissioned by RMGC, considering the delivery options involving various entry points to Romania. Due to the size and weight of the equipment to be delivered, the selected option was road transport from the entry point to Romania, either from Constanta or from western border crossing points, depending on the manufacturer location. Non-SHLO equipment will follow the same route.

The road and railroad infrastructure is continuously improving in Romania. Further road assessment is planned before Project implementation. Based on the results of this assessment, the selected transport options might include railroad sections, as to minimize traffic impacts and associated risks. Transport of certain components of the mining equipment will require the use of oversize vehicles. The risks involved by the presence of SHLO vehicles include traffic jams, especially in urban areas. The state of the roads and the weather conditions may create further difficulties for this type of transport.

5.1.8 Doré Bullion Shipments
During the operations phase, RMGC will make periodic shipments of its products, doré bullion, to a precious metal refinery. Due to the intrinsic value of such transports, terrorist and criminal activities have also been considered. RMGC has provided a set of specific measures to ensure transport security.

5.1.9 Personnel Transport
It is estimated that, on a daily basis, a number of about 400 people will require transportation from their residences in Câmpeni or Abrud to the Project site and back. RMGC has taken the necessary measures to ensure proper operation of site personnel transport.

5.2 Selection of the Cyanide Delivery Route
The study of the risks associated to sodium cyanide deliveries involved four alternative transport corridors. Identification of individual risks was conducted based on a complex analysis including land survey and the application of quantitative risk assessment methodologies for various accident scenarios. As a general risk mitigation measure, it would be preferable that railroad transport should be given priority, even if this would involve longer total transport time, to locations as close as possible to the Project site.
The risk assessment study considered the use of four road alignments for the transport of sodium cyanide. Railroad transport is planned from the loading station of the Degussa, Wesseling (D) company to the road vehicle transfer point selected for each investigated alternative.

According to the study, the lowest risks associated to sodium cyanide transportation are associated to the following route: from Wieseling (Germany) – Sopron (Hungary) – Cluj-Napoca (railroad) to Roșia Montană (road vehicles). Compared to the other options, it involves a better equipped railroad terminal. The road alignment also involves lower risk compared to the others, due to the absence of railroad crossings and the general state of the roads, as well as to the short distances on which it runs close to water bodies.

Risk mitigation measures involving selection of the SLS transport system, careful planning and monitoring of the vehicles, emergency response measures, will contribute to a significant reduction of risks, down to acceptable levels.

5.3 Preliminary Risk Assessment

5.3.1 Construction Phase

Road accidents occurring during the transport of construction materials to the site areas are assigned medium probability, due to the rigorous organization of all these works, to the selection of the most suitable transport routes, ongoing staff training, and the provision of adequate transport equipment.

Such accidents may cause more or less serious injuries to one or several people and material damage.

5.3.2 Operation Phase

- Spills of chemicals/fuels associated to traffic/transport accidents may occur due to faulty equipment, operator error, weather conditions, earthquakes, terrorist threats or protest actions. The probability of occurrence is very low given the security measures adopted by the company. A terrorist attack is a low probability event (even if higher than for an armed attack) and, as it may not be anticipated, its effects would certainly be very serious. The seriousness of such an event depends on where it occurs and the size of the accident. Mitigation measures provided in case of accident may help reduce the effects of fuel/chemical spills. The vulnerable points along the route are urban agglomerations, the proximity of service stations, or of watercourses.

- Fires and explosions associated to traffic/transport accidents may occur due to faulty equipment, operator error, weather conditions, earthquakes, terrorist threats or protest actions. The probability of occurrence is very low given the security measures. The seriousness of the consequences may be mitigated by the strict application of accident response plans. The seriousness of such an event will depend on where it occurs. The sensitive areas will include urban agglomerations, where the number of casualties would be substantial.

- Potential release of sodium cyanide briquettes during transport to the Roșia Montană Project site may occur due to a road accident caused by faulty equipment, operator error, weather conditions, earthquakes, terrorist or protest threats. The probability of occurrence is very low, as the sturdy structure of the transport container can protect the cyanide content and help prevent environmental spills.

- Should the accident result in damage to the transport container, the seriousness may be increased if the cyanide is washed by waters. A serious event in such circumstances would be the transport container falling and breaking into a major watercourse. HCN concentrations released into the air may depend on where the accident occurs.
5.3.3 **Closure Phase**

- Road accidents occurring during the transport of decommissioned equipment and materials from the site are assigned medium probability, due to the rigorous organization of all these works, to the selection of the most suitable transport routes, ongoing staff training, and the provision of adequate transport equipment.

Such accidents may cause more or less serious injuries to one or several people and material damage.

5.4 **Qualitative Risk Analysis**

In the tables 7-20, 7-21 and 7-22 are presented the risk quantification matrix developed based on the investigated transport accident scenarios.

In setting the values associated with the probability and seriousness levels, consideration is given to the existence of technical safety structures provided in the design.

The results of qualitative risk analysis show that all the accident scenarios considered involve low or very low risks. However, it was considered useful and necessary to provide a more detailed analysis, based on a quantitative risk assessment for scenario no. 3 of the operation phase, where the consequences might be major, and therefore classify it as a *potentially major accident* especially as it involves cyanide.
### Table 7-20. Construction Phase

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Road/railroad traffic accidents in the delivery of goods and materials</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Explosion or fuel or other liquid contaminant spills and subsequent environmental or health impacts</td>
<td>Assessment and selection of suppliers and carriers of good repute and experience, detailed contractual requirements and responsibilities regarding delivery control, monitoring and reporting by the suppliers and carriers</td>
</tr>
</tbody>
</table>

### Table 7-21. Operation Phase

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chemical/fuel spills associated with traffic/transport accidents</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Impacts on soil, sub-soil, and potential health effects</td>
<td>Assessment and selection of suppliers and carriers of good repute and experience, detailed contractual requirements and responsibilities regarding delivery control, monitoring and reporting by the suppliers and carriers, strategic planning and selection of delivery routes.</td>
</tr>
<tr>
<td>2</td>
<td>Fires and explosions associated with traffic/transport accidents</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>Explosion or fire with subsequent health and environmental impacts</td>
<td>Assortment and selection of suppliers and carriers of good repute and experience, detailed contractual requirements and responsibilities regarding delivery control, monitoring and reporting by the suppliers and carriers, strategic planning and selection of delivery routes.</td>
</tr>
<tr>
<td>3</td>
<td>Potential release of sodium cyanide briquettes during transport to the RM Project site</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>Potential break of transport container and cyanide spill into watercourses or seepage to soil or groundwater</td>
<td>Assortment and selection of suppliers and carriers of good repute and experience, detailed contractual requirements and responsibilities regarding delivery control, monitoring and reporting by the suppliers and carriers, strategic planning and selection of delivery routes.</td>
</tr>
<tr>
<td>4</td>
<td>Road and occupational accidents</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>Injury to the operators or other road users, material damage</td>
<td>Assortment and selection of suppliers and carriers of good repute and experience, detailed contractual requirements and responsibilities regarding delivery control, monitoring and reporting by the suppliers and carriers, strategic planning and selection of delivery routes.</td>
</tr>
</tbody>
</table>

### Table 7-22. Closure Phase

<table>
<thead>
<tr>
<th>No.</th>
<th>Hazard</th>
<th>Probability</th>
<th>Seriousness</th>
<th>Risk</th>
<th>Potential Impact</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Road/railroad traffic accidents in the delivery of goods and materials</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Explosion or fuel or other liquid contaminant spills and subsequent environmental or health impacts</td>
<td>Assessment and selection of suppliers and carriers of good repute and experience, detailed contractual requirements and responsibilities regarding delivery control, monitoring and reporting by the suppliers and carriers</td>
</tr>
</tbody>
</table>
6 Potential Major Accidents

6.1 Project compliance with GD 95/2003

Government Decision 95/2003 (transposing Directive 96/82/EC - Seveso II Control of Major Accident Hazards into Romanian law) establishes control measures for activities entailing major-accident hazards involving dangerous substances, in order to prevent such types of accidents and limit their impacts on public health and the quality of the environment. The provisions of this Decision apply to activities involving the presence of hazardous substances in quantities that are equal to or exceeding those provided in the Annex no. 2, also considering the legal provisions regulating workplace environment, and especially those related to workplace health and safety.

Under this regulation, the terminology has the following meanings, as follows:
- “presence of dangerous substances” – actual or anticipated presence of such substances on the site, or their presence if assumed to be generated in losing control over an industrial chemical process;
- “hazardous substance” – any pure chemical substance, mix of substances or preparations provided in the Annex no. 2, that exist in the form of raw materials, products, byproducts, waste or intermediate products, including substances that may reasonably be assumed to be generated in the event of an accident. Mixtures and preparations must be dealt with as hazardous substances.

Directive 2003/105/EC-Seveso III, brings a number of additions and changes aiming to extend its applicability and regarding:
- chemical and thermal processing and storage involving the use of hazardous substances, in the exploitation of minerals in mines, quarries, or by means of boreholes;
- operational residue disposal facilities, including tailing ponds or dams containing dangerous substances n particular when used in connection with the chemical and thermal processing of minerals.

Changes and additions have also been operated in the annex listing the substances and categories of substances and relevant quantities.

Relevant qualifying quantities, which need to be considered in implementing the provisions regarding major accident hazard controls, are the maximum quantities that might be present on the site at any given time. Dangerous substances in quantities equal to or less than 2 % of the relevant qualifying quantity shall be ignored for the purposes of calculating the total quantity present if their location within an establishment is such that it cannot act as an initiator of a major accident elsewhere on the site. Based on the data contained in the Project design documentation, we estimated the quantities of hazardous substances that will be present on the site.

6.1.1 Sodium Cyanide Storage

The estimated average cyanide consumption is 37.7tons/day, and considering that the stock has to cover for about 7 days of operation, the amount of stocked cyanide on site would be about 265 tons.

It will be stored as 20% solution in the 216 m³, or 260 t storage tank (52 tons NaCN). The rest of the NaCN will be stored as a dry flake solid in the standard 16 t bulk containers in which it is delivered (i.e. about 14 pcs totaling 224 t).
6.1.2 Carbon in Leach (CIL) Circuit
There will be two parallel sets of 7 leaching tanks, each of 5000 m³ nominal volume. The slurry specific weight is about 1.4 and it containd free cyanide in concentrations of about 300 mg/L.

This is equivalent to a total 7 X 2 X 5000 m³ X 1.4 = 98000 t stored amount of slurry.

6.1.3 Tailings Thickener
The slurry in the tanks is treated with a flocculant solution in the feeding tank of the tailings thickener, with a volume of about 80 m³) then is fed into the 3700 m³ thickener located outdoors in a containment tank. The tank and thickener content (on average) is considered identical to that of the CIL tanks.

The overflow is relatively clear and has an estimated total cyanide content of 219 mg/L, and the thickened underflow (about 60% solids) an estimated total cyanide content 181-189 mg/L, or WAD cyanide 177-187 mg/L).
This is equivalent to a total 3780 X 1.4 = 2300 t stored amount of slurry.

6.1.4 Gold Desorption/Processing Area
The precious metals are stripped from the activated carbon by means of a hot alkaline solution containing cyanide (about 2% NaOH and 3% NaCN) obtaining a rich gold and silver solution which is stored in special containers, four of about 280 m³ capacity each (4 pcs), a buffer tank of elution solution of about 180 m³ (located outdoors, in a containment tank and a 30m³ buffer tank of stripping solution located inside the facility.

Therefore, the total stored amount f solution will be about (4 x 280 + 180 + 30) x 1.1 = about 1460 t.
LPG is stored in an above-ground tank located next to the heating plant, of 50 t capacity (which will cover for about 3.5 days).

6.1.5 DETOX Installation
There are two detoxification reactors, of 1700 m3 each. The suspension goes in at relative density about 1.45 and total cyanide concentrations 219 mg/L and goes out at max. 10 mg/L WAD cyanide.

The DETOX facility will therefore store 2 x 1700 x 1.45 = 4930t.

6.1.6 Lime Storage/Preparation
Raw quicklime in the form of clots is stored in a covered silo, of 860 t capacity, with lime powder stored in a 600 t silo.

The rinsing water used in the scrubber is recycled from a lime wash preparation reactor, of nominal volume 738 m3. The resulting suspension is about 15 % CaO, with density 1.09. The amount of lime wash stored at the facility is 738 m³ x 1.09 = 805 t.

6.1.7 Detox Reagent Management
The metabisulfite preparation reactor capacity is 40 m3 the storage tank a capacity of 160 m3. The preparation contains about 20% metabisulfie, has relative density about 1.48. The amount of metabisulfite stored at the facility is therefore (40 + 160) m3 x 1.48 = 300t.
The copper sulfate preparation reactor has a capacity of 27 m3. The preparation contains about 15 % copper sulfate, has relative density about 2.28. The amount of copper sulfate stored at the facility is about 27 m3 x 2.28 = 61 t.

The flocculant preparation reactor (Ciba Magnafloc 5250) has a capacity of 68 m3. The preparation contains about 0,25 % flocculant, has relative density about 1. The amount of flocculant solution stored is about 68 m3 x 1 = 68 t.
6.1.8 Chemical Reagent Storage
The chemical reagents and compounds are stored at the reagent warehouse in quantities allowing independent operation for about 7 days, as follows:
- Flocculant: supplied in 1000 kg big bags stored in warehouse: about 10 t.
- sodium hydroxide: supplied in 1000 kg big bags stored in warehouse: about 50 t.
- sodium metabisulfite: supplied in 1000 kg big bags stored in warehouse: about 120 t.
- copper sulfate: supplied in 1000 kg big bags stored in warehouse: about 10 t.
- mercury – assumed to result with the precious metals and recovered in a specially designed facility. stock: about 1 t.
- sodium hypochlorite – supplied in 200 L drums (containers) with stored amount about 24 drums, i.e. about 5 t.

6.1.9 Sodium Hydroxide Storage
The sodium hydroxide solution, of concentration 20% and relative density about 1.2 is stored in a 40 m³ storage tank located within a specially designed structure together with a solid NaOH dissolution vessel of 20 m³ capacity.
The total stored amount is 60 m³ x 1.2 = 72 t.

6.1.10 Hydrochloric acid Storage
The 32% hydrochloric acid solution of relative density 1.15 is supplied in special tankers and stored in an outdoor 40 m³ storage tank located within a specially designed, covered structure with a containment tank.
The total stored amount is 40 m³ x 1.15 = 46 t.

6.1.11 Oxygen Plant
It provides 90% pure oxygen at a maximum flow rate 250 kg/hr at pressure 400 kPag. The installation is placed indoors, and the buffer vessel outdoors.
The total stored amount estimated is max. 2 t.

6.1.12 Fuel Storage
The fuel storage facility on the process plant site will include an aboveground, outdoor diesel tank placed in a containment vat (~ 800.000 L = 520 t) and an underground gasoline tank (~ 20.000 L = 15t)

6.1.13 Process Water Tank
Process water mainly consisting of recycled clarified (cyanide containing) water from the TMF pond is stored in a 12000 m³ (t).

6.1.14 Pipes and Pumping Systems at the Process Plant
They provide the handling of various solutions and suspensions between different process steps and are estimated to store about 2% of the quantities stocked in the tanks.

6.1.15 Pipeline Routes

6.1.15.1 Cetate Wastewater Pipeline
The acid water captured in the pond will be pumped to the wastewater treatment plant, located in the processing plant. The 300-mm pipeline will be buried and about 2km long, therefore storing about 140 m³ (t) ARD.
6.1.15.2 Tailings Delivery Pipeline
The treated tailings will be pumped into the TMF. The 5.2 km-long pipeline will be 800-900 mm in diameter and will be adequately insulated to prevent leaks. The amount of suspensions it may hold is about 2600 m$^3 \times 1.45 = 3800$ t.

6.1.15.3 Clarified Water Pipelines
- barge-to-plant: about 900 m$^3$ (t)
- secondary containment -to-TMF : 100 m$^3$ (t)

6.1.16 Tailings Management Facility
It will store about 1000000 - 3000000 m$^3$ (t) clarified (process) water containing about 5 mg/L cyanide (about 5 t CN).
Note: the decant tailings are considered disposed of, and therefore not included in the calculations.

6.1.17 Cetate ARD Catchment Dam
It will store about 500000 m$^3$ (t) ARD

6.1.18 Explosives storage
Considering the estimated annual consumption of 7500 t ANFO, the estimated stock is about 100 t ammonium nitrate (80 t in the semi-buried storage facility, and 10 t in the warehouse) and about 5 t dynamite (4 t in the semi-buried storage facility, and 1 t in the warehouse). The caps and wicks will be stored separately (an estimated annual use of 37500 caps and wicks will mean that about 7500 will be kept in stock, i.e. about 500 kg explosive material). Based on these estimates, the quantity of hazardous substances on the site was calculated as a total and by category, as provided by the Notification Procedure approved by MWFP Order 1084/2003 and the results are presented in Annex no.1.

The attached Annex no.2 shows the stocks of hazardous substances present on the whole Project site, compared to the relevant quantities provided in the Directive. As most of the hazardous substances in stock exceed both the upper and the lower relevant specific quantity limits, the site ranks in the upper limit of relevant specific quantities and is therefore required to send to the local environmental authority and the local civilian protection authority a Safety Report on its operations to prevent major accident risks.

As the Project involves different locations (relatively distant from each other) for some of the facilities involving hazardous substances, a separate assessment of compliance with the Seveso provisions was developed for each. The attached Annex no.2 show the situation of hazardous substance stocks on the process plant site, at the TMF, at the Cetate Water Catchment Dam and at the explosive storage facility. As the amounts of hazardous substances stored at the process plant (with potential hazards associated with toxicity and eco-toxicity), the TMF, and the ARD catchment dam and pond (with potential hazards related to eco-toxicity) exceed both the lower and the upper thresholds of specific relevant quantities, these facilities will classify under the upper relevant specific quantity and therefore subject to the Seveso provisions. As regards the explosives storage facility, a calculation of the global coefficient indicates less than 1 values for both the lower and the upper thresholds, therefore this facility will not be subject to the Seveso provisions.

6.2 Quantitative Analysis of the Identified Major Accidents
Under the Extractive Waste Managing Directive, major-accident hazards must be identified and the necessary features must be incorporated into the design, construction, operation and maintenance, closure and after-closure of the waste facility in order to prevent such accidents and to limit their adverse consequences for human health and the environment, including any transboundary impacts.
If necessary, the operator shall demonstrate, through a risk assessment that takes site-specific conditions into account, that WAD cyanide concentration need not be lowered below the 10 mg/l limit provided by the Directive.

The operator also needs to adopt and implement systematic major hazard identification procedures under normal and abnormal operating conditions and assess the probability and seriousness thereof and must alert the general public on the nature of the main major accident hazards, including of the potential impacts on the local population and the environment.

Under GD 95/2003 on the control of major accident hazard activities involving dangerous substances, a *major accident* means any fire, explosion, or accidental release of dangerous substances in quantities of at least 5% of the relevant quantity established, as well as any accident that has at least one of the following consequences:

### 6.2.1 Injury to people or damage to real estate
- a death,
- injury of six people in the facility followed by hospitalization for at least 24 hours,
- hospitalization of one person outside the facility for at least 24 hours,
- damage to one/several housing units off site and destruction thereof as a result of the accident,
- evacuation or displacement of people for more than 2 hours (persons x hours): the calculated value must be at least 500,
- interruption of service in drinking water, electricity, gas or telecommunications supply for more than 2 hours (persons x hours) if the value resulting from multiplying the number of affected persons by the number of hours of service interruption is at least 1000.

### 6.2.2 Immediate adverse environmental effects

Permanent or long-term damage to terrestrial habitats:
- 0.5 ha or more of a habitat of ecological or conservation value, protected under the law,
- 10 ha or more of a more extensive habitat, including farmland.

Significant or long-term damage to riparian or coastal habitats:
- 10 km or more of the length of a river or canal,
- 1 ha or more of the area of a lake or pond,
- 2 ha or more of a delta,
- 2 ha or more of a coastal water or open sea,

Significant damage to an aquifer or groundwater (1 ha or more)

### 6.2.3 Impacts on goods
- damage to facility goods the lei value of which is equivalent to M€ 0.5
- damage to off site goods the lei value of which is equivalent to M€ 0.2
6.2.4 **Transboundary damage**
Any accident involving the presence of a dangerous substance that causes impacts outside the national territory.

6.2.5 **Any accident or failure, considered of special technical concern for the prevention of major accidents and limit the consequences thereof.**

6.3 **Presentation of the Physical-Mathematical Models Used in Assessing the Consequences of Major Accidents**

6.3.1 **Toxic Gas Dispersion - the SLAB Model**
To assess the way in which HCN and Chlorine disperse into the air, dispersion was modeled using the SLAB software, which simulates the atmospheric dispersion of heavier-than-air gas emissions. The initial version of this software was developed by Morgan, with further developments funded by USAF Engineering and Services Center (since 1968) and the American Petroleum Institute (since 1987). The current version of the SLAB software may deal with situations like: instant releases, of finite duration or ongoing, from various sources: liquid pool evaporating on the ground, horizontal or vertical jet located at various elevations above ground (discharge stacks) or instant releases at ground level.

SLAB View is a Windows interface for the SLAB software, which simulates the atmospheric dispersion of heavier-than-air gas emissions developed by Lakes Environmental Software, a Canadian company.

Atmospheric emission dispersion is calculated by the solutions to the mass conservation, momentum, energy and species equations.

The SLAB software is based on the superficial layer theory. The description of concentration variations in the gas plume is done by a series of differential equations based on the conservation of total mass and components, energy, and impulse in the three directions. This model is supplemented by equations describing the shape of the gas plume and equations for gas physical properties modeling. Gas dispersion simulation using the SLAB software integrates modeled equations with wind direction.

Atmospheric dispersion of the spill is calculated by the solutions to the mass conservation, momentum, energy and class/category/species equations. Conservation equations are spatially averaged in order to treat the plume as a stable smoke stripe, a transitive smoke cloud, or a combination of the two, depending on the spill duration. A continuous discharge (very long duration of the source) is treated as a stable smoke stripe. For a finite discharge, cloud dispersion is initially described using the stable smoke stripe mode and will remain in the smoke stripe mode as long as the source is active. With the closure of the source, the cloud is treated as a smoke cloud and further dispersion is calculated using the transitive smoke cloud mode. For an instant smoke release, the transitive smoke cloud dispersion mode is used throughout.

Over time, the predictions provided by the SLAB model have been compared with extensive sets of laboratory data or data from dispersion experiments conducted in real situations. In these comparisons, the SLAB modeling results proved accurate.

EFFECTSGis 5.5 is a Windows interface, including a mini-GIS interface and was built to analyze the effects of industrial accidents and their consequences.

