RMG Gold Ltd.

Environmental Impact Assessment Report of
Exploitation of Sakdrisi Mine Heap Leaching Enterprise Area

Name of enterprise: RMG Gold Ltd.
Location of enterprise: Bolnisi municipality, settlement Kazreti
Type of activity: Gold recovery from quartzite ores using heap leaching method

Tbilisi, 2013
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5. Short economic and geographic characteristics of the project site

5.1 Location and Infrastructure

The research territory is located in Dmanisi (Western part) and Bolnisi municipalities. The valley of the deposit is stretched from the South-East to the North-East along the river Mashavera; at the territory of its left tributaries –Kviratskhoveli and Orsakdrisi. The Sakdrisi deposit is located in very convenient geographic, climatic and economic conditions; on the territory where transport and energy infrastructures are developed; in 80 km distance from Tbilisi; in the borderline zone with Azerbaijan and Armenia.

According to the physical-geographical conditions, the territory of the construction site is included in the region of the Zemo Khrami plateau, in particular in intermediate zone between of Dmanisi plateau and Kvemo Kartli lowland. Its terrain has low and medium height hills. There are two types of the terrains in this region.

The first of them is developed on the tuffs’ and tuff breccias’ regions and is represented by the smooth relatively soft forms. The second is developed in dacites’ and albitophires’ regions and has sharper positive terrain forms.

The territory is hilly. The altitude is 470-950 m. In general, the slopes of the ravines and the mountains create here erosive complex configuration relief.

The climate is subcontinental, with moderately dry, short, relatively warm winter and long hot summer. The mean annual temperature is +18.2°C. The climatic conditions of the region give possibility to carry out geological research, obtain the ore and process it throughout the year.

50% of the territory is covered with the forest. The slopes are mainly forested. Their inclination is varying. Slightly inclined slopes are often followed by steep slopes.

The territory selected for the heap leaching enterprise is located at the left bank of the river Khundziskhevi (Khiratslkhoveli stream) – the left tributary of the river Mashavera. The micro relief of the area is represented in the following way: the bottom of the slope at the riverbed is steep, with 30-40°inclination. The relative height of the steep bottom from the riverbed to the edge of the terrace above the floodplain is 10-15 m. But according to the engineering design of heap leaching enterprise, at present, the height of the edge of the terrace above the floodplain is increased by 5-15 m as a result of the ground disposed on it.

After the mentioned edge, the slope’s lower part is flattened for construction purposes and for arrangement of the infrastructure on it. This levelled part stretches about 250 meters in the west. There are adsorption (with activated carbon filter) column, reservoirs for loaded solution, intermediary and spoil solutions, also pumps for pumping the solution. Apart from this, in this area, there is a reservoir for mixing the cyanide solution required for processing and also the building of the laboratory. In the west, there is a reservoir for the storm water. At this location the width of the levelled area increases and reaches, approximately, 400 meters. At this polygon, there are office containers and a sanitary point, which will be discharged in the canalization reservoir.

After the flattened polygon the terrain is changing into more inclined slope. The slope, at the top of the relatively narrow section, at approximately 100 m, is treated. The ground is cut and the slope is flattened and compacted. This very ground was used for the preparation of the foundation of the territory. Proceeding from this, there is no problem of disposal of the extra ground at this location. At
the flattened and compacted slope, a geotextile, which is impermeable for the solution (the Poly-Chlore Vinyl film, so call HDPE - *High-density polyethylene*), is laid.

After this, the terraces will be made on the slope using the ground that was cut at this location. Each of the terraces will be cleaned, fattened, coverer with fine dispersal inert materials (finely crushed local ground), compacted and also covered with impermeable geotextile layer (HDPE). At the foundation of the heap, which has an inclination of approximately 60 degrees, a drainage system of cyan solutions will be arranged and gold containing quartzites crushed to the required size will be piled. Thus, the heap will suite to the terrain of the hill. The heaps will be arranged in 8-10 m tiers. On their surface a system of supplying and sprinkling the cyanide solutions will be arranged. The entire height of the heap will be approximately 30 meters.

The eastern part of the polygon located at the top of the storm water reservoir has not been treated yet. The ground cut from the territory is put on this area. This ground will be used in the future for arranging the leaching polygon.
<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="General view" /></td>
<td>General view of the polygon infrastructure</td>
</tr>
<tr>
<td><img src="image2" alt="General view" /></td>
<td>General view of the polygon infrastructure</td>
</tr>
<tr>
<td><img src="image3" alt="Access road" /></td>
<td>Access road</td>
</tr>
<tr>
<td><img src="image4" alt="Basement" /></td>
<td>Basement for the leaching polygon</td>
</tr>
<tr>
<td><img src="image5" alt="Eastern part" /></td>
<td>Eastern part of the area</td>
</tr>
<tr>
<td><img src="image6" alt="Storm water" /></td>
<td>Storm water reservoir</td>
</tr>
</tbody>
</table>
In the upper forested zone relief there are sharply noticeable 10-15 m height cornice rocks, which are presented by volcanic (lava), strong, presumably, basalt rocks.

The rivers of the researched area belong to the Mtkvari watershed. The springs of Sakaflano and waters from alluvial sediments of river Folatadauri are used for drinking.

The territory is densely populated. The majority of the village inhabitants carry out agricultural activities (vineyards, orchards, husbandry).

An electrified railway crosses the territory of Shida Karti for 150 km distance. In this line, there is South Georgia line Tbilisi-Marabda-Akhalkalaki railway line, which will join Turkish railway system, according to TRASECA project.

The length of the asphalt paved roads is up to 800 km. Among these roads, there is an interstate main line, which connects Georgia with Armenia.

The territories of the municipalities are crossed by water supply system routes, irrigation systems, cable communication lines, gas main pipes – among them those connecting with neighboring countries. Bako-Shah Deniz- Ersum gas pipeline crosses the ore containing region of the territory in its northern part, in 20km distance from Sakdrisi deposit.

The energy demand of the mentioned territories is supplied by two hydro power plants, Gardabani thermal power plant and more than 150 km long, high voltage, main electric power line.

The goods are transported mainly by railway. The distance by railway to the ports of Poti and Batumi is 450-550 km and to the port of Baku – 550 km.

In the close vicinity to the border of the ore containing region (direct distance 20-30 km), in the territory of the neighbouring country – Armenia, there are deposits of precious, nonferrous metals and barite, which have been intensively exploited up to the last period. On their basis, up to 1991, there was a big metallurgical plant, which produced annually 50-55 thousand tons of refined copper and other valuable goods.

5.2 Short description of natural-climatic conditions of the enterprise location territory (according to engineering design norms “Construction climatology” (PN 01.01-08))

The data on Kazreti is taken from the mentioned norm: the altitude is 600 m a.s.l., barometric pressure - 930 pa. According to the scheme of the construction-climatic division map (map-scheme #1), Kazreti belongs to lig sub region of the II region. The main climatic parameters of this sub region are given in the tables below:

<table>
<thead>
<tr>
<th>Climatic region</th>
<th>Climatic sub region</th>
<th>Average temperature in January °C</th>
<th>Average temperature in July °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>IIb</td>
<td>From -5 to -2</td>
<td>From +21 to +25</td>
</tr>
</tbody>
</table>
### Table 5.2.2 Air temperature

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>Annual</th>
<th>Absolute minimum °C</th>
<th>Absolute maximum °C</th>
<th>Average °C of The coldest period</th>
</tr>
</thead>
<tbody>
<tr>
<td>easiest</td>
<td>-0.3</td>
<td>1.2</td>
<td>5.0</td>
<td>10.5</td>
<td>15.8</td>
<td>19.7</td>
<td>22.1</td>
<td>22.3</td>
<td>18.7</td>
<td>13.2</td>
<td>6.8</td>
<td>2.1</td>
<td>11.4</td>
<td>-27</td>
<td>39</td>
<td>-0.4</td>
</tr>
</tbody>
</table>

### Table 5.2.3. Amplitude of air temperature

<table>
<thead>
<tr>
<th>Parameter</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>Average monthly</th>
<th>Maximum monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average monthly</td>
<td>8.5</td>
<td>9.5</td>
<td>10.5</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>11.5</td>
<td>11</td>
<td>11.5</td>
<td>11</td>
<td>11</td>
<td>8.5</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Maximum monthly</td>
<td>19</td>
<td>20</td>
<td>21.1</td>
<td>21.5</td>
<td>21.6</td>
<td>22.5</td>
<td>21.5</td>
<td>22</td>
<td>21.5</td>
<td>20.6</td>
<td>19</td>
<td>19.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 5.2.4 Relative air humidity

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>Annual average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative air humidity, %</td>
<td>65</td>
<td>66</td>
<td>68</td>
<td>68</td>
<td>70</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>73</td>
<td>76</td>
<td>74</td>
<td>64</td>
<td>70</td>
</tr>
</tbody>
</table>

### Table 5.2.5 Amount of precipitation

<table>
<thead>
<tr>
<th>Amount of precipitation, mm</th>
<th>24 hour maximum, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>110</td>
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</tbody>
</table>

### Table 5.2.5 Snow cover

<table>
<thead>
<tr>
<th>Weight of the snow cover, kpa</th>
<th>Number of days of snow cover</th>
<th>Water content of the snow cover, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>24</td>
<td>32</td>
</tr>
</tbody>
</table>

### Table 5.2.7 Normative values of the wind pressure

<table>
<thead>
<tr>
<th>W0 once in a year, kpa</th>
<th>W0 15 once in a year, kpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.23</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Table 5.2.8 Wind parameters

<table>
<thead>
<tr>
<th>1</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>N</th>
<th>NE</th>
<th>E</th>
<th>SE</th>
<th>S</th>
<th>SW</th>
<th>W</th>
<th>NW</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>20</td>
<td>24</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>11</td>
<td>8</td>
<td>16</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>34</td>
<td>43</td>
<td></td>
<td>56</td>
<td>27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.3 Background Radiation

At the territory of Bolnisi municipality, there is no radiation anomaly.

To assess radioactive level of ambient air layer over the soil, define the gamma radiation background, operative station of hydro meteorological and environmental monitoring service work over the whole territory of Georgia. According to their regular observation data, in the east Georgia the radioactive pollution level is 10-17 micro roentgens an hour, while in the west Georgia it is 11-12 micro roentgens an hour. Based on this data, gamma radiation background index is less than what is permissible (20-30 mR/h) for Bolnisi municipality territory and it is safe for people working here. The technological process of the enterprise, at any stage of its operation, does not consider use of machinery or equipment, which would become a source of ionizing radiation.

5.4 Geology

5.4.1 Geomorphology

There is a sequence of tectogenic, volcanogenic and erosive forms of relief on the territory of Bolnisi municipality. In the western part of the region there is eastern wing of Javakheti plateau, which is disintegrated by ravines. From the south of the territory of the region, there is Loki range northern wing (slope), which has complex geological structure. It is very disintegrated by intensive erosive-denudation process. The greater part of the region is occupied by Kvemo Kartli plane, which is developed in the tectonic depression between the mountains. The river terraces are clearly shaped in the plane.

The studies area is located on the left bank of the river Khundziskhevi – left tributary of the river Mashavera. Its micro relief is represented in the following way: the foundation of the slope at the riverbed is steep, with 30-40\(^\circ\) inclination. The relative height of the steep foundation from the riverbed to the edge of the terrace above the floodplain is 10–15 m. After the mentioned edge, the inclination of the slope is sharply reducing and its average inclination, to the direction of the ravine bed significantly reduces and varies within the range of 10-20\(^\circ\). The surface of the construction site is smooth and wavy. Up from the construction site, the inclination of the slope gradually increases and after approximately 200-250 meters the slope becomes steep.

The information about the lithological constitution of the construction site and adjacent territory is taken from the geological reports made in the Soviet time and also from those made in the last years (1997-2011) for studying Sakdrisi deposit. The data from the fund was confirmed by the engineering-geological research made in the territory by “Geoengineering” Ltd. According to this research, the construction site is made of rocks of lower part of the Gasandami Suite sub layers from upper Cretaceous so called “baked tuffs” – ignimbrites. The suit of the rocky layers, over the whole territory of the construction side, is covered by the quaternary deposit layers of different thickness.
5.4.2 Geology of the Region

LEGEND

- modern alluvial sediments
- Shorsheleti basalts
- Eocene sandstones and conglomerates, andesitic lavas and lava breccias, carbonate clays
- Limestone, sandy limestone and tuff breccias
- Andesite-basalt ignimbrites, tufts and sandy carbonates
- Ingimbrites, linings of tufts and sandy carbonates, dacite and riebit lavas
- Riebit and dacite pheodolast tufts, lavas and lava breccias
- Glaucoconitic sandy limestone, gravae and conglomerates
- Linings of sandstones and alevrolites, base conglomerates
- Riebit tuffs with sandy lime lenses
- Jurassic sandstones, alevrolites and clays; andesites, basalts and their tuffs
- Quartz Diorite Gneiss, mica graffitti xitos and quartzite
- Paleozoic graffitti and graffitti xitos and Quartz insertions
- Quartz porphryrites and Riebit tufts, limestone xitos linings
- Andesit-basalt dykes
- Diabase intrusions
- Riebit intrusions
- Dacite intrusions
- Diorite intrusions
- Trachiriolite intrusions
- Lithologic border
- Fault
5.4.3 Hydrogeology

The river Mashavera flows in the south from the ore containing valley. The absolute altitude of its riverbed points between Kviratskhovlis and Fostiskedi areas varies in 640-675 m range.

The Kviratskhovlis and Fostiskedi areas are divided by the river Mashavera’s tributary – Khundziskhevi. Its highest absolute altitude within the deposit area is 700 m.

The main part of the studied CH1+CH2 category reserves is located upper from the erosive basis of the river Mashavera. This upper part is located in convenient hydrogeological conditions. According to the observations of many years, there was no underground water flow (in research tunnels); in intensive precipitation periods in the tectonic zones the maximum water flow was 4.0 Lit/sec. The contents of these waters is hydrocarbonate calcium, sulfate and sodium, with 0.14 1.5 g/l mineralization.

In tectonic clefts there are pressured water bodies (with hydro carbonate calcium, sulfate sodium and sulfate calcium composition) having small discharge (0.02 – 0.9 l/sec). They have static, shortly ending nature; have insignificant dynamic resources and cannot create any important problem when treating the upper part of the ore deposit. This was proved when making a test processing at the quarry of the Kviratskhoveli area of the Sakrdisi deposit (during 2009). The processing was carried out between 950 m and 840 m layers. No ground waters were encountered and recorded at these layers. As for the waters caused by atmospheric precipitation, they were quickly drained due to the filtration of the rocks.

