CHAPTER V

HYDROGEOLOGICAL-GEOENGINEERING CHARACTERISTICS AND MINING TECHNICAL CONDITIONS

A. VOLUME –ITEMS OF DATA COLLECTION WORK

According to approved project, in the prospecting, exploration works of Vang Tat-Xan Xay-Attapu Gold Mine, Laos P.D.R. there have been carried out following work items: Data collection, general hydrogeological-geoengineering survey, rotary drilling for sampling, slug test: water withdrawing and pouring, Collection and analysis of soil, rock, and water mechanic-physical samples. On the basis of obtained results, assessment on implement of work items can be made as follows:

V. 1. COLLECTION OF DATA AND INFORMATION

The collection of data had been carried out from the stage of the project establishment, during project implementation and before writing final report on the results of the project. Collected data are:

- Geological data: Geological map of Indochina, scale 1/1.000.000 and Geological and mineral resources of Laos, scale 1/200.000 compiled by geologists of Vietnam and Laos.

- Meteorological and hydrological data were collected from some meteorological-hydrological stations related to prospecting area in a period of 5 years from 1998 to 2003. These data were collected from Attapu, Saravane, Đak To meteorological-hydrological stations, etc.

All collected data and information were synthesized serving well for implementation of the project and establishment of final report.

V. 2 . HYDROGEOLOGICAL – GEOENGINEERING SURVEY

The geological, hydrogeological-geoengineering survey has been carried as designed in the project. The survey was constructed at an area of 3km^2 (in the area of detailed exploration of 3km^2). The survey trips were arranged along streams, laterite roads, trails and predicted engineering lines on the map. Survey points were mainly concentrated in predicted exploration engineering such as trench, drill hole, walls as open pits in the mine.

The volume of survey is equal approved volume of the project:

- Field hydrogeological-geoengineering survey: 3km^2

- Office regulation: 3km^2.

The data of the geological, hydrogeological-geoengineering survey have timly served for the further prospecting work items. The results of the geological, hydrogeological-geoengineering survey indicate that it is necessary to change some predicted drilling sites which were arranged on the sites of no potential on gold ore (LK1-T27^{A}, LK1-T28^{A}, LK1-T29, LK1-T29^{A}, LK1-T30, LK1-T30^{A}) or impossible to make drilling platform (LK1-T14^{A}), etc. The change of some above-mentioned predicted sites has been agreed by the partners, corresponding to practical construction of the exploration project.

Table V-1: Volume of hydrogeological - geoengineering surveys works

STT	Survey point	Amount	Thin sections	Water samples
1	Survey points on cover	482	0	
2	Geological survey points	66	15	
3	Bedrock survey points	133	75	
4	Survey points at artificial outcrops	15	6	
5	Stream survey points	91	4	8
6	Hydrogeological outcrops	03	2	1
7	Trench survey points	01	0	
8	Drift survey points	04	0	3
Total		**795**	**102**	**12**

V.2. HYDROGEOLOGICAL – GEOENGINEERING MONITORING

This work was developed during hydrogeological-geoengineering survey and field survey (from 24/3/2008 to 15/7/2008) including:

- 04 monitoring stations for surface water: 02 stations were arranged on Ker stream at the East of the mine; the station QT1 controls water current running to the mine, the station QT2 control water current running out the mine. The stations QT3 and QT4 measure water current running out mining pits (at the West). Their main task is to monitor water current, air temperature, water temperature which is developed from the end of march to July 15, 2008. Measurement period: a time/3 days in the dry season (from 3/2008 to 30/4/2008); a time/5 days in the rainy season (from 1/5/2008 to 15/7/2008).

- Monitoring drift for hydrogeological-geoengineering survey was carried out in 3 engineering which have been done and are under construction. The aim of monitoring is to describe characteristics of soil and rocks, their petrographic composition, structure, texture, weathering level, fracture, depth attitude, relationship with surrounding rocks, permeability and water-bearing possibility, appearance and stable depth of water, collection of water samples for their analysis of chemical composition, etc, especially to focus in description of ore beds and their features such as thickness, development direction, rock azimuth, colour, existing forms, and ore content.

- Monitoring drill holes for hydrogeological-geoengineering survey was carried out in 14 geological exploration drill holes with the aim to determine composition, structure, texture, weathering level, fracture, etc of rocks. The whole information and data were collected through description of every drilling interval, percentage of sampling, amount of solution loss, measuring water level before dropping drill rod and after its pulling , measuring the depth of appearance and stable level of water, measuring air temperature, water temperature. Monitoring results are shown in the table V - 3.