The software was developed by TNO Built Environment and Geosciences, a Dutch expert group that also developed the Dutch Yellow Book and the Green Book.
Simulation results are displayed as text or in graphical format. The user may opt for the mini-GIS interface, where digital maps may also be used. On these maps, the software will display the calculated iso-property contours (pressure, concentration, radiated heat, etc.). Fire and explosion simulations have been conducted with the following software models:

6.3.1.1 Explosion in vapor cloud model - the Multi-Energy Method
The model was developed by Van der Berg and published in Journal of Hazardous Materials, vol. 12, in 1985.

The model considers that an explosion occurs in a vapor cloud only if the cloud is in an area with obstacles, causing turbulence in the cloud and where the cloud is limited by the obstacles. The part of the cloud not located in such an area will burn without exploding. The theory was checked experimentally. Before starting the simulation, the mass of the explosive substance in the cloud needs to be calculated.

6.3.1.2 Methods for fires and thermal radiations
In computing the heat radiated by given flame shape, the software uses the Thomas equation and the Burgess equation. The Thomas equation is used to calculate flame length L:

\[
L/D = f(m'', \rho_{\text{air}}, D)
\]

Where:
- \( m'' \) – combustion rate, \([\text{kg}/(\text{m}^2\text{s})]\)
- \( \rho_{\text{air}} \) – air density, \([\text{kg}/\text{m}^3]\)
- \( D \) – spill diameter, \([\text{m}]\)

Combustion rate \( m'' \) is calculated using the Burgess equation:

\[
m'' = f(\Delta H_c, \Delta H_v, C_p, T_b, T_a)
\]

Where:
- \( \Delta H_c \) – combustion heat of the flammable material at boiling temperature, \([\text{J/kg}]\)
- \( \Delta H_v \) – vaporization heat of the flammable material at boiling temperature, \([\text{J/kg}]\)
- \( C_p \) – specific heat, \([\text{J}/(\text{kgK})]\)
- \( T_a \) – ambient temperature, \([\text{K}]\)
- \( T_b \) – boiling temperature of the liquid, \([\text{K}]\)

Simulations of toxic dispersion in the ambient air, fires and explosions, the high mortality radius and the irreversible lesion radius were also calculated. These are the distances on which the value calculated for the specific indicator for the considered type of accident exceeds the reference threshold for the respective area. The reference thresholds considered are given in the table 7-23.

<table>
<thead>
<tr>
<th>Type of scenario</th>
<th>Indicator</th>
<th>Threshold I: (HIG MORTALITY)</th>
<th>Threshold II: (non-reversible lesions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air dispersion</td>
<td>Toxic dispersion</td>
<td>LC50</td>
<td>IDLH</td>
</tr>
<tr>
<td>Fire</td>
<td>Fire ball radius</td>
<td>200 kJ/m2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jet-fire</td>
<td>12.5 kW/m2</td>
<td>5 kW/m2</td>
</tr>
<tr>
<td></td>
<td>Pool fire</td>
<td>12.5kW/m2</td>
<td>5 kW/m2</td>
</tr>
<tr>
<td></td>
<td>Flash fire</td>
<td>LFL</td>
<td>0.5 LFL</td>
</tr>
<tr>
<td></td>
<td>BLEVE</td>
<td>fire ball radius</td>
<td>200 kJ/m2</td>
</tr>
<tr>
<td>Explosion</td>
<td>UVCE</td>
<td>0.3 bar</td>
<td>0.07 bar</td>
</tr>
<tr>
<td></td>
<td>CVE</td>
<td>0.3 bar</td>
<td>0.07 bar</td>
</tr>
</tbody>
</table>
These areas are displayed on the map in the form of concentric circles originating at the point of damage (toxic emission, explosion, fire, etc.).

6.4  Risk Analysis

The qualitative risk analysis allowed identification of the following accident scenarios (for the operations phase) that may be considered potentially major accidents:

6.4.1  Mining Operations Areas

6.4.1.1  Explosions during in-pit mixing of ANFO.
The explosive quantities used for pit blasting are about 6 to 8 t for each blasting, therefore significant enough were the ammonium nitrate and fuel oil mix to explode before being placed into the drillings and detonated in a controlled manner.
Due to routine measures explosive handling measures and to the fact that it will only be handled by certified (and properly qualified) persons, such accidents have a very low probability of occurrence. Also, the possibility of the ANFO mix exploding at ambient temperature is very unlikely, in normal operating conditions, as the ignition temperature of the NH4NO3 is at least 1600C, and that of fuel oil >500C.

On the other hand, the seriousness of such an accident may be great, involving the lives of all the people present at the work front and the equipment in the area. Ammonium nitrate, if not mixed with organic substances, may burn without exploding, even at temperatures higher than 1600C, but if mixed with organics, such as fuel oil, explosion is inherent, and the damages are significant on a few meter radius, depending on the blasted amount. At more than 2100C, ammonium nitrate will thermally break down, and if mixed with organic substances pressurized, the breakdown will be explosive.

From similar accidents, however, it is known that a 20 t stock of NH4NO3 exploded at Mihaiesti, after the transport vehicle overturned, resulting in human casualties and the formation of a crater several meters wide around the accident site. The explosion was assumed to occur due to the ignition of the hauling truck diesel tank that got mixed with the ammonium nitrate to create the necessary conditions for the load to explode. Therefore, should the ANFO mix explode at the open pit, the explosion radius would affect all the personnel in the vicinity of the mixture preparation equipment, at the work front, and the equipment on the work front, and might cause the crumbling of the open pit benches and access roads.

6.4.2  Process Plant

6.4.2.1  Total destruction of plant facilities
The total destruction of plant facilities may only be caused by terrorist, or classic weapon or nuclear attack. Therefore, damage may be caused to the HCl tank (including containment) and to the NaCN solution tank, the tanks containing enriched solution, to one or more leaching tanks, leading to spillage of their entire content.

Considering hydrochloric acid solution concentration 32% and density 1.15 kg/l, the maximum amount of pure HCl contained in the spill will be 7360 kg.
Considering cyanide solution concentration 23 % and density 1.25 kg/l, the maximum amount of pure NaCN contained in the spill will be 86250 kg. The sodium cyanide solution also contains variable quantities of sodium hydroxide (1-3%) and sodium carbonate (0.5-2.5 %). For the calculation, we shall consider the solution containing minimum 1% NaOH, i.e. 3750 kg.
In these circumstances, a perfect mix of the two solutions will initially assume neutralizing the hydrochloric acid with the sodium hydroxide in the cyanide solution based on reaction:

\[
\text{NaOH} + \text{HCl} = \text{NaCl} + \text{H}_2\text{O}
\]

where 3422 kg HCl will be used with a residual 3938 kg reacting with the sodium cyanide to form hydrocyanic acid:

\[
\text{NaCN} + \text{HCl} = \text{HCN} + \text{NaCl}
\]

The resulting amount of HCN is 2913 kg, with 5287 kg NaCN being used. Therefore, HCN concentration in the resulting solution will be 9.1 g/l (0.337 mol/l).

It is theoretically possible to have a failure causing a hydrochloric acid spill followed by an overlapping cyanide spill, when the amount of released hydrocyanic acid would be maximum. In this situation, the acid will be neutralized by the sodium hydroxide and sodium cyanide until the acid is exhausted, with the solution then diluted by excess cyanide. The maximum release of hydrocyanic acid would occur initially, when the heat released in the exothermic neutralization reaction will strongly heat a relatively low amount of liquid.

HCN release would be maximum if the 20 m3 of hydrochloric acid spill at the same time as an equimolecular amount of sodium cyanide solution, i.e. 18.4 m3. The so-formed mix (38.4m3) will contain 2913 kg HCN, therefore the HCN concentration will be 75.86 g/l (2.8 mol/l). In this situation, it may be considered that all of the resulting HCN will instantly become gaseous and disperse in the ambient air near the breakage.

Considering the results obtained in the simulations of HCN dispersion into the air in the modeled accident (Annex no 5) it may be considered that in certain situations and weather conditions, unfavorable to dispersion, persons within a radius of about 40 of the emission source and that would be surprised by the toxic cloud for more than 1 minute without respiratory protection equipment will almost certainly die. It may also be considered that, on a radius of about 310 m, persons exposed for more than 10 minutes may suffer serious intoxications that may also lead to death. Toxic effects may occur in persons up to about 2 km downwind of the process plant.

**Operating errors and/or failures in the measurement and control devices, resulting in a lower pH in the leaching tank, thickener and/or DETOX slurry and accidental emissions of hydrocyanic acid.**

To assess the seriousness of the impacts that might be caused by a breakdown resulting in massive hydrocyanic spills into the air, we have simulated its dispersion using the SLAB model above.

For exposure to have health impacts, a person should be in the spill area, within the HCN cloud, without respiratory protection, for a certain period of time, the effects getting more serious with exposure time.

The air quality regulations in force for protected areas (STAS 12574 / 87) do not provide a maximum acceptable concentration for HCN, but the Health and Safety Norms require a peak acceptable concentration of 1 mg/m3 = 0.83 ppm (not to be exceeded at any time during the day)and an average acceptable concentration of 0.3 mg/m3 (for an 8 hr averaging time accounting for a work shift).

Literature shows that exposure to concentrations of 2000 ppm is lethal in one minute (LC50 - Lethal concentration with 50% death of victims), exposure to concentrations of 100-300 ppm I lethal in 10-60 minutes, and for concentrations of 20-40 ppm, specific symptoms of poisoning will occur. Therefore, these concentration levels of hydrocyanic acid were considered representative and were used in the simulations, with the attached reports showing graphically, in different colors, the various areas affected by concentrations of hydrocyanic acid exceeding the above levels. IDLH areas (Immediately Dangerous to Life or Health air concentration values) were also calculated for 50 ppm for 30 minutes exposure.
(ambient concentration of any toxic, corrosive or suffocating substance that poses an immediate threat for life or may cause irrevocable or delayed adverse effects on health, or intervene an individual's capacity to escape a dangerous atmosphere.

All the HCN dispersion simulations were developed for the worst dispersion conditions including:

- Wind speed \( v = 0.5 \) m/s
- Atmospheric stability class stable.
- The following additional conditions were also considered:
  - Concentrations were calculated at the level of 2 m above ground;
  - Average ambient temperature: 5 °C
  - Relative air humidity: 80%.

The following possible situations were also included in the analysis:

**Accidental HCN emission from the CIL tanks**

The accident may be caused by the inadequate quality of the lime wash combined with faulty pH monitoring systems.

**Calculation of emission rate**

Input data:
- Emission surface area = 14 x 274.5 = 3843 m²
- Tank diam. 18.7 m
- Tank area 274.5 kJ/m²
- Cyanide concentration in the tank: 300 g/l CN (565 mg/l NaCN)

Calculation formula:

\[
E = ([0.013 \times [HCN(aq)] + 0.46} \times A \times T / 10^6) \times 1000
\]

where:
- \( E \) = HCN emission (kg)
- \([HCN(aq)] = [NaCN] \times 10^{(9.2 - pH)} \)
- \([NaCN] = \) NaCN concentration in the CIL tanks (mg/l)
- \( pH = \) pH in the CIL tanks
- \( A = \) Total surface area (m²) of the CIL tanks (m²)
- \( T = \) Emission period (hours)

<table>
<thead>
<tr>
<th>No.</th>
<th>PH</th>
<th>HCN emission (kg/sec)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>0.000615</td>
<td>Normal operating conditions:</td>
</tr>
<tr>
<td>2</td>
<td>10,5</td>
<td>0.000884</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>0.001734</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9,5</td>
<td>0.004421</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>0.012918</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>8,5</td>
<td>0.039788</td>
<td>Simulated Situation</td>
</tr>
</tbody>
</table>

In conducting the simulations, the worst possible scenario was considered, i.e. when pH values are maintained at 8.5 over a period of time of more than 2 hours and the pH drop simultaneously affects all the 14 CIL tanks.

**Results**:
The area affected by concentrations of 290 ppm over a 10 min exposure time is within a circle of 36 m radius and the 50 ppm IDLH threshold for 30 min exposure will be reached
over an area of 157.5 m radius. The center of these circles is the middle of the CIL tanks platform.
The impacted areas are shown in graphic form in Annex no.6. and the instant cloud concentrations (max. 290 ppm) in Annex no.7.

**Accidental HCN emission from the decanter**
The accident may be caused by a drop of pH in the CIL tanks combined with an overdose of flocculant solution and faulty pH monitoring systems.

**Calculation of emission rate**
Input data:
- Emission surface area = 1385 m²
- Decanter diam. 42 m
- Decanter area 1385 m²
- Cyanide concentration in the decanter: 219 g/l CN (412 mg/l NaCN)

Calculation formula:
\[
E = (0.013 \times [\text{HCN}_{\text{aq}}] + 0.46) \times A \times T / 10^6 \times 1000
\]
where:
- \(E\) = HCN emission (kg)
- \([\text{HCN}_{\text{aq}}]\) = \([\text{NaCN}] \times 10^{(9.2 - \text{pH})}\)
- \([\text{NaCN}]= \text{NaCN concentration in the decanter (mg/l}\)
- \(\text{pH} = \text{pH in the decanter}\)
- \(A = \text{Total surface area (m²) of the decanter (m²)}\)
- \(T = \text{Emission period (hours)}\)

<table>
<thead>
<tr>
<th>No.</th>
<th>pH</th>
<th>HCN emission (kg/sec)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>0.00021</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10.5</td>
<td>0.00028</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>0.000504</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9.5</td>
<td>0.00121</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>0.003443</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>8.5</td>
<td>0.010504</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>0.032835</td>
<td>Simulated Situation</td>
</tr>
</tbody>
</table>

In conducting the simulations, the worst possible scenario was considered, i.e. when pH values are maintained at 8 over a period of time of more than 2 hours.

**Results:**
The area affected by concentrations of 300 ppm over a 10 min exposure time is within a circle of 65 m radius and the 50 ppm IDLH threshold for 30 min exposure will be reached over an area of 104 m radius. The center of these circles is mid-distance between the two DETOX facilities.

The impacted areas are shown in graphic form in Annex 8. and the instant cloud concentrations (max. 572 ppm) in Annex no.9.

**Accidental HCN emission from the DETOX facility**
The accident may be caused by a drop of pH in the reactors generated by an overdose of metabisulfite solution and/or copper combined with faulty pH monitoring systems.

**Calculation of emission rate**
Input data:
\[Emission \text{ surface area} = 2 \times 132.7 = 265 \text{ m}^2\]
Reactor diam. 13 m  
Reactor area 132.7 kJ/m²  
Cyanide concentration in the reactor:
   a. inflow 180 mg/l CN (339 mg/l NaCN) 
   b. outflow 10 mg/l CN (19 mg/l NaCN) Note: normally, reactor concentrations should be max. 10 mg/l WAD  
calculated average 179 mg NaCN  

Calculation formula:
   $$E = (0.013 \times [\text{HCN(aq)}] + 0.46) \times A \times T \times 10^6 \times 1000$$
where:
   - $E$ = HCN emission (kg) 
   - $\text{HCN(aq)}$ = $[\text{NaCN}] \times 10^{(9.2 - \text{pH})}$ 
   - $[\text{NaCN}]$ = NaCN concentration in the reactor (mg/l) 
   - $\text{pH}$ = pH in the reactor 
   - $A$ = Total surface area (m²) of the reactors (m²) 
   - $T$ = Emission period (hours) 

<table>
<thead>
<tr>
<th>No.</th>
<th>pH</th>
<th>HCN emission (kg/sec)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>6.10992E-05</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9.5</td>
<td>0.000119711</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>0.000305342</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8.5</td>
<td>0.00089236</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>0.002748673</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7.5</td>
<td>0.00861885</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>0.027181981</td>
<td></td>
</tr>
</tbody>
</table>

Table 7-26 Calculated emission rate 

In conducting the simulations, the worst possible scenario was considered, i.e. when pH values are maintained at 7 over a period of time of more than 2 hours and the pH drop simultaneously affects both reactors. 

**Results**:
The area affected by high 1900 ppm concentrations for a 1 min exposure time is located within a 10 m radius circle. The area affected by concentrations of 300 ppm over a 10 min exposure time is within a circle of 27 m radius and the 50 ppm IDLH threshold for 30 min exposure will be reached over an area of 33 m radius. The center of these circles is mid-distance between the two DETOX facilities. 

The impacted areas are shown in graphic form in *Annex no. 10*. and the instant cloud concentrations (max. 1900 ppm) in *Annex no. 11*. 

6.4.2.2 Explosion of the LPG storage tank 
The LPG storage tank has a 50 ton capacity and is located outdoors, near the heating plant. The simulation was conducted for the worst case scenario, considering an explosion of the full tank. In the figure 7.16 are presented the effects on people in the explosion area:
Figure 7.16  The effects of the explosion of the LPG storage tank on people in the area

Burns based on distance
Burns [%]
Distance [m]
lethal burns based on distance, 2nd degree burns based on distance, 1st degree burns based on distance

Threshold I with heat radiation 12.5 kW/m² is within a 10.5 m radius circle and Threshold II, of heat radiation 5 kW/m² is within a circle of 15 m radius.
The results of this simulations are shown in *Annex no.15*

6.4.2.3  Damage and/or fire at the fuel tanks
The fuel storage facility contains two types of fuel, i.e. 800 m³ diesel and 20 m³ gasoline.
Diesel is stored in an outdoor tank placed in a containment vat, and the gasoline is stored in a sunken tank.

Gasoline storage in an underground tank does not involve risk, therefore fire and explosion simulations will only refer to the diesel tank.
Simulations were conducted for the worst case scenarios, considering ignition and combustion all the diesel.
The following situations were considered:

**Fire in the tank**
The fire will start in the fuel tank caused by a terrorist attack or by failure to comply with the operating conditions.

Threshold I with heat radiation 12.5 kW/m² is within a 10.5 m radius circle and Threshold II, of heat radiation 5 kW/m² is within a circle of 15 m radius.
The results of these simulations are shown in *Annex no.12*
Fire in the containment vat covering 600 m² after the entire tank content has spilt into it.
Threshold I with heat radiation 12.5 kW/m² is within a 22.5 m radius circle and Threshold II, of heat radiation 5 kW/m² is within a circle of 31 m radius.
The results of these simulations are shown in Annex no.13

Vapor explosion in the tank when it is full of vapors 800 m³)
Maximum overpressure is 0.2 bar and located in the tank, without reaching Threshold I at overpressure higher than 0.3 bar and Threshold II at overpressure higher than 0.07 bar is within a circle of 272 m radius.
The results of these simulations are shown in Annex no.12

6.4.2.4 Suicidal attempt
Although such an event may be considered a major accident because it would more than likely end in the person’s death, a quantitative assessment is practically impossible to conduct. Preventive measures will be implemented in restricting access to the areas where cyanide and cyanide containing solutions are handled and psychological checks will be conducted upon recruitment and periodically afterwards for all the workforce will help reduce the risk of such incidents to an acceptable level.

6.4.3 Tailings Management Facility

6.4.3.1 Potential Failure Scenarios involving the Tailings Management Facility
Of all the events potentially able to affect the integrity of the TMF, summarized in Section 4, two main scenarios have been reviewed quantitatively: overload due to massive landslides and dam failure due to constructive faults, possibly combined with extreme natural events.

Overloading
In order to estimate the effects of TMF overloading following a landslide involving the penetration of solid materials into the pond, two cases have been investigated, the first occurring 1.25 years from startup, the second 17 years into operations.

- **Case 1:** moment 1.25 years, starter dam rise 739 m, with a spillway at elevation 738 m. The volume of water in the decant pond, under normal operating conditions, is about 1,000,000 m³. The safety volume of the pond is 2,581,980 m³ plus the additional available volume equivalent to two summer PMFs, 2,500,000 m³. In normal conditions, there would be a free volume of about 4,000,000 m³, that might cope with the landslide material. Considering colluvial depth about 5 m, it gives an area of 800,000 sq. m landslide material to be taken over by the TMF without causing overflow. Should the respective area be a square, its side would measure 895 m. If the TMF is filled to capacity (2,581,890 m³), a further 2,500,000 m³ will be left available to cope with a 5 m deep 500,000 sq. m slide, equivalent to a square of about 700 m long sides. In case of catastrophic precipitation, considering that the freeboard is reduced to 1 m, the free volume in the pond will be 612,265 m³. In this case, it will be able to cope with the amount of material equivalent to a square slice of side 495 m. In the case of a PMF, the volume of the solid slide will dislodge an equivalent volume of water in the pond. Assuming a slow slide, at less than 0.5 mm/s (43.2 m/day), the 495 m side slice will end up in the pond in 11.5 days, causing a water discharge of 2,218 m³/hr. This volume, less than 1m³/s, may be handled by the spillway. At high sliding speeds, the overflow might be over the dam crown. The analysis of slide potential on the adjacent slopes of the TMF indicate a low slide tendency, typically in the form of small quantities of material. It is very unlikely that the slide might involve slides more than 50x50 m, that would generate a volume of 12,500 m³. Even if several slides occur at the same time, the volume of dislodged material may only cause minor incidents. At the considered point in time, there...
would be no waste rock accumulations in the Cârnic stockpile, that might slide into the pond.

- **Case 2:** according to the design data, in year 17, the pond will be able to receive, apart from the volume of process water, an additional volume of water equivalent to 2 PMF events, i.e. 5,500,000 m³. Following the rationale above, potential landslides have the capacity to generate hazardous situations. In the case of a PMF event, even if the slide potential is enhanced by excessive soil moisture, the available volume, 2,750,000 m³, may cope with possible quantities of material resulting from slides.

The Cârnic stockpile will have a volume of 46,617,741 m³. Assuming that 10% of the total volume will slide, the resulting amount would be 4,661,774 m³, of which about half, i.e. 2,330,887 m³, could end up in the pond. This quantity can be handled by the TMF, even in combination with a PMF event.

**Dam failure**
The designed TMF is extremely robust, containing several safety measures in addition to most structures that exist worldwide. The design particulars include:

- containment capacity for 2 consecutive PMFs (an extraordinary safety measure, unique in Romania);
- with each dam rise, a spillway will be constructed to discharge excess water from potential extreme events in a controlled way. This will help prevent bank erosion downstream of the dam;
- the starter dam, built of rockfill, with an impervious core, embankment slope 2H:1V downstream and 1.75H:1V upstream;
- The main rock fill dam, of centerline construction and ultra-conservative slopes (3H:1V) for the downstream face. Typically, the slopes for such hydrotechnical structures range between 1.5H:1V and 1.75H:1V;
- a drainage system at the bottom of the waste rock pile and a filter layer between the rock beds, to reduce the water content and stabilize the stored material;
- a monitoring system installed on and near the dam, to provide timely signals regarding potential instability situations, excessive rise of the groundwater in the dam body, excessive increase of the water volume stored in the decant pond.
- implementation of a strict Quality Assurance program, in all the dam building phases.

Even though these safety measures have been provided, two hypothetical accident scenarios were considered, to assess possibility of occurrence and consequences. Such situations might occur, in extreme situations, due to constructive faults, possibly combined with extreme natural events.