Below the points at 640 m and 675 m a.s.l., the hydro geological conditions have not been studies enough (presumably, hydrogeologic conditions here are more complex) and they should be clarified during additional research.

Based on the analogy with Madneuli ore deposit, we can assume that water inflow in deep layers in some periods can be more than 150-170 m3/h and crossing certain layers it is expected to have flash splash of water mass (40-60 m3/h), which will be shortly over due to the reduction of discharge.

It has to be mentioned that at the Kviratskhoveli area of the Sakrdisi gold and copper-gold ore containing deposit, during operation of the quarry, there has not been ground water inflow. Appearance of the ground water before 720 m layer is less likely to be expected. Below the 720 m point at the surface of the quarry it will have no more exit, it flows dawn to the depth.

Up to the present the works for taking the water out are limited to the measures for the maximum reduction of the amount of the surface water in quarry caused by the atmospheric precipitation; this considers arrangement of a ditch of the upper side with the section of S=0.75 m, l = 110 m.
5.4.4. Tectonics

From a tectonic point of view the Madneuli-Poladauri subzone is a thick syncline with differently oriented small sized brachyfolds and arched uplifts. In the central part of the subzone the existence of a deep seated fault is expected. Strong silification of this zone and ore occurrence may be associated with this fault. Deposits occur at the South-Easternmost end of the Zurab-Nabakrevi brachyanticline. The anticline is slightly asymmetrical, the angle of inclination of the north-eastern wing is 50-60°, and the angle of inclination of the south-western wing – 30-40°. The similar anticlinal fold is observed South-East of the anticline the angle of inclination of the North-Eastern wing of which is 30°, and the angle of inclination of the south-western wing is 20-40°. The space between the anticlinal folds is formed by wide synclines (inclination of wing up to 10-20°).

Faults of different types and zones of interlayer dissection and rupture are developed along with the folded structures. Fault patterns of four orders can be distinguished within the Sakdrisi deposit; they differ from each other in scales (spatial traction and displacement amplitude). The only fault of the first order is the north-east oriented fault considered to be the South-Eastern board of the subsidence caldera. It extends more than 2.5 km. Its north-western edge is some hundred meters lower.

The map of seismic zoning of Georgia

The only fault of the second order is located southward (slope azimuth 310-330°, angle 75°). Displacement amplitude along this fault is difficult to determine, however it runs rather long distance within the deposit. 3 faults of the third order oriented north-west are discovered too. They cross the faults of the first and second orders and substitute them at the some tens of meters long section. This structure divide the deposit into the following separate sites: Kviratskhoveli, Postiskedi, Mamulisi da Kachagiani. A right vertical fault of elevated type is located between the Kviratskhoveli and Postiskefi (horizontal azimuth 296°), between Postiskedi and Mamulisi –the right elevated fault (slope azimuth 40°, angle 50-60°),between Mamulisi and Kachagani – steep fault (slope azimuth 40°, angle 85-90°). Some faults of the fourth order oriented north-west and spreading to some hundred meters are discovered. Displacement amplitude varies from some meters to the first tens of meters.
According to the construction standards and rules currently active in Georgia ("earthquake proof construction, pn 01.01-09), the seismicity of the studied sites is 9 by MSK64 seismic intensity scale with the non-dimensional index of seismicity – 0.30.

5.4.5. Mineralization

The Sakdrisi deposit is associated with the anticlinal fold having a number of differently oriented faults. Mineralized extrusives penetrated into the fault of the arched part of the fold and the Sakdrisi lopolith indicated that the anticlinal fold should be developed during intrusion of magma diapir. These formation may be satellites of a deeply seated granodiorite massif.

The deposit is built of sediments of the Mashavera layer represented by tuff-turbidites, tuffites, carbonate sandstones and marls. Sublayers with syngenetic pyrite are often found in the tuff-turbidite layer which probably play a role of a geochemical barrier during hydrothermal reactions.

Secondary quartzrocks and argillizated rocks with gold-sulphide mineralization are developed as a result of hydrothermal change of the Mashavera layer.

Metasomatosis develops more actively in tuffites and pyroclastic rocks. The joint of secondary quartzrocks with side rocks and the underlayer is uneven and brecciated. Similar brecciated zones can be distinguished within the secondary quartzrocks in the joints with the relict rocks. Mineralization of concentrated gold and gold-copper is associated with these zones. The wide zone (100-250 m) of brecciated rocks in an ore bearing zone located between the ore bearing faults and oriented North-East.

The Sakdrisi deposit is an epithermal deposit due to its mineral composition and hydrothermal character. It has a complicated structural-morphological texture conditioned by both pre mineralization and post mineralization tectonics.

A complicated structure of certain ore bearing sites, existence of blind zones and tectonic faults of the complex system create favorable conditions for ore accumulation at the pre mineralization stage, while at the later stage complicates the morphology and mineralized zones and bodies.

Zoning of metasomatosis and ores is observed at the deposit: its upper part (0-50 m) is built of quartz-adular and quartz-albite barite-gold bearing secondary quartzrocks, middle part (50-200 m) – quartz-montmorillonite and montmorillonite argizilites and secondary quartzrocks, while its lower part (200-600 m) – propylitized tuffs of varying intensity.

Zoning is conditioned by the existence of two types of ores in the deposit: gold-copper ores at lower level and gold-quartz ores at the upper level. Gold-quartz ores lay on gold-sulphide ores and are manifested in the form of grains and thin veins which form relatively thick gold-quartz zones. Gold-sulphide ores are characterized by steep north-western inclination. Copper-sulphide ores are probably inclined to the south, however should be specified.

Mineralization is not even – ore bearing sites alternate with almost sterile sites.

Contours of ore bearing bodies are determined as a result of sapling. Ore bearing zones correspond to Au ≥ 0.2 g/t cut-off grade. Within ore bearing zones the industrial ores with Au ≥ 0.4 g/t cut-off grade are outlined. Standard ores make 50% of the ore bearing zones and 41-61% of sites (41% - Postiskedi and 61% Kachagiani). Ore bearing bodies have a complicated morphology and internal structure due to bulging, stretching and branching both horizontally and vertically.
An oxidation zone where iron oxides and hydroxides, jarosite and malachite are developed at the expense of primary sulphides is widespread at the deposit. Quartzrocks of this zone are yellowish-rusty. Below the oxidation zone a zone of secondary enrichment of sulphides is found, where chalcosine, covelline and bornite are recorded. Primary sulphides located beneath of this zone are sound. Mineral composition of the Sakdrisi ores are presented in the Table below.

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Hypogene</th>
<th>Supergene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>pyrite peacock ore</td>
<td>malachite, azurite, limonite, covelline, chalcosine, delafossite, hematite</td>
</tr>
<tr>
<td>Secondary</td>
<td>native gold, fahl ore, sphalerite, galena</td>
<td>tenorite, brochantite, bornite, goethite, cerussite</td>
</tr>
<tr>
<td>Rare</td>
<td>electrum, marcasite, enargite, petzite, bismuthine, native copper, aikinite, magnetite, molybdenite, hessite, native silver</td>
<td></td>
</tr>
<tr>
<td>Vein minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main</td>
<td>quartz, barite, sericite, calcite</td>
<td></td>
</tr>
<tr>
<td>Secondary</td>
<td>ankerite, dolomite, dickite, alunite, gypsum, jarosite, zeolite, kaolinite, montmorillonite</td>
<td></td>
</tr>
</tbody>
</table>

Gold bearing ores of the Sakdrisi deposit and their derivatives contain 30-70% of natural gold in ores and 28-55% in tailings. Ores contain 30-67% and tailings contain 40-60% embedded gold with clear surfaces. Ores and their derivatives contain insignificant amounts of coarse dispersive gold in sulphides. There is almost no gold associated with silicates.

5.4.6. Engineering-geological conditions

1. The study area of the northern site of the Sakdrisi deposit is inclined to the south, i.e. to the Khundziskhevi river at an angle 7-12°. The surface of the area is wavy and flattened with insignificant man-induced irregularities. No significant geodynamic (physical-geological) process or phenomenon is not observed within the area. The studies revealed only 5 lithological varieties of soils and rocks. Groundwater was recorded at a depth of 15-17 m in H1 and H2 wells drilled in 2011 at the riverbed of the Kundziskhevi river. Due to the existing environmental factors the complexity of engineering-geological conditions of the area is of the category II (medium complexity);
2. The construction site is bordered and continued by the steeper slope from the north. During heavy rains and snowmelt the development of strong streams of surface waters on this slope is expected. These streams will flow into the Khundziskhevi river crossing the construction site;
3. From the lithological point of view 3 types of loamy soils and 2 types of rocky soils. Deluvial-proluvial soil layers (layer 1 and layer 1a) spreading across the construction site are found under the 0.2-0.7 m thick layer of topsoil. Under these soil layers the residual soils - clays (layer 2) developed as a result of rock depletion are located. The quaternary soils contain fine pebble in
different amounts, while the content of fine pebble in residual soils lower. Under these layers the main rocks – andesite-basalts and ignimbrites (layer 3 and layer 4) are found.

4. According to the results of field and laboratory tests of soil permeability the filtration coefficient varies between 0.029 m/24h - 0.0001 m/24h, which is characteristic for loamy soils.

5. The master plan of the project should consider construction of a system of canals to collect and remove surface runoffs from the construction site.

6. Point and continuous foundations or slabs can be considered for different types of buildings depending on loads of these structures on the ground.

7. If the wavy relief of the construction site has to be flattened the cut soils can be used for embankments considering the standard data of soil trampling. Soils trampling factors shall be determined prior to their use since these factors differ by sites. Topsoil shall not be used in embankments. Topsoil shall be cut and removed from the construction sites of buildings, canals and embankments.

8. According to the results of chemical analysis the soils are not aggressive toward concrete.

9. Design resistance (R0)* of foundation soils by specific layers (according to the local standards СНиП 2.02.01-83) is:
   - layer 1 _ 0.35 mPa;
   - layer 1a _ 0.35 mPa
   - layer 2 _ 0.3 mPa

10. According to the construction standards and rules currently active in Georgia (“earthquake proof construction, pn 01.01-09), the seismicity of the northern site of the Sakdrisi is 9 by MSK64 seismic intensity scale with the non-dimensional index of seismicity – 0.30.

Main rivers of the region (Khrami, Mashavera) and their numerous tributaries form V-shaped gorges in mountains. Downstream these gorges gradually transform into wide floodplain. The river gorges are developed mainly in hard lavas resistant to weathering (dolerites, andesites, basalts, dacites). This quality of formations determined the steepness of the slopes and existence of vertical cornices.

The second important factor of the development of mudflows, i.e. a source of mudflow built of friable rocks, such as conglomerates, clay-shale, argillite, etc. is not recorded on the territory of the municipality. Therefore mudflows within the hydrographical network of the Bolnisi municipality is not expected.

The risk of the development of landslides is also very low, since the slopes are built of rocks resistant to weathering and slightly watered.

5.4.7. Soils

Chestnut and solty soils compex is developed on the plane loessial loams and alluvial layers within the territory of the Bolnisi municipality. Dark chestnut carbonate soils occupy large areas in the Mashavera river gorge. On the river banks alluvial, mainly alluvial carbonate soils are found. In foothill areas chestnut soils are substituted with brown forest soils. At higher elevations (above 900 m) forest podzolized grey soils are developed.
6. Description of the surface water bodies of the region

The Mashavera river

The Mashavera river is the largest water body on the territory of the Bolnisi municipality. It originated from the junction of the rivers Sarpdere and Naziklich. These rivers flow from the eastern slope of the mountain Emlikli (3053,6 m). The mountain is located on the on the range named Sveli Mtebi (Kechuti), 0,2 km lower the village Pantiani at a height of 1358 m.

The Mashavera river flows into the river Ktsia-Khrami from the right side, at a distance of 41 km from its junction, 35 south of the village Arukhlo, at a height of 390 m above sea level.

The length of the river is 66 km, total head – 968 m, mean inclination – 14,7%, area of the watershed – 1390 km², mean height – 1240 m.

Main tributaries of the river: the rivers Saprdere (length 19 km), Nazigelichi (12 km), Kamarlo (18 km), Mamutli (21 km), Karakliska (13 km), Moshevani (25 km), Ukangori (13 km), Kheta (22 km), Bolnisi (Poladauri) (42 km) and Talaverchai (17 km). All tributaries flow into the Mashavera river in the mountainous part of its watershed up to the village Kveha. No large tributaries except Bolnisi (Poladauri) enter the river downstream within 27 km.

The width of the river varies between 2 m (at the village Bolnisi) and 20 m (at the village Javakhi), dominantly - 12 m.

The depth of the river is 0,4 – 0,6 m (at rip sections) and 0,8 – 1,2 m at deep sections, dominantly – 0,8 m.

The velocity is 1,5 – 2 m/sec and 0,6 – 0,9 m/sec accordingly, dominantly 1,2 m/sec.

The water regime of the river has been studied from 1927.

The Mashave river is characterized by spring high waters and unstable low water during the rest of the year. Spring high waters start in the beginning of April. Downstream high waters start in mid March. Floods reach maximum in mid May. Afterwards the water level decreases. Downstream the water level decreases in the end of April due to the intensive use of water for irrigation purposes.

No hazardous hydrological events are observed at the river.

The river is fed by snowmelt, rain and ground waters.

Maximum discharge is 108 m³/sec (19.05.1959), and minimum – 0,65 m³/sec (16.03.1945, the village Didi Dmanisi).