Table V – 2 : Hydrogeological-geoengineering monitoring stations

No	Station	Coordinates		Monitoring data
		X	Y	
1	Station QT1	1657724.38	759258.87	Stream monitoring
2	Station QT2	1656256.05	759175.71	Stream monitoring
3	Station QT3	1657624.74	758146.74	Stream monitoring
4	Station QT4	1656984.15	758485.42	Stream monitoring
5	Survey drift 6-1	1657639.94	758786.15	Spring water level monitoring
6	Survey drift 5-2	1657236.23	758804.08	Spring water level monitoring
7	Survey drift 1-3	1656416.75	758995.35	Spring water level monitoring
8	LK2-T15^{A}	1657527.12	758844.73	Slug (pouring) test
9	LK1-T18^{A}	1657234.87	758895.56	Slug (withdrawing) test
10	LK2-T20^{A}	1657025.61	758864.04	Slug (withdrawing) test
11	LK2-T20	1657083.13	758863.94	Slug (pouring) test
12	LK1-T23	1656771.96	758964.11	Slug (pouring) test
13	LK1-T26	1656493.00	758964.00	Slug (pouring) test
14	LK2-T15	1657578.06	758864.26	Exploration bore hole
15	LK1-T19	1657179.11	758837.09	Exploration bore hole
16	LK1-T19^{A}	1657128.46	758641.72	Exploration bore hole
17	LK2-T19^{A}	1657129.56	758687.87	Exploration bore hole
18	LK1-T22	1656875.60	758649.87	Exploration bore hole
19	LK1-T25^{A}	1656526.45	758853.64	Exploration bore hole
20	LK1-T26^{A}	1656426.64	759019.43	Exploration bore hole
21	LK1-T30	1656083.80	758973.27	Exploration bore hole

V - 3 : WATER WITHDRAWING AND POURING SLUG TEST

1- Implementation volume

The volume of water withdrawing and pouring slug test (hydrogeological and geoengineering experiment) according to the project is included 14 drill holes. In fact, there were implemented only a half of the planned volume, ie 6 drill holes in a working area of 3km^{2}. The results of slug test are expressed in the table V – 3.

Water withdrawing at 2 drill holes (LK1-T18^{A}, LK2-T20^{A}): 18 shifts; water pouring at 4 drill holes (LK1-T15A, LK2-T20, LK1-T23, LK1-T26): 36 shifts. The volume of slug test water withdrawing and pouring is the same as designed in the project.

Measurement of hydraulic backwash includes 15.65 shifts (designed in project are18 shifts), decreased 2.35 shifts, this decrease is corresponding with practical implementation conditions, the reason is that one drill hole planned to test by water withdrawing but changed to be tested by water pouring.

Table V – 3 : Results of withdrawing and pouring slug tests

No	Bore hole number	withdrawing and pouring test slug timing (shift)		Hydroulic backwash (shift)		Results of withdrawing and pouring slug tests				
		Designed	Real	Designed	Real	Static water level (m)	Current		Lowering water level (m)	Current ratio (l/sm)
							l/s	m^3/ng		
1	LK1-T15^A	9,0	9,0	0	0	Not meet yet	0,18	10.8	30,00	
2	LK1-T18^A	9,0	9,0	6,0	5,9	6,5	0,78	67,39	12,40	0,063
3	LK2-T20	9,0	9,0	0	0	25,2	0,221	13,25	17,20	
4	LK2-T20^A	9,0	9,0	6,0	9,75	2,0	1,039	89,77	6,52	0,159
5	LK1-T23	9,0	9,0	0	0	25,2	0,315	18,87	9,20	
6	LK1-T26	9,0	9,0	6,0	0	32,5	0,055	3,31	22,50	
Total		54,0	54,0	18,0	15,65					

2. Equipment and slug test methods

a. Water withdrawing slug test

- The equipment used for water withdrawing and pouring slug test for drill holes is air compressor. The purpose is to clean drilling mud and solution and materials filled up fissures and fractures in rocks and clearances in filtering pipe, to primarily determine hydrogeological parameters of the drill holes taking as a basis for designing formal water withdrawing slug test. Time for withdrawing is 3 shifts for every drill hole.

It was carried out single water withdrawing with a time of water level lowering lasting through 6 shifts. The aim of water withdrawing slug test is to control water current, to monitor water level lowering to stable one. The least stable time is 8 hours .

At the end of water withdrawing slug test, there was taken one weter sample for alround analysis according to the request of the project, the measurement of hydraulic backward has been done right at the moment when the water withdrawing slug test was stopped until the water level was completely backwarded.

b-Water pouring slug test

In order to determine the hydrogeological parameters, permeability of rock in ventilation zone. The water pouring slug test was carried out at drill holes through weak rock bed, strongly weathered rock as well as at drill holes which did not met water stable level, or deep water stable level, that did not allow to arrange water pouring slug test.

The time for water pouring slug test at a drill hole is similar to that of water withdrawing slug test: pump for washing drill hole – 3 shifts; water pouring slug test: 6 shifts.