In simulating tailings flows in case of dam break, the Jeyapalan model was used. This model was developed for the exclusive purpose of simulating Newtonian – type fluid flow conditions (tailings, sludge, etc). Due to the inherent limitations of the model, resulting from a simplification of reality by using a limited number of input parameters, accident effects are typically overestimated. The Jeyapalan model does not take into account the shape of the dam or of the breach, the site topography, the flow rate in Corna Valley, roughness coefficients or other physical parameters. Therefore, in most cases, the results will describe the "worst case". Two main scenarios have been considered, a failure of the starter dam, and of the final dam, respectively.

**Failure of the main dam (rise 739 m)**
Assumptions:

- it is assumed that the construction schedule for the dam is delayed, due to bad weather, and there is pressure to recover the delay, which might lead to reduced quality assurance requirements;
- the quality of the quarried materials used as rock fill is insufficient to ensure the building rate at the dam;
- alternative sources of material are proposed to cover the deficit;
- the existence of several material supply sources induces additional difficulties to the team in charge of quality assurance;
- during a night shift, a quantity of lower quality material is placed and then covered, before the QA team has had a chance to identify it;
- the non-compliant section is in the last 40 m below the dam crown, a location selected due to the because it would be close to the completion deadline. Additionally, in later stages of construction, the pace would be sped up, due to a reduced working front, which might explain why the inadequate material was not noticed by the QA team.

Accident occurrence:
Based on the above assumptions, it is presumed that a break will develop and extend 40 m down from the crown, one third of the dam length. To calculate the distance that the split tailings would travel after the accident, we used the Jeyapalan model, of internationally acknowledged reliability. The model, however, does not consider the mobilization of the rock mass downstream of the impacted portion, which would in fact reduce the distance covered by the tailings.

Modeling results and potential consequences:
The results of modeling give a 0.6 km range of tailings flow. In such conditions, the advancing front of this flow would extend 0.8 km downstream of the starter am, a little way upstream of the point of confluence with the Abrud River. Most of the material will be stopped by the secondary containment dam. The extent of the tailings flow is shown in Exhibit 8.

Failure of the main dam (rise 840 m)
Assumptions:
in the advanced stages of operation, attention paid to the dam structure has diminished, and the mine no longer produces materials of adequate quality to use as rock fill; it is assumed that, in order to avoid opening a new open pit, unsuitable material will be used for the last 60 m, at the tp of the dam.

Accident occurrence:
Based on the above assumptions, it is presumed that a break will develop in the dam body, 60 m deep into the dam. The Jeyapalan model was used for the simulation. The simulation model does not take into account the mobilization of the rock mass, which would partly stop the flow, and reduce the distance covered by the tailings.

Modeling results and potential consequences:
Modeling gives a 1.6 km reach downstream of the dam for the tailings flow. The flow front will advance nearly as far as the point of confluence with the Abrud River. The modeling results and the map representation of the tailings flow are shown in Exhibit 9. Under both the scenarios above, water will also spill out of the decant pond and the pores of the tailings mass, and affect terrestrial and aquatic ecosystems.
6.4.3.2 Propagation of the flood wave and cyanide transportation downstream

To prevent the impacts of the potential pollution wave, cyanide transportation in river water was assessed for the whole distance to the Hungarian border. This was based on hypothetical assumptions, for the maximum possible effect. The model does not take into account chemical attenuation nor dispersion phenomena occurring as the pollutant plume travels down the river.

The amount of contaminated water in the river system originates in two sources: decant water in the pond itself, assumed to empty completely, and water in the tailings mass pores.

It is assumed that, after the spill, the formerly saturated tailings will have reduced porosity, which will cause a release of interstitial water. The two failure scenarios – starter dam and final dam break, respectively – were considered and two values for the volume of mobilized tailings and two levels for the flow rate in the downstream rivers, respectively were estimated – average flow, i.e. normal regime, and maximum flow, i.e. flood regime. This resulted in six different scenarios (Table 7-27). The spill of water and tailings will involve 24 hr constant flow rate.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1a</th>
<th>1b</th>
<th>1c</th>
<th>2a</th>
<th>2b</th>
<th>2c</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong></td>
<td>starter</td>
<td>starter</td>
<td>starter</td>
<td>final</td>
<td>final</td>
<td>final</td>
</tr>
<tr>
<td><strong>River flow</strong></td>
<td>medium</td>
<td>medium</td>
<td>maximum</td>
<td>medium</td>
<td>medium</td>
<td>maximum</td>
</tr>
<tr>
<td><strong>Water Volume in the pond (m³)</strong></td>
<td>1.000.000</td>
<td>1.000.000</td>
<td>1.000.000</td>
<td>3.000.000</td>
<td>3.000.000</td>
<td>3.000.000</td>
</tr>
<tr>
<td><strong>Breach depth (m)</strong></td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>Tailings saturation (%)</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td><strong>WAD cyanide conc. in pond water/pore water (mg/l)</strong></td>
<td>4.0/6.0</td>
<td>4.0/6.0</td>
<td>4.0/6.0</td>
<td>4.0/6.0</td>
<td>4.0/6.0</td>
<td>4.0/6.0</td>
</tr>
<tr>
<td><strong>WAD Cyanide quant in pond (kg)</strong></td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
<td>12000</td>
<td>12000</td>
<td>12000</td>
</tr>
<tr>
<td><strong>Spilt tailings volume (Mm³)</strong></td>
<td>0.6</td>
<td>5.3</td>
<td>0.6</td>
<td>7.8</td>
<td>27.7</td>
<td>7.8</td>
</tr>
<tr>
<td><strong>Spilt pore water volume (Mm³)</strong></td>
<td>0.32</td>
<td>2.12</td>
<td>0.32</td>
<td>3.31</td>
<td>11.74</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Average spilt cyanide conc. (mg/l)</strong></td>
<td>4.1</td>
<td>4.8</td>
<td>4.1</td>
<td>4.4</td>
<td>5</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Cyanide transfer into the river system (kg/hr)</strong></td>
<td>186</td>
<td>339</td>
<td>186</td>
<td>703</td>
<td>1220</td>
<td>703</td>
</tr>
<tr>
<td><strong>Cyanide concentrations in rivers - representative sections (mg/l)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arieș - Câmpeni</td>
<td>2.1</td>
<td>3</td>
<td>0.08</td>
<td>3.5</td>
<td>4.2</td>
<td>0.26</td>
</tr>
<tr>
<td>Arieș – Turda</td>
<td>1.4</td>
<td>2.1</td>
<td>0.05</td>
<td>2.8</td>
<td>3.6</td>
<td>0.21</td>
</tr>
<tr>
<td>Mureș – Alba Iulia</td>
<td>0.4</td>
<td>0.8</td>
<td>0.03</td>
<td>1.3</td>
<td>1.9</td>
<td>0.09</td>
</tr>
<tr>
<td>Mureș – Arad</td>
<td>0.3</td>
<td>0.5</td>
<td>0.03</td>
<td>0.86</td>
<td>1.3</td>
<td>0.09</td>
</tr>
</tbody>
</table>

6.4.3.3 Potential impacts on human settlements

According to the modeling, the solid fraction of the tailings released after dam break may cover an area 1.6 km down Corna Valley, downstream of the dam. This mass of material would impact elements of the Project (secondary containment dam, wastewater treatment station, access roads) as well as population and property in Corna Valley, downstream of the dam. Dam break may also trigger the release of cyanide bearing water, creating a flood. Correct operation of the monitoring system will allow the early warning of the downstream population and the adoption of mitigation measures. The implementation of an adequate accident prevention and response program will help avoid loss of life.
6.4.3.4 Potential impacts on terrestrial and aquatic ecosystems
A dam break, with spill of water from the decant pond and the pores of the tailings mass, may generate significant effects on terrestrial and aquatic ecosystems. Impact on the terrestrial ecosystems will consist of tailings covering the land in Corna Valley downstream of the dam, up to the point of confluence with the Abrud at the farthest. Downstream of this point, there may be a flood of cyanide bearing water in certain concentrations. The flood wave may physically impact on biota on the impacted land (displacement, drowning, physical shock caused by water-borne objects) and physiological effects, due to the presence of toxicants in the water, respectively.

The effect on aquatic ecosystems will primarily depend on the cyanide concentrations in the water. Chapter 7.5.1 Identification of hazardous substances used in the Project contains a description of cyanide effects on aquatic life.

6.4.3.5 Potential impacts on the physical environment
Following a dam break, the main impact on the physical environment will consist of the tailings covering an area proportional to the tailings spill. Recovery of the impacted land after such an event is costly and laborious.

6.4.3.6 Potential transboundary effects
Transboundary impacts relate to the possibility of the contamination plume reaching the territory of a neighboring state through the river system. To assess this possibility, a simulation of cyanide dispersion in river water was conducted for the whole distance to the Hungarian border. The results of this simulation show that, at the border, the Mures river might bear maximum cyanide loads ranging between 0.03 and 1.3 mg/l.

6.4.3.7 Development of HCN on the pond surface
Simulated emissions of HCN from the TMF pond surface and of their dispersion into the ambient air as presented in Chapter 4.2 show that the level of 400μg/m³ hourly average and 179μg/m³ 8hr average will not be exceeded. These HCN concentrations are only slightly over the odor threshold (0.17ppm) and much below potentially dangerous concentrations. The first symptoms of cyanide poisoning may appear for an exposure of HCN concentrations of 20-40 ppm, and they may be identified as headache, sleepiness, dizziness, weakness and a racing pulse, deep and fast breathing, a flushed face, nausea and vomiting. Cyanides do not accumulate nor deposit and, therefore, chronic exposure to sub-lethal concentrations will not cause death. There is no evidence of carcinogenic, teratogenic or mutagenic effects caused by chronic exposure to cyanides.

6.4.4 Cetate ARD Catchment Dam

6.4.4.1 Dam break and breach development
Flood modeling was in case of a break in Cetate dam was based on the design parameters obtained from the hydro-meteorological study Assessment of rainfall intensity, frequency and runoff for the Roșia Montană Project - Radu Drobot, the natural features of the impacted area (topography, river network, etc.), and the design parameters of the Project structures (dam height, reservoir volume, spillway capacity, pumping flow, etc.). This was achieved by means of the rain-runoff type modeling software HEC-HMS (Hydrological EngineeringCenter – Hydrological Modeling System).

The hydrograph resulting for dam break was obtained by application of the BREACH model based on the above parameters. Based on these input parameters, the BREACH model helped predict the following breach parameters:
- break time: 1hr;
- final breach breadth at the base: 20 m;
• breach slope inclinations: 1,11:1(H:V);
• final breach elevation at the base: 710 m ASL.
• Total spill volume: 800000 m³ (under normal operating conditions the volume stored in the pond is about 500000 m³).

After the hydrograph was obtained by means of the above model, a modeling for downstream attenuation was also developed. This involved assessing energy loss in the river bed using the values of the Manning constant. The Manning coefficient used in the model for the downstream talweg was 0.04. For the cross section of the valley slopes value 0.06 was selected for its corresponding to the maximum values of watercourses with grass, friable rocks and boulders (Chow, 1959). The slope between the transversal profiles at talweg level was obtained by digital topography in the range of 4.5% near Cetate Dam and a minimum 0.3% at kilometer 9.7. The general average slope was established at 1.6%.

The main results obtained in the application of the FLDWAV model in FLDWAV Inundation Map (exhibit 10) for Maximum Peak Flow from the Cetate Dambreak Report regarding the maximum flood wave height on various flow sections are given in table 7-28.

### Table 7-28. The main results obtained in the Cetate Dambreak simulation

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Propagation (hours)</th>
<th>Max. time (m³/s)</th>
<th>Max. flow (m³/s)</th>
<th>Max. speed sc</th>
<th>H water (m)</th>
<th>H above base flow (m)</th>
<th>base</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.6</td>
<td>1206</td>
<td>6.5</td>
<td>5.8</td>
<td>4.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.6</td>
<td>1204</td>
<td>14.0</td>
<td>6.1</td>
<td>4.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>0.6</td>
<td>1205</td>
<td>9.0</td>
<td>2.8</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>0.6</td>
<td>1203</td>
<td>10.8</td>
<td>4.2</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>0.6</td>
<td>1204</td>
<td>7.5</td>
<td>2.4</td>
<td>2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>0.7</td>
<td>1202</td>
<td>5.6</td>
<td>4.3</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.7</td>
<td>0.7</td>
<td>1200</td>
<td>3.2</td>
<td>5.0</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>0.8</td>
<td>1192</td>
<td>3.7</td>
<td>4.7</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.7</td>
<td>0.8</td>
<td>1183</td>
<td>4.5</td>
<td>4.2</td>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>0.8</td>
<td>1177</td>
<td>2.3</td>
<td>3.4</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.9</td>
<td>0.8</td>
<td>1067</td>
<td>2.5</td>
<td>6.2</td>
<td>4.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.4</td>
<td>1.0</td>
<td>935</td>
<td>7.5</td>
<td>7.1</td>
<td>4.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.9</td>
<td>1.1</td>
<td>915</td>
<td>4.7</td>
<td>5.7</td>
<td>4.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.4</td>
<td>1.1</td>
<td>913</td>
<td>4.9</td>
<td>3.9</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>1.2</td>
<td>877</td>
<td>5.2</td>
<td>3.3</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table shows that, during the propagation time of the maximum flow down to the last section considered (10.5 km) is 1.2 hr (1 h 12 min) at maximum flow in the last section 877 m³/s and water depth about 3.3 m or 2.3 m above the base flow. In the above section, the highest flow rate recorded on the Aries under natural conditions was 870 m³/s in March 1981 (Șerban P, Nasăleanu, I, 1981) and on the Abrud at its flow into the Aries 163 m³/s in December 1995. The flood hydrographs for the five different sections downstream of the dam are shown in Figure 6-2 of the Hydrographs (flow vs time) of the Cetate Dambreak Report. A review of these will show a slight attenuation of the hydrograph downstream of the dam. The peak of the flood hydrograph is about 4.9 above base flow immediately downstream of the dam and in the narrow Abrud valley 5.9-7.5 km downstream of the dam.

The broader Aries alley allows the flood wave to propagate on a significantly wider bed, which results in a highly attenuated hydrograph.

After applying the sensitivity study, it was found that only in changing the time of the breach development will the results change. Thus, if the dam break occurs in a shorter time (0.5 hr instead of 1 hour) the height of the flood wave will increase by 1 m, and for a slower breach (4 h instead of 1 h) the flood wave will decrease by 1.9 m on average.
6.4.5 Explosives storage

6.4.5.1 Explosion or fire at the storage facility.

Theoretical and practical consideration on explosive decomposition

An explosion is a fast, complex, physico-chemical process of explosive substance decomposition, accompanied by an equally fast conversion of the potential explosive energy into environmentally destructive mechanical work. The name explosion is a generic term, describing a massive, instant release of heat accompanied by important increase of pressure. An explosion process is characterized by four features: the very high speed of transformation reactions, the exothermal nature of the transformation, the shock wave and the formation of gaseous reaction products.

Explosion caused by the fast combustion of an air dispersive, liquid or solid system propagating at sub-sonic speed is known as a deflagration.

Ultra fast combustion of combustible mixtures or substances propagating at supersonic speeds, in the order of kilometers per second, and accompanied by a shockwave is known as a detonation. The causes of explosion may be physical (increase of vapor or gas pressure due to temperature rise) or chemical (chemical reactions resulting in fast change of the reactants, accompanied by heat release). Explosive substances are substances or mixtures that decompose very fast, forming large quantities of high temperature gas.

Characteristic indicators of shock wave in air include:

- local fire;
- local destruction;
- blow effect;
- initiation of decomposition of other explosive substances;
- long-distance projection of cutting, hurtful or incendiary objects.

In situations where the detonation of an explosive material takes place, the destructive effects are felt at a distance due to the propagation of the shock wave into the environment. The blow effect is a consequence of the discontinuity of pressure characterizing the shock wave, that is caused in the atmosphere by the explosive detonation. The resulting shock wave may be characterized by a pressure profile, i.e. the curve that gives pressure versus space for a given moment in time, or pressure versus time at a certain point in space (figures 7.17 and 7.18).
In a certain point in space, the following characteristic magnitudes of the shock wave may be defined:

- maximum overpressure in the shock wave front $\Delta P_{\text{max}}$
- pressure increase speed $S$ (severity)
- momentum of the positive phase $I_+$ and duration of the positive phase $t_+$
- momentum of the negative phase $I_-$ and duration of the negative phase $t_-$
- arrival time $t_a$

All these parameters are univocally related to each other; their magnitude, and hence the intensity of the shock wave will mainly depend on the environmental conditions (density and compressibility) and on the properties of the explosive substance (loading density, potential, etc.). The initial intensity of the shock wave does not depend on its magnitude and shape, but on the properties of the explosive substance.

In calculating these magnitudes, a number of relations are used, some of which are empirical, with the theoretical results within acceptable limits compared to practical determinations.

The momentum of the two phases is given by the relations:
By extrapolating data measured at different distances, we can obtain pressure dependence on time at distances close to the explosion source, and by further interpolation of the resulting curve \( p = f(t) \), we can calculate the compression caused by the shock wave at any point in the fluid.

As a result of the shock wave passage, the fluid undergoes compression and heating. The degree of fluid heating at the front of the shock wave may be assessed by the Hugoniot equation:

\[
E = E_2 - E_1 = (p + p_0)(v_0 - v)
\]  

where: \( E \) - the energy increase in the fluid unit of volume at the front of the shock wave.

The more the fluid is compressible, the greater the difference of the \( v_0 \) and \( v \) values for a pressure value \( p \) and this will determine use of heat in the fluid compression.

Solving Hugoniot’s equation requires knowledge of the fluid state equation or the compressibility law. To this end, Tet’s equation may be used:

\[
p = A\left[\left(-\frac{\rho}{\rho_0}\right)^n - 1\right]
\]

where \( \rho \) and \( \rho_0 \) are the fluid densities after compression and before compression, respectively, and \( A \) and \( n \) are experimentally determined constants.

In order to characterize pressure at the shock wave front, several relations have been proposed, including:

\[
p(t) = p_0 + \Delta p_f (1 - t / t_p) e^{-\frac{bt}{t_p}}
\]

[1.5]

\[
p(t) = p_0 + \Delta p_f (1 - t / t_p) e^{-b\left[1 + \frac{g}{(1 - \frac{\beta}{\rho})}\right]}\]

[1.6]

\[
p(t) = p_0 + \Delta p_f (1 - t / t_p)\left(\frac{ae}{t_p} + (1 - a)e^{-\frac{ft}{t_p}}\right)
\]

[1.7]

and for the negative phase relation:

\[
p(t) = p_0 - p_\infty \left(\frac{t}{T}\right)(1 - \frac{t}{T}) e^{-\frac{4t}{T}}
\]

[1.8]

On the other hand, modern shock scaling laws assume a similarity between the behavior of the environment and magnitudes of concern in the explosion of various explosives by conversion into TNT equivalent. These are simpler and provide an acceptable level of safety, in keeping with the values used in the tests.

According to this theory, the overpressure at the shock wave front can be calculated by:
\[ \Delta p_f = \frac{808 \left[ 1 + \left( \frac{Z}{4.5} \right)^2 \right] \text{Pa}}{\sqrt{1 + \left( \frac{Z}{0.048} \right)^2 \sqrt{1 + \left( \frac{Z}{0.32} \right)^2 \sqrt{1 + \left( \frac{Z}{1.35} \right)^2}}} \]  

[1.9]

where:

- \( \text{Pa} \) – air pressure at the time of the detonation [bar];
- \( Z \) – scaled distance [m];

and

\[ Z = f_d \frac{R}{W^{1/3}} \]  

[1.10]

where \( f_d \) – the distance factor;
- \( R \) – space separating the objective from the load [m];
- \( W \) – TNT equivalent of the explosive quantity [kg].

Another formula used in calculating overpressure is:

\[ \Delta p_f = 0.84 \lambda + 2.7 \lambda^2 + 7 \lambda^3 \]  

[1.11]

where

\[ \lambda = f_d \left[ \frac{R}{W^{1/3}} \right]^{-1} \]  

[1.12]

The effect of the shock wave on various objectives and obstacles encountered will depend on the value of these characteristics.

The form of the pressure profiles and the characteristic values of the shock wave will depend on a number of parameters, including:

- distance to the objective;
- mass, nature and form of the explosive;
- nature and physical characteristics of the explosive containment;
- nature and physical characteristics of the environment;
- distance and position of the load in relation to the obstacles.

### 6.5 The blow effect and remote destruction

The shock wave in air, accompanied by an intense, but short lived light effect, is a natural consequence of a detonation. This physical disturbance will cause damage to living organisms, buildings, and objects subject to it. Note that, the sudden pressure increase is followed by an important depression. These fast variations of pressure in the environment act upon living organisms causing internal or external lesions and even death. Minimal survival or injury distances have been determined experimentally in establishing the psycho-pathological effects of the blow.

The distance is given by:

\[ d = K \sqrt[3]{Q} \]

where:

- \( d \) is the distance between the explosion spot and the exposed person;
- \( Q \) is the TNT equivalent load;
- \( K \) is a coefficient in accordance with the types of effects on organisms and its values range between 1 and 8, depending on the maximum overpressure recorded at the front of the shock wave.
If the substance is enclosed in a metal or non-metal container, then apart from the effect of overpressure at the shock wave front, the more important effect of the splinters will also be felt; they will be projected at initial speed:

\[ v = \sqrt{2Q_e \left( \frac{M}{\omega} + K \right)^2} \]  

where:
- \( Q_e \) – explosion heat of one kg of exploasive;
- \( \omega \) – quantity of explosive substance initiated;
- \( M \) – quantity of the casing material;
- \( K \) – casing design constant.

And the safety distance will be calculated by:

\[ R = k W^{1/3} \]

where:
- \( R \) – safety distance;
- \( W \) – TNT equivalent of the explosive substance
- \( k \) – protection constant.

Overpressures at the front of the shock wave determining effects on beings, material goods and environmental actors were also determined experimentally. They refer to the type and severity of the damage caused to them and are tabulated. As an example, 0.2 bar overpressures may be borne by humans at no danger, once 1 bar values are reached, the shock wave may cause lesions in the ears and lungs, and 6 bar will cause the death of 100% of the exposed subjects.

### 6.6 Considerations on the explosion risk for ammonium nitrate and dynamite

The most common form in which ammonium nitrate can be found is as a chemical fertilizer. It comes in a variety of forms, but they are classified into two groups, based on the nitrogen content. All fertilizers containing more than 28% nitrogen are considered potentially hazardous.

Generally speaking, the risk associated to the use of ammonium nitrate is low. Safety increases in the case of fertilizers if they are manufactured in compact non-porous form, as this will not allow absorption of impurities that might enhance explosion susceptibility. In regard to its hazardous properties, they are determined by the physical properties of the material (particle size, porosity, density). The chemical properties (purity, stabilizers, moisture), environmental factors (containment, compatibility with other materials) and conditions such as temperature or pressure.