Annual discharge is not distributed evenly by seasons: spring – 40,0% of annual runoff, summer – 30,8%, fall – 16,8%, winter – 12,4%.
Main hydrological parameters of the Mashavera river are given in the table:

Table 6.1. Main hydrological parameters of the Mashavera river

<table>
<thead>
<tr>
<th>Control section</th>
<th>Source</th>
<th>Up to the junction of the Moshevani river</th>
<th>The village Dmanisi</th>
<th>Up to the junction of the Bolnisi river</th>
<th>Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed, km$^2$</td>
<td>147</td>
<td>373</td>
<td>570</td>
<td>855</td>
<td>1390</td>
</tr>
<tr>
<td>Mean height of watershed, m</td>
<td>2240</td>
<td>1820</td>
<td>1660</td>
<td>1390</td>
<td>1240</td>
</tr>
<tr>
<td>Average annual discharge, m$^3$/sec</td>
<td>1,90</td>
<td>3,77</td>
<td>5,09</td>
<td>5,90</td>
<td>7,78</td>
</tr>
<tr>
<td>• Average long-term discharge</td>
<td>1,37</td>
<td>2,72</td>
<td>3,72</td>
<td>4,26</td>
<td>5,62</td>
</tr>
<tr>
<td>• 75% occurrence</td>
<td>0,79</td>
<td>1,57</td>
<td>2,13</td>
<td>2,46</td>
<td>3,24</td>
</tr>
<tr>
<td>• 97% occurrence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum discharge, m$^3$/sec</td>
<td></td>
<td></td>
<td>60,8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Average long-term discharge</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>• 1% occurrence</td>
<td>129</td>
<td>221</td>
<td>283</td>
<td>355</td>
<td>467</td>
</tr>
<tr>
<td>• 2% occurrence</td>
<td>109</td>
<td>186</td>
<td>239</td>
<td>300</td>
<td>394</td>
</tr>
<tr>
<td>• 5% occurrence</td>
<td>80,8</td>
<td>138</td>
<td>177</td>
<td>222</td>
<td>292</td>
</tr>
<tr>
<td>• 10% occurrence</td>
<td>68,7</td>
<td>117</td>
<td>150</td>
<td>180</td>
<td>248</td>
</tr>
<tr>
<td>Mean of winter low water m$^3$/sec</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>• 75% occurrence</td>
<td>1,46</td>
<td>1,88</td>
<td>2,35</td>
<td>2,42</td>
<td>2,88</td>
</tr>
<tr>
<td>• 97% occurrence</td>
<td>1,02</td>
<td>1,32</td>
<td>1,64</td>
<td>1,69</td>
<td>2,02</td>
</tr>
<tr>
<td>Long-term amplitude of water level variation, m (mean/maximum)</td>
<td></td>
<td></td>
<td>0,96/1,97</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
Laboratory observations of the quality of the water of the Mashavaera river are being carried out by the LEPL National Environmental Agency of the Ministry of Environment and Natural Resources Protection of Georgia 500 m downstream of the junction of the Kazretula river. The environmental laboratory of JSC “RMG Copper” implements a regular monitoring of the water quality at the same location.

During the recent years the concentrations of polluters varied within the following ranges:

- copper – 0,007-0,7 mg/l
- zinc – 0,01-3,9 mg/l
- iron – 0,17-0,36 mg/l
- cadmium – <0,001 mg/l

**The Kviratskhoveli stream**

The Kviratskhoveli stream is a left tributary of the Mashavaera river. Its length is 3,5 km, mean annual discharge – 0,06 m³/sec, maximum discharge - 0,5 m³/sec.

Regular hydrological observations and monitoring of water quality are not being carried out. Only periodical data of observations carried out in current and previous years by the environmental laboratory of JSC Madneuli (currently “RMG Copper”) is available. This information has been used during the development of the present document.

Monitoring is being carried out at the Kviratskhoveli site of the Sakdrisi deposit. The site is crossed by the Kviratskhoveli stream. A number of low rivers were registered at this site in the previous years, however most of them have been almost dried out last year.

Monitoring is being implemented on a monthly basis. Water samples are being taken at the crossing of the Kviratskhoveli stream and the motor road. This site gives the possibility of monitoring diffuse and point runoffs from the deposit. In 2010-2011 the monitoring of this site of the Sakdrisi deposit has been carried out at the three points of the Kviratskhoveli stream. Due to the drying of the upstream section of the Kviratskhoveli stream only one sampling point was used in 2012 and 2013. Table 6.2 contains the averaged data of chemical analysis of water carried out in 2012-2013, and the Table 6.3 – the averaged data of chemical analysis of water carried out in 2010-2011.

**Table 6.2. Averaged data of chemical analysis of water carried out in 2012-2013**

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>PH</th>
<th>Cu²⁺</th>
<th>Zn²⁺</th>
<th>Fetotal</th>
<th>SO₄²⁻</th>
<th>Ca²⁺</th>
<th>HCO₃⁻</th>
<th>CL⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing of the Kviratskhoveli stream and the motor road</td>
<td>7.7</td>
<td>0.08</td>
<td>0.08</td>
<td>0.06</td>
<td>65</td>
<td>90</td>
<td>135</td>
<td>22</td>
</tr>
</tbody>
</table>
Table 6.3. Averaged data of chemical analysis of water carried out in 2010-2011

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>PH</th>
<th>Cu²⁺</th>
<th>Zn²⁺</th>
<th>Fetotal</th>
<th>SO₄²⁻</th>
<th>Ca²⁺</th>
<th>HCO₃⁻</th>
<th>Cl⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Mashavera river up to the Sakdrisi deposit</td>
<td>7.8</td>
<td>0.04</td>
<td>0.04</td>
<td>0.22</td>
<td>7</td>
<td>62</td>
<td>65</td>
<td>21</td>
</tr>
<tr>
<td>Spring of the Kviratskhoveli site</td>
<td>7.6</td>
<td>0.23</td>
<td>0.41</td>
<td>0.05</td>
<td>192</td>
<td>184</td>
<td>317</td>
<td>17</td>
</tr>
<tr>
<td>Crossing of the Kviratskhoveli stream and the motor road</td>
<td>7.9</td>
<td>0.09</td>
<td>0.08</td>
<td>0.04</td>
<td>47</td>
<td>80</td>
<td>120</td>
<td>21</td>
</tr>
<tr>
<td>The Kviratskhoveli stream at the gallery 39</td>
<td>7.9</td>
<td>0.09</td>
<td>0.08</td>
<td>0.05</td>
<td>45</td>
<td>81</td>
<td>122</td>
<td>22</td>
</tr>
<tr>
<td>The Kviratskhoveli stream up to the gallery 42 (baseline)</td>
<td>7.9</td>
<td>0.08</td>
<td>0.08</td>
<td>0.04</td>
<td>40</td>
<td>77</td>
<td>120</td>
<td>22</td>
</tr>
<tr>
<td>The Mashavera river downstream Sakdrisi</td>
<td>7.8</td>
<td>0.04</td>
<td>0.04</td>
<td>0.19</td>
<td>14</td>
<td>70</td>
<td>73</td>
<td>21</td>
</tr>
</tbody>
</table>

Note: chemical analysis of wastewaters is carried out using Spectrophotometer DR/2400 (manufactured in USA by "HACH").
9. Alternatives

9.1. Technology

Comparison of alternative options of gold mining designing criteria, feasibility study, technology and operation has been carried out as far back as in 1994-1995 in the context of the quartzrock ore stockpiled on the territory of the copper deposit of JSC Madneuli.

For the purpose of optimization of gold reclamation two main technologies were discussed:

- Carbon in pulp;
- Heap leaching.

Investment and operation costs required for the implementation of each method were evaluated. The environmental impact factor was assessed for each method as well.

The evaluations show that the both methods are economically acceptable technologies, however CIP methods allows to recover additional amount of gold.

Based on the data of the companies operating worldwide and considering the local conditions the investment and operating costs for each methods were estimated. Creation of an enterprise for processing of a given amount of materials per year using heap leaching method requires less investment costs than an enterprise operating using CIP technology. Extra costs of a CIP enterprise are associated with an expensive crushing equipment and electricity required for crushing quartzrock ore into particles of less than 0.1 mm in size. Investments are needed also for iron tanks and ripping.

Heap leaching is less costly than CIP, since the operation of a crushing unit of the CIP enterprise require considerable resources.

The main difference between these two methods in terms of impact n the environment and investment/operation costs is that when using CIP method the treatment of tailings, clearing of a large area from plants and construction of a tailings dam for 12 million tons of liquid waste is required which are associated with more risks. In case of heap leaching such infrastructure is not needed. Heap leaching involves the application of weak cyanide solution onto a heap of crushed ore placed on an impervious high density polyethylene (HDPE) pad liner within a totally closed circuit. Dissolution of gold occurs within the heap as the cyanide solution percolates downward through the crushed ore. The method of leaching is used throughout Australia and other gold producing countries. This method of gold reclamation is widely used in the USA as the most cost effective and environmentally friendly method of silver and gold reclamation. Heap leaching is a method acceptable from environmental point of view since it involves application of weak chemicals and does not require the construction of a tailings dam. Moreover, all chemicals and water used during the process are reused and therefore they are not discharged into the environment. That part of cyanide which is retained in ore heaps after leaching can be easily deactivated by water in which cyanide is decomposed due to an oxidation process taking place as a result of exposure to hydrogen peroxide.

9.2. Alternative locations

Alternative locations were discussed in 1994-1995 when the company obtained a license on exploration-development of the so-called Sakdrisi site of the well-known deposits of the Bolnisi group and a decision on using the above heap leaching technology was made. At that times the company was selecting production sites for heap leaching. The company had limited alternatives, since the local relief and the location of the Sakdrisi deposit did not provide multiple options that met the criteria used in mining for selecting this type of areas. These criteria include:
On the basis of a many years’ experience and economic calculations the so-called Abulbuki site (discussed in the present EIA) has been selected as the most acceptable location of a heap leaching enterprise. It is located on the open area of the slope north of the Kviratskhoveli site of the Sakdrisi deposit on the left bank of the Kviratskhoveli stream. This location is the most acceptable both from economic and environmental point of view. Specifically, this site is located as close as possible to the Sakdrisi deposit and as far as possible from the population. This will result in drastic reduction of the movement of heavy machinery in the settlements and atmospheric emissions, as well as the impact of dust and noise generated by the enterprise.

### 9.3. Zero alternative

Zero alternative is an option when the implementation of the project is not deemed appropriate and therefore it will not be implemented. Taking into account that all ore mined at the Sakdrisi deposit is being processed at the enterprise of the JSC RMG Gold – former “Quartzite” located at a distance of about 8 km from the Sakdrisi site, this is an undesirable alternative from economic and social-environmental standpoint. More than 8 km haulage distance is not economically feasible. Moreover, intensive movement of heavy machinery on the Kazreti-Sakdrisi section affects both the local population and the Ponichala-Marneuli-Guguti motorway of international importance.

Therefore, if the mentioned project is not implemented the development of the so-called Sakdrisi site of the well-known deposits of the Bolnisi group and ore mining will have no sense, which will have a negative impact both on the state and local budgets and the well-being of the population.
10. General information

10.1. The Sakdrisi deposit

The Sakdrisi deposit is located at a distance of 7-7.5 km from the JSC “RMG Copper” deposit and at a
distance of 3.5 km from the Kazreti settlement.

The ores of the Sakdrisi deposit are almost similar to the ores of the Madneuli deposit by characteristics.
They are located close to the surface and can be effectively processed together with the ores of the
Madneuli deposit using the modern technologies applied at JSC RMG Copper and Ltd RMG Gold.

Mining of gold bearing quartzrocks and gold-copper ores in an amount of about 2 million tons a year is
considered at the operating Kviratskhoveli experimental industrial mine of the Sakdrisi deposit.

The area of the explored reserves of the Sakdrisi deposit is 0.4 km², it is 2000-2100 m long (from south-
west to north-east) and 60-280 m wide. Copper bearing ores extracted at the Sakdrisi deposit will be
processed at the concentrating mill of the JSC RMG Copper using the existing infrastructure.

10.2. Production processes

10.2.1. Technological cycle

Brief description of the technological cycle of the enterprise:

- Ore extraction at the mine of the Sakdrisi deposit using drilling and blasting method;
- Disposal of the dead rock at the dumpsite allocated for dead rocks;
- Transfer of the ore to the crushing and sorting unit where the ore will be crushed into particles
  of required size;
- Transportation of the crushed ore to the heap by motor vehicles;
- Application of weak cyanide solution to the heap to bleach precious metals contained in the
  ores and directing gold containing solution to the pond;
- Directing gold containing solution from the pond to the adsorption column (activated charcoal)
  for adsorption of precious metals contained in solution on the activated charcoal;
- Draining and packing the saturated charcoal for further transportation;
- Transportation of the loaded charcoal to the plant of RMG Gold (former Quartzite)
  o desorption of precious metals from the charcoal through application of acid;
  o melting the received concentrate to get Dore (gold-silver alloy) - the final product of the
    enterprise.

10.2.2. Description of production processes

The heap leaching method is used to recover gold from gold bearing quartzrocks of the Sakdrisi deposit.
This method has considerably less impact on the environment compared to other technologies (1. Кучное
выщелачивание золота – Чекушин Т.В., Естественные и технические науки, 2008, #3,
similar to the processes already introduced at Quartzite Ltd.
Main technical characteristics of the enterprise are shown in the table 10.2.1.1.

Table 10.2.1.1. Main technical characteristics

<table>
<thead>
<tr>
<th>Name</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>t/year</td>
<td>2 000 000</td>
</tr>
<tr>
<td>Maximum output per shift for extraction of gold bearing quartzrocks</td>
<td>t</td>
<td>2 070</td>
</tr>
<tr>
<td>Maximum output per shift for extraction of copper ore</td>
<td>t</td>
<td>1 055</td>
</tr>
<tr>
<td>Maximum output per shift for opening</td>
<td>t</td>
<td>6 500</td>
</tr>
<tr>
<td>Number of shifts per day</td>
<td>shift</td>
<td>2</td>
</tr>
<tr>
<td>Duration of a shift</td>
<td>hour</td>
<td>8</td>
</tr>
<tr>
<td>Lifespan (including shutdown works)</td>
<td>Year</td>
<td>4.5</td>
</tr>
<tr>
<td>Overall slope angle</td>
<td>degree</td>
<td>45-50</td>
</tr>
<tr>
<td>Angle of the workable bench</td>
<td>degree</td>
<td>70-80</td>
</tr>
<tr>
<td>Angle of the nonworkable bench</td>
<td>degree</td>
<td>60</td>
</tr>
<tr>
<td>Volume of mining operations without rock disintegration coefficient (total)</td>
<td>m</td>
<td>8 930 530</td>
</tr>
<tr>
<td>Industrial reserves of gold bearing ore without depletion</td>
<td>t</td>
<td>4 096 260</td>
</tr>
<tr>
<td>Industrial reserves of gold bearing ore including depletion and production losses</td>
<td>t</td>
<td>4 541 930</td>
</tr>
<tr>
<td>Industrial reserves of copper ore without depletion</td>
<td>t</td>
<td>2 699 900</td>
</tr>
<tr>
<td>Industrial reserves of copper ore including depletion and production losses</td>
<td>t</td>
<td>2 993 650</td>
</tr>
<tr>
<td>Depletion for the both ores</td>
<td>%</td>
<td>12</td>
</tr>
<tr>
<td>Volume height of gold bearing ore</td>
<td>t/m³</td>
<td>2.52</td>
</tr>
<tr>
<td>Volumes of dead rocks disposed at the dumpsite considering the rock disintegration coefficient</td>
<td>m</td>
<td>7 100 000</td>
</tr>
<tr>
<td>Area of the mine (on the plan)</td>
<td>ha</td>
<td>16.68</td>
</tr>
<tr>
<td>Average haul distance to the dumpsite of dead rock</td>
<td>km</td>
<td>1.4</td>
</tr>
<tr>
<td>Radius of the hazardous zone in terms of blowout of fragments</td>
<td>m</td>
<td>655</td>
</tr>
<tr>
<td>Radius of the hazardous zone in terms of seismic effect</td>
<td>m</td>
<td>300</td>
</tr>
<tr>
<td>Mean operational coefficient of opening for depleted ore (without rock disintegration coefficient)</td>
<td>m/t</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>t/t</td>
<td>2.08</td>
</tr>
</tbody>
</table>

The production process starts with the creation of heap leaching sites. In this case they will be constructed north-west of the 5th site of the Sakdrisi deposit, on the 100 m long hill slope located at a distance of 600 m. The slope will be terraced using locally cut soils which will be used for the foundation of the site. Therefore, according to the project, the problem of extra soil is already resolved. Each terrace will be cleaned, leveled, covered with fine grained inert materials (local ground), trampled and covered with impervious high density polyethylene (HDPE). At the base of a heap, with the angle of inclination of about 60° a drainage system of cyanic solutions will be installed. Gold bearing quartzrocks crushed into particles of required size will be put in heaps. Therefore the heap will fit into the relief of the hill. The heaps will be placed in the form of 10 (8) m tiers on the surface of which a cyanic solution supply and irrigation system will be installed. The total height of the heap will reach 30 m.