Main equipments for water pouring slug test include: water pump, valve controlling pouring water into drill holes, meter measuring water current running into drill holes, rule measuring water level.

Experimental method is monitoring water stable current Q, necessary to pour into drill hole, so that a water pipe H is stable. Stable time for water current pouring into drill hole is 8 hours.

Picture II-3: Water withdrawing slug test at drill hole LK1-T18A

Photo: Lương Văn Vấn, 2008

3. The quality of the data and the experimental results

The data of water withdrawing and pouring slug test at drill holes have been adequately collected and are always updated, carefully took their notes in the books in accordance with recent procedures.

The hydrogeological parameters were calculated based on the data of water withdrawing slug test by the software Aquifer Test.

The hydrogeological parameters calculated based on the data of water pouring slug test by following methods:

- After M.E Harr, McGraw-Hill (1962), For monitoring a stable water current it is necessary to pour water into drill hole so that the water pipe H is stable.

Permeability coefficient k is determined by following formula:

$$k = \frac{Q.Ln(\frac{L}{D} + \sqrt{1 + \left(\frac{L}{D}\right)^2})}{2\pi.L.H} \quad \text{(m/day and night)}$$

- After Dobrovolxki with a non-pressure aquifer impregnate through drill wall.

$$K = \frac{0{,}366.\ Q\ (\lg R - \lg r)}{ho(ho - H)} \quad \text{(m/day and night)}$$

Where:

h- Test water pipe which is equal to difference in height between water level in test drill hole and underground stable water level.

L- Length of test fragment.

r- Drill hole radius.

R- Influence radius

Ho- Difference in height between water level in test drill hole and the bottom of aquifer and the bottom of in turn test drill holes.

H- Difference in height between the bottom of drill holes and underground stable water level.

The results of calculating permeability coefficient by the above-mentioned methods are similar.

The practical implementation work allow to make some remarks: The designed water withdrawing and pouring slug tests with methods, withdrawal time is quite suitable, meeting the main purpose ie to determine water volume withdrawn out from each drill hole serving well for drainage of the mine.

4- Remains

Due to the requested progress of the drilling work, so the carried out at the beginning of the rainy season water withdrawing slug tests serving for drainage of the mine are not completely met the practical hydrogeological conditions of the mine.

V - 4 : SAMPLING AND ANALYSIS OF SAMPLES

- The total amount of samples to be collected for their analysis as approved by the project is 14, collected samples are 14; The sampling sites are as follows:

+ At the monitoring station of surface water: 04 samples (TQT1, TQT2, TQT3, TQT4)

+ In Investigation drift: (L. 6-1, 5-2, 1-3)

+ At the survey points on the hydrogeological-geoengineering survey trips: 05 samples (ĐKS11, 170, 412, 478, 773).

+ In the drill holes for water withdrawing slug tests: 02 samples (LK1-T18^A, LK1-T20^A).

- Colliform samples: planned 02, collected 02 (ĐKS470 and L. 5-2).

- Soil physic-mechanic samples: planned 06 samples, collected10 samples which were taken from walls, pillars of ore bodies that are planned to mine by open pit in order to determine full soil physic-mechanic norms such as: composition of grains, self permeability, specific gravity, volume capacity, porosity, saturability, viscosity limit, plasticity limit, compression strength, tension strength, internal friction angle, cohesive power, Coefficient of settlement compression. Soil physic-mechanic samples were taken from bore holes: LK1-T18^A 04 samples, sampling depth from 2.0 to 24m); LK1-T22 (13.0m); LK1-T25^A(13.0m); LK1-T26 02 samples (33.0 and 45.0m); LK2-T16^A 02 samples (9.0 and 30.0m).

- Rock physic-mechanic samples were not planned, due to practical situation of the project required to take additionally 15 samples. Rock physic-mechanic samples were taken from drill core, every sample includes 6 pieces with a length of sample being ≥10cm for analyzing showings (norms): volume, specific gravity, cut strength, tension strength, cohesive strength, internal friction angle, porosity, softening coefficient. Number and sampling sites are presented in table **V**-5.

Table V – 4 : Sampling sites and number of rock physic-mechanical samples

No	Number of samples	Sampling sites	Sampling depth (m)	Type of rocks
1	MS1	LK1-T13	31.6-34.6	Brown altered schist
2	MS2	LK1-T14	34,0-36,0	Brown altered schist
3	MS3	LK1-T15A	51,6-55,6	Brown altered schist
4	MS4	LK1-T20	39,0-42,0	Ash black horny schist