When fed enough energy, ammonium nitrate can decompose thermally. However, the main risk associated to it is the maintenance of fire, even in the absence of air, due to the oxidizing properties and the presence of oxygen in its molecule. Thermal decomposition initiates at temperatures over 169 dgr. Celsius, but becomes notable at over 200 dgr. For pure ammonium nitrate, decomposition stops as soon as the energy source is removed, but in combination with materials or compounds that act as catalysts in the break down reaction (combustible materials, acids, chlorides, metal ions, etc.) it will be self-sustaining. In principle, ammonium nitrate may detonate if impure. This means that neither open fire, nor friction, nor starter sources such as gas explosion may cause detonation. There are only two ways in which an explosive decomposition may be initiated: initiation by another explosive, or transition from thermal decomposition or deflagration. For both ways, it should be noted that the presence of organic impurities strongly influences the ease of initiating an explosion. Dynamite is a strong 2nd order explosive, with a positive oxygen balance and an important volume of gases. Practically, dynamite is the form in which trinitroglycerine can be safely
handled. Dynamite is rather insensitive to impact, friction and shock. Moreover, in certain conditions, it may burn without triggering an explosive reaction. The problem most often associated with the use of dynamite relates to its safe storage, as nitroglycerine tends to leave the inert mixture and form fine droplets on the surface, which highly increases the risk in usage.

At temperatures above 80 deg. Celsius, nitroglycerine in the dynamite starts decomposing. At temperature above 135 deg., the decomposition process becomes violent, and at 218 deg. Explosion occurs.

Unlike ammonium nitrate, dynamite is far more susceptible to accidents that may initiate explosive decomposition.

6.6.1 Assessment of potential impacts
Ammonium nitrate is stored in an above-ground facility, and its construction is not antiexp as follows:
- 80 tons in the underground facility, closed in storage;
- 20 tons in the working shed.
TNT Equivalent, $e_{\text{TNT}} = 0.32$

Dynamite is stored in an underground facility, north-east of the ammonium nitrate storage and connected to surface by an underground passage, as follows:
- 4 tons in the underground facility.
- 1 ton in the working shed.
TNT Equivalent, $e_{\text{TNT}} = 0.9$

Considering that the more dangerous material is dynamite, two of the working hypotheses consider that the explosion will be initiated by it. However, because of the safety measures adopted in storing most of the quantity underground, the effects of a dynamite explosion as such will have negligible impacts on the above-ground environment (effects consist in potential collapse of the underground passage where dynamite is stored). Therefore, we start from the assumption that a dynamite explosion will trigger explosion of the ammonium nitrate storage facility, placed above ground, and were the impacts on the human environment are much more serious. The assumptions will also include the "worst case scenario" – the maximum credible accident.

In calculating overpressures at the front of the shock wave that may cause damage to goods and affect human health, the similarity laws above and tables of correspondence will be used.

In investigating substance behavior in explosion, the following working assumptions will be considered:

6.6.1.1 Initiating detonation of the ammonium nitrate from a substance explosion in the work shed
It is assumed that explosion of the substances present in the work shed will initiate an explosion of the main ammonium nitrate storage facility. Therefore, there will be two explosions: first to explode would be the 20 t of ammonium nitrate and 1 t of dynamite, ten the second explosion will involve the 80 t of ammonium nitrate. However, the effects would be cumulative, as the initiation of the second explosion will occur shortly after the first ($< 10^{-1}$ s).
6.6.1.2  Initiation of ammonium nitrate by the buried dynamite
In this case, it is assumed that initiation of the nitrate storage facility is due to the development of an explosive reaction in the underground dynamite storage facility. The over pressure developed will have two effects: it will cause an earthquake after the collapse of the underground passage and initiate the detonation of ammonium nitrate in the main storage facility. It is also assumed that the initiation of the stored nitrate will trigger initiation of the substances in the work shed.

6.6.1.3  Explosion of the ammonium nitrate storage facility
The third alternative assumes ammonium initiation in storage. A secondary effect would be explosive initiation of the substances in the working shed. As all the above scenarios involve an equivalent quantity of explosive material, the results will be similar. The figures 7.19 and 7.20 show the results of the simulations:

Figure 7.19  Overpressure Chart at the explosion of the ammonium nitrate storage facility

![Overpressure Chart](image-url)
6.6.1.4 Explosion of the work shed
In this hypothesis it is assumed that initiation of the substances in the work shed will not initiate ammonium nitrate in the storage facility. The figures 7.21 and 7.22 show the results of the simulations.
Figure 7.22  The effect on humans and goods at the explosion of the work shed

<table>
<thead>
<tr>
<th>Hypotheses 1,2,3 Distance (m)</th>
<th>Effect</th>
<th>Hypothesis 4 Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Detailed pulmonary accidents</td>
<td>25</td>
</tr>
<tr>
<td>65</td>
<td>Complete destruction of buildings</td>
<td>35</td>
</tr>
<tr>
<td>110</td>
<td>Overtur of vehicles</td>
<td>60</td>
</tr>
<tr>
<td>145</td>
<td>Partial destruction of supporting reinforced concrete structures</td>
<td>70</td>
</tr>
<tr>
<td>160</td>
<td>Eardrum break, important damage to buildings with a metal support structure</td>
<td>90</td>
</tr>
<tr>
<td>220</td>
<td>Destruction of concrete wall buildings, destruction of oil product tanks</td>
<td>130</td>
</tr>
<tr>
<td>480</td>
<td>Knock people down, destruction of lightweight walls, bending of metal plates</td>
<td>280</td>
</tr>
<tr>
<td>900</td>
<td>Mortar falling off and insignificant damage to buildings</td>
<td>500</td>
</tr>
<tr>
<td>2700</td>
<td>Break of normal window panes</td>
<td>1500</td>
</tr>
</tbody>
</table>

Annex no.16 shows extended effects on the area surrounding the storage facility. Account should also be taken of the splinter effect compounding the effects of the shock wave, and occurring due to the fact that the explosive substance is located in a building that will be destroyed by the blast. Therefore, a minimum safety distance is required, - see the table 7-30.

Table 7-30   The minimum safety distance required in case of an explosion

<table>
<thead>
<tr>
<th>Hypotheses 1,2,3 Distance (m)</th>
<th>Minimum safety distance for:</th>
<th>Hypothesis 4 Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1440</td>
<td>building protection</td>
<td>830</td>
</tr>
<tr>
<td>3845</td>
<td>people protection</td>
<td>2200</td>
</tr>
</tbody>
</table>

6.6.2   Road accident involving a vehicle providing on-site transportation of explosives.

Such explosions are of lesser magnitude than those at the storage facility, therefore it is considered that the effects are similar to those of hypothesis 4 above. It should be noted, however, that in this case the effects will involve both the operating personnel (drivers, security) and people and goods potentially at the site of the explosion. Site routes for
explosive transportation are so selected as to avoid the process plant location, which will greatly reduce the consequences of such an accident.

6.6.3 Offsite haulage routes

6.6.3.1 Potential release of sodium cyanide during transport to the RM Project site

Assessment of rail transport-related risks
The transport route section AGL-Wesseling-CT Wanne/Herne is served by a local rail carried with which the manufacturer, DEGUSSA, has established good business relationships, and operated on a daily basis. The operator has a very good transport safety track record. On the section CT Wanne/Herne -Sopron (HU) the shipment will be operated by the largest pan – European railroad operator, INTERCONTAINER, which serves a vast network and operates a very efficient shipment tracking system. Goods trains traveling to various junctions in Europe have a high degree of reliability and priority on the routes they serve. Sopron (HU) is a major junction for all the East and South European countries, with a large transport volume and good functionality of connections.

Upon arrival at the Sopron HU terminal, Hoyer Romania will take over shipment control and monitor it to its final destination, at Cluj-Napoca. The Sopron (HU) – Cluj-Napoca section has high reliability and safety standards, based on long experience and historic cooperation. The long experience of the carrier (the HOYER Company) in operating trains to Sopron junction (HU), cooperation with the railroad operators, is a guarantee of event free transportation along this route. Sopron (HU) is an important railroad junction for HOYER, the operation of connections to date is appreciated as very good.

Satellite GPS tracking systems may also be used by the carrier, HOYER. Such systems may be additional to transport monitoring at different points along the route. Hoyer- dispatch will check on arrival according to the transport schedule at all the control points and, if necessary, will take immediate steps to identify the position of the railtrucks. Maximum delays of one day (except for contingent evens) have only rarely been recorded on the selected transport route.

Assessment of road transport-related risks
From the rail terminal in Cluj Napoca, transport to Roşia Montană will be organized by road, for about 110 km. Special vehicles will be provided by the carrier (Hoyer, Romania) according to the general company standards - global SHE (Safety, Health, Environment) and TQM (Total Quality Management). Hoyer are certified for hazardous shipments. The route presents risks in crossing te urban areas of Cluj-Napoca and Alba Iulia. The rail terminal is also considered a risk area, as it is not fenced off. Hazardous road segments have been identified at the exit from Cluj-Napoca, and on the winding road near Roşia Montană. Another risk area identified was the watercourse Somesul Mic. Other risks are posed by the presence of fish ponds close to the road in Turda area. The probability of accidents occurring in urban areas may be considerably reduced by scheduling the transports at off peak hours. The risks posed by the state of the rail terminal may be reduced by building a fence. In assessing the risks associated to the selected road transport routs, we used the Zurich Hazard Analysis method. The principle of this method is risk identification with probability of occurrence and their consequences or effects in case of occurrence. Effect and probability of occurrence are identified and presented in a system of coordinates. The purpose is to identify the risks located in the red hazardous area of the chart and then identify the necessary measures to reduce the risk, so as to place it in the green area of the chart, either by reducing the probability of occurrence or by reducing the consequences or effects should the event occur. The risks represented in the green area of the chart are tolerable, while the risks in the red area require mitigation measures.

Cluj-Napoca - Alba Iulia Route
Distance: about 95 km
### Table 7-31. Vulnerable areas alongside Cluj-Napoca – Alba Iulia rode

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Code</th>
<th>Vulnerable areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1</td>
<td>Terminal/Cluj-Napoca</td>
</tr>
<tr>
<td>1.0</td>
<td>2</td>
<td>Urban area Cluj-Napoca</td>
</tr>
<tr>
<td>3.6</td>
<td>3</td>
<td>Somesul Mic River on the right</td>
</tr>
<tr>
<td>4.5</td>
<td>4</td>
<td>Bridge over the Somesul Mic</td>
</tr>
<tr>
<td>5.2</td>
<td>5</td>
<td>Hitch hikers</td>
</tr>
<tr>
<td>7.3</td>
<td>6</td>
<td>Segment of very dangerous road for about 25 km.</td>
</tr>
<tr>
<td>31.7</td>
<td>7</td>
<td>Fish farms on both sides of the road</td>
</tr>
<tr>
<td>32.5</td>
<td>8</td>
<td>Turda Municipality</td>
</tr>
<tr>
<td>48.9</td>
<td>9</td>
<td>Bridge over the Aries</td>
</tr>
<tr>
<td>57.5</td>
<td>10</td>
<td>Pond on the right</td>
</tr>
<tr>
<td>62.9</td>
<td>11</td>
<td>Sheep on the road</td>
</tr>
<tr>
<td>66.6</td>
<td>12</td>
<td>Bridge</td>
</tr>
<tr>
<td>68.5</td>
<td>13</td>
<td>Aiud Municipality</td>
</tr>
<tr>
<td>88.2</td>
<td>14</td>
<td>Bridge over a dry bed</td>
</tr>
<tr>
<td>94.2</td>
<td>15</td>
<td>Viaduct</td>
</tr>
<tr>
<td>97.5</td>
<td>16</td>
<td>Alba Iulia Municipality</td>
</tr>
</tbody>
</table>

Alba Iulia – Zlatna Route
Distance: about 35 km
Time: about 1 hour
Mobile phone connection: Available throughout, Orange and Connex.

### Table 7-32. Vulnerable areas alongside Alba Iulia – Zlatna rode

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Code</th>
<th>Vulnerable areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>15</td>
<td>Alba Iulia Municipality</td>
</tr>
<tr>
<td>4.9</td>
<td>17</td>
<td>Locality of Micesti</td>
</tr>
<tr>
<td>13.5</td>
<td>18</td>
<td>Road over a ditch</td>
</tr>
<tr>
<td>31.2</td>
<td>19</td>
<td>Locality of Metes</td>
</tr>
<tr>
<td>35.7</td>
<td>20</td>
<td>Locality of Fenes</td>
</tr>
<tr>
<td>35.7</td>
<td>21</td>
<td>Locality of Fenes</td>
</tr>
</tbody>
</table>

Zlatna - Rośia Montană Route
Distance: about 37 km
Time: about 1 hour
Mobile phone connection: Available throughout, Orange and Connex.

### Table 7-33. Vulnerable areas alongside Zlatna - Rośia Montană rode

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Code</th>
<th>Vulnerable areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>22</td>
<td>Town of Zlatna</td>
</tr>
<tr>
<td>0.5</td>
<td>23</td>
<td>Road close to a ditch</td>
</tr>
<tr>
<td>2.3</td>
<td>24</td>
<td>Serpentines most of the way to Rośia Montană</td>
</tr>
<tr>
<td>36.4</td>
<td>25</td>
<td>Urban area izvorul Aampoiuil Road crossing forested area</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>Rośia Montană Town</td>
</tr>
</tbody>
</table>

The results of applying the ZHA – Zurich Hazard Analysis on the selected route are shown in the figure 7.23.
Figure 7.23. The results of Zurich Hazard Analysis applied on the transport route

Cluj Napoca (RO) => Rosia Montana (RO)

Without measures

With measures

The meaning of the indicators employed are:

a. For the effects
   IV Insignificant
   III Minor
   II. Moderate
   I. Major

b. For probability
   F. Rare (improbable) - Frequency of occurrence less than $10^{-6}$
   E. Unlikely - Frequency of occurrence between $10^{-5}$ and $10^{-6}$
   D. Possible - Frequency of occurrence between $10^{-4}$ and $10^{-5}$
   C. Probable - Frequency of occurrence between $10^{-3}$ and $10^{-4}$
   B. Almost certain - Frequency of occurrence between $10^{-2}$ and $10^{-3}$
   A. Very probable - Frequency of occurrence over $10^{-2}$

6.7 Risk Assessment Methodology.

6.7.1 Toxicological and Eco-Toxicological Characteristics of the Main Hazardous Substances

6.7.1.1 The Effects of Cyanides on Public Health

Cyanide is an extensively used and very valuable industrial chemical and certainly a fast acting poison and can kill in minutes if first aid is not available. Cyanide is eliminated from the body in the liver and it is not a known carcinogenic. People suffering from non-fatal intoxication will recover completely and fast, and experience has shown that if people are not exposed to concentrations far in excess of the regulated limits for longer periods of time, there will be no long term effects. Although a very toxic chemical that has to be handled with care, it rarely is the cause of accidental death.
Fluid or gas HCN may get into the body by inhalation, ingestion or skin contact. Skin absorption will be enhanced by cuts, rashes or moisture. Inhaled cyanide salts are very quickly dissolved and come into contact with wet teguments. HCN toxicity for humans depends on the length of the exposure. Due to the variability of the dose-response effects from one individual to another, toxicity is expressed as the lethal concentration or dose for 50% of the exposed population (LC$_{50}$ or LD$_{50}$). LC$_{50}$ for gas HCN is 100-300 ppm. Inhalation of cyanide concentrations within this range will trigger death in 10-60 minutes, and the time will be shorter for higher concentrations. Inhalation of 2000 ppm HCN will trigger death within a minute. LD$_{50}$ for ingestion is 50-200 mg, or 1-3 mg per kg of body weight. For skin contact, LD$_{50}$ is 100 mg (in the form of HCN) per kg of body weight.

Irrespective of the pathway, once inside the body, the biochemical action of cyanides is the same. Once they have got into the blood stream, the cyanides will for stable complexes with cytochrom oxidase, and the enzymes that contribute to electron transfer in the cell mitochondria during the ATP stasis. In the absence of a well functioning cytochrome oxidase, the cells may use the oxygen in the blood, which causes cytotoxic hypoxia, or cell suffocation. The lack of the necessary oxygen would change metabolism from aerobic to anaerobic, as lactates accumulate in the blood. The combined effects of hypoxia and lactic acidosis is depressurizing of the central nervous system, which may stop respiration and entail death. for a higher lethal dose, cyanides will poison and affect other organs and systems in the body, even the heart.

The first symptoms of cyanide poisoning may appear for an exposure of HCN concentrations of 20-40 ppm, and they may be identified as headache, sleepiness, dizziness, weakness and a racing pulse, deep and fast breathing, a flushed face, nausea and vomiting. These symptoms may be followed by convulsions, pupil dilatation, wet skin, low and fast pulse, shallow breathing. At the end, heart beat slows down or becomes irregular, body temperature goes down, the lips, face and extremities become blue, the person gets into a coma and death follows. These symptoms may also occur at concentrations below the lethal dose, but will be reduced, the body will detoxify, and the contaminants will be eliminated in the form of tiocyanates.

The physiopathology of cyanide intoxication is due to an interruption of the cytochrome enzyme system which causes a stop in cell production of ATP, metabolic acidosis, and a reduction of oxygen consumption. These changes will determine an alteration of the cardiovascular system and the central nervous system. Acute cyanide intoxication triggers coma and convulsions as well as cardiac arrhythmia. Chronic exposure to cyanides, has been observed to cause skin irritations, dermatitis, irritation of the upper respiratory tract, and exposure to high levels of cyanides caused slight aerial disturbances. The central nervous system is one of the target organs for cyanide toxicity. Cyanides affect memory at the same time reducing dopamine and hydroxy-triptamine levels in the hippocampus. This effect is enhanced by malnutrition preceding cyanide administration. The body has several cyanide detoxification mechanisms. Most cyanides react with tio sulfates in enzyme catalyzed reactions forming tio-cyanates. Tiocyanates are eliminated in the urine within days. Although cyanides are several orders of magnitude more toxic than tiocyanates, if the latter’s concentration in the body increases, following chronic exposure to cyanide, and determine thyroid disorder. Cyanides display an even higher affinity for metemoglobin than for cytochrom oxidases, and will prefer to combine into cyam-metenglobine. If these or other detoxification mechanisms occur when the dose and exposure time are not too high, they can prevent acute cyanide poisoning from becoming lethal.

Some antidotes have advantages over the natural detoxification mechanisms of the body. Intravenously administered Na tiosulfate makes the released sulfur intensify the conversion of cyanides into tiocyanates. Amyl, Na nitrites and dimethylaminophenol (DMAP) are used to increase the blood level of methemoglobin, which will then connect to cyanides to form non-
toxic cyanmethemoglobin. Cobalt compounds are also used to form stable, non-toxic, cyanide compounds, but, with nitrites and DMAP, Co is also a toxic. Cyanides do not accumulate nor deposit and, therefore, chronic exposure to sub-lethal concentrations will not cause death. However, chronic exposure may become hazardous when the individual’s diet includes cyan containing plants, such as manioc. Chronic exposure to cyanides may cause lesions of the optic nerve, optic atrophy and malfunction of the thyroid.

There is no evidence of carcinogenic, teratogenic or mutagenic effects caused by chronic exposure to cyanides.

6.7.1.2 The Effects of Cyanides on the Environment

In the environment, cyanide is naturally produced by various bacteria, algae, fungi and many species of plants including beans (coffee, chicken peas), fruit (apple, cherry, pear, apricot, peach, plum and almond stones and seeds), vegetables of the cabbage family and roots (potatoes, radishes, turnips). Incomplete combustion during forest fires is considered a main source of environmental cyanide. Industrial activities including gold extraction have the potential of releasing cyanides into the environment, at much higher concentrations than from natural sources. Although cyanide reacts fast in the environment by degrading and forming complexes and salts of various stability, this may have adverse effects on living organisms.

Impacts on aquatic organisms

Cyanide is a poison that acts fast and prevents the use of oxygen at cell level. The high toxicity of cyanides for aquatic life was long studied and so it was found that the HCN molecule is the main cause of cyanide toxicity. The toxicity of most solutions of cyanidated complexes tested on fish is mainly attributable to the HCN resulting from the dissociation of complex forms. Although the acute levels of toxicity vary based on certain parameters such as the season, the species, other aquatic parameters, free cyanide concentrations of 0.005,003 mg/l are considered non-hazardous for aquatic organisms.

The degree of dissociation of the various complexes and metalcyanides, in equilibrium, will increase with a decrease of concentration and of pH. The cyanide-zinc and cyanide-cadmium complexes almost all dissociate in very diluted solutions, so that these complexes can be very toxic to fish in any pH. For the same dilution, dissociation of the nickel-cyanides is much lower, and the most stable cyanide complexes are those involving copper. Acute toxicity of diluted solutions containing anions of the complex forms of silver-cyanide or copper-cyanide for fish may be due, totally or in most part, to the non-dissociated ions, although complex ions are much less toxic than HCN.

Complex ions of iron-cyanide are very stable and non-toxic. In the dark, the acute toxicity levels of HCN are only recorded for not very diluted solutions. Nevertheless, these complexes are subject to fast and extensive photolysis, with HCN generation, following direct exposure to the sunlight of the diluted solutions. Decomposition under the influence of light depends on exposure to ultraviolet light and it is reduced if the water is poorly lit in deep waters, in high turbidity, or in shaded areas.

Fish and aquatic invertebrates are extremely sensitive to cyanide exposure. Free cyanide concentrations of 5.0 to 7.2 μg/l, will reduce swimming performance and reproductive capacity in most fish species. Other adverse effects include delayed mortality, pathology, halted breathing, osmo-regulatory disturbances and altered growth algorithms.

Concentrations of 20 -70 μg/l of free cyanides cause the death of many species, while levels in excess of 200 μg/l are very toxic to most fish species. Invertebrates will suffer non-lethal effects at 18-43 μg/l free cyanides and lethal effects at 30-100 μg/l (although levels of 3 to 7 μg/l have caused the death of amphipods (Gammarus pulex)).
Algae and macrophytes may tolerate much higher levels of free cyanide than fish and invertebrates, and will not show any adverse effects at 160 μg/l or more. Aquatic plants are not affected by cyanides in concentrations that are lethal to many fresh water species, marine fish and invertebrates. However, different sensitivities to cyanide may result in changes of the plant community structure, with cyanide exposures causing the dominance of less sensitive species.

The sensitivity of aquatic bodies to cyanide is specific to each species and affected by the water pH, temperature and oxygen content, as well as by the life cycle and condition of the body.

**Impacts on birds**
Reported LD₅₀ for birds ranges between 1,43 mg/kg body weight (wild duck) to 11,1 mg/kg body weight (domestic chicken). Symptoms such as short breath, blinking, drooling and lethargy appear 1-5 minutes after ingestion in the more sensitive species and within up to 10 minutes in the less sensitive. Exposures to high doses have caused breathing problems followed by repeated swallowing in all the species. Mortality typically appears in 15-30 minutes; however, birds that can survive for half an hour will recover, probably due to the fast metabolisation of the cyanides into tiocyanates and its fast disposal.