The ore will be crushed into particles of a size which is optimal for leaching (80% - 12.5 mm). During the same process the ore will be mixed up with lime (2-3 kg/t). Lime plays a role of protecting alkali and prevents hydrolysis of sodium cyanide which can occur if pH drops below 9 in the heaps.
This measure prevents the release of hydrocyanic acid into the ambient air, pollution of the workspace with highly toxic substances and ensures observance of work safety standards.

As a rule, the rocks extracted at the mine are characterized with high humidity and during crushing the generation of large volumes of dust is not expected.

A canal for collecting and directing gold-cyanide solutions into a special pond will be constructed at the heap drainage. The canals and the ponds will be covered with impervious geotextile. The ponds are designed for collecting gold-saturated, half-saturated and gold free cyanide solutions and storm waters. The capacity of the pond designed for storm waters is 36 000 m³, while the capacity of other ponds is 18 000 m³ each. The ponds are equipped with solution level measuring-control equipment to prevent leaking of cyanic solutions into the environment. The pond designed for storm water will be used for recharging other ponds losing water due to evaporation and technological processes.

0.05% solution of sodium cyanide will be applied to heaps for leaching. If the rocks are resistant to leaching the concentration of sodium cyanide can be increased by 0.01%. Solution is pumped from the pond into the main pipeline and flows up to the top of each cell of the heap through a special devise. The main pipelines distribute solution in lateral distribution pipes which are separated from each other by 10 m and are laid along each operational cell. Application of solution occurs by sprinkling. The sprinklers are installed in every 10 m, they are equipped with regulators to ensure even application of solution.

The leach circuit is implemented in the following sequence: cyanide solution is applied to only one cell of the heap. These process lasts few days. When the second cell is watered the gold containing cyanide solution drains from the first cell. These cycles are repeated as many times as needed until the end of the process gold leaching. Solutions of the first leaching flow into the pond of saturated solutions, and solutions of the secondary cycle into the pond of half-saturated solutions.

Solution of the pond of saturated solutions flow into the adsorption columns of activated charcoal. The processed solution is than directed to the pond collecting gold-free solutions. In this pond with the capacity 18 000 m³ the concentration of sodium cyanide solution and pH are corrected. After this process this solution are diverted for watering. The above-mentioned indicates that within the heat leaching site water circulates in a closed system and discharge of water into the environment is excluded.

This cycle of the heap leaching process ends with adsorption of gold on activated charcoal. When adsorbent – activated charcoal is saturated with gold, it will be unloaded from columns and sent to the existing Dore plant of the Ltd RMG Gold – former Quartzite.

Therefore, at the heap leaching site of the Sakdrisi deposit the extraction, crushing and heaping of gold bearing, gold leaching and adsorption on activated charcoal will take place. While the cycle of gold reclamation – desorption from adsorbent (elution), electrolysis, melting, adsorbent regeneration will occur at the existing plant of the Ltd MRG Gold.

After completion of the heap leaching process the heaps will be washed with water, detoxicated and left at the site. The issue of their further recovery will be discussed as a separate plan and project at the operation stage.

10.2.3. Production infrastructure

A heap leaching production site has a simple infrastructure. The site consists of:

- heap terraces
• the pond for industrial water supply at the Kviratskhoveli stream
• 3 tanks for saturated and halfsaturated cyanide solutions
• two spare tanks
• water intake tank
• crusher
• workshop
• adsorption column of activated charcoal
• cyanide tank
• warehouse of reagents
• laboratories
• warehouses
• offices, dressing rooms, restrooms, recreation rooms.

Most of the infrastructure, specifically the buildings will be simple structures constructed at the sited prepared in advance.

An international motor road Ponichala-Marneuli-Guguti (border with the republic of Armenia) runs south of the production site. The site is connected with this motor road with a secondary road which will be widened for the project purposes.

The production site is provided with the transmission line feeding from the electric transformer owned by JSC RMG Copper.

The main gas pipeline Tsiteli Khidi-Tsalka-Akhalkalaki owned by the Oil and Gas Corporation of Georgia runs throughout the leased area. The pipeline restricts mining operations at the Kachagiani deposit of the Sakdrisi site and therefore relocation of this section is planned.

The is no water supply infrastructure at the production site.
10.2.4. Spill localization and leak detection

Environmental measures have been paid a special attention during the development of all aspects of the project. The whole facility has been defined as a system with zero discharge and the measures ensuring the integrity of the environment have been considered.

There are two measures in place ensuring protection of the environment:

- measures for localization of those chemicals which may affect the environment
- leak detection system to control the reliability of localization structures.

The secondary means of localization will be designed and constructed at all sites where chemicals have to be used and stored. The main warehouse of chemicals will be locked. Only heads of shifts will have an access to the chemicals. The secondary means of localization are constructions which will be designed and constructed in a way to contain the primary means of localization (e.g. steel tanks).

A leak detection pipe will be installed in the lump between the membranes at the lowest corner of the pool. The pipe will run along the sloped wall of the pool. The leak detecting pipe will help to detect leakage of solution into the system and do sampling.

The secondary means of localization are designed in a way to contain 110% of the volume of the largest tank of the area in case of a leakage from any tank.
11. Water use

11.1. Water supply

For the operations to be carried out at the Sakdrisi deposit and the heap leaching site the rented motor vehicles and machinery will be used and their washing, technical maintenance, oil replacement and other relevant activities will not take place on the territory of the heap leaching site. Therefore industrial waste waters, waste oils and other will not be generated at the site.

At the heap leaching site water will be used for industrial and drinking-household purposes.

The system of industrial water supply is a closed circuit. To compensate water losses (evaporation, watering of roads, etc.) runoff of production sites will be used, while the water reserves will be recharged from the Kviratkhoveli stream. For this purpose a small pond will be constructed at a distance of 50-60 m south-west of the production site. The pond will be connected with the reserve tank via pipeline. During low water period at the stream water will be provided by tank cars on the basis of an agreement made with the Bolnisi Water Supply and Drainage Service Center. The major part of water used for industrial purposes is spent to compensate water evaporation, especially in summer. The quantity of used water per month will be around 5000 m$^3$.

A storm water pool will be constructed to collect industrial and storm waters flowing from heap leaching site. Its capacity will allow the retain maximum amount of two months rains occurring once in 10 years. The mean annual precipitation in the city of Bolnisi is 512 mm, in the neighboring city of Dmanisi – 698 mm. Maximum amount of precipitation is recorded in May-June. Amount of precipitation recorded during this period in Dmanisi is 215 mm (almost one third of the annual precipitation). The pool of storm water will be able to receive twice as much waters as the volumes of maximum precipitation.

In the beginning water will be brought by tank cars. In the future the construction of a water supply system at the site is planned. Bottled water will be used for drinking.

11.2. Pond at the Kviratskhoveli stream for industrial water supply

As it has been stated above a small pond will be constructed at a distance of 50-60 m south-west of the production site. Water from the pond will flow to the filtration facility and then to the reserve pool. For this purpose a dam will be constructed in the Kviratkhoveli riverbed. An artificial filter built of cobble and gravel will be constructed upstream. The parameters of the dam will be as follows:

- material - concrete
- section - quadrangular
- shape - circus
- width - 13.3 m
- height - 5 m
- thickness - 2 m

A 1000 mm diameter emptying iron pipe will be placed at the bottom of the dam. 1.5 m upstream of the dam a sluice will be installed to regulate flow if needed. On the left side of the dam, on its top a 4 m long and 0.5 m deep spillway will be constructed. On the right side of the dam a polyethylene discharge pipe will be installed to direct water from the pond to the filtration unit. From the filtration unit water will flow to the reserve tank.
11.3. Quantity of water required for household purposes

The quantity of water required for drinking-household purposes will be calculated by the formula:

\[ Q = (A \times N) \text{ m}^3/\text{day}; \]

where:
- \( Q \) – quantity of water required for household purposes
- \( A \) – total number of workers per day, in this case \( A = 80 \) workers;
- \( N \) – standard quantity of water required by a worker for drinking-household purposes during a shift, in this case \( N = 0.025 \text{ m}^3/\text{day} \);

Therefore the quantity of water required for drinking-household purposes per day will be:

\[ Q = (80 \times 0.025) = 2 \text{ m}^3/\text{day}, \text{ or } 0.083 \text{ m}^3/\text{hr} \]

11.4. Potential pollution sources of surface waters

11.4.1. Point source of pollution:

Mine water flowing from mines and dumpsites of different sites is a point source of pollution (Discharge #1)

The calculations showed that the maximum discharge of these waters per hour is 209 \text{ m}^3/\text{h}.

The project of mine development considers the possibility of the development of aggressive acidic and sulphate water during extraction of ore from ore bearing zones. During accumulation of dead rocks containing non-industrial sulphide particles the leaching of different metals under the influence of precipitation will occur. This may lead to environmental pollution.

To study these processes in more details RMG Gold contracted Scientific Practical Center of Biotechnology "Ecology" to carry out the modeling of migration of heavy metals from the rocks of the dumpsite of the Sakdrisi deposit into the environment in conditions of natural process of biological leaching.

The modeling of the migration of chemical elements, especially at the initial stage of mine development gives the possibility to predict the parameters such as: chemical composition of dumpsite runoff, change in acid/alkaline balance, the role of bioleaching (passive or active) in the migration of elements. Modeling also gives the possibility to determine those physical, chemical, climatic and biological factors which may have a limiting effect on migration of ions of heavy metals. Only based on this data the environmental actives can be effectively planned at any stage of the operation of heap leaching site.

The subject of the study was dead and unconditional rocks of the dumpsite of the Sakdrisi mine.

The report of model testing of the migration of heavy metals from dumped rocks of the Sakdrisi deposit into the environment is presented in Appendix 3.

As a result of the above materials it was decided to discharge mine water into the environment only after their treatment with physical and chemical methods.
Two options of treatment of mine waters with physical-chemical methods and schemes are discussed below.

The Kviratskhoveli stream is a low river and often dries out in summer. Mine waste waters will be discharged directly into the Mashavera river via pipes or ditches.

Therefore the Mashavera river is considered to be a recipient of treated mine wastewaters. Thus, the calculation are made taking into account the hydrological and hydrochemical characteristics of the Mashavera river. The calculations are given below.

As for industrial and storm waters flowing from the heap leaching site, they will circulate within a closed technological cycle and will not be released into the environment.

11.4.2. Household waste waters from the administrative and supporting units of the Sakdrisi deposit and heap leaching site.

The calculations showed that the quantity of water required for drinking and household purposes equals to:
\[ Q = 2 \, m^3/day, \text{ or } 0,083 \, m^3/hr. \]

Wastewaters make 80% of consumed waters, therefore the quantity of household waste waters from the administrative and supporting units of the Sakdrisi deposit and heap leaching site per day and per hour equals to:
\[ Q = 1,6 \, m^3/day, \text{ or } 0,067 \, m^3/hr. \]

These household wastewaters flow into the impervious septic tank. Wastewaters will be removed on a regular basis with sewage drain cleaning machines by the Kazreti settlement community service on the basis of a relevant agreement with the Ltd RMG Gold.

Therefore, household waste waters generated at the site will not be discharged into water bodies.

11.5. Drainage

11.5.1. Mine wastewaters

As it has been stated above the project of mine development considers the possibility of the development of aggressive acidic and sulphate waters during extraction of ore from ore bearing zones. During accumulation of dead rocks containing non-industrial sulphide particles the leaching of different metals under the influence of precipitation will occur. This may lead to environmental pollution. The mentioned mine waters consist of the following:

- storm waters generated on the territories of the mines of different sites, dumpsites of dead rocks and stockpiles of gold bearing ores;
- low-yield pressure waters flowing in tectonic fractures, as it has been stated in the part of this document related to hydrogeological study the flow of these waters is 0.02-0.09 l/sec;
- maximum flow of waters of tectonic zones – 4.0 l/sec.

11.5.1.1. Calculation of the quantity of mine wastewaters

The quantity of mine wastewater is the sum of the quantities of storm waters, low-yield pressure waters flowing in tectonic fractures and waters of tectonic zones. Calculations are made using the above data:
Storm wastewaters

The quantity of storm wastewaters is calculated with the following formula:

\[ Q = 10 \times F \times H \times K \]

where:

Q – is the quantity of storm waters, \( \text{m}^3/\text{hr} \)
F – area of the territory, ha

The areas (ha) of the mines of different sites, dumpsites of dead rocks and other production sites are given below:

area of the mine of the Sakdrisi -1 site:
\( S = 85000 \text{ m}^2 \),

area of the mine of the Sakdrisi -2 site:
\( S = 45000 \text{ m}^2 \),

area of the mine of the Sakdrisi -3 site:
\( S = 64000 \text{ m}^2 \),

area of the mine of the Sakdrisi -4 site:
\( S = 12000 \text{ m}^2 \),

area of the mine of the Sakdrisi -5 site:
\( S = 160000 \text{ m}^2 \),

area of the dead rock dumpsite 1:
\( S = 50000 \text{ m}^2 \),

area of the dead rock dumpsite 2:
\( S = 185500 \text{ m}^2 \),

area of the dead rock dumpsite 3:
\( S = 320920 \text{ m}^2 \),

area of the dead rock dumpsite 4:
\( S = 72400 \text{ m}^2 \),

area of poor rock stockpile:
\( S = 2000 \text{ m}^2 \),

area of the crushing site:
\( S = 27000 \text{ m}^2 \),

total area – 973,82 thousand \( \text{m}^2 \) or 97.4 ha.