WAD cyanide ingestion in birds may cause delayed death. It appears that birds will drink WAD cyanide containing water that is not immediately fatal, but will be triggered in the acidic conditions of the stomach and produce sufficiently high levels of cyanide to become toxic. Sub-lethal effects of bird exposure to cyanide, such as increased susceptibility to predators, have not been investigated in detail.

**Impacts on mammals**
The effect of cyanide on mammals is common, due to the large number of cyanide containing fodder, such as sorghum, Sudan grass and corn. When these are cultivated in dry conditions, accumulation of cyanogenic glycosides is enhanced in some plants, and improve their use as fodder.

Reported LD₅₀ for mammals ranges between 2,1 mg/kg body weight (coyote) to 10,0 mg/kg body weight (laboratory rats). Acute poisoning symptoms including initial excitability and muscle tremor, salivation, teary eyes, defecation, urination and heavy breathing, followed by muscular discordance, gasping and convulsions appear mainly within 10 minutes of ingestion. In general livestock sensitivity to cyanide decreases from cattle to sheep, to horses to pigs. Deer seem to be very tolerant of cyanide toxicity.

**Cyanide presence in soil**
Almost all the cyanides in soils impacted by cyanide pollution are in the form of iron complexes, predominantly ferro-ferric cyanides. Free cyanides are not detectable in such soils, except immediately after the spill. Ferro-ferric cyanides are often stable and not very mobile, especially in the acid conditions associated with the soils on such sites, and so have low toxicity. Ferro-ferric cyanides becomes soluble with a pH increase (pH more than 6), but the resulting hexa-cyano ferrate ion will also have low toxicity, due to insignificant dissociation into free cyanides. Other complexes or meta-cyanide salts are not associated with the soils on such sites in significant quantities to increase toxicity concerns. Although UV radiation may convert iron cyanide complexes into very toxic free cyanides, the kinetics of this photo-degradation in soils is not known. Even so, photo-degradation is only relevant on the surface, and the resulting gas will quickly dilute and disperse into the ambient air to non-toxic levels.

Although present in the environment and available in many plant species, cyanide toxicity is not extensive, due to a number of significant factors. Cyanide has reduced persistence in the environment and does not bioaccumulate or deposit in any of the studied mammals. No
biological development of cyanide has been reported in the food chain. Although chronic cyanide intoxication does exist, cyanide has low chronic toxicity. Repeated sub-lethal doses of cyanide determine cumulative adverse effects. Many species can tolerate cyanide in substantial quantities, but only in intermittent long-term sub-lethal doses.

6.7.2 Analysis of Health Risks in the Case of Accidental Emissions to the Air
The approach to occupational and accidental exposure to HCN for this case involved:

- comparison of the health risks for workers in the three accident impact zones, in terms of spatial distribution of hazardous substance concentrations in the workplace air;
- comparison of the health risks for workers in the accident impact zones, in terms of spatial distribution of hazardous substance concentrations in the workplace air versus workers on the site at a given time.

For item 1, the assessment was made based on the fact that at concentrations above LC50 in air 2 m above ground (which includes the normal breathing height for humans) lethal effects will occur almost instantly (within 1 minute), and at concentrations above the IDLH ("immediately dangerous for life and health air concentration values"), half of them will develop important acute effects due to behavior leading to a lack of immediate response measures as described above.

Statistical processing indicates that there are significant differences between severe effects in the workers exposed to accidental HCN concentrations as described in the cited annexes, depending on the impact area (as described in the above annexes) in which they happen to be the time of the accidental exposure. In other words, a classification of the workforce by category based on the exposure levels in the impact area shows the same major health risks, which requires the implementation of a consistent program for the whole impact area. When risk assessment is performed for the workers exposed to various workplace HCN concentrations (as described in the above annexes) it is found that the differences between areas of different concentrations within the impact zone are not statistically significant. This behavior translates into high serious risk for the entire area impacted by the accidental emission, as spatially characterized in the above-mentioned annexes) The model has relatively good sensitivity and specificity for a 0.75 cut-off.

For item 2, the assessment was made considering the scenario under item 1, to which we included the staff potentially present on the site at a given time, assuming that they are exposed to workplace air concentrations above the acceptable regulated values for occupational exposure, even if the estimates show that occupational exposure for that facility is not exceeded under normal operating conditions. For this latter case, it was considered that a relatively high percentage (10%) may develop important acute effects, even if literature does not mention them.

The regression coefficient shows that the health effects developed by the workers in the high concentration areas from the accidental emission of HCN into the workplace air are statistically significant even if all the workforce on the site at a given time are included.

A more complex processing of risk assessment of health effects on all the site workers exposed to HCN (considering effects in the accident area versus effects site-wide) shows significant higher risks for the exposed workers conducting activities on the site at a given time. The model has high sensitivity and specificity for a 0.5 cut-off.

6.7.3 Social Risk Analysis
Quantitative risk assessment includes the determination of individual risk (IR) and social risk (SR)
According to the definition, *individual risk* is the frequency of individual death due to a potentially polluting event. The individual is assumed unprotected and present in the area throughout the exposure time. 

*Social risk* is the frequency of an accident with at least \(N\) simultaneous fatalities. Social risk is represented by a FN diagram, where \(N\) is the number of fatalities and \(F\) the cumulated frequency of accidents with at least \(N\) deaths. FN diagrams do not always refer to the number of dead, but also of injured or loss, of which about 30% may be loss of human life (Trevor Kletz, *Hazop and Hazan*, 4th edition, 1999, pg.95).

### 6.7.3.1 Calculation of Individual Risk and Social Risk

The calculation method for *IR* and *SR* involves the following steps:

- defining an evaluation grid for the area of concern;
- calculating Individual Risk;
- calculating Social Risk.

Performance of these calculations involves a knowledge of statistical data regarding the weather conditions in the impacted area.

#### Step 1. Defining the calculation grid

This step involves defining an evaluation grid for the area of concern. The central points of the grid cells are known as *grid points*. Individual Risk is calculated for each grid point in the area of concern. The size of a grid cell must be small enough not to influence precision in calculating RI. Selection of the cell size will also depend on the distance the pollutant effect will cover. The next step at this stage is to assess the population that might exist within each cell.

#### Step 2. Calculating Individual Risk

Individual risk is calculated separately for each grid cell. The frequency of individual death is calculated separately for each grid point, for each situation considered, for each weather condition and for each probable wind direction. Individual Risk for one grid point is calculated as a sum of contributions from each investigated situation.

The algorithm used in assessing IR for a grid point is as follows:

1. selecting a case that might pose a risk. The frequency of such an event to occur is \(f_{\text{event}}\) and is calculated;
2. selecting a weather situation and a wind direction and speed. The frequency of such an event to occur is \(P_{\text{metPwd}}\) and results from the weather data for the exposure zone;
3. simulating pollutant dispersion under the specific conditions of the situation selected under 1 and 2 of this algorithm;
4. calculating death probability, \(P_{\text{dec}}\), considering the pollutant toxicity. Death probability is calculated based on the following relation:

\[
P_{\text{dec}} = \frac{1}{2} \left[ 1 + \text{erf} \left( \frac{\text{Pr} - 5}{\sqrt{2}} \right) \right] \quad (4)
\]

where:

\[
\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_{0}^{x} e^{-t^2} dt \quad (5)
\]

is the error function, and Pr the *probit* function of death due to toxicant exposure calculated by:

\[
\text{Pr} = -19,2 + \ln(D) \quad (6)
\]

where:
is the toxic dose inhaled following exposure during time \( t \) to the gas cloud containing variable pollutant concentrations \( c \).

Calculating the contributions \( \Delta R_I \) for every scenario, weather condition, death effect, for each grid point is based on relation:

\[
\Delta R_I = f_{\text{event}} P_{\text{meto}} P_{\text{dv}} P_{\text{dec}}
\]

where:
- \( f_{\text{event}} \) - probability of occurrence of the investigated case;
- \( P_{\text{meto}} \) - probability of the weather situation
- \( P_{\text{dv}} \) - probability of wind direction and speed
- \( P_{\text{dec}} \) - probability of death,

Individual Risk – \( IR \), results from adding up all the cases for each grid point based on relation:

\[
RI_{\text{total},i} = \sum_{\text{event}} \sum_{\text{meto}} \sum_{\text{vant}} \Delta R_I
\]

**Step 3. Calculating Social Risk**

Calculation of Social Risk involves calculating the probable number of deaths \( N \) for every grid point and every case considered. At the end, the cumulated frequency of all the situations with at least \( N \) deaths is calculated.

The algorithm in assessing \( SR \) is as follows:

- selecting a situation of the type:
- considered situation, of frequency \( f_{\text{event}} \);
- weather situation and a wind direction and speed, of frequency \( P_{\text{meto}} P_{\text{dv}} \);
- selecting a grid point. Estimating the number of people in the grid cell, \( N_{\text{pop},i} \);
- calculating the death fraction \( F_{\text{dec},i} \) based on the situation obtained by the selections made under 1 (a and b) and 2 of the algorithm.
- calculating the probable number of deaths in the grid cell, \( \Delta N_i \):

\[
\Delta N_i = F_{\text{dec},i} \cdot N_{\text{pop},i}
\]

where:
- \( \Delta N_i \) - number of expected deaths in grid point \( i \);
- \( F_{\text{dec},i} \) - fraction of deaths in grid point \( i \);
- \( N_{\text{pop},i} \) - number of people in the grid cell, \( i \);

Repeat 1-4 for each event, weather class, wind direction and speed, calculating the total number of expected deaths in each case by relation:

\[
N = \sum_{i=1}^{\text{grila}} \Delta N_i
\]

Social risk assessment will be represented by curve \( FN \), where the \( X \) axis will give the number of deaths \( N \) (on a logarithmic scale of minimum value 1) and the \( Y \) axis the cumulated frequency of accidents \( F \) where the number of deaths is equal to or greater than \( N \) (on a logarithmic scale of minimum value \( 10^{-9}/\text{yr} \)).

The results of the quantitative risk assessment for the RM Project based on an analysis of the potentially major accident scenarios are shown in figure 7.24.
It may be seen that all the investigated situations have given a calculated individual risk below the acceptable limit, and the social risk also ranges below the acceptable limits.

6.7.4 Assessment of Cumulated Health and Environmental Risks

Health and environmental risk assessment was seen as a priority by the European Conference for Environment and Health, London, 1999. The Executive Summary of the Proceedings states that there is an urgent need for methods and systems for the assessment of such risks with low costs, and one of the goals should be the assessment of specific susceptibility of individuals and populations to environmental and health risks. An improvement is recommended of the exposure and impact assessment methodologies and a further development of risk characterization by means of the quantity of chemicals.

After the industrial spills of toxic chemicals on the Lower Danube in early 2000, the Italian Ministry of the Environment and the World Health Organization (WHO/OMS in RO) developed a pilot project of rapid environmental and health risk assessment (REHRA) on secondary rivers of the Lower Danube Basin.

At the extraordinary meeting of the European Environment and Health Committee (EEHC) in Vienna, support was expressed for the association initiative of the Italian Government and the WHO in developing a proposal for the pilot project to create and trial a method based on the rapid environment and health risk assessment, with the following recommendations:

- The Pilot Project should be open to any entrant and all the stakeholders, including the civil society, are invited to contribute to the formulation of the technical action plan and the actual implementation of the Project.

- The Pilot Project is relevant for UN/ECE Convention on Protection and Use of Transboundary Waterways and International Lakes and for the Protocol on Water and Health as well as for UN/ECE Convention on Transboundary Impacts of Industrial Accidents, UN/ECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters and EU Seveso II Directive.
Industry should be directly involved in the Pilot Project, as it can contribute to various aspects such as risk and hazard assessment, management and control, prevention and emergency response, the health execs of chemicals and waste, and the best available technologies.

The Project methodology was developed by a team of experts selected by the IME and the WHO out of a pool of specialist organizations. The methods and technical documents consulted or used in developing this methodology include:

- Aarhus and Espoo Convention - Annexes listing potentially hazardous industrial activities;
- Helsinki Convention on the Protection and Use of Transboundary Waters and International Lakes and its Protocol on Water and Health;
- UN/ECE Industrial Accidents Convention;
- SEVESO II - EC Directive - Annex 1, concerning dangerous substances;
- EC/JRC - Major Accident Reporting System (MARS).

The Pilot Project proposes, implements and trials an integrated approach to rapid environment and health risk assessment in the case of major industrial accidents occurring in very hazardous or abandoned industrial facilities in selected geographical areas. Risk assessment techniques for an adequate level for the accuracy required in the rapid approach are created for the identification of the most negative scenarios that might follow a serious accident and systematic and consecutive application, providing the countries involves with an active means of preventing, monitoring and managing predictable risks and associated emergencies in protecting health and the environment.

Hungary, Bulgaria and Romania have implemented and applied this methodology on selected areas. In Romania, implementation was provided in Ministerial Order 1406 of 3/3/2003 approving the Rapid Environmental and Health Risk Assessment Methodology, of the Ministry of Waters and the Environment.

6.7.4.1 Introduction to the Rapid Environmental and Health Risk Assessment (REHRA) Methodology

Rapid Environmental and Health Risk Assessment – REHRA refers to the immediate and acute consequences of an accident involving a spill of toxic chemicals on an industrial site. This method is applicable to both existing sites and those under development or in the design stage.

The basic structure of this methodology can be broken down into four principal elements:
1. Hazard indicator of the area and ranking thereof
2. Assessment of the area health and environmental risks and ranking
3. Environment and health vulnerability indicator
4. Major accident log

The first and the second items refer to rapid assessment. The third item is an additional information base for the verification of assessment results. The fourth element is considered secondary, but useful in the recording, analyzing and concluding on major accidents.

Site Hazard Indicator and ranking

Site Hazard Indicator and ranking; is the probability of an accident occurring on the chemical site – the SHI indicator is calculated in relation to the following:

- Hazardous sites inventory
- Hazardous substance classification and inventory
- Natural hazard inventory
Site Hazard Indicator and ranking

Environment and Health Risk Assessment and ranking
Environment and Health Risk Assessment and ranking is the global risk for the area; it combines SHI probabilities and simplified consequence analysis. The calculation may be broken down into three steps:

- Environmental and health classification and inventory of the area
- Rapid assessment of an accident's consequences on the environment and health
- Rapid assessment of area-related risks and ranking

This procedure generates a final site risk indicator (SRI).

Environment and Health Vulnerability Indicator
The Environment and Health Vulnerability Indicator is the estimated vulnerability of the site area. The GEHVI is based exclusively on environmental and health aspects of the general area and can be calculated in four steps:

- Population vulnerability indicator
- Environment vulnerability indicator
- Economic vulnerability indicator
- Environment and health vulnerability indicator

The global scheme of the REHRA approach is shown in Figure 7.25.
Figure 7.25. Outline of the Global REHRA Approach
6.7.5 Assessment of the Site Health and Environmental Risks and Ranking

6.7.5.1 Hazard Assessment

Site General Indicator (SGI)
SGI represents the probability of something not working well on the industrial site, leading to a potential accident, due to the existence of two competing and simultaneous causes: Process configuration, represented by the Site Technological Factor (STF), defined as the sum of values associated to each of the following elements:

- Site Age
- Process Control
- Type of Operations
- Operating Conditions
- Loading / Unloading Operations

which are the key parameters influencing the accident probability of occurrence. The elements are generally independent from each other and may be deemed to have the same weight in the final summing.

The level of organization of the environmental and health management, represented by the (SOF).

Dangerous substance indicator (DSI)
The dangerous substance indicator (DSI) is calculated based on the total amount of hazardous substances handled and/or stored on the site, in correlation with the relevant quantity under Annex 1 of the Seveso Directive.

Natural Hazard Indicator (NHI)
The Natural Hazard Indicator (NHI) is a combination of independent factors that are relevant for one or more natural hazards (areas exposed to frequent flooding, high seismicity, frequent landslides, earth movements or high soil instability).

The site hazard indicator (SHI) is a composite parameter representing the potential hazard (probability of occurrence) of a major accident, without considering further environmental and health consequences.

The table 7-34 shows the calculated values for the above indicators:

Table 7-34 Indicators of hazard assessment

<table>
<thead>
<tr>
<th>Calculated indicator</th>
<th>Process Plant</th>
<th>TMF</th>
<th>Cetate Pond</th>
<th>Explosives storage</th>
<th>Site-wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGI</td>
<td>1.9</td>
<td>2</td>
<td>1.95</td>
<td>2</td>
<td>1.95</td>
</tr>
<tr>
<td>DSI</td>
<td>8.71</td>
<td>6.89</td>
<td>6</td>
<td>2</td>
<td>8.84</td>
</tr>
<tr>
<td>NHI</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SHI</td>
<td>3.56</td>
<td>3.99</td>
<td>3.89</td>
<td>1.75</td>
<td>3.64</td>
</tr>
</tbody>
</table>

6.7.5.2 Health and Environmental Risk Assessment;
The components that are subject to assessment of seriousness classify into three broad categories:

- People
- Environmental media
- Economic resources
A general seriousness factor is calculated for each category, according to the estimated consequences for the area. These factors include:

- CP – general seriousness factor for people
- CE – general seriousness factor for the environmental media
- CEC – general seriousness factor the economic resources

**The general seriousness indicator**

For each identified accident, an Environment and Population General Indicator (EPGI) is calculated as a sum of the three specific factors above.

**Risk indicator for one accident**

In terms of risk, for an identified accident, the relationship between frequency and seriousness is generally expressed as a product, hereinafter called the Accident Risk Indicator (ARI).

**Site risk indicator**

Representation of the final site risk indicator value is done based on the Site Risk Indicator (SRI), shown as the maximum value for each identified ARI. The final risk is the most negative situation possible, that might be caused by the investigated industrial activity. The table 7-35 shows the calculated values for the above indicators:

<table>
<thead>
<tr>
<th>Calculated Indicator</th>
<th>CP</th>
<th>CE</th>
<th>CEC</th>
<th>EPGI</th>
<th>ARI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. HCN emission in the CIL area</td>
<td>1</td>
<td>0.42</td>
<td>0</td>
<td>0.8</td>
<td>1.71</td>
</tr>
<tr>
<td>2. LPG Explosion</td>
<td>1.33</td>
<td>0</td>
<td>1.25</td>
<td>1.04</td>
<td>1.95</td>
</tr>
<tr>
<td>3. Diesel tank explosion</td>
<td>1</td>
<td>0</td>
<td>1.25</td>
<td>0.80</td>
<td>1.71</td>
</tr>
<tr>
<td>4. Diesel tank fire</td>
<td>0</td>
<td>0</td>
<td>1.25</td>
<td>0.09</td>
<td>0.57</td>
</tr>
<tr>
<td>SRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.95</td>
</tr>
<tr>
<td>5. HCN emission in the TMF area</td>
<td>0</td>
<td>0.83</td>
<td>0</td>
<td>0.18</td>
<td>0.81</td>
</tr>
<tr>
<td>6. TMF dam break</td>
<td>3</td>
<td>5.42</td>
<td>2.5</td>
<td>3.48</td>
<td>3.56</td>
</tr>
<tr>
<td>SRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.56</td>
</tr>
<tr>
<td>7. Cetate dam break</td>
<td>2.67</td>
<td>4.17</td>
<td>1.25</td>
<td>2.89</td>
<td>3.24</td>
</tr>
<tr>
<td>SRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.24</td>
</tr>
<tr>
<td>8. Explosion at the storage facility</td>
<td>1</td>
<td>0.83</td>
<td>1.25</td>
<td>0.98</td>
<td>1.89</td>
</tr>
<tr>
<td>9. Explosion in handling explosives</td>
<td>1</td>
<td>0.42</td>
<td>1.25</td>
<td>0.89</td>
<td>1.8</td>
</tr>
<tr>
<td>SRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.89</td>
</tr>
<tr>
<td>10. NaCN Transport accident</td>
<td>1</td>
<td>2.92</td>
<td>1.25</td>
<td>1.43</td>
<td>2.28</td>
</tr>
<tr>
<td>SRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.56</td>
</tr>
</tbody>
</table>

**6.7.5.3 General Environment and Health Vulnerability Assessment**

Assessment of environmental and health vulnerability may provide additional information on how the external environment might be affected by a potential accident.

The General Environment and Health Vulnerability Indicator (GEHVI) is the weighted sum of:

- PVI – the population vulnerability indicator
- EVI – the environment vulnerability indicator
- ECVI – the economic vulnerability indicator

PVI Calculation will consider the potential effects of an accident on the surrounding population (residents and site workers).

EVI is calculated considering the site-specific environmental media that might be endangered (rivers, lakes, soil and groundwater, fauna and vegetation).
ECVI is calculated considering the local economic components that might be endangered (livestock, agriculture, aquaculture, industry and business).

The values of specific weighting coefficients were established in terms of the impacts of each category of the general vulnerability indicator (the impact on population was established as the most critical, impact on economic activities as the lowest, while environmental impacts are considered medium).

The table 7-36 shows the calculated values for the above indicators.

**Table 7-36   Indicators of general environment and health vulnerability assessment**

<table>
<thead>
<tr>
<th>Calculated indicator</th>
<th>Process Plant</th>
<th>TMF</th>
<th>Cetate Pond</th>
<th>Explosives storage</th>
<th>Site-wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVI</td>
<td>3.91</td>
<td>3.24</td>
<td>2.57</td>
<td>2</td>
<td>4.81</td>
</tr>
<tr>
<td>EVI</td>
<td>2.33</td>
<td>4.17</td>
<td>3.83</td>
<td>2.25</td>
<td>4.92</td>
</tr>
<tr>
<td>ECVI</td>
<td>1.25</td>
<td>3.75</td>
<td>2.50</td>
<td>1.25</td>
<td>3.75</td>
</tr>
<tr>
<td>GEHVI</td>
<td>3.38</td>
<td>3.48</td>
<td>2.84</td>
<td>2</td>
<td>4.76</td>
</tr>
</tbody>
</table>

For an assessment (in terms of risk) of the investigated site based on the indicators calculated as above, the following classification scale is used – Table 7-37.

**Table 7-37   Classification scale of environment and health vulnerability assessment**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 0 to 1.6</td>
<td>Low</td>
</tr>
<tr>
<td>From 1.6 to 3.6</td>
<td>Moderate</td>
</tr>
<tr>
<td>From 3.6 to 6.4</td>
<td>High</td>
</tr>
<tr>
<td>From 6.4 to 10</td>
<td>Very high</td>
</tr>
</tbody>
</table>

The Figure 7.26 shows a comparison of seriousness and risk levels associated to potential major accidents:
It may be seen that in most accidents the seriousness of the consequences is low, except for dam break in the two pond facilities, and the risk is moderate except for fire in the diesel tank and hydrocyanic emissions on the TMF surface, which are low. The Figure 7.27 shows a comparison of probability risk and vulnerability associated to the relevant safety sections of the project:
With the exception of the explosives storage facility, the probability of major accidents occurring in the investigated area will exceed the moderate level threshold. The risks associated to potential accidents are generally moderate with the exception of the TMF, where they exceed this threshold. The vulnerability of areas around the safety sections considered is moderate, but high for the site as a whole.
7 Emergency Planning

As indicated in the previous Sections, the RM Project is regulated by the Seveso Directive on the control of major accidents involving hazardous substances, and therefore the Safety Report will provide further information on safety and emergency response measures.

Another requirement is the development of the Internal Emergency Plan in compliance with MAI Order no. 647 of 5/16/2005 approving the Methodological Norms on the development of emergency plans in case of accidents involving hazardous substances.

Emergency planning is based on a management policy by which RMGC commits to create, establish, implement and maintain an environmental, health and safety management system in compliance with the Romanian law and international standards. This policy states the intention of RMGC to minimize the risks associated to operations that might affect the environment, the staff, the neighboring communities and visitors, and provides guidelines for the control and containment of the impacts of any emergency situation that might occur.

In previous sections, we have identified a number of potential accidents associated to Roşia Montană Project, included to:

- the construction, operation and decontamination of the process plant and ancillary facilities;
- the excavation and transport of overburden, ores, and tailings materials;
- cyanide transport and handling on and off site;
- the storage, handling and potential spills of cyanide and other chemicals on site;
- the storage, handling and potential spills of fuels, lubricants, and other flammable materials on site;
- the transport, handling, storage and accidental detonation of explosives
- the on-site handling of wastewaters and storage in the TMF
- the handling, transport and storage or disposal of inert, hazardous waste and recyclable materials;
- vehicle operation;
- storage of compressed gases;
- the structural stability of earthworks (walls, roads, waste rock stockpiles, earth stockpiles, primary and secondary containment dams);
- structural fires (office buildings, dormitories, process plant or warehouses);
- power cuts;
- medical emergencies caused by disease or accidents;
- natural disasters (thunderbolt, forest fires, torrential rain, avalanche, floods, earthquakes, strong wind, landslides, etc.);
- human threats, such as terrorist threat/attack, illegal weapons, bomb threat/attack, vandalism, sabotage, or civil destruction.

In response to such accidents, a number of Standard Operating Procedures (SOPs) will be developed for accident prevention and emergency management. An outline of the SOP contents is presented in the table 7-38.
Table 7-38. Standard Operating Procedures (SOPs) for accident prevention and emergency management

<table>
<thead>
<tr>
<th>Emergency response preparedness</th>
<th>Safety preparedness, drills and staff meetings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency response equipment – maintenance, inspection and testing of hazardous materials storage and handling</td>
<td>Cyanide unloading and storage</td>
</tr>
<tr>
<td>Evacuation procedures</td>
<td>Carbon filtering operation</td>
</tr>
<tr>
<td>Site Security</td>
<td>Cyanide Detoxification Process</td>
</tr>
<tr>
<td>Explosives management</td>
<td>Inspection of cyanide handling tankers, pipes, and other facilities</td>
</tr>
<tr>
<td>Fuel facility management</td>
<td>Maintenance and Calibration of Hydrogen Cyanide Monitoring Equipment</td>
</tr>
<tr>
<td>On-site fueling operations</td>
<td>Decontamination of Cyanide Handling Equipment</td>
</tr>
<tr>
<td>Investigation, reporting and record keeping of accidents and near accidents</td>
<td>Corrective and Preventive Action for Environmental and Social Action Program Non-compliance</td>
</tr>
<tr>
<td>Electrical safety</td>
<td>Environmental and Social Management System</td>
</tr>
<tr>
<td>First aid provision</td>
<td>Performance Verifications</td>
</tr>
<tr>
<td>Hearing protection</td>
<td>Management review</td>
</tr>
<tr>
<td>Respiratory protection</td>
<td>Waste disposal</td>
</tr>
<tr>
<td>Evacuation procedures</td>
<td>Wastewater management</td>
</tr>
<tr>
<td>Safe evacuation of persons</td>
<td>Inspection or proves plant operations</td>
</tr>
<tr>
<td>The use of equipment</td>
<td>Emergency Notification Process</td>
</tr>
<tr>
<td>Personal Protection Equipment</td>
<td>Air Monitoring at the Process Plant /Equipment</td>
</tr>
<tr>
<td>Vehicle and crane safety</td>
<td>Operations and Maintenance of the Catchment Dam</td>
</tr>
<tr>
<td>Access to close spaces</td>
<td>Operations and Maintenance of the Cetate wastewater Dam</td>
</tr>
<tr>
<td>Work areas, ladders and scaffolding</td>
<td>Erosion control in mine planning</td>
</tr>
<tr>
<td>Protection against falls</td>
<td>Tailings erosion control considerations</td>
</tr>
<tr>
<td>Fire protection</td>
<td></td>
</tr>
<tr>
<td>Routine safety inspections</td>
<td></td>
</tr>
<tr>
<td>Emergency power supply for cyanide handling equipment</td>
<td></td>
</tr>
<tr>
<td>General inspection</td>
<td></td>
</tr>
<tr>
<td>Compliance checks</td>
<td></td>
</tr>
</tbody>
</table>

The main purpose of the Emergency plan is to provide a detailed guideline for the staff and contractors.

Definition of the Main Concepts and Terminology

- **State of emergency** – exceptional event, that by its size or intensity, poses a threat to the life and health of the population, the environment, important material and cultural assets, and where the re-establishment of normality requires the adoption of urgent measures and actions, allocation of additional resources and consistent management of the deployed forces and facilities.

- **Class A, B, C State of Emergency** – classification of a state of emergency based on the size of the impact area, speed of evolution and destructive effects of the events causing it;

- **State of emergency management** – all of the activities developed and procedures used by the decision makers in: evaluating the information and assessing the situation, developing forecasts, establishing alternative actions and implementing then in order to restore normality;

- **Environmental media monitoring** – a surveillance process necessary for the systematic evaluation of the environmental parameter dynamics;

- **Emergency management** – identification, recording and evaluation of events, triggering factors, stakeholder notification, population warning, limitation, removal or mitigation of risk factors and negative effects and impacts caused by the respective exceptional events;

- **Intervention** – timely action taken by the specialist structures,

- in order to prevent a deterioration of the state of emergency, limit or remove its consequences, as applicable;
• Evacuation – a protective measure taken in the case of imminent threat of a state of emergency, and consisting of removing, in an organized manner, from the affected or potentially affected areas, the categories or groups of persons or goods and their relocation in areas that provide protection;

• Notification, information – transmission of certified information on the imminence of or actual occurrence of serious events to the local public administration authorities, the public and neighboring communities, in order to avoid surprise and implement protective measures;

• Alarm – transmission of warning messages/ signals to the public regarding the imminence or occurrence of exceptional events of serious consequences;

• Site, objective – the land associated to the company where the emergency situation was created.

In an emergency situation, it is very important to know the size of the incident immediately, in order to adopt the adequate level of intervention.

The following event classification system aims to communicate to the site and off-site response teams what intervention would be required.

At the time of the initial reporting or identification of an emergency, incident classification should be done as soon as possible by the staff with the best information regarding the incident. These persons typically include:

• the first response persons (those who discover the incident)
• the emergency coordinator on the site
• the Manager, Environmental department, and
• the Manager, Health and Safety department

Often, the situation around an emergency incident may change or new information may come up to dictate a change in the incident classification. This change may be an increase or decrease the incident classification level. Typically, the decision to change the incident classification will be taken by the people listed above, together with the Incident Commander, if one was assigned.

7.1 Emergency Definition and Classification Based on Seriousness

7.1.1 Class A emergency (local emergency)
A class A emergency is that emergency involving one facility on the site. This emergency includes the following situations:

• a minor incident that can be handled with limited resources and means and has no dangerous consequence outside the facility (e.g. a contained fire, minor spills from an installation, etc.);
• an accident that may be solved by internal specialist forces, not involving the entire site;
• an accident that does not have effects beyond the site fence and does not require the involvement of authorities outside;
• no alarm device is activated outside the facility;
• activity (the productive process) does not need to stop throughout the facility (site), but some parts thereof may stop operation;
evacuation is not necessary, but there may be restrictions of access to the impacted area;
explosion scenarios are not included under Class A, any emergency of this type is classified in the next higher class.

7.1.2 Class B Emergency (Site emergency)
A class B emergency is that one where the local emergency conditions persist or worsen and therefore affect/may affect other facilities. This emergency includes the following situations:
- an accident involving site-wide intervention;
- the situation might call for intervention from outside forces (resources);
- an accident is supposed not to have effects beyond the site fence or potential limited effects off site;
- a partial or total stop of activities on the site might be required;
- the visitors and workforce not involved in the intervention must leave the workplaces and regroup at meeting places (safe places);

7.1.3 Class C Emergency (emergency off site)
A class C emergency consist in a severe incident that involves or may involve much of the site and affects/may affect the population and environment off site. This emergency includes the following situations:
- all of the site emergency personnel is involved in the emergency management;
- the accident has certain effects off site on extended areas and the incident calls for the intervention of external forces (means);
- activity must stop on the site;
- the personnel not involved in managing the emergency must be evacuated, and in case of uncontrolled developments, a general evacuation is needed;
- the local authorities off site need to be alerted to take steps in protecting the population and the environment.

7.2 Organizing Emergency Response
General organization of emergency response for the Roșia Montană Project is presented in the Figure 7.28.
Figure 7.28. General organization of emergency response for the Roșia Montană Project
The Emergency Coordinator and the Incident Commander are key persons in organizing emergency response. The main differences between their respective roles include:
The Emergency Coordinator is responsible for maintaining emergency response training on the site and for making the initial decisions on how to respond to an emergency, i.e. the emergency classification level and the necessary resources.

The Incident Commander is the person in charge at the site of the accident, i.e. controls the emergency response teams, decides what resources are necessary, coordinates the emergency response teams and communicates with the people outside the accident site. The Emergency Coordinator plays a continuous role within the organization (and has designated replacements), while the Incident Commander is an ad hoc designation and only lasts for the duration of the incident, of the documentation and final closure of the emergency.

7.3 Specific Intervention Procedures

7.3.1 Potential Hydrocyanic Acid Releases

7.3.1.1 Intervention:

- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, depending on the potential impact off site, immediate coordination with the external emergency plan.
- Notification and evacuation of areas downwind, emission containment, if possible, followed by immediate medical assistance to the exposed personnel.
- Incident investigation and preventive and corrective action.
- Implementation of other specific emergency actions.

7.3.2 Potential Emissions of Cyanide Solutions from the Process Plant, after Tank, Pipe or Valve Failure

7.3.2.1 Intervention:

- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), immediate coordination with the external emergency plans of the local communities.
- Notification and evacuation of areas downwind, emission containment, if possible, followed by immediate medical assistance to the exposed personnel.
- Pumping of spilt solutions from the secondary containment back into the cyanidation process.
- Use of earth stripping equipment to build emergency containment areas as necessary in the case of secondary containment failure and immediate remediation of contaminated soils.
- Incident investigation and preventive and corrective action.
- Implementation of other specific emergency actions.

7.3.3 Leaks in the Mine Waste Piping Systems

7.3.3.1 Intervention:

- Immediate implementation of the Accidental Spill Prevention and Control Plan at Level B.
• Initiation of immediate process plant operation stop, stop of detoxified residue pumping.
• Spill containment, pumping of spilt solutions from the secondary containment into the TMF.
• Initiation of repairs, inspection of welded components and acceptance of testing in the repaired sections, prior to restarting process plant operations.
• Use of earth moving equipment to build emergency embankments, if existing containment is affected.
• Incident investigation and preventive and corrective action.
• Implementation of other specific emergency actions.

7.3.4 Break of Corna Tailings Dam or Secondary Containment Dam

7.3.4.1 Intervention:
• Immediate implementation of the Accidental Spill Prevention and Control Plan Level C, immediate alert and mobilization of the local and site organizations, immediate coordination with the external emergency plans applicable to the local communities.
• First aid administration.
• Immediate notification and potential evacuation of residents downstream of the Secondary Containment Dam and of the town of Abrud.
• Immediate notification of the site management and of the local, regional and national authorities; notification of the representatives of the relevant legislative and military institutions, in case of potential terrorist attack.
• Implementation of emergency systems, closing of the process plant and tailings pipes and start of site stabilization activities (e.g.: repair breaks, build embankments, reinforcement and dike and diversion structures) to the extent required by the incident.
• Incident investigation and preventive and corrective action.
• Implementation of other specific emergency actions.

7.3.5 Overload of the Tailings Management Facility and/or of the Secondary Containment System (without Dam Break)

7.3.5.1 Intervention:
• Immediate implementation of the Accidental Spill Prevention and Control Plan Level C, immediate alert and mobilization of the local and site organizations, immediate coordination with the external emergency plans applicable to the local communities.
• First aid administration.
• Immediate notification and potential evacuation of residents downstream of the Secondary Containment Dam and of the town of Abrud.
• Immediate notification of the site management and local, regional and national authorities.
• Implementation of emergency systems, closing of the process plant and tailings pipes and start of site stabilization activities (e.g.: reinforcement of weakened dam sections) to the extent required by the incident.
• Incident investigation and preventive and corrective action.
• Implementation of other specific emergency actions.
7.3.6 **Rock/Mud Slide off the Waste Stockpiles.**

7.3.6.1 **Intervention:**
- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C (depending on the potential impact off site), and potential coordination with the applicable external emergency plans of the local communities.
- First aid administration.
- Potential notification and evacuation of residents downstream of the slide.
- Alert and organization of local and site organizations in charge of emergency interventions.
- Notification of the mine management and the local and regional authorities.
- Incident investigation and preventive and corrective action. Changing and developing the area stability plan, re-establishment of the water management structures; additional monitoring provisions.
- Implementation of other specific emergency actions.

7.3.7 **Pit Wall Failure**

7.3.7.1 **Intervention:**
- Immediate implementation of the Accidental Spill Prevention and Control Plan at Level B. Evacuation of all the RMGC and contractor staff from the impacted pit. Immediate notification of the mine management and of the competent authorities.
- First aid administration.
- Incident investigation and preventive and corrective action. Changing and developing the area stability plan, re-establishment of the water management structures; additional monitoring provisions.
- Implementation of other specific emergency actions.

7.3.8 **Explosion during ANFO Preparation**

7.3.8.1 **Intervention:**
- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), and immediate coordination of the RMGC response team with the carrier representatives and with the nearest emergency response organization.
- Contact with and coordination of the medical team and other intervention actions, together with the local authorities
- coordination with the representatives of the relevant legal and military authorities, if there is knowledge or suspicion of intentional anthropogenic action.
- Incident investigation and preventive and corrective action.
- Implementation of other specific emergency actions.

7.3.9 **Explosion of Blasting Agents in the Explosive Storage**
7.3.9.1 Intervention:
- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), and potential coordination of the RMGC response team with the carrier representatives and with the nearest emergency response organization.
- First aid administration.
- Contact with and coordination of the medical team and other intervention actions, together with the local authorities.
- Coordination with the representatives of the relevant legal and military authorities, if there is knowledge or suspicion of intentional anthropogenic action.
- Site security, immediate initiation of actions to detect and neutralize any non-exploded material, notification and potential evacuation of residents of neighboring protected areas.
- Incident investigation and preventive and corrective action.
- Implementation of other specific emergency actions.

7.3.10 Premature/Unpredictable Explosion of Explosives at the Blasting Front

7.3.10.1 Intervention:
- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), and potential coordination of the RMGC response team with the carrier representatives and with the nearest emergency response organization.
- Probable injuries; require first aid administration.
- Contact with and coordination of the medical team and other intervention organizations, and the local authorities.
- Blasting front security, immediate initiation of actions to detect and neutralize any non-exploded material, notification and evacuation of RMGC employees and of the residents of neighboring protected areas.
- Incident investigation and preventive and corrective action.
- Implementation of other specific emergency actions.

7.3.11 Fires or Explosions of Occupied Buildings or Process Areas

7.3.11.1 Intervention:
- Immediate evacuation of the areas or buildings and notification of the personnel downwind and of the fire brigade.
- The fire brigade intervention in fire control and first aid provision.
- Coordination with the representatives of the relevant legal and military authorities, if there is knowledge or suspicion of intentional anthropogenic action.
- Incident investigation and preventive and corrective action.
- Implementation of other specific emergency actions.

7.3.12 Fires and Explosions Associated with Traffic/Transport Accidents
7.3.12.1 Intervention:

- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), and potential coordination of the RMGC response team with the carrier representatives and with the nearest emergency response organization.

- Contact with and coordination of the medical teams and other intervention organizations, and the local, regional and national authorities, according to the emergency plans of the affected communities.

- Spill/explosion site security, immediate initiation of actions control fires and monitor air quality, treatment and evacuation of injured personnel, notification and evacuation of residential areas downwind.

- Incident investigation and preventive and corrective action.

- Environmental restoration of the site and communication actions.

- Implementation of other specific emergency actions.

7.3.13 Fires and Explosions Associated with Fuel Storage and/or Handling

7.3.13.1 Intervention:

- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), and immediate coordination of the RMGC response team with the carrier representatives and with the nearest emergency response organization.

- Contact with and coordination of the medical team and other intervention organizations.

- Spill/explosion site security, immediate initiation of actions control fires and monitor air quality, treatment and evacuation of injured personnel, notification and evacuation of residential areas downwind.

- Incident investigation and preventive and corrective action.

- Environmental restoration of the site and communication actions.

- Implementation of other specific emergency actions.

7.3.14 Chemical Spills on the Process/Storage Sites

7.3.14.1 Intervention:

- Evacuation of the area and notification of the downwind personnel, followed by activation of the hazardous material ("Hazmat") intervention team and initiation of spill control actions. Intervention of the medical teams in providing first aid to the exposed personnel.

7.3.15 Chemical and / or Fuel Spills Associated with Traffic/Transport Accidents

7.3.15.1 Intervention:

- Evacuation of the area and notification of the downwind personnel, followed by intervention of the "Hazmat" team and initiation of spill control actions, intervention of the medical teams in providing first aid to the exposed personnel.

- Immediate implementation of the Accidental Spill Prevention and Control Plan at level B or C, (depending on the potential impact off site), and immediate coordination with emergency plan of the affected community; notification and evacuation of the affected areas down the slope; spill containment, alert and mobilization of the local and site organizations in charge with emergency intervention, notification of the mine
management and of the local, regional, and potentially international authorities, development and implementation of the environmental restoration plans for the impacted areas.

7.3.16 Fuel Spills Associated with Fuel Storage and/or Handling

7.3.16.1 Intervention:

- Evacuation of the area followed by intervention of the “Hazmat” team and initiation of spill control actions, intervention of the medical teams in providing first aid to the exposed personnel.
8 Alternative Options and Associated Risks

A key aspect of the design process was the use of risk assessment and design options in generating projects that minimize accident risks – and, should they occur, minimize their impacts.

This section provides a summary description of the alternatives considered an integral part of environmental impact assessment from a risk perspective. The location of the Project is fixed, based on the geology of the mined deposit. There is a small possibility to consider alternative ways of accessing the deposit (e.g. underground excavation or a different configuration of open pit operation), but this has little relevance in relation to local community and environmental exposure.

The following alternative strategic options have been identified for the development of the Roșia Montană Project:

- The “no action” alternative, where no mine would be developed;
- Alternative locations for various Project components, e.g. Process Plant, TMF, etc.;
- Timing alternatives, where the Project would be developed later in the future;
- Process alternatives, such as replacing cyanide in gold extraction.

Key major accidents that might be relevant in considering design alternatives are the use of sodium cyanide in ore processing and waste disposal in the TMF. Other hazards associated to the normal operating conditions are generally of medium or low importance in considering design alternatives.

As a result, this section will focus on the following Project alternatives:

- Project cancellation or delay;
- The use of cyanide;
- Location and design of the Process Plant.

8.1 Project Cancellation or Delay

The “no Project” option means canceling the project before starting any construction activity. This would mean avoiding any hazard associated to cyanide transport, storage or use. It would also mean avoiding any danger associated to the building and operation of a new Tailings Pond.

This option would not remove the environmental hazards and risks, as the Project site contains an area affected by two thousand years of mining, and the active mine and process plant of RoșiaMin. Canceling the Roșia Montană Project would remove an important source of investment in the region, estimated at US$ 605 million, and also prevent a mechanism for the mitigation of existing environmental problems generating from historic mining operations and rehabilitation of the current mining sites. Thus, Project cancellation would create or maintain the following hazards:

- The presence of unstable slopes on the waste rock dumps and landfills, unstable slopes of older mines;
- Surface and groundwater contamination from acid rock drainage (ARD) from abandoned tailings ponds and waste dumps.
Surface and groundwater and soil contamination by mobile heavy metals and sediments from historic mining operations.

Ongoing and constant risks of injury and health impacts related to these hazards will directly affect the local community, as well as the soils and the wildlife. Potential impacts in this regard include, for instance, ongoing pollution of the rivers, which affects aquatic life and restricts the use of river water by the local communities. Soil washing by winds and runoff affects the soil and might affect agricultural uses.

Major accidents might still occur in the abandoned mines and as a result of seismic activity, or extreme weather conditions. Most of the slopes of the old mines are left as such, with no attempt at creating safe and stable surfaces. No measures have been taken to provide adequate drainage or re-vegetate (the latter would not be successful in the absence of physical and chemical stability). In many instances, the slopes are crossed by temporary access roads. Therefore, a storm or a moderate seismic action have the potential to mobilize large volumes of tailings and initiate landslides. Considering how close the houses are to these conditions, even if the “no project” alternative were selected, local community exposure to risk would continue.

The second alternative in this category is postponed project, in the hope that some non-identified process might further reduce environmental impacts. This process would involve, for example, the use of a decant agent other than cyanide, an aspect investigated in the following sections. However, even if a new technology were discovered in the future, the time before the discovery, the inherent risks, or its efficacy in the case of Roșia Montană are totally unknown. Such considerations are, therefore, unpractical in making decisions of this kind.

8.2 The Use of Cyanide

The use and storage of cyanide as a chemical in ore processing are important in regard to major accident hazards. A number of alternative approaches to extractive procedures and alternative agents for the extraction of gold out of the ore are presented below.

8.2.1 Alternative Technologies

A number of alternative gold extraction technologies have been considered, including:

- Cyanide recovery process
- Flotation process for the recovery of free gold;
- Filtration processes, where physical methods fail;
- A combination of the above.

A number of combinations of non-cyanide gravitational and flotation technologies have been assessed. In all cases, gold recovery was considered uneconomical in the absence of an additional extraction step. Moreover, application of such technologies will not exclude the building of the tailings pond and therefore the risks associated to its existence.