It should be taken into account that according to the project the simultaneous mining at two or more mines can be expected if the Sakdrisi 5 and Sakdrisi 4 are developed. It means that only in this case the need of simultaneous discharge of mine waters from two mines may arise. In other cases these waters can be temporarily stored in the hollows of respective mines and in dry weather directed to the treatment facility existing at that time.

Therefore, storm waters from the following areas have to be directed to the treatment facilities at one time (without interruption of the mining process):

from the mine of the Sakdrisi 5 site - 160 000 \( \text{m}^2 \);
from the mine of the Sakdrisi 4 site - 12 000 \( \text{m}^2 \);
from the four dumpsites of dead rock - 628 820 \( \text{m}^2 \);
from the stockpile of poor ore - 2 000 \( \text{m}^2 \);
from the crushing site - 27 000 \( \text{m}^2 \);

Total area is 829,82 thousand \( \text{m}^2 \), i.e. to calculate the quantity of storm waters the area (F) in ha will be 82.98 ha,

H – precipitation mm/hr
According to the data of the National Environmental Agency, the average monthly precipitation in 2003-2009 was 46.3 mm/month, or 1.54 mm/hr. Assuming that duration of rainfall is 2 hours a day, the amount of precipitation per hour will be 0.77 mm/hr.

K - a factor depending on the cover type. In this case it equals to 0.3.

Therefore,

\[ q_{\text{st}} = 10 \times 82.98 \times 0.77 \times 0.3 = 191.7 \text{ m}^3/\text{hr} \]

i.e. the maximum quantity of storm water that can be generated at different production sites at one time is:

\[ q_{\text{st}} = 191.7 \text{ m}^3/\text{hr}, \text{ or } 53.3 \text{ l/sec}. \]

Flows of low-yield tectonic fractures (0.02-0.09 l/sec) and maximum flows of waters of tectonic zones – 4.0 l/sec shall be added to this amount to get the quantity of mine waste waters per hour:

\[ q_{\text{mine}} = 53.3 + 0.9 + 4.0 = 58.2 \text{ l/sec}, \text{ or } 209.5 \text{ m}^3/\text{hr}, \]

Accordingly, the total quantity of mine wastewaters is 209.5 m³/hr.

11.5.2. Drainage of household wastewaters

At it has been stated above the quantity of household waste waters from the administrative and supporting units of the Sakdrisi deposit and heap leaching site per day and per hour equals to:

\[ Q = 1.6 \text{ m}^3/\text{day}, \text{ or } 0.067 \text{ m}^3/\text{hr}. \]

These household wastewaters flow into the impervious septic tank. Wastewaters will be removed on a regular basis with sewage drain cleaning machines by the Kazreti settlement community service on the basis of a relevant agreement with the Ltd RMG Gold.

Therefore, household waste waters generated at the site will not be discharged into water bodies.

11.6. Principal scheme of treatment of acidic waters drained from mines and dead rock dumpsites.

The ore of the Sakdrisi deposit belongs to the type of poor, weak and moderate sulphide ores. Therefore the development of acid drain waters from mines and dead rock dumpsites as a result of oxidation of sulphide minerals of heavy metals is expected after opening and operation of the mine. This type of waters will emerge in about 2-3 years. The oxidation processes are developed under the action of thionic bacteria as well as electrochemical processes induced in the accumulation zones of different sulphide minerals with participation of air, oxygen and water. Oxidation products are iron, copper, zinc and cadmium sulphates and sulphur oxide derived from oxidation of stoichiometrically excessive sulphur. These drain waters may contain all the above substances in different quantities and concentrations and pH probably will be equal to 2.5-3 (Table 11.4.1). Discharge of these waters into the environment without neutralization/treatment is not allowed. Therefore drain waters will be treated-neutralized in accordance with the following scheme:
Such schemes of waste water treatment are used in practice of cleaning of wastewaters of similar mines (Баймаханов М.Т. и др. Современные методы очистки цеховых вод цветной металлургии. М., <Цветметинформация>, 1980 г.). This scheme is based on the following: $SO_4^{2-}$ ions are blocked in insoluble compound $CaSO_4$ (Gypsum) which during settling captures hydroxides of heavy metals derived in the process of neutralization. Formation of these almost insoluble compounds from diluted solutions is expected when pH has the following values:

Fe(OH)$_3$ – pH=3; Cu(OH)$_2$ – pH=5; Fe(OH)$_2$ and Zn(OH)$_2$ – pH=6 and Cd(OH)$_2$ – pH=7 (Краткий справочник химика, М. <Химия>, 1963 г.)

Therefore, by adding lime milk under the conditions of gradual increase of pH, the parameters of allowable discharge specified by the relevant regulations can be met. The resulted sediments periodically will be transported to the dump site, while neutralized and treated water will be discharged in accordance with the relevant standards.

Table 11.4.1 Typical and model composition of mine waters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Typical composition of mine waters</th>
<th>Model composition of mine waters</th>
<th>MAC for a water body of the household use category</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>2,5-3,0</td>
<td>2,4</td>
<td>6,5-8,5</td>
</tr>
</tbody>
</table>
### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Typical composition of mine waters</th>
<th>Model composition of mine waters</th>
<th>MAC for a water body of the household use category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Cu(^{2+})</td>
<td>110-145</td>
<td>375</td>
<td>1,0</td>
</tr>
<tr>
<td>Zinc Zn(^{2+})</td>
<td>155-460</td>
<td>343,8</td>
<td>1,0</td>
</tr>
<tr>
<td>Total iron, Fe(_{\text{total}})</td>
<td>1550-1560</td>
<td>2062,5</td>
<td>0,3</td>
</tr>
<tr>
<td>Sulphates, SO(_4^{2-})</td>
<td>6400-6560</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The above scheme of water treatment is a conceptual scheme it means that is can be changed in accordance with the problems emerging at the operation stage. It should be also taken into account that the flow of acidic waters will start after deepening of the mine, therefore they cannot be expected at the first stage of mine development.

### 11.7. Calculation of the limits of Maximum Allowable Discharge (MAD) of the discharged pollutants

To calculate the limits of Maximum Allowable Discharge of pollutants discharged with wastewaters the calculation of dilution of wastewaters and waters of the surface water body has to be made on the basis of the following document: Regulations on calculation of the limits of Maximum Allowable Discharges of pollutants discharged with wastewaters into surface water bodies approved by the Minister of Environment protection by the Order #169 made on June 27, 2012.

Limits of Maximum Allowable Discharge have to be determined for a single point discharge, in particular for mine waters flowing from different production sites.

The mentioned mine waters consist of:

- storm waters flowing from the mine of the Sakdrisi 5 and 4 sites, the four dumpsites of dead rock, the stockpile of poor ore and the crushing site;
- low-yield pressure waters flowing in tectonic fractures, as it has been stated in the part of this document related to hydrogeological study the flow of these waters is 0.02-0.09 l/sec;
- maximum flow of waters of tectonic zones – 4.0 l/sec.

Based on the calculations the total discharge of wastewaters is assumed to be 209.5 m\(^3\)/hr, or 58.0 l/sec.

Due to the quality of wastewaters the calculations have to be made for the following substances:

- copper
- zinc
- iron
- cadmium
- sulphates

The Kviratskhoveli stream is a low river and often dries out in summer. Therefore, mine waste waters will be discharged directly into the Mashavera river via pipes or ditches.

The Mashavera river is considered to be a recipient of treated mine wastewaters. Thus, the calculations of dilution are made taking into account hydrological and hydrochemical characteristics of the Mashavera river.

The following initial data were used to calculate Maximum Allowable discharges for wastewaters (calculations are made for the most unfavorable hydrological conditions):
Table 11.5.1.

<table>
<thead>
<tr>
<th>Table 11.5.1.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average long-term runoff of the Mashavera river with 75% probability of</td>
<td>3,72 m³/sec</td>
</tr>
<tr>
<td>occurring at the design section of discharge of wastewaters - Q</td>
<td></td>
</tr>
<tr>
<td>Design distance between the discharge point and the design section</td>
<td>500 m</td>
</tr>
<tr>
<td>downstream – L</td>
<td></td>
</tr>
<tr>
<td>Average velocity of the Mashavera river at the design section - V</td>
<td>1,1 m/sec</td>
</tr>
<tr>
<td>Average depth of the Mashavera river at the design section - H</td>
<td>0,7 m</td>
</tr>
<tr>
<td>Baseline concentration of the Mashavera river water*</td>
<td></td>
</tr>
<tr>
<td>Copper Cu²⁺</td>
<td>0,04 mg/l</td>
</tr>
<tr>
<td>Zinc Zn²⁺</td>
<td>0,06 mg/l</td>
</tr>
<tr>
<td>Total iron, Fe_total</td>
<td>0,1 mg/l</td>
</tr>
<tr>
<td>Cadmium Cd²⁺</td>
<td>&lt; 0,0008 mg/l</td>
</tr>
<tr>
<td>Sulphates, SO₄²⁻</td>
<td>60 mg/l</td>
</tr>
<tr>
<td>Total discharge of mine wastewaters - q</td>
<td>0,058 m³/sec</td>
</tr>
</tbody>
</table>

*Analysis are made at the laboratory of RMG Copper

11.7.1. Discharge 1

Maximum allowable discharge limits are defined for each study element taking into account baseline concentration, water use category, MACs and assimilation capacity of substances present in the water body.

Maximum allowable discharge limits of specific pollutants for all water use categories are determined by the formula:

\[ MAD = q C_{MAD} \]

where

\[ q \] – approved discharge of wastewaters in m³/sec;

\[ q C_{MAD} \] – concentration of pollutants in wastewaters in mg/l (g/m³).

\[ C_{MAD} \] is calculated taking into account the reciprocal of the dilution after discharging wastewaters into water bodies.

The following formulas are used in the calculations:

For suspended particles:

\[ C_{MAD} = \sigma \left( \frac{Q}{q} + 1 \right) + C_i \]

where:

\[ \sigma \] – is a factor indicating the level of dilution of waste and river waters (dilution factor);

\[ Q \] – river design flow, m³/sec;

\[ q \] – maximum discharge of waste waters, m³/sec;

\[ P \] – allowable growth of the concentration of suspended particles in the rivers after discharge of waste water, mg/l (established by the Rules of Protection of Surface Waters from Pollution);

\[ C_i \] – baseline concentration of suspended particles in the river (canal);
For biological oxygen demand (BOD):

\[ C_{BOD} = \frac{a \cdot Q \left( C_t - C_r \cdot 10^{kt} \right)}{Q - 10^{kt}} + \frac{C_t}{10^{kt}} \]

where:

- \( C_t \) – is maximum allowable value of BOD in mg/l at the reference section after mixing up waste and river (canal) waters;
- \( C_r \) – baseline value of BOD in the river (canal) in mg/l;
- \( 10^{kt} \) – a factor indicating the rate of oxidation of organic matters in water bodies.

For other pollutants, including the present case:

\[ C_{MAD} = \frac{aQ}{Q} \left( C_{MAC} - C_t \right) + C_{MAC} \]

where:

- \( C_{MAC} \) – is maximum allowable concentration of pollutants established according to the category of a water body in mg/l;
- \( C_t \) – baseline concentration of pollutants in the water body in mg/l;

Reciprocal of the dilution of waste waters flowing into the river – \( n \) has to be calculated with the following formula:

\[ a = \frac{1}{1 + \frac{Q \beta}{q}} \]

where:

- \( n \) – is a factor indicating the level of mixing and dilution of waste and river (canal) waters;
- \( Q \) – design flow of the river in m³/sec, at this section of the Mashavera river equals to 3.72 m³/sec;
- \( q \) - approved discharge of wastewaters in m³/sec; in this case is 209 m³/hr, or 0.058 m³/sec;
- \( a \) - a factor indicating the level of dilution of waste and river waters.

According to the Rodziller’s formula:

\[ \beta = e^{-\alpha \sqrt{L}} \]

where:

- \( \beta \) – is an intermediary factor to be calculated as follows:

\[ L \] – is a distance between the discharge point and the design section downstream in meters. In this case it equals to 500 m.
\( \alpha \) – a coefficient which considers hydraulic factors of mixing and is calculated using the following formula:

\[
\alpha = \frac{E}{\sqrt{h}}
\]

\( l \) – a factor depending on the discharge point. If the discharge point is near the river bank it equals to 1.

\( i \) – river curve factor to be calculated with the formula:

\[
i = \frac{L_1}{L_2}
\]

\( L_1 \) – is a distance between the discharge point and the design section downstream in meters. In this case it equals to 500 m;

\( L_2 \) – the shortest distance between these two points. In this case it equals to 455 m.

\( E \) – turbulent diffusion coefficient and equals to:

\[
E = \frac{V \cdot H}{200}
\]

where:

\( V \) – average velocity of the river at the design section and in this case equals to 1,1 m/sec.

\( H \) – average depth of the river at the design section and in this case equals to 0,7 m.

Using these data:

\[
E = \frac{0.7 \times 1.1}{200} = 0.00385
\]

\[
i = \frac{200}{180} = 1.1
\]

\[
\alpha = 1 \times 1.1 \sqrt{\frac{0.00385}{0.058}} = 0.45
\]

\[
\theta = e^{-0.45} = 0.072
\]

\[
a = \frac{1 + \frac{3.72}{0.058} \cdot 0.072}{0.165} = 0.165
\]

Maximum Allowable Discharge Concentrations for copper, zinc, cadmium and sulphates are determined by the formula:

\[
C_{MAD} = \frac{\alpha Q}{\sqrt{\eta \left(C_{MAC} - C_i\right) + C_{MAC}}}
\]

therefore, maximum allowable discharge limits will be:

**copper:**

\[
C_{MAD} = 0.165 \times 3.72 : 0.058 \times (1.0 - 0.04) + 1.0 = 10.583 \times (1.0 - 0.04) + 1.0 = 11.16 \text{ mg/l};
\]
MAD_{cop.hr.} = 11,16 \text{ g/m}^3 \times 209,5 \text{ m}^3/\text{hr} = 2338 \text{ g/hr};  \\
MAD_{cop.yr.} = 11,16 \text{ g/m}^3 \times 1835220 \text{ m}^3/\text{yr} = 20,5 \text{ t/yr}.

**zinc:**  
\[ C_{MAD} = 0,165 \times 3,72 : 0,058 \times (1,0 - 0,06) + 1,0 = 10,95 \text{ mg/l}; \]  
MAD_{zinc.hr.} = 10,95 \text{ g/m}^3 \times 209,5 \text{ m}^3/\text{hr} = 2294 \text{ g/hr};  \\
MAD_{zinc.yr} = 10,95 \text{ g/m}^3 \times 1835220 \text{ m}^3/\text{yr} = 20,1 \text{ t/yr}.