8.2.2 Alternative Extraction Agents

A number of alternative gold extraction agents (other than cyanide) have been assessed historically. In the past, a common practice was gravitational concentration followed by mercury amalgamation. However, this practice creates potential environmental problems, including pollution and bioaccumulation. Cyanidation was discovered in the 1880s, as a cheap alternative, with applications in several kinds of ores. Cyanide has since been used for about 80% of the world gold production and about 92% of gold production in the last 20 years.
A number of alternative gold extraction agents have been considered, including:

8.2.2.1 Tiosulfate
In recent years, tiosulfate has been considered a potential replacement of cyanide due to its lower environmental impact. The main problem in tiosulfate leaching is the high reagent consumption. Moreover, the process is slow, and an acceptable leaching efficiency may only be obtained in the presence of ammonia, using copper as an oxidant. High reagent consumption makes tiosulfate leaching unprofitable, despite potential environmental benefits. Currently, there is no industrial scale method for tiosulfate gold recovery.

8.2.2.2 Thiourea
Compared to cyanides, thiourea has several advantages, such as low sensitivity to metals (Pb, Cu, Zn, As), low sensitivity to residual sulfur and higher efficiency in recovering gold from pyrites, calcopyrites and carbonaceous deposits. In spite of the efficient use of thiourea as a gold leaching agent, the industrial application of this process involves some negative aspects:

- thiourea is more expensive than cyanide;
- thiourea consumption is high (it oxidizes very easily);
- gold recovery steps require a more complex technology.

Although less toxic than cyanide, thiourea may be carcinogenic and needs handling with care.

8.2.2.3 Haloid Systems
Before the use of cyanide, chlorine was the most widely used leaching reagent in recovering gold from concentrated ore. Although gold decomposition with chlorine is a much faster procedure than that involving cyanide, small concentrations of sulfur or other reactive components are sufficient in the ore composition to use up the excess reagent, and reduce the gold ion to metal gold.

Gold extraction by chlorination is a more complex process than cyanidation, for several reasons:

- it requires rubberized stainless steel equipment, due to acidic and oxidizing conditions;
- the use of gas chlorine requires very strict safety measures, due to the very high health risks.

Bromine has only recently been used in gold extraction, although the technology was discovered a long time ago. Bromine offers a number of advantages, including: fast extraction, low toxicity and adaptability to a broad range of pH values.

Due to the high decomposition rate and low recovery costs, bromine leaching has an advantage over cyanide, but reagent consumption is very high and, because it can combine with other elementary species, obtaining very toxic products, the costs of maintaining strict conditions and environmental costs would be exorbitant.

8.2.2.4 Bio-Leaching
The most significant progress achieved in this field was the development of the BIOX process (Biological oxidation) for the treatment of refractory gold ores. This provides economic benefits and is environmentally acceptable.

The BIOX method has both advantages and disadvantages with a direct impact on applicability. One advantage is the absence of toxicants and toxic effluents, the simplicity of the operations facility, and the generation of a stable Fe/As residue. However, bio-oxidizing
processes are very sensitive to water quality, which may increase the operating and neutralization costs considerably.

By assessing these alternatives, it was concluded that they are generally less efficient, more expensive, require more sophisticated operating conditions (e.g. high temperatures and low pH), require high concentrations and volumes of extraction agents (which increases the probability of accidents due to the large quantities handled and stored) and/or pose health and environmental risks that are similar or higher than those of cyanide. Moreover, application of such technologies will not exclude the building of the tailings pond nor the risks associated to its existence.

More than 90% of the gold extraction operations worldwide nowadays use cyanide as filtration agent. It is a proven process, of known risks and well established risk management and minimization measures.

8.3 TMF Location

The initial assessment made for the Project identified nine separate potential locations for the decant pond, in four different valleys, as follows:

- Tolăcești Valley (3 sites)
- Abruzel Valley (2 sites)
- Corna Valley (3 sites)
- Seliște Valley (1 site)

During the design stage, other options have also been considered (as well as combinations of options), including the use of the facility at Roșia Poieni (these site locations are shown on the Exhibit 5.3 – Chapter 5 – “Alternatives”) Other sites have been excluded due to insufficient available volume, high population density, distance to the process plant. The 9 locations and 13 potential combinations thereof have been compared, considering a broad range of technical, social, economic and environmental factors. Aspects related to partial displacement of the population were also considered, each of the reviewed options requiring more or less ample relocation. Based on the technical and environmental considerations, two locations were selected, and in 2001 assessed in detail: Corna Valley and Seliște Valley.

In regard to the above locations, it is considered that the hazard created by the location of the tailings pond is comparable in all cases. A detailed comparative analysis of the alternatives is provided in Section 5 of the EIA. As the region is well populated, all the valleys have communities, and variations between the risks and consequences of various options are small.

8.3.1 Corna Valley

Corna Valley provides additional benefits compared to the other alternatives, because of its proximity to the plant and the pits. Furthermore, the tailings dam will provide containment of the waste, but also, of the runoff from waste dumps and accidental spills (e.g. from a burst pipe). Transport and pumping distances are shorter, which will further reduce accident risk. The available volume is enough for the entire quantity of waste resulting from operations throughout the Project lifetime. The development of the TMF will involve relocating some of the relatively sparse population of Corna Village. Simulations of major accident occurrences have shown that under very extreme conditions, that might cause a dam break, tailings slide would only reach 0.8 to 1.6 km downstream of the dam toe, therefore limited to within the Corna Valley. For such very unlikely cases, efficient prevention and intervention measures have been provided for emergency situations.
8.3.2 The tailings pond at Roșia Poieni
The tailings pond at Roșia Poieni is currently used for the disposal of the tailings of the copper mine at Roșia Poieni. The opportunity of disposing of the waste from Roșia Montană on the same site has been investigated. Due to operational, environmental and water quality constraints, the waste flows from the copper mine and those of Roșia Montană may not be mixed. Thus, another facility would be required for the residue, while the Roșia Poieni operation continues, which would not be beneficial in terms of hazard and risk reduction.

8.3.3 Seliște Valley
Seliște Valley is currently occupied by a pond developed on a small starter dam, and further developed into a dam built with the coarse fraction of the tailings. The current elevation of the dam crest is about 60 m. An alternative that may be applied is the building of a rock fill dam, to contain both the current landfill and the waste resulting from the Project. The main shortcoming of Seliște Valley is the insufficient available volume it can provide, which will require another tailings facility development on another location. Also, the building of a big dam and pond on the site of an existing facility, without adequate data regarding the substrate on which the initial pond developed, will introduce a further risk factor.

8.3.4 Abruzel Valley
Abruzel Valley provides two locations for TMF siting. The pumping distance for tailings disposal is very long, and the available volume insufficient for the amount of tailings that will result from the operation.

8.3.5 Ștefanca Valley
Ștefanca Valley, located west of Roșia Poieni, currently hosts two landfills of the copper mine operation. The tailings pumping distance is very long, and the storage volume available is limited.

8.3.6 Tailings backfilling into the excavation voids
Tailings backfilling into the excavation voids was also assessed, but this option would be very difficult and costly, because the first open cast mine will only reach its final elevation 13 years after startup. Backfilling would further restrict later work, if additional reserves were identified.
9 Conclusions

Chapter 7 is a review of the natural and technological hazards and risks that might occur in the Roşia Montană mining Project, focusing especially on aspects related to the probability of occurrence of potential technological Project related accidents. This Chapter defines the frequency with which such accidents might occur, based on the design data and literature and as revealed by the mitigation and control measures proposed for implementation, in the design or management, in order to reduce risks to the extent possible. Remediation measures for the general consequences of major accidents are also provided.

The analysis of hazards and risks associated to the Roşia Montană Project will point out the relatively high risk of the future activity due to its size and the presence of important quantities of dangerous substances. The use of cyanide and the placing of tailings into the TMF are the main risk factors. Potential transboundary impacts at the Romanian-Hungarian border may only occur in the case of hypothetical accidents caused by extreme situations in which Corna Dam would break and discharge the contained water into the environment (Abrudel Stream – Aries River – Mures River).

Analysis results suggest that the safety measures, prevention measures, implementation of the environmental and risk management systems, as provided by the Project, will reduce the identified risks to acceptable levels under the most restrictive norms, standards, the best practices and the relevant national and international recommendations. Quantitative risk assessment was based on computing the level of risk as a product of the seriousness (consequence) and the probability of the investigated event. Using the information obtained from the analysis, an event's risk was placed in a probability/consequence type matrix. The FN diagram frequency – consequence (loss of materials or number of fatalities) summarizes the results of analyses so conducted and gives a graphical representation of the specific social risk of the Roşia Montană Project correlated with the socially acceptable risk. The results are transposed into diagrams of the following kind available in literature, and that highlight the following comparative analysis shown in Figures 7.29 and 7.30.
As can be seen in Figures 7.29 and 7.30, Roşia Montană Project may be considered as having a medium level of risk and therefore acceptable under all international regulations in the field.
The extent of the risk assessment and the intensity of prevention and mitigation measures should be proportionate to the risk involved. Simple hazard identification models and quantitative risk analysis are not always sufficient and therefore detailed assessment is necessary. There are several methods used in quantitative risk assessment. Selection of a specific technique depends on the accident scenario analyzed.

More detailed analysis is conducted for accident scenarios that, based on the qualitative assessment, are found to be potentially major, of probability more than 10, i.e. may occur more frequently than 1,000,000 years and major consequences, therefore a risk level higher than 15 (on a scale of 1-25). As the Project falls under the Seveso Directives on the control of major industrial accidents with important health and environmental effects involving dangerous substances, specific analysis and assessment guidelines must be followed.

Methods of estimating accidental atmospheric spills and dispersion modeling are therefore used to assess the seriousness of the consequences. Specific simulation methods are also applied for the assessment of consequences of potential explosions or fires. The results of simulations of breaches developing in the Corna TMF or Cetate ARD catchment dam wall were used in assessing the consequences of such events.

A global assessment of the risks associated with the Roşia Montană Project is obtained by the quick environmental and health risk assessment methodology initially developed by the Italian Ministry of the Environment and the World Health Organization.

Natural hazard and risk identification and analysis presents key data and information in assessing potential technological accidents. Thus:

- in designing the Tailings Management Facility, the design parameters were chosen to fully cover the characteristic seismic risk for this area. These seismic design parameters adopted for the TMF and other facilities on the proposed site result in a safety factor much greater than the minimum accepted under the Romanian and European design standards for such facilities.

- in the sector physically impacted by the Project, the risk of floods will remain very low due to the small catchments (controlled by the Roşia and Corna Streams) the area affected by the operation, and the creation of containment, diversion and drainage hydrotechnical structures for storm waters on the site, and in the Abrud catchment in general.

- risks caused by meteorological events have been reviewed and used in assessing the hazards of the affected technological processes.

The analysis of morphometrical parameters and their correlation with other sets of information on the natural slopes on and near the site shows that the (qualitatively estimated) landslide occurrence risk is low to moderate and its consequences will not cause major impacts on the structural components of the Project.

There is no significant risk associated with resource depletion. Mining activities are planned judiciously, so as to extract only the profitable gold and silver resources and only the necessary construction rock for the Project. The management of the mining concession site will minimize reserve "sterilization" (limitation of future access to the reserves. In assessing technological hazards and risks, the quantity of hazardous substances on the site was calculated as a total and by category, as provided by the Notification Procedure approved by MWFEP Order 1084/2003. Based on an evaluation of hazardous substances in stock on the Project site in relation to the relevant quantities provided by the Directive, the Project ranges between the upper and the lower limits, and is therefore required to send to
the local environmental authority and the local civilian protection authority a Safety Report on its operations to prevent major accident risks.

Due to the Project size and the distance between facilities handling hazardous substances, these have been assessed separately in regard to the Seveso provisions. These facilities rank in the upper limits of the specific relevant quantities and are therefore regulated by the Seveso Directive, except for the explosives storage facility, which, at a global coefficient lesser than 1, will not be under those provisions.

In assessing the consequences of major accidents involving dangerous substances, physical-mathematical models accepted internationally and especially at EU level, and the current version of the SLAB (Canada) software have been used, the latter for the atmospheric dispersion of denser than air gases, that may handle a multitude of situations and scenarios. Similarly, the EFFECTSGis 5.5 (Netherlands) software, developed for the analysis of the effects of industrial accidents and of consequences.

Several scenarios were considered in response to the internal legislative requirements, especially related to the implementation of the Internal Emergency Plans (GD 647/2005).

The conclusions of the risk assessment for major accidents were:

- The total destruction of plant facilities may only be caused by terrorist attack with classic or nuclear weapons. Simultaneous damage to the HCl tank (including containment) and to the NaCN solution tank, the tanks containing enriched solution, to one or more leaching tanks, that may cause HCN dispersion into the air. At the same time, under certain situations and weather conditions unfavorable to dispersion, people within 40 m of the emission source, surprised by the toxic cloud for more than 1 minute without respiratory protection equipment, will most certainly die. It may also be considered that, on a radius of about 310 m, persons exposed for more than 10 minutes may suffer serious intoxications that may also lead to death. Toxic effects may occur in persons up to about 2 km downwind of the process plant.

- Operating errors and/or failures in the measurement and control devices, resulting in a lower pH in the leaching tank, thickener and/or DETOX slurry and accidental emissions of hydrocyanic acid. The area affected by concentrations of 290 ppm over a 10 min exposure time is within a circle of 36 m radius and the 50 ppm IDLH threshold for 30 min exposure will be reached over an area of 157.5 m radius. The center of these circles is the middle of the CIL tanks platform.

- Accidental HCN emission from the decanter. The accident may be caused by a drop of pH in the CIL tanks combined with an overdose of flocculant solution and faulty pH monitoring systems. The area affected by concentrations of 300 ppm over a 10 min exposure time is within a circle of 65 m radius and the 50 ppm IDLH threshold for 30 min exposure will be reached over an area of 104 m radius. The center of these circles is mid-distance between the two DETOX facilities.

- Accidental HCN emission from the DETOX facility. The accident may be caused by a drop of pH in the reactors generated by an overdose of metabisulfite solution and/or copper combined with faulty pH monitoring systems. The area affected by high 1900 ppm concentrations for a 1 min exposure time is located within a 10 m radius circle. The area affected by concentrations of 300 ppm over a 10 min exposure time is within a circle of 27 m radius and the 50 ppm IDLH threshold for 30 min exposure will be reached over an area of 33 m radius. The center of these circles is mid-distance between the two DETOX facilities.

- Explosion of the LPG storage tank. The LPG storage tank has a 50 ton capacity and is located outdoors, near the heating plant. The simulation was conducted for the worst case scenario, considering an explosion of the full tank. Threshold I with heat
radiation 12.5 kW/m² is within a 10.5 m radius circle and Threshold II, of heat radiation 5 kW/m² is within a circle of 15 m radius.

- Damage and/or fire at the fuel tanks. Simulations were conducted for the worst case scenarios, considering ignition and combustion all the diesel (fire in the tank, or in the containment vat, when full of diesel).

- Corna Dam break and breach development. Two credible accident scenarios were considered in simulating tailings flow out of the TMF, and six credible scenarios for the flow of decant water and tailings pore water, with significant effects on the terrestrial and aquatic ecosystems, in different weather conditions.

- Tailings flow may occur along Corna Valley, on a 800 m (starter dam break) or over 1600 m reach should the Corna dam break in its final stage.

- In regard to water quality impacts, cyanide concentrations in the water in the shape of a pollution plume may reach Arad, near the Romanian-Hungarian border on the Mures River, in concentrations ranging between 0.03 and 0.5 mg/L. Due to inherent mathematical limitations in the models, these values and the accident effects are considered overestimated. Therefore, the results describe the “worst case scenario” based on extreme dam break assumptions for the Corna Dam.

- Development of HCN on the pond surface. Simulated emissions of HCN from the TMF pond surface and of their dispersion into the ambient air as presented in Chapter 4.2 show that the level of 400μg/m³ hourly average and 179μg/m³ 8hr average will not be exceeded. These HCN concentrations are only slightly over the odor threshold (0.17ppm) and much below potentially dangerous concentrations.

- Cetate Dam break and breach development. Flood modeling was in case of a break in Cetate dam was based on the design parameters obtained from the hydro-meteorological study Assessment of rainfall intensity, frequency and runoff for the Roşia Montană Project - Radu Drobot. The breach characteristics were predicted using the BREACH model, and the maximum height of the flood wave in various flow sections was modeled using the FLDWAV software. The assumptions included a total 800000 m³ discharge for one hour, when the peak of the flood hydrograph is about 4.9 m above base flow immediately below the dam and in the narrow Abrud valley 5.9-7.5 km downstream of the am, while in the last section considered (10,5 km) water depth s about 2.3 m above base flow and the maximum flow rate 877 m³/s. Further, the broader Aries valley allows the flood wave to propagate on a significantly wider bed, which results in a highly attenuated hydrograph. These results describe the “worst case scenario” based on extreme dam break assumptions.

- Accidents during cyanide transportation. Due to the large quantities of cyanide handled (about 30t /day) the risks associated to this activity were assessed in detail using the ZHA- Zurich Hazard Analysis method. As a consequence, the optimum transport route was selected from the manufacturer to the Process Plant, e.g.:

- from Wesseling Germany to Cluj-Napoca transport will be by rail, using train cars belonging to the largest pan-European railway operator, INTERCONTAINER;

- From the rail terminal in Cluj Napoca, transport to Roşia Montană will be organized by road, for about 110 km, in special vehicles to be provided by the carrier (Hoyer Romania). The route presents risks in crossing the urban areas of Cluj-Napoca and Alba Iulia. The hazardous road segments have been identified at the exit from Cluj-Napoca, and on the winding road near Roşia Montană. Another risk area identified was the watercourse Somesul Mic. Other risks are posed by the presence of fish ponds close to the road in Turda area.

Cyanide transport (in solid state) will exclusively involve special SLS (Solid to Liquid System) containers, 16 tons each. The ISO compliant container will be protected by a framework with
legs, which allows separation from the transport trailer for temporary storage. The wall is 5.17 mm thick, which, together with the protective framework, provides additional protection to the load in case of accident. This system is considered BAT [77] and is currently one of the safest cyanide transportation options.
10 Legal framework

GD no. 541/2003 for the setting of some measures to limit the aerial emissions of certain polluters originating from large burning installations

GD no. 95/2003 for the control of the activities involving major accident hazards in which dangerous substances are involved

Law no. 645/2002 for the approval of the Government Emergency Ordinance no. 34/2002 on the prevention, reduction and integrated control of pollution

Procedure of 25/02/2004 for the evaluation of the security report on the activities involving major accident hazards in which dangerous substances are involved

Order no. 1144/2002 for the creation of the Register of polluters emitted by the activities under the art. 3 paragraph (1) letter g) and h) of the Government Emergency Ordinance no. 34/2002 for the prevention, reduction and integrated control of pollution and their reporting method

Order no. 347/2004 for the method of notification of the environmental protection public authorities regarding the limiting of the large burning installations operations, in order to derogate from the observance of the emission limit values, according to the provisions of the Government Decision no. 541/2003

Order no. 712/2003 for the approval of the Guide on the drafting of program proposals of the progressive reduction of the annual emissions of sulphur dioxide, nitrogen oxides and powders originating from large burning installations

EGO no. 34/2002 for the prevention, reduction and integrated control of pollution

Notification Procedure of activities involving major accident hazards in which dangerous substances are involved

Procedure of 22/12/2003 for the notifying of a major accident
11 Bibliography


ESG et al., 2005; Roşia Montană Project Environmental Impact Assessment.


MWH, 2005, Roşia Montană Project Engineering Review Reports “Geotechnical Design Parameters”.


Surdeanu, V., 1992, Corelaţii între alunecări de teren şi alte procese denudaţionale, Studia Univ. „Babeş-Bolyai”, Geographia, Cluj-Napoca.


MWH, Assessment of rainfall intensity, frequency and runoff for the Roşia Montană Project, prepared by Radu Drobot, May 2004


MWH, Roşia Montană TMF Dambreak Study, January 2006.


MWH, TMF Dam break scenarios for use in Rosia Montană EIA, February 2006.


RMGC, Section 2, Technological Processes, November 2005.

RMGC, Section 4.1., Water, November 2005.

RMGC, Section 4.8., Socio Economic Environment, March 2005.


***Date climatice şi hidrometrice furnizate de RMGC


*** Standardele româneşti de clasificare a barajelor - STAS 4273-83.


TNO, 1997, Methods for the Calculation of Physical Effects, „Yellow Book”, Cpr. 14E, Olanda, Haga, Ediția III.

REHRA: http://www.euro.who.int/watsan/CountryActivities/20030729_10

EFFECTSGIS 5.5: http://www.mep.tno.nl/software/indexen.html

SLABVIEW: http://www.weblakes.com/lakeslb1.html


Proiectul Aurul Roşia Montană, Investigaţia geotehnică a amplasamentului şi baza raportului de proiectare - (No. RPT0010-ER-Geotech).


Proiectul Aurul Roşia Montană, Planul pentru Management de Mediu şi Social.

Proiectul Aurul Roşia Montană, Planul pentru Managementul Cianurilor.

Proiectul Aurul Roşia Montană, Planul de Urgenţe pentru Scurgeri şi de Pregătire la Urgenţă (Urgenţă COLD 121 (laşuri de decantare – riscul de accidente).

Standarde româneşti pentru clasificarea barajelor – STAS 4273-83 (Constructii hidrotehnice – clasificarea pe clase de importantă).

Standarde româneşti pentru clasificarea barajelor – NTLH 021 (Norme tehnice pentru lucrări hidrotehnice).

Standarde româneşti pentru inundaţii– STAS 4068/2-87.

Linii directoare româneşti pentru proiectarea barajelor de reţinere – P.D. 19-72.

CDA (Canadian Dam Association), 1999, Linii directoare pentru siguranţa barajelor.

Evaluarea cantitativă a riscurilor asociate laşurilor, Februarie 2005.

Documentation for Immediately Dangerous to Life or Health Concentrations (IDLH): NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95) May 1994.


ANCOLD, 1994, Guidelines for Risk Assessment, Sydney, Australia.