**iron:**  
\[ C_{MAD} = 0,165 \times 3,72 : 0,058 \times (2,01 - 0,1) + 21,0 = 21,1 \text{ mg/l}; \]  
MAD_{ir.hr} = 21,1 \text{ g/m}^3 \times 209,5 \text{ m}^3/\text{hr} = 4420,5 \text{ g/hr};  \\
MAD_{ir.yr} = 21,1 \text{ g/m}^3 \times 1835220 \text{ m}^3/\text{yr} = 38,7 \text{ t/yr}.

**cadmium:**  
\[ C_{MAD} = 0,165 \times 3,72 : 0,058 \times (0,001 - 0,0008) + 0,001 = 0,0031 \text{ mg/l}; \]  
MAD_{cad.hr} = 0,0031 \text{ g/m}^3 \times 209,5 \text{ m}^3/\text{hr} = 0,65 \text{ g/hr};  \\
MAD_{cad.yr} = 0,0031 \text{ g/m}^3 \times 1835220 \text{ m}^3/\text{yr} = 0,0057 \text{ t/yr}.

**sulphates:**  
\[ C_{MAD} = 0,165 \times 3,72 : 0,058 \times (500 - 60) + 500 = 5157 \text{ mg/l}; \]  
MAD_{sul.hr} = 5157 \text{ g/m}^3 \times 209,5 \text{ m}^3/\text{hr} = 1080392 \text{ g/hr};  \\
MAD_{sul.yr} = 5157 \text{ g/m}^3 \times 1835220 \text{ m}^3/\text{yr} = 9464,2 \text{ t/yr}.

As it has been stated above maximum allowable concentrations of suspended particles in wastewaters are calculated by the formula:

\[ C_{MAD} = p \left( \frac{C_f \cdot Q}{Q + 1} \right) + C_f \]

P is allowable growth of suspended particles in the river after wastewater discharge in mg/l. For the Mashavera river it equals to 0,75 mg/l.  
Baseline concentration of suspended particles in the Mashavera river (analysis is done at the laboratory of the JSC RMG Copper) is 43 mg/l.

Maximum allowable discharge limits for suspended particles are calculated using the above data:

**suspended particles:**  
\[ C_{MAD} = 0,75 \times (0,165 \times 3,72 : 0,058 + 1) + 43 = 374 \text{ mg/l}; \]  
MAD_{s.p.hr} = 374 \text{ g/m}^3 \times 209,5 \text{ m}^3/\text{hr} = 78353 \text{ g/hr};  \\
MAD_{s.p.yr} = 374 \text{ g/m}^3 \times 1835220 \text{ m}^3/\text{yr} = 686,4 \text{ t/yr}.

Note: maximum allowable concentration for iron is established at 2,0 mg/l as in European countries (Switzerland, Austria).
13. Waste Management

13.1 Generated Waste

The main volume of the waste produced at the enterprise is made of the technological waste, in particular – spoil from the rocks, which is created as a result of recovering the ore from the quarry.

It is planned to dispose the waste rocks at 4 dump sites located near the quarry. The total volume of the rocks that will be disposed at the dumps sites will be 7 100 000 m³. The maximum capacity of the dump sites, in case of arranging 5 tiers, is 7 200 000 m³.

As the wasted rocks stored near the quarry will cause one of the negative impacts on the soil, it is planned to restore the territory of solid waste dump area after its exploitation. RMG Ltd. has big experience of carrying out the similar works during many years of its operation.

The main environmental advantage of the heap leaching is that the production process generates relatively small quantity of the waste.

Any kind of chemical solution will reenter the production cycle. Other type of wastes like filters and oily cloths, waste oil, inert materials produced as a result of technical service and construction activities will be handed to the contracted organization for waste management according to the contract conditions.

The scrap metal will be given for recycling.

13.2 Management of Hazardous Substances

The substances which have harmful impact on human health or environment during their improper use, accumulation, storage or incorrect utilization belong to the category of hazardous substances. Correct environmental management implies implementation of the relevant measures for avoiding environmental pollution with hazardous substances. For this purpose the working personnel will be required to:

1. know which hazardous substances are present at the industrial territory;
2. clearly distribute the responsibilities among the persons who are in charge of disposal-neutralization of the hazardous substances;
3. clearly understand existing and potential risks related to the transportation, storage, use and disposal of the mentioned substances;
4. reduce the likelihood of using and producing hazardous substances;
5. construct the storages for hazardous substances, where the mentioned substances can be kept safely in any circumstances;
6. have the waste taken away by the relevant subcontractor for their treatment or proper disposal to ensure that there will be minimum or no impact on the environment;
7. find alternative ways for neutralization of the mentioned substances (reuse, recycling and the secondary products);
8. implement physical control and procedural measures during normal or irregular working processes to avoid that hazardous substances flow away;

9. elaborate action plans for emergency situations for reducing the negative impact on the environment in case of a spillage or a leakage;

10. monitor disposal of any type of waste in the environment to identify the leakage of the hazardous substances and define the scale of the impact.

The below are listed chemical substances that will be used in the process of gold recovery. The list is not exhaustive and it includes only those substances, which are toxic or will be used in large quantities.

**Lime**

Purpose: Control of the pH of the solution  
Source: Terjola region, Georgia  
Transportation: Trucks  
Storage: Will be stored in the bunker of the storage  
Use: 2 000–2 500 tons annually

**Sodium-cyanide**

Purpose: Dissolution of the gold in the circle of leaching and washing  
Source: Rustavi, Georgia  
Transportation: Trucks  
Storage: Sodium-cyanide will be stored in the sealed hermetic containers of the supplier in the safe, specially allocated place. The station for preparation of the solution is designed in the way that it allows localization of the spillage in case of accident. The reservoir for mixing the cyanide solution have a barrier around it. The spilled liquid will be directed in the water suction pump made in the concrete flood, from where it will be pumped to the reservoir of the loaded solution covered with HDPE (High-density polyethylene). The control of the inventory will be implemented through comparing the invoice documents from the supplier with the serial number of the containers.  
Use: Approximately 300 tons annually.

**Sodium hydroxide (caustic soda)**

Purpose: Regulation of pH during mixing cyanide and preparing the removing solution  
Source: Turkey  
Transportation: Trucks; in the site territory it will be transported in solid form with 25 kg sacs.  
Storage: The sacs will be kept in a stall, which will have a concrete floor and will be protected with an iron grill. In accordance to the requirement, sodium hydroxide will be directly added to the cyanide preparation system prior to adding cyanide or to added to the removing solution contained in the cistern.  
Use: Approximately 15 tons annually.

**Coal**

Purpose: Will be used for carbon adsorption columns for adsorbing metals on them.  
Source: The Netherlands.
13.2.1 Transportation

The majority of the above mentioned products will be supplied from the city of Ankara (Turkey); a transporting contractor, which will be based in Ankara, will implement the transportation. Periodically, transportation with trucks from Poti will be added to the main transportation line. The majority of the stock will be transported with transport containers. Lime will be supplied locally using the dump trucks. Coal will be brought to the port of Poti with sea transport and will be brought to the working territory of RMG Gold Ltd. in the containers loaded on the trucks. Diesel will be transported with cisterns, which will be loaded with 10 000L.

In the process of supplying the cyanide, the contractor is obliged to bring the goods to the working area. All transportation procedures and emergency response plans will be checked in advance to make sure that they satisfy the acceptable standards.

13.2.2 Transportation of Sodium Cyanide

The sodium cyanide is being supplied by Rustavi Chemical Group of Enterprises (Combinat), which is located in 25 min driving distance from Tbilisi and about 2 hours - from Kazreti. GLM Worldwide Trade (GLMWT) is a company from which the required sodium cyanide will be purchased for the project. Transportation of every lot of sodium cyanide, from Rustavi to RMG Gold Ltd. area, will necessarily require a police escort. An official body issuing a permit approves: needed transportation means, the emergency response procedures of GLMWT and also the equipment used for safe transportation of sodium cyanide.

Sodium cyanide will be transported with hermetic steel barrels. The locked containers with sodium cyanide will be kept in a specially protected building within the working area. Procedures for safe handling, storage, use and spillage avoidance will be given in the relevant documentation.

13.2.3. Sodium Cyanide

This chapter described the management of hazardous substances and puts emphasis on sodium cyanide, which is potentially especially hazardous for the environment and causes human fatality in case of improper management. Society has fearful attitude to the industrial technologies which use cyanide. Actually, if this type of production processes are correctly managed, the risk of harmful impact on human health and environment is reduced to the acceptable level.

Cyanide is a widespread and an important industrial chemical substance. It is mostly known for being used in mining, but it is also used in the industrial processes like steel and plastic production. Cyanide is especially known for being used in treating minerals.

It is more than 100 years that cyanide is used in gold production. Despite the fact that it is very poisonous chemical and requires special attention during its use, the cases of human death caused by cyanide are rarely recorded. In the 20th century, in mining industry of Australia and the North America there was not recorded any incident of a death caused by cyanide poisoning. (Department of Environment, Australia, 1998).
Ion of cyanide (CN⁻), according to its toxicity, is an “active agent” in the process of gold leaching as well as in the biological systems. Cyanide is included in different admixtures, which have different levels of toxicity.

To illustrate this we can bring the following example: 1000 g NaCN is equivalent of 530g CN⁻.

Many microorganism in nature generate chemical substances containing cyanide. It participates in chemical processes of about 2 650 types of plants. Thus, small amount of cyanide are naturally encountered in surface and underground waters. If any concentration of cyanide was poisonous, then humans and animals would be at risk when using peaches, apricot seeds, bamboo sprouts and almonds for food.

Table 13.2.2.1

<table>
<thead>
<tr>
<th>Source of cyanide</th>
<th>Cyanide content ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>salt</td>
<td>Up to 13</td>
</tr>
<tr>
<td>Coffey</td>
<td>Up to 6</td>
</tr>
<tr>
<td>Smoke of a cigarette</td>
<td>Up to 1600</td>
</tr>
<tr>
<td>Sorgo</td>
<td>Up to 25</td>
</tr>
<tr>
<td>Limur beans</td>
<td>1-31</td>
</tr>
<tr>
<td>Almond</td>
<td>25-100</td>
</tr>
</tbody>
</table>

Source: Orica chemicals Sodium Cyanide Technical Manual

13.3 Storing Fuel and Lubricants

The vehicles and machinery will be rented. Therefore, their fueling, technical service, oil change, washing and other similar types of works will not take place at the territory of the quarry and the heap leaching enterprise. And no waste water or solid waste will be generated from this kind of activities at the site.

The petrol and diesel needed for the passenger cars and also the lubricants will be stored at the territory of the enterprise, in the covered warehouse. Fuel and lubricants will be put in specially prepared impermeable reservoirs. The volumes of these reservoirs in case of an accidental spill can hold 110% of the biggest reservoir’s volume.

Different chemical reagents and sodium cyanide will be kept in the same conditions. There will be a specially arranged warehouse with an impermeable concrete floor and a drainage to prevent leakage in case of a spill. The building will be necessarily ventilated and locked. The release of the hazardous substances will be strictly controlled only in accordance to procedure of the internal regulations.
14. Environmental Impact and Mitigation Measures

14.1. Surface Waters

It is planned to localize the whole amount of the storm water from the production areas. The storm water, which is outside of these areas, e.g. roads, will be directed to the drainage system.

A construction reservoir, covered with HDPE, for the storm water from heap leaching polygon will be located at the lowest point and the water will run itself into it. The water will be pumped back from this reservoir to the leaching circle for filling the volume lost due to evaporation.

The process of heap leaching takes place in a closed system without losing the solution participating in it, except evaporated water. Proceeding from this, no chemical solution will be released into environment.

Domestic sewage water from the administrative and supplementary buildings of the Sakdirsi quarry and heap leaching area are directed to the impermeable cleanable container; from there it will be periodically taken by special vehicles of the communal service of Kazrety settlement, in accordance to the agreement made with RMG Gold Ltd. Therefore, there will be no release of the domestic waste water from the administrative and supplementary buildings of Sakdirsi quarry and the heap leaching area.

14.2 Atmospheric air

According to the dispersion calculation, it turned out that during the working operations, the air quality at the nearest settlement area adjacent to the enterprise will not exceed the legally established norms.

14.2.1. Dust

The dust that will be taken by air will be produce during the mining operations, transport movement, crushing and wind erosion. The greater part of the produced dust will settle on the territory of the quarry. The area were the most dangerous dust will be created is crushing point located in the west from the heap leaching area. At this location, which will allocated the highest number of workers, there will be a potential hazard of producing the main volume of the dust.

Reduction of dust emission will be implemented through water splashing systems, which will be installed at the crushing and transferring points. New crushing equipment’s construction considers bunker of a loading truck, which will also mitigate the emissions.

In internal roads the reduction of dust produced by the transport movement is implemented by watering the transportation roads. As a rule, this includes several trips during a day. Every trip uses 8 m$^3$ of water.

The dust produced at the laboratory, when crushing and grinding the samples will be collected in “dust collector”, which will filter the dusty air and move the dust into a container. From here it will be regularly discharge in the heaps, which will be immediately wetted. As a result the dust will be wash down into the heap.

14.2.2. Exhaust from diesel engine

The machinery required for earth works uses diesel fuel. At the expansion stage, the machinery recommended for the earth works will be equipped with the engines working with newest
technologies. Supplying fuel with high pressure will significantly reduce the combustion emissions. The volume of the emission is reduced drastically (by 75%) through electronic control of limits of the fuel volume and timing of supply.

14.2.3. Impact and management

The impact on the air quality during the running operations is minimal and any kind of change is not expected. When processing and recovering the gold, gas emission, as a rule, are very low. Suppression of dust at the transportation roads is quite easy using water trucks and splashing systems. Rehabilitation/reinstating the vegetation will mitigate the dust volume in the air to the minimum.

Humidity of the material for crushing is the most critical variable in terms of controlling the dust volume around the crushing equipment. Washer splashing is a part of the cycle, while the covered transferring channels between the conveyers can hold any dust produced at these critical points.

Lime has two functions in the process of gold recovery. It is used for creating alkaline environment for safe use of cyanide and it also acts as joining substance. When the lime is mixing with crushed ore, which has humidity of 8-10%, the small particles create agglomerates. As soon as crushed ore is loaded at the heap leaching polygon, it is watered with alkaline solution, which is causing immediate washing of the small parts located near the surface down into the heap. When placed ore is not watered and dries on the surface, there is a very low likelihood that the wind will create the dust, because it is neither fine nor separated.

14.3. Waste

Limiting and reducing waste generation is as important as its recycling and disposal. In this sphere the main goal is to:

- Avoid waste generation;
- Reduce volume of waste generation;
- If possible, utilize the waste;
- Treat the waste at the location were it was generated to decrease its harmful qualities;
- Dispose the waste.