### Annex no.1  List of hazardous substances on the site

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>CAS Number</th>
<th>Location</th>
<th>Total storage capacity (to)</th>
<th>Physical state</th>
<th>Storage</th>
<th>Storage conditions</th>
<th>Storage conditions</th>
<th>Hazardousness</th>
<th>Risk phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sodium cyanide</td>
<td>0143-33-9</td>
<td>NaCN warehouse</td>
<td>224</td>
<td>Solid flakes</td>
<td>ISO containers</td>
<td>Outdoors</td>
<td>- outdoor under awning Indoor Secondary Containment System</td>
<td>Very toxic</td>
<td>R26/27-28-32-50/53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>260</td>
<td>20% solution</td>
<td>Metal tanks + piping</td>
<td></td>
<td>Secondary Containment System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Hydrochloric acid</td>
<td>7647-01-0</td>
<td>HCl warehouse</td>
<td>46</td>
<td>32% solution</td>
<td>Tank</td>
<td>- open air under awning Indoor Secondary Containment System</td>
<td>Secondary Containment System</td>
<td>Toxic, corrosive</td>
<td>R 35-37</td>
</tr>
<tr>
<td>3</td>
<td>Sodium hydroxide</td>
<td>1310-73-2</td>
<td>Reagent warehouse</td>
<td>50</td>
<td>Solid</td>
<td>Big-bag 1000 kg</td>
<td>indoor</td>
<td>Secondary Containment System</td>
<td>Corrosive</td>
<td>R 35-36-37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NaOH warehouse</td>
<td>72</td>
<td>20% solution</td>
<td>Metal tanks + piping</td>
<td></td>
<td>indoor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Cyanide containing slurry</td>
<td>CIL area</td>
<td>98000</td>
<td>Suspensions with 300mg/l cyanide</td>
<td>Metal tanks + piping</td>
<td>- outdoors Secondary Containment System</td>
<td></td>
<td>Secondary Containment System</td>
<td>Toxic</td>
<td>R 28-32-50/53</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>CAS Number</td>
<td>Location</td>
<td>Total storage capacity (to)</td>
<td>Physical state</td>
<td>Storage</td>
<td>Storage conditions</td>
<td>Hazardousness Risk phases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------</td>
<td>------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>---------------------------------</td>
<td>--------------------------</td>
<td>--------------------------------------------------------</td>
<td>--------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decanter</td>
<td>5300</td>
<td></td>
<td>5300</td>
<td>Suspensions with 0.01 oz/l cyanide</td>
<td>Structure (concrete+metal)+piping</td>
<td>-outdoors Secondary Containment System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DETOX</td>
<td>4930</td>
<td></td>
<td>4930</td>
<td>Suspensions with 10-180 mg/l cyanide</td>
<td>Metal tanks + piping</td>
<td>-outdoors Secondary Containment System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plant to TMF pipe</td>
<td>3800</td>
<td></td>
<td>3800</td>
<td>Suspensions with 10mg/l cyanide</td>
<td>HDPP Pipeline</td>
<td>-outdoors</td>
<td>Toxic R 51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>CAS Number</td>
<td>Location</td>
<td>Total storage capacity (to)</td>
<td>Physical state</td>
<td>Storage</td>
<td>Storage conditions</td>
<td>Hazardousness</td>
<td>Risk phases</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>------------</td>
<td>---------------------</td>
<td>----------------------------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td>-------------------------------------</td>
<td>---------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cyanide rich</td>
<td></td>
<td>Ellution area</td>
<td>1460</td>
<td>Solution: 2% NaOH and 3% NaCN</td>
<td>Metal tanks + electrolytic cells piping</td>
<td>-outdoors -indoors Secondary Containment System</td>
<td>Toxic R 28-32-50/50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>solution;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Process Water</td>
<td></td>
<td>Tank</td>
<td>12000</td>
<td>5mg/l CN solution</td>
<td>Metal tanks + piping</td>
<td>-outdoors -Secondary Containment System</td>
<td>Toxic R 51-53</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TMF to process tank and SCS to TMF pipelines</td>
<td>1000</td>
<td>5mg/l CN solution</td>
<td>HDPP Pipeline</td>
<td>-outdoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TMF</td>
<td>1000000</td>
<td>5mg/l CN solution</td>
<td>TMF</td>
<td>-outdoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>CAS Number</td>
<td>Location</td>
<td>Total capacity (to)</td>
<td>Physical state</td>
<td>Storage</td>
<td>Storage conditions</td>
<td>Hazardousness Risk phases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>------------</td>
<td>-----------------------------------</td>
<td>---------------------</td>
<td>---------------------------------</td>
<td>---------------------</td>
<td>---------------------------------------------------------</td>
<td>---------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ammonium Nitrate</td>
<td>6448-52-2</td>
<td>Explosives warehouse</td>
<td>100</td>
<td>Solid minimum 28 % N</td>
<td>in silos</td>
<td>In special warehouse</td>
<td>Oxidant R 8-9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Explosives</td>
<td></td>
<td>Explosives warehouse</td>
<td>5</td>
<td>-</td>
<td>Original packaging</td>
<td>In special warehouse</td>
<td>Explosive R 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Lime wash</td>
<td></td>
<td>Lime warehouse</td>
<td>805</td>
<td>Suspension 15 % CaO</td>
<td>Metal tanks + piping</td>
<td>-outdoors Secondary Containment System</td>
<td>Corrosive R 38-53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Slaked lime</td>
<td>1305-62-0</td>
<td>Lime warehouse</td>
<td>600</td>
<td>Powder</td>
<td>Silos</td>
<td>-outdoors</td>
<td>Corrosive R 36-37-38</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quicklime</td>
<td>1305-78-8</td>
<td>Lime warehouse</td>
<td>860</td>
<td>Clots</td>
<td>Silos</td>
<td>-outdoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>LPG</td>
<td>68476-85-7</td>
<td>Heating plant (elution area)</td>
<td>50</td>
<td>Liquefied gas.</td>
<td>Metal tank</td>
<td>-outdoors</td>
<td>Extremely flammable R 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Oxygen</td>
<td>7782-44-7</td>
<td>Oxygen Plant</td>
<td>2</td>
<td>Pressurized gas</td>
<td>Metal tank</td>
<td>-outdoors</td>
<td>Oxidant R 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>CAS Number</td>
<td>Location</td>
<td>Total storage capacity (to)</td>
<td>Physical state</td>
<td>Storage</td>
<td>Storage conditions</td>
<td>Storage conditions</td>
<td>Hazardousness Risk phases</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------</td>
<td>-----------------</td>
<td>------------</td>
<td>-----------------------------</td>
<td>----------------</td>
<td>---------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Diesel Fuel</td>
<td>68476-34-6</td>
<td>Fuel storage</td>
<td>520</td>
<td>Liquid</td>
<td>Metal tank</td>
<td>-outdoors</td>
<td>Secondary Containment System</td>
<td>Flammable R10</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Gasoline</td>
<td>8006-61-9</td>
<td>Fuel storage</td>
<td>15</td>
<td>Liquid</td>
<td>Metal tank</td>
<td>-sunken</td>
<td></td>
<td>Flammable R 11</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Sodium hypochlorite;</td>
<td>7681-52-9</td>
<td>WWTP</td>
<td>5</td>
<td>Liquid</td>
<td>Plastic barrels</td>
<td>- open air under awning</td>
<td></td>
<td>Toxic/oxidant R8-31-34-51</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Metabisulfite</td>
<td>7681-57-4</td>
<td>Reagent warehouse</td>
<td>120</td>
<td>Solid</td>
<td>Big-bag 1000 kg</td>
<td>-indoors</td>
<td></td>
<td>Toxic/oxidant R22-31-41-51</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Metabisulfite</td>
<td>7681-57-4</td>
<td>DETOX</td>
<td>300</td>
<td>20 % solution</td>
<td>Metal tanks + piping</td>
<td>-indoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Copper Sulphate</td>
<td>7758-99-8</td>
<td>Reagent warehouse</td>
<td>10</td>
<td>Solid</td>
<td>Big-bag 1000 kg</td>
<td>-indoors</td>
<td></td>
<td>Toxic/irritant R22-36/38-50/53</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Copper Sulphate</td>
<td>7758-99-8</td>
<td>DETOX</td>
<td>72</td>
<td>15 % solution</td>
<td>Metal tanks + piping</td>
<td>-indoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>ARD</td>
<td></td>
<td>Cetate Pond</td>
<td>500000</td>
<td>ARD</td>
<td>Catchment pond</td>
<td>-outdoors</td>
<td></td>
<td>Toxic R 51</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>CAS Number</td>
<td>Location</td>
<td>Total storage capacity (to)</td>
<td>Physical state</td>
<td>Storage</td>
<td>Storage conditions</td>
<td>Hazardousness Risk phases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>------------</td>
<td>------------</td>
<td>-----------------------------</td>
<td>----------------------------</td>
<td>----------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
<td>--------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Mercury</td>
<td>7439-97-6</td>
<td>Reagent warehouse</td>
<td>1</td>
<td>Liquid</td>
<td>Special packaging</td>
<td>-indoors</td>
<td>Toxic R 23-33-50/53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Flocculant</td>
<td></td>
<td>Reagent warehouse</td>
<td>10</td>
<td>Solid</td>
<td>Big-bag 1000 kg</td>
<td>-indoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DETOX</td>
<td>68</td>
<td>0.25 % solution</td>
<td>Metal tanks + piping</td>
<td>-outdoors Secondary Containment System</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Annex no.2  Relevant quantities of hazardous substances identified within the processing plant boundaries – according to Seveso Convention

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Category under SEVESO</th>
<th>Relevant amount (to)</th>
<th>Calculated coefficient</th>
<th>Total storage capacity (to)</th>
<th>Physical state</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>lower limit</td>
<td>upper limit</td>
<td>lower limit</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Sodium cyanide</td>
<td>T3.1 Very toxic</td>
<td>5</td>
<td>20</td>
<td>44.80</td>
<td>11.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>20</td>
<td>52.00</td>
<td>13.00</td>
</tr>
<tr>
<td>2</td>
<td>Hydrochloric acid</td>
<td>T3.2 Toxic</td>
<td>20</td>
<td>200</td>
<td>2.30</td>
<td>0.23</td>
</tr>
<tr>
<td>3</td>
<td>Sodium hydroxide</td>
<td>T3.2 Toxic</td>
<td>20</td>
<td>200</td>
<td>2.50</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>200</td>
<td>3.60</td>
<td>0.36</td>
</tr>
<tr>
<td>4</td>
<td>Cyanide containing slurry</td>
<td>T3.2 Toxic</td>
<td>20</td>
<td>200</td>
<td>4900.00</td>
<td>490.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>200</td>
<td>265.00</td>
<td>26.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>200</td>
<td>246.50</td>
<td>24.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T3.9i Hazardous for the environment</td>
<td>100</td>
<td>200</td>
<td>38.00</td>
<td>19.00</td>
</tr>
<tr>
<td>5</td>
<td>Cyanide rich solution;</td>
<td>T3.2 Toxic</td>
<td>20</td>
<td>200</td>
<td>73.00</td>
<td>7.30</td>
</tr>
<tr>
<td>6</td>
<td>Process Water</td>
<td>T3.9ii Hazardous for the environment</td>
<td>200</td>
<td>500</td>
<td>60.00</td>
<td>24.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>500</td>
<td>5.00</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>500</td>
<td>5000.00</td>
<td>2000.00</td>
</tr>
<tr>
<td>7</td>
<td>Technical Ammonium Nitrate</td>
<td>T1.1</td>
<td>350</td>
<td>2500</td>
<td>0.29</td>
<td>0.04</td>
</tr>
<tr>
<td>8</td>
<td>Explosives</td>
<td>T3.5.</td>
<td>10</td>
<td>50</td>
<td>0.50</td>
<td>0.10</td>
</tr>
<tr>
<td>9</td>
<td>Lime wash</td>
<td></td>
<td>200</td>
<td>500</td>
<td>4.03</td>
<td>1.61</td>
</tr>
<tr>
<td></td>
<td>Siaked lime</td>
<td>T3.9ii Hazardous for the environment</td>
<td>200</td>
<td>500</td>
<td>3.00</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Quicklime</td>
<td></td>
<td>200</td>
<td>500</td>
<td>4.30</td>
<td>1.72</td>
</tr>
<tr>
<td>10</td>
<td>LPG</td>
<td>T1</td>
<td>50</td>
<td>200</td>
<td>1.00</td>
<td>0.25</td>
</tr>
<tr>
<td>11</td>
<td>Oxygen</td>
<td>T1</td>
<td>200</td>
<td>2000</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>12</td>
<td>Diesel Fuel</td>
<td>T1</td>
<td>2500</td>
<td>25000</td>
<td>0.21</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Gasoline</td>
<td></td>
<td>2500</td>
<td>25000</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>13</td>
<td>Hypochlorite</td>
<td>T3.9ii Hazardous for the environment</td>
<td>200</td>
<td>500</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Category under SEVESO</td>
<td>Relevant amount (to) lower limit</td>
<td>Calculated coefficient lower</td>
<td>Calculated coefficient upper</td>
<td>Total storage capacity (to)</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------</td>
<td>----------------------------------------</td>
<td>---------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>14</td>
<td>Metabisulfite</td>
<td>T3.9ii Hazardous for the environment</td>
<td>200</td>
<td>0.60</td>
<td>0.24</td>
<td>120</td>
</tr>
<tr>
<td>15</td>
<td>Copper Sulphate</td>
<td>T3.9ii Hazardous for the environment</td>
<td>200</td>
<td>0.05</td>
<td>0.02</td>
<td>10</td>
</tr>
<tr>
<td>16</td>
<td>Wastewater</td>
<td>T3.9ii Hazardous for the environment</td>
<td>200</td>
<td>2500.00</td>
<td>1000.00</td>
<td>500000</td>
</tr>
<tr>
<td>17</td>
<td>Mercury</td>
<td>T3.2 Toxic</td>
<td>20</td>
<td>0.70</td>
<td>0.28</td>
<td>140</td>
</tr>
</tbody>
</table>
Annex no.3  The location of the safety areas within Roşia Montană Project site
Annex no.4  Hazard sources identified within the processing plant boundaries
Annex no.5  Simulated HCN emission dispersion at the processing plant total destruction

Simulated conditions:
- Atmospheric stability: Stable
- Wind speed: 0.5 m/s
- Average measuring height of the wind: 5 m
- Atmospheric temperature: 5 ºC
- Relative humidity: 80 %
- Type of emission: spontaneous emission
- Mass released: 2913 kg HCN

- Impacted area by 50 ppm HCN for 30 minutes exposure.
- Impacted area by 300 ppm HCN for 10 minutes exposure
- Impacted area by 2000 ppm HCN for 1 minutes exposure

SLAB View – Lakes Environmental Software
Annex no.6  Simulated HCN emission dispersion from the CIL tanks

Simulated Conditions
- Wind speed: 0.5 m/s
- Average wind measurement height: 5 m
- Air temperature: 5 °C
- Relative humidity: 80 %
- Emission duration: more than 2 hours
- Average emission flow rate: 0.039788 kg/s (at pH = 8.5)
- After the accident occurs, the cloud will stabilize within about 5520 s.

- Area impacted by 50 ppm HCN for a 30 min exposure
- Area impacted by 290 ppm HCN for a 10 min exposure

SLAB View – Lakes Environmental Software
Annex no. 7  Simulated HCN emission dispersion from the CIL tanks

Simulated Conditions
Atmospheric stability: stable.
Wind speed: 0.5 m/s
Average wind measurement height: 5 m
Air temperature: 5 °C
Relative humidity: 80 %
Emission duration: 2 hours
Average emission flow rate: 0.039788 kg/s (pH = 8.5)

- Area impacted by instant concentrations of 1 to 20 ppm HCN, considered the attention zone
- Area impacted by instant concentrations of more than 20 ppm HCN, considered the toxic zone

SLAB View – Lakes Environmental Software
Annex no. 8  Simulated HCN emission dispersion from the slurry thickener

Simulated Conditions
Atmospheric stability: stable.
Wind speed: 0.5 m/s
Average wind measurement height: 5 m
Air temperature: 5 ºC
Relative humidity: 80 %
Emission duration: 2 hours
Average emission flow rate: 0.032835 kg/s (pH = 8)
After the accident occurs, the cloud will stabilize within 1120 s.

- Area impacted by 50 ppm HCN for a 30 min exposure
- Area impacted by 300 ppm HCN for a 10 min exposure

SLAB View – Lakes Environmental Software
Annex no.9  Simulated HCN emission dispersion from the slurry thickener

Simulated Conditions
- Wind speed: 0.5 m/s
- Average wind measurement height: 5 m
- Air temperature: 5 °C
- Relative humidity: 80 %
- Emission duration: 2 hours
- Average emission flow rate: 0.032835 kg/s (pH = 8)

Area impacted by instant concentrations of 1 to 20 ppm HCN, considered the attention zone

Area impacted by instant concentrations of more than 20 ppm HCN, considered the toxic zone

SLAB View – Lakes Environmental Software
Simulated Conditions
Atmospheric stability: stable.
Wind speed: 0.5 m/s
Average wind measurement height: 5 m
Air temperature: 5 °C
Relative humidity: 80 %
Emission duration: 2 hours
Average emission flow rate: 0.0271819 kg/s (pH = 7)
After the accident occurs, the cloud will stabilize within 1000 s.

- Area impacted by 50 ppm HCN for a 30 min exposure
- Area impacted by 300 ppm HCN for a 10 min exposure
- Area impacted by 1900 ppm HCN for a 1 min exposure

SLAB View – Lakes Environmental Software
Annex no.11  Simulated HCN emission dispersion from the DETOX facility

Simulated Conditions
Atmospheric stability:: stable.
Wind speed: 0.5 m/s
Average wind measurement height: 5 m
Air temperature: 5 °C
Relative humidity: 80 %
Emission duration: 2 hours
Average emission flow rate: 0.0271819 kg/s (pH = 8.5)

- Area impacted by instant concentrations of 1 to 20 ppm HCN, considered the attention zone
- Area impacted by instant concentrations of more than 20 ppm HCN, considered the toxic zone

SLAB View – Lakes Environmental Software
Annex no.12  Simulated fire in the diesel storage tank.

Simulated Conditions
Wind speed: 2 m/s
Air temperature:  15 °C
Relative humidity: 80 %
Tank diameter 12 m
Tank area size: 113 m³

- Area of heat radiation greater than 5 kW/m², where irreversible lesions may occur.
- Area of heat radiation greater than 12.5 kW/m², high mortality area.
- Tank contour

EFFECTSGis 5.5 – TNO Industrial Safety Software
Annex no.13  Simulated diesel fire in the retention tank.

Simulated Conditions

- Wind speed: 2 m/s
- Air temperature: 15 ºC
- Relative humidity: 80 %
- Retention tank area size: 600 m²

- Area of heat radiation greater than 5 kW/m², where irreversible lesions may occur.
- Area of heat radiation greater than 12.5 kW/m², high mortality area.
- The shape of the retention tank is considered virvular

EFFECTSGis 5.5 – TNO Industrial Safety Software
Annex no.14  Simulated diesel explosion in the storage tank.

Simulated Conditions
Wind speed: 2 m/s
Air temperature: 15 °C
Relative humidity: 80 %
Amount of diesel vapors: 7079 kg

- Area of overpressure greater than 0.07 bar, where irreversible lesions may occur
- Area of overpressure greater than 0.3 bar, high mortality area

EFFECTSgis 5.5 – TNO Industrial Safety Software
Annex no.15  Simulated explosion of the LPG storage tank.

**Simulated Conditions**
- Wind speed: 2 m/s
- Air temperature: 15 ºC
- Relative humidity: 80 %
- Amount of LPG: 50 t

- Green: Area of overpressure greater than 0.07 bar, where irreversible lesions may occur.
- Red: Area of overpressure greater than 0.3 bar, high mortality area.

EFFECTSGis 5.5 – TNO Industrial Safety Software
Annex no.16  Effects of an explosion at explosives storage facility

Simulated Conditions

- Amount of explosives involved: 100 t nitrate and 5 t dynamite

- Area of serious effects on people (over 0.2 bar)

- Area of effects on goods (over 0.03 bar)
Annex no.17  Modeling of risks associated to accidental exposure to HCN of employees working within impacted area and from the plant site

*Linear regression for accidental exposure to HCN (Annexes 6, 7, 8, 9, 10 and 11) for the workers in the impact area:*

| hcn     | Coef.  | Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|---------|--------|-----------|-------|-----|---------------------|
| ef_hcn  | 88.63636 | 285.4861 | 0.310 | 0.761 | -528.1188          | 705.3915          |
| _cons   | 175    | 244.4757  | 0.716 | 0.487 | -353.1576          | 703.1576          |

*Risks of accidental exposure to HCN (Annexes 6, 7, 8, 9, 10 and 11) for the workers in the impact area:*

| ef_hcn | Odds Ratio | Std. Err. | z    | P>|z| | [95% Conf. Interval] |
|--------|------------|-----------|------|-----|---------------------|
| hcn    | 1.000523   | .0016196  | 0.323| 0.747| .9973538           | 1.003702           |

Logistic model for ef_hcn

<table>
<thead>
<tr>
<th></th>
<th>True</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D  ~D Total</td>
</tr>
<tr>
<td>+</td>
<td>11  4  15</td>
</tr>
</tbody>
</table>
Chapter 7 Risks

Section 12: Appendix


Total | 11 | 4 | 15

Classified + if predicted Pr(D) >= 0.5
True D defined as ef_hcn =~ 0

---

|                         | Pr( +| D)  | Pr( -|~D) | Pr( D| +)  | Pr(~D| -) |
|-------------------------|----------|----------|----------|----------|
| Sensitivity             | 100.00%  | 0.00%    |          |          |
| Specificity             |          |          | 73.33%   |          |
| Positive predictive value |          |          |        |          |
| Negative predictive value |          |          |          |          |

---

|                         | Pr( +|~D)  | Pr( -| D) | Pr(~D| +)  | Pr( D| -) |
|-------------------------|----------|----------|----------|----------|
| False + rate for true ~D | 100.00%  | 0.00%    |          |          |
| False - rate for true D  |          |          | 26.67%   |          |
| False + rate for classified + |          |          |        |          |
| False - rate for classified - |          |          |        |          |

---

Correctly classified 73.33%

---

Logistic model for ef_hcn

number of observations = 15
area under ROC curve = 0.4091
Area under ROC curve = 0.4091
Risks of accidental exposure to HCN (Annexes 6, 7, 8, 9, 10 and 11) for the workers on the entire site

|            | Coef.   | Std. Err. | t     | P>|t| | [95% Conf. Interval] |
|------------|---------|-----------|-------|------|---------------------|
| hcn        |         |           |       |      |                     |
| ef_hcn     | 217.9202| 66.79924  | 3.262 | 0.002| 84.43261 351.4079   |
| _cons      | 5.6561  | 32.08932  | 0.176 | 0.861| -58.46928 69.78148  |

|            | Odds Ratio | Std. Err. | z     | P>|z| | [95% Conf. Interval] |
|------------|------------|-----------|-------|------|---------------------|
| hcn        | 1.045608   | 0.0167299 | 2.787 | 0.005| 1.013327 1.078918   |
Logistic model for ef_hcn

<table>
<thead>
<tr>
<th>Classified</th>
<th>D</th>
<th>~D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>-</td>
<td>5</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>50</td>
<td>65</td>
</tr>
</tbody>
</table>

Classified + if predicted Pr(D) $\geq .5$
True D defined as ef_hcn $\neq 0$

Sensitivity $\Pr( + | D)$ 66.67%
Specificity $\Pr( - | ~D)$ 90.00%
Positive predictive value $\Pr( D | +)$ 66.67%
Negative predictive value $\Pr( ~D | -)$ 90.00%

False + rate for true ~D $\Pr( + | ~D)$ 10.00%
False - rate for true D $\Pr( - | D)$ 33.33%
False + rate for classified + $\Pr( ~D | +)$ 33.33%
False - rate for classified - $\Pr( D | -)$ 10.00%

Correctly classified 84.62%
number of observations = 65
area under ROC curve = 0.8000