As it was mentioned, the advantage of the gold recovering through leaching is that it generates relatively small amount of harmful waste.

In modern enterprises certain procedure and practical measures are established, which are mandatory for reaching the safest international best practice of production to reduce negative impact on humans and environment to minimum. Below is the list of the measures, which will be taken during the project implementation:

- Establishment of general planning procedures, considering closure and rehabilitation of the mine, which is based on the risk assessment for maximum benefit and responsibility and reducing impact on the environment.
- Teaching initial and running management of chemical admixtures to the management, workers and subcontractors, among them to those who will be in direct contact with the mentioned admixtures. This training has to include the daily tasks of the personnel as well as their actions in emergency situations with regards to the chemicals;
• Elaborate well defined responsibilities for each of the employees by means of clear chain of orders and directives and effective communication systems;
• Establish safety procedures for transportation, storage, use and disposal of the chemicals;
• Circulate all chemicals in the closed cycle of heap leaching;
• Regularly audit chemicals and check the management procedures according to the needs;
• Elaborate a monitoring program for chemicals though sampling in working and natural environment, storing, analyzing and reporting.

The main part of the solid waste, which is expected to be generated at the enterprise, will be plastic materials from packaging and barrels of cyanide steel.

The greatest part of the waste generated at the enterprise will be inert, which can be disposed at an ordinary licensed landfill. The barrels will be buried on the heaps using auto loaders (special machinery).
Waste oil, which will be produced from technical service of the equipment, will be kept in 200 l barrels. Afterwards the waste oil will be removed from the territory of the enterprise by a contractor organization - Sanitari Ltd.

14.4. Vegetation
According to the order of the Minister of Environmental Protection and Natural Resources #190 dated 03.05.10. for enabling RMG Gold Ltd. implement the next stage of the mining works, 80.39 ha of state forestry land located in the Kvemo Kartli Regional Forest Management, was transferred into the category of “Land of Special Purpose” for implementing “special forest use”; this land area was allocated to “Kvartsiti” Ltd i.e. RMG Gold Ltd.

Thus, RMG Gold Ltd. was given the right to carry out “special forest cutting” for implementing the next stage of mining in a territory specially allocated for its use, on the condition that special purpose cutting will not touch the Red List species (please, see the taxation data in Annex 4).

The works implemented by RMG Gold ltd. will not have any other kind of impact on the local flora.

Simultaneous and final restoration of the areas of the project territory is an important task for RMG Gold Ltd. Apart from general restoration, RMG Gold Ltd. will render the territory of the enterprise in safe and stable conditions through liquidating the pollution and minimizing the erosion.

14.5. Fauna
Heap leaching works may have negative impact on the birds, if they will use water from the industrial reservoirs. This kind of events are not expected because there are other water sources close to the project site. If needed, the company is ready to purchase a special equipment for controlling the birds (already scared by the industrial process) to prevent them from approaching the reservoir.

Besides this, it has to be mentioned that since RMG Gold Ltd. started the works (in March 1997) no incidents of damaging or killing the wildlife were recorded due to the operation activities.
**14.6 The Monuments of Material Culture and Location of Archaeological Importance**

During the project implementation, no monuments of material culture and no location of the archaeological importance will be destroyed or damaged.

**14.7 Noise**

The distance of noise pollution produce by the enterprise is insignificant due to the acoustic barrier created by the relief, vegetation and the fact that the project area is far from the settlements and is located at higher altitude compared to them.

**14.8 Visual Impact**

The project area is located high in the mountains. The topography of the location hides almost the whole project site. Apart from this, the vegetation restored after the project completion will hide the heaps of the leached ore.
15. Prevention of accidents

Based on analysis of the technology used in the activities at Sakdrisi deposit, the possible scenarios of emergency situations were defined. Prevention of the accidents should be made according to it.

Possible emergency situation during the enterprise operation are:

- Leakage or spillage of hazardous chemicals;
- Accidents related to the safety;
- Heavy weather conditions;
- Natural disasters.

A responsibility zone will be defined where implementation of the measures for liquidation of impact from spilling hazardous chemicals must be controlled. Administration has developed Emergency (extreme) Situation Action Plan for prevention and liquidation of result of a spillage. The Emergency (extreme) Situation Action Plan is attached to ESIA report.

Potential impact – accidental events

Attention is paid to the following key issues:

Type of a potential incident

The type of the potential incidents, which may affect the operation of the enterprise are:

- An accident of a loaded truck resulting in spillage of hazardous substance;
- Breaking of HDPE of the polygon or reservoir;
- Damage of the linkage of high pressure irrigation pipe resulting in leakage of the liquid from HDPE;
- Poor condition of reservoir for preparation or storage of sodium-cyanide solution;
- Breaking an industrial pipe;
- Overfilling of reservoir system in case of irregularly heavy precipitation (presumably, the solution in the reservoir will be already diluted to non-hazardous concentration);
- Accidental increase of the acidity of the cyanide solution (damaging pipes) and emission of HCN gas.

The most important impact caused by the enterprises activity can be an accident during transportation, which will cause the spillage of chemicals. This kind of risk requires big attention and it is necessary to elaborate response plans for unpredicted events for timely intervention in incident.

Chemicals in the environment

In terms of environmental impact, the most toxic is cyanide, Hydrochloric acid (HCl) or caustic soda.

Volume of chemicals

The above mentioned reagent, except lime, are used in big quantities.

Result of spillage

If spillage happens at the enterprise area, considering the chemical composition of the soil rocks, it is less likely that cyanide will reach the surface water bodies (see Chapter 16).

Possibility of risk management
Spillage of chemicals or fuel is the most important ecological threat related to the activities of the heap leaching enterprise. But the likelihood of incident is very low, careful operator will elaborate management procedures ensuring operative and effective response which minimizes environmental impact.
16. Environmental Action Plan

16.1. Objectives
The project as well as the environmental baseline conditions are described in the report. It reviews the issues that can have potential impact on the environment and the measures ensuring mitigation of these impact to minimum.

Environmental Action Plan (EAP) summarizes the responsibilities taken by RMG Gold and shows the relevant structure.

The plan has four main objectives:

- Assess the nature, the degree and the environmental importance and determine the quantitative aspects of impact of GRM Gold Ltd.’s Sakdirsi quarry and heap leaching enterprise operation on the environment;
- Reduce the environmental impact to minimum and constantly improve environmental compliance;
- Implement the requirements of the Ministry of Environment and Natural Resources Protection;
- Ensure implementation of measure described in the environmental report and those given in EAP.

16.2. Responsibilities

- Arrange a modern type of purifying facility for highly effective purification of the generated “acid” waters of quarry;
- Take measures for avoiding any kind of diffuse release;
- Make initial record of water use according to the defined form;
- Present to the Ministry of Environment and Natural Resources Protection (MoENRP) precise information on quantity of the water discharged (released) and its composition;
- If the acceptable levels of released waters are exceeded, the relevant measures are to be taken and in parallel enterprise coordinator (person in charge of the environmental protection) should inform the MoENRP about this. The information should include the causes of the excess release, the measures taken against it, also extreme levels of emergency situations and related pollution of the water bodies.
- Release of influent quarry water into surface water bodies will be made only if the norms define by Maximum Allowable Discharge (MAD) are satisfied and if measure are taken for avoiding any kind of diffused sources of release;
- Establish a regular monitoring system according to the below given Water Monitoring Program.
- for satisfying the norms of MAD, avoid pollution of the surface waters with influent waters and implement the measures mention in the Plan for Satisfying MAD Norms and Avoiding Pollution of Surface Waters.
18. Liquidation of Enterprise

In case of the enterprise liquidation, a special project will be elaborate to define the required means for restoring the initial state of the environment.

Management of RMG Gold Ltd. is responsible to elaborate the mentioned project. Liquidation of the enterprise in accordance to the existing rule should be agreed with the authorized bodies and information should be given to all interested parties – physical as well as legal bodies.

The project must consider the rules and the sequence for terminating the technological processes, dismantling the building facilities and disassembling the equipment; also rules and conditions for carrying out drainage works, safety and environmental measures, neutralizing and disposing hazardous substances, implementing rehabilitation works etc.
19. Project Closure

After finishing operation for terminating the exploitation and disassembling the equipment and devices, the company will conduct general restoration of the territory including the industrial area. The following measures will be taken:

- Reduction of the erosion to minimum using drainage, which will give the right direction to the precipitation water;
- Re-cultivation of certain territories in accordance to the relevant project;
- Preparation of the territories for vegetation planting;
- Planting relevant vegetation species.
20. Main conclusions and recommendations

20.1 Main conclusions

With compiling the present documentation justifying the environmental protection, the direct and indirect impact on human health and safety, atmospheric air, soil, water bodies, flora and fauna were studies, revealed and described; along with the relations of the issue with social-economic factors.

The qualitative assessment environmental impact shows that special attention and review is required for the issues related to the protection of the water resources, which are discussed in details in the project of MAD norms.

1. Potential negative impact on aquatic environment can possibly be caused as a result of the impact by the waters under the damp sites and the quarry.

The impact of the dead rocks on the environment can be divided into three stages:

- The first stage, when the natural oxidation of the rock is taking place and microorganisms “infect” the rock. The duration of this stage is 24 months (+, - 3 months). During this period we should not expect natural (biological and chemical) leaching effect from dead rocks of Sakdrisi ore. The first stage is characterized with oxidation-reduction potential (PE) and increase of SO4- ions.

- The second stage is when the dump site is already formed, the direction of the water movement is identified, the organic substances enter the rocks of the dump site, develop and accumulated there. This period is characterized with a change of acid-alkaline balance towards acidity (pH 4). Duration of the second stage, considering specifics of the rock at the Sakrdisi dump site is presumably 60 months (+, - 3 months);

- The third stage, a stationary phase, is characterized with physical-chemical equilibrium, pH 3, concentration of ions in the water is more than MAD, but the index is stable. This period lasts until the dump site exploitation is not finished.

2. The enterprise will have one constant organized discharge of influent water: Discharge of quarry waters.

Discharge of quarry waters in the surface water bodies is permissible if the norms established by MAD are complied and if all measures will be taken to avoid any kind of diffuse discharge.

The quarry waters will be discharged only after their collection at one location and purification using physical-chemical methods. Two physical-chemical purification methods are reviewed for this purpose. This will allow comply with the international requirements as well as those established by Georgian legislation.

As for industrial-storm influent waters from leaching the gold bearing quartzite, they will be included in the closed technological cycle and the possibility of their migration to environment is excluded.
• A collection reservoir is considered for collecting influent storm waters from this location. Its volume is calculated for a record amount of precipitation from two month long rain, which can be expected with 10 year returning period. In the city of Bolnisi, an average annual amount of precipitation is 512 mm, in nearby city of Dmanisi – 698 mm. The maximum amount of the precipitation comes in May-June period; for Dmanisi its maximum amount is 215 mm (almost one third of the annual mean precipitation in Dmanisi). The volume of the storm water reservoir is calculated for twice bigger volume of precipitation than that from the leaching polygon and reservoirs.

Domestic wastewater is directed to impermeable cleanable container from where it will be regularly moved with a septic tank machine of the communal service of Kazreti settlement in accordance to the contract mad with GRM Gold Ltd. Consequently, the wastewaters will not be discharged from the administrative and supplementary buildings of Sakdrisi quarry and heap leaching area.

3. It is necessary to establish a regular monitoring according to the Water Monitoring Program given in chapter 20.1.

4. For satisfying the norms of MAD and avoiding pollution of surface water with wastewaters, it is necessary to implement the measures considered in Plan for Satisfying the MAD Norms and Avoiding Pollution of Water Bodies (see Chapter 11).

20.2. Main Recommendations

As it was mentioned above, a typical project of mining enterprise – dumping site should be regarded as an artificially created bio-inert system. From the moment when dumping site exploitation launched, starts also impact of the artificially created bio-inert system on ecosystems; and the older the dumping side is, the more noteworthy is its impact. Therefore, the earlier the prevention measures are taken, the easier it will be to minimize this negative impact and obtain sustainable results. This detail is important in terms of financial economy for environmental measures.

As it is known, the most difficult is to localize the waters flowing from the established dump sites and to collect them into one point. While in case of a new dump site, localization of water is possible, which is the most important objective of solving ecological problem of old dump sites.

Thus, based on the project parameters and also actual data, if during the implementation of the planned activity, the enterprise satisfies the requirements of technical regulations, carry out planned measures and will be guided by recommendations presented in the environmental document made for passing the procedure of obtaining an environmental permit, it is possible to make qualitative as well as quantitative assessments for the mentioned enterprise; and if the project is implemented in accordance to these assessments:

1. Georgian legislation will not be violated;
2. Ecological norms of Georgia will not be violated;
3. Implementation of the project will be reasonable because of its location, contents and the scale.
Annex

Annex 1: Layout map of enterprise location
Annex 2: Layout plan indicating wastewater discharge sources

Model testing of migration of heavy metals from the rocks of the dumpsite of the Sakdrisi deposit into the environment in conditions of natural biological leaching

1. Introduction

Mining wastes containing toxic elements such as copper, zinc, iron and other heavy metals are the sources of one of the most hazardous technogenic pollutions. Mine is the typical facility of the mining enterprise where the whole range of unconditional and mineralized rocks is accumulated.

Generally the assessment of the environmental state of the areas with high technogenic loads is carried out on the basis of comparison of quantities of each pollutant with respective maximum allowable concentrations. This method determines only the level of pollution and does not provide the possibility for predicting the spread of pollution in soils and water and determining the cause-and-effect relationship between pollutants and factors contributing to their spread.

In this case soils and water form a single system. Water transports pollutants which are deposited in soils. Moreover, migration of pollutants in this systems is two-way: from soil to water and vice versa. As a result a sophisticated complex “common system of ion exchange” is formed where the migration of chemical elements to the specified directions and the development of physical-chemical-biological factors determining this migration take place.

Therefore modeling the migration of chemical elements, especially at the initial stage of mine development gives the possibility to predict the parameters such as: chemical composition of dumpsite runoff, change in acid/alkaline balance, the role of bioleaching (passive or active) in the migration of elements. Modeling also gives the possibility to determine those physical, chemical, climatic and biological factors which may have a limiting effect on migration of ions of heavy metals. Only based on this data the environmental actives can be effectively planned at any stage of mining.

Therefore the subject of the study are dead and unconditional rocks of the dumpsite of the Sakdrisi ore mine, specifically barite-gold and copper bearing “secondary quartzrocks” (dumpsite of the Sakdrisi deposit). The aim of the study is: predictive assessment of the migration of heavy metals in the environment as a result of natural leaching. For this purpose the following tasks have to be accomplished:

- Modeling the migration of heavy metals in conditions of maximum humidity and biological leaching under different thermal regimes;
- Determining chemical composition of water based on the result of model testing;
- Determining acid/alkaline balance during model testing;
- Determining the role of biological leaching (passive or active) in migration of heavy metals;
- Determining the role of physical, chemical and climatic and biological factors as limiting factors in migration of ions of heavy metals.

2. Used methodology

2.1 Conditions of model testing

130 kg of rocks Model testing was used in model testing. The rock was crushed into three fractions:

5-3 cm, 3-1,5 cm, 1,5 cm, 0,75 cm. Each fraction was divided into five equal parts and placed into special pans 20 kg in each. To create optimum conditions for water leakage the fractions were placed in the pans in the following order: coarse fraction, medium fraction and fine fraction. 10 liters of water was added to each pan. pH of this water was equal to that of rain water (pH of clean rain water is 5,6).
Each pan was equipped with a special perforated pipe used for watering the pans. Circulation of water took place once in 24 hours. Different thermal regimes were established in the pans. Specifically: pan #1 - temperature +15°C -50°C; pan #2 - temperature +35°C; pan #3 - temperature +5°C; pan #4 - temperature -5°C; pan #5 - temperature +25°C. pH of water was monitored every day. Every seventh day after the beginning of testing the laboratory analysis of iron, zinc and copper ions migrated into water was done (using atomic adsorption method). Duration of testing was 14 days.

2.2 Microbiological study
The system “rock-water-microorganisms” was used in model testing. Microorganisms of genus Thiobacillus: Thio. Ferrooxidans (ferrobacterium) and Thio. Thiooxidans were obtained from the runoff of the Madneuli deposit dumpsite using the special solid mineral culture medium (Leten, 9K and Waksman culture media). The obtained pure colonies were placed into distilled sterilized water and a suspension 10-10 ml was prepared. On the seventh day after the beginning of testing the suspension was poured into the pens #1, #2, #3 and #4. Thio. Ferrooxidans microorganisms were not introduced into the pan #5 (control). Monitoring of the quantity of ferrobacteria in the pans took place every third day after their introduction through placing the samples of water drained from the pans on culture medium (Leten, 9K and Waksman culture media).

The system “rock-water-microorganisms” was used in the study. In this system the reproduction and spread of ferrobacteria stimulated through adding biogenic elements ((NH)4SO4-0,05gr/l; KH2PO4- 0, 05gr/l)) and acid correction (10N H2SO4 –0,1ml/10l).

3. Analysis of obtained results

3.1 Study of the dynamics of natural leaching of heavy metals
Bacterial leaching is a capacity of microorganism existing in the nature to transform a chemical element from polycrystalline mineral substance into ionic form (in water solution) selectively. Bacterial leaching is an accompanying natural process of mining of iron and sulphur bearing ores and plays an important role both in the migration of heavy metals and the development of acid waters. Bioleaching has been increasingly used in mining industry for selective reclamations of nonferrous metals.

The mechanism of bacterial leaching is complicated and based on enzymatic oxidation from Fe2+ - to Fe3+ - by chemoautotrophic (synthesizes organic substances required for cells using iron electrons), acidophilic, iron oxidizing bacteria Thiobacillus ferrooxidans (Th.f). The donor of electrons in this process is iron, the acceptor is oxygen, while Th.f. is an electron carrier which accelerates the oxidation process and regeneration of ferrous sulphate Fe2(SO4)3, which is a strong oxidant of sulphide minerals. At that time the acid/alkaline balance changes towards acidity:

\[
\begin{align*}
\text{CuFeS}_2 + 4O_2 & \rightarrow CuSO_4 + FeSO_4 & (1) \\
4FeSO_4 + 2H_2SO_4 + O_2 & \rightarrow Fe_2(SO_4)_3 + 2H_2O & \text{regeneration} & (2) \\
CuFeS_2 + 2Fe_2(SO_4)_3 & \rightarrow CuSO_4 + 5FeSO_4 + 2S^0 & (3) \\
S^0 + H_2O + 3/2O_2 & \rightarrow H_2SO_4 & (4) \\
2Fe_2(SO_4)_3 + 2CuS + 2H_2O + 3O_2 & \rightarrow 2CuSO_4 + 4FeSO_4 + 2H_2SO_4 & (5)
\end{align*}
\]

Oxidation of sulphide minerals if Th.f. is present can take place directly or indirectly. In the first case the oxidation of minerals occur with participation of the enzyme system of microorganisms:

\[
Fe_2^+ \text{ Fe}_3^+ \text{ e}^- \text{ cit.b } \text{ cit. c } \text{ cit. a} \_1/2 O_2 + 2H^+ \]

(6)
In the second case sulphide minerals oxidate as a result of influence of Fe2(SO4)3 and H2SO4 which are by-products of bacterial activity according to the formulas 2, 4 and 5. In our case, in model testing the leading role was played by the second manner of natural leaching.

The diagrams below illustrate the obtained results:

**Cu mg/kg**

Diagram 1. Quantity of copper ions migrated into water in 14 days under different thermal conditions. Pan #1 – temperature +150C; pan #2 – temperature +350C; K – control.

**Zn mg/kg**

Diagram 2. Quantity of zinc ions migrated into water in 14 days under different thermal conditions. Pan #1 – temperature +150C; pan #2 – temperature +350C; K – control.

**Fe mg/kg**

Diagram 3. Quantity of iron ions migrated into water in 14 days under different thermal conditions. Pan #1 – temperature +150C; pan #2 – temperature +350C; K – control.
The diagrams show that temperature play an important role in bioleaching, specifically, increase of temperature accelerates the process of natural leaching and vice versa. It should be mentioned that in the control pan K, where acidity had not been corrected and ferrobacteria had not been introduced the level of leaching was insignificant, the pH balance changed towards alkalinity and increased from 5.6 up to 6.6. Therefore, it can be predicted that the process of oxidation at the first stage of the operation of the dumpsite will be very slow.

To facilitate the growth of microorganisms biogenic substances were introduced into the rocks during the model testing. It is well known that newly cut rocks contain almost no soluble nitrogen and phosphorous biogenic substances which are limiting factors for the growth and development of microorganisms.

The diagrams below illustrate the relationship between the growth rate of microorganisms and the concentration of nitrogen and phosphorous containing salts.

**Quantity of ammonium sulphate gr/l**

Diagram 4. The relationship between the quantity of Th.f. and the concentration of ammonium sulphate in culture medium

**Quantity of potassium dihydrophosphate gr/l**

Diagram 4. The relationship between the quantity of Th.f. and the concentration of potassium dihydrophosphate in culture medium
The diagrams show that the growth rate of Th.f. and the concentrations of nitrogen and phosphorous containing salts in culture medium (up to certain upper limit $N_{\text{max}} = 3\text{g/l}$) are in linear relationship and are limiting factors for the development of microorganisms.

Therefore the biogenic substances will have an important limiting role in the process of the development of microorganisms at the dumpsites of newly cut rocks. This will have an indirect negative impact on the speed of the leaching and changing acid/alkali balance towards acidity.

It is well known that the concentration of nitrogen and phosphorus at the dumpsites of newly cut ore bearing rocks is at the minimum level of the demand of ferrobacteria which restricts their development. With time the quantity of nitrogen and phosphorus in water increases due to migration of biogenic elements with water, sand, dust and vegetation developed on the dumpsite. This leads to the increase of the lag phase of the microorganisms which is observed in the process of heap bioleaching at dumpsites [1,2,3].

The mentioned process starts in parallel with the creation of a dumpsite and lasts around 24 months. Therefore duration of the first stage of change of chemical and physical characteristics of water leaking from dumpsites can be assumed to be 24 months. During this period of time the effect of bioleaching from the rocks of the dumpsites of the Sakdrisi deposit cannot be expected (unless dead rock rich in sulphide minerals are dumped or acid waters from other dumpsites flow into the territory of the dumpsite). Therefore the quantity of ions in water will be minimal (within MAC) and pH will vary within 6,6 – 5,6.

**3.2 Determining the dynamics of the acid/alkaline balance of dumped rocks of the Sakdrisi deposit during model testing**

Determination of the water holding capacity of rocks and the reaction of rocks with acid is one of the most important stages of testing.

For this purpose 20 kg of rocks were placed in each pan and added 10 l of water. 3 l of water was retained by the rocks. At the same time the process of reaction of the rocks with acid was observed. There is a certain category of rocks which enter into reaction and disacidify acids. Carbonate rocks belong to this category. Our task was to study the dynamics of the chemical impact of the dumped rock of the Sakdrisi deposit on acid/alkaline balance.

During model testing the rock oxidation process was artificially accelerated under the conditions of thermal regime favorable for the development of microorganisms. Acceleration was done according to the scheme characteristic for the process of rock oxidation under the influence of microorganisms of genus Thiobacillus. Specifically, along with the development of Thiobacillus thioparus, Thiobacillus thiooxidans, Thiobacillus ferrooxidans, at the first stage pH of the rock reaches 3,1 as a result of the influence of Thiobacillus thioparus and Thiobacillus thiooxidans, and at the second stage pH reaches 1,9 on the buckhound of the growth of the quantity of microorganisms and as a result of the influence of Thiobacillus thiooxidans and Thiobacillus ferrooxidans [3,4].

Therefore, the artificial reduction of pH during testing occurred only two times, in other cases water drained for sampling was poured back into pans without acid correction.

Diagram 5 illustrates the obtained results.
Diagram 5. Dynamics of pH changes

The diagram shows that on the background of artificial reduction of pH in temperatures favorable for the development of microorganisms (+15°C and +35°C) pH reached its initial value (pH 5.6) in 48 hours after the contact with rocks in the first case and in 240 hours in the second case.

Therefore, it can be stated that the dumped rocks of the Sakdrisi mine affect the acid/alkaline balance like carbonate rocks and contribute to its change towards alkalinity (unless dead rock rich in sulphide minerals are dumped or acid waters from other dumpsites flow into the territory of the dumpsite).

3.3 Determining the dynamics of the acid/alkaline balance of dumped rocks of the Sakdrisi deposit in low temperature during model testing

Observation of the dynamics of the acid/alkaline balance in low temperatures (-5°C and +5°C) through modeling winter period was one of the important stages of testing. The rocks were oxidized in the similar manner as in the previous test. The obtained result are presented in the Diagram 6.

pH

Diagram 6. Dynamics of pH changes in low temperatures

The diagram shows that pH does not increase in low temperatures and the rocks retain their acid reaction, since the movement of ions in low temperatures is minimized and the rate of chemical reactions is slow. Therefore the interaction between acid and the rock was limited. Although we had to
melt rocks needed for sampling and at that time the temperature was increasing by $6^\circ$C, the change of acidity (change towards to alkalinity) was insignificant.

Therefore the change in acidity in winter is not expected. During low temperatures ($+5^\circ$C and lower) acidity in surface waters and upper layers of the dumpsite will retain at the level recorded before cooling. However, it shall be taken into account that with the growth of the dumpsite water contained in its lower layers will not freeze due to the exothermic nature of natural leaching and after flowing from the dumpsite the pH balance will be relatively stable until the rise of outside temperature.

**Conclusion**

Based on the above we can conclude:

1. The impact of the dumped rocks of the Sakdrisi mine on the environment can be divided into three stages:
   - The first stage when the natural oxidation of rocks and their “infection” by microorganisms occur. Duration of this stage is 24 months ($\pm$ 3 months). During this period the effect of natural leaching (biological and chemical) of dumped rocks of the Sakdrisi mine cannot be expected (unless dead rock rich in sulphide minerals are dumped or acid waters from other dumpsites flow into the territory of the dumpsite). Therefore the quantity of ions in water will be minimal (within MAC) and pH will vary within 6,6 – 5,6. The first stage is characterized by oxidation-reduction (PE) and increases quantities of SO4- ions;
   - The second stage when the dumpsite is already formed, directions of runoffs are outlined, organic substances penetrate, develop and accumulate into the rocks of the dumpsite. This period is characterized by the change of pH balance towards acidity (within pH 4). During this period the migration of ions of nonferrous metals into water solutions occur. Therefore their concentrations of dumpsite runoffs will exceed MAC. As a rule, zinc ions will exceed MAC first, afterwards copper and iron. Duration of this stage will be presumably 60 months ($\pm$ 3 months) taking into account the specifics of the damped rocks of Sakdrisi mine;
   - The third stage, a static phase, characterized by physical-chemical balance, pH 3, concentration of ions in water exceeds MAC, concentrations values do not vary. The mentioned period will last until the end of the operation of the dumpsite;

2. The intensity of natural leaching (biological and chemical) will increase in summer;

3. Leaching slowed down (not stopped) in low temperatures. During the winter period of the second and third stages leaching of nonferrous metals from the dumpsite of dead rocks will occur. The intensity of leaching in winter will be slower than in summer;

4. The dumped rocks of the Sakdrisi mine affect the acid/alkaline balance like carbonate rocks and contribute to its change towards alkalinity (unless dead rock rich in sulphide minerals are dumped or acid waters from other dumpsites flow into the territory of the dumpsite). This will play an important role at the first stage of the operation of the dumpsite and prevent the development of acid waters;

5. Changes in acidity in winter is not expected due to low temperature. During low temperatures ($+5^\circ$C and lower) acidity in surface waters and upper layers of the dumpsite will retain at the level recorded before cooling. However, it shall be taken into account that with the growth of the dumpsite water contained in its lower layers will not freeze due to the exothermic nature of natural leaching and after flowing from the dumpsite the pH balance will be relatively stable until the rise of outside temperature. It means that during the winter periods of the second and especially third stages the lowest values of the acidity will be recorded in surface waters and upper layers of the dumpsite.
Recommendations

As it has been stated above a typical facility of the mining enterprise – dumpsite shall be considered as an artificial bio-inert system in the development of which both the living organisms and chemical-physical processes observed in the rocks (if not affected they can be considered as an inert material being untouched underground for million years) participate. From the moment of the launch of the dumpsite the artificial bio-inert system exerts the influence on ecosystems. This influence increases with the time. The dumpsite undergo several stages until it becomes a bio-inert system thus increasing the pressure on the environment. Therefore taking preventive measures at the earliest possible stages will enable to minimize the negative impact of this system and reach sustainable results. This will also reduce the costs of environmental measures.

At the first stage of the operation of the dumpsite the construction of a simple biopool for deacidification of waters drained from the dumpsite will be sufficient. At the second stage the method of sorption of heavy metals shall be applied. The most difficult task is to localize waters draining from old dumpsites, but the case of a new dumpsite water draining from it can be easily localized. Localization of runoffs is the most crucial environmental issue for the old dumpsites.