5	MS5	LK1-T20A	57,0-58,2	Ash black horny schist
6	MS6	LK1-T21	56,0-57,0	Ash black horny schist
7	MS7	LK1-T21A	54,5-55,5	Ash black horny schist
8	MS8	LK1-T25	40,9-42,9	Ash black horny schist
9	MS9	LK2-T13	45,7-46,7	Hard, light quartzite
10	MS10	LK2-T13A	15,8-17,0	Hard, light quartzite
11	MS11	LK2-T14	26,0-28,0	Brown altered schist
12	MS12	LK3-T20A	30,8-32,5	Ash black horny schist
13	MS13	LK2-T16A	40,1-43,1	Ash black horny schist
14	MS14	LK2-T21	95,4-96,4	Ash black horny schist
15	MS15	LK1-T27A	34.3-35.4	Ash black granodiorite

Water samples were taken at survey and mapping, water withdrawing slug tests sites. Soil and rock physic-mechanic samples were taken from drilling core. Amount and types of samples were collected as designed in the project. Sampling methods, samples' preservation, transportation and storing time from collection to analysis are ensured technical requirements.

Analysis of alround water samples and soil physic-mechanic samples was done in the laboratory of Mien Trung (Central) Hydrogeological-geoengineering Division locating in Nha Trang city, Khanh Hoa province. Colliform samples were analyzed in Gia Lai Department of Science and Technology. Rock physic-mechanic samples were analyzed in Khai Hoan Construction Consulting Company LTD locating at 311-Truong Son str. Pleyku city, Gia Lai province. Amount of collected samples is expressed in table V – 4 - 1.

Quality of samples' analysis is met the technical requirements, keeping allowed accuracy. The results of samples' analysis allows assessing quality of underground water in the prospecting area on the basis of quality norms on the underground water TCVN 1329/2002 and geoengineering conditions and, by the way, to add the data for assessing the hydrogeological-geoengineering conditions of the Mine.

Table V – 4 - 1 : Amount of samples

No	Sample type	Amount	Collected
1	Water samples for comprehensive analysis	14	14
2	Water samples for colliform analysis	02	02
3	Soil samples for their physic-mechanical analysis	06	10
4	Rock samples for their physic-mechanical analysis	15	15
	Total	37	41

B. HYDROGEOLOGICAL-GEOENGINEERING CHARACTERISTICS AND MINING CONDITIONS

V . 5.HYDROGEOLOGICAL-GEOENGINEERING CHARACTERISTICS

On the basis of the study on water-bearing possibility of the ground in the area and its petrographic composition, the mine can be divided into following aquifers:

1- Holocene mixed sedimentary aquifer (zone) (apdQ_{IV})

This aquifer locates in stream valleys at the West, Southwest of the study area with an area of $0.04km^2$. Its composition consists of cobble, boulders mixed with sand, gravel, powder and botanic matters, its thickness is from 0.5 to 1.0 m.

Water is storing in ground holes, and it is non-pressure water. Underground water level varies by the seasons, it is shallow in the rainy season, but in the dry season goes down to the variable amplitude between two seasons from 0.5 to 1.5 m. In general, the water-bearing possibility of the ground is weak with low water current in some places $Q \leq 0.2l/s$.

Chemically, this water is bicarbonate calcium magnesium. Total mineralization is 0.02-0.05g/l. The hardness of the water is from 10 to 50.

Thus, the drainage of this aquifer is not a big problem. The hardness of this water is much smaller than allowed one, other components are in the allowed norms it is suite for drinking.

2. Fracture-fissure aquifer in the Late Proterozoic - Early Paleozoic sediments of Nui Vu Formation (PR_3 – $Є_1$ *nv_1*)

This aquifer is distributed widely in the study area with an area of about $2.85km^2$. Geological formation included 3 parts from the bottom to the top as follows:

Lower part:

This part includes thin-bedded laminated clayey aleurolite, forming thick horny horizon, quartz horn, biotite horn. The rock hard, laminate to black. This formation is mainy seen at the East of the exploration area, forming a belt of sub-meridional direction.

Middle part:

It is composed of thin-bedded clayey schist, black schist bearing a little graphite. Under metamorphism, this bed altered into greenized bed consisting mainly of quartz and sericite. The results of geophysical measurement show that its thickness is unstable, varying from 0 to 200m, in the form of wedge expanding to the center of the area and narrowing at the West of the exploration area.

Upper part:

This is a thick-bedded quartzite. Quartzite is leucocratic, consisting mainly of monomineral sandy quartz. Its thickness varies from about some tens metres to 180 m. This bed is conformably overlay on clayey schist and quartz-sericitized schist, distributing to the North of the area and narrowing at the South and concentrating at the high part of the relief.

The rock is fractured, massive with low water-bearing ability. However, upper part of the rock was weathered into friable ground (middle part) with a thickness usually of 40m (LK1–T19^{A}) to >120.6m (LK1–T19), which can be a place of water storage in the rainy season, but dry in the dry season. The data on water withdrawing slug test from bore holes LK1-T18A, LK1-T22^{A} indicate that the water current is from 0.7 to 1.039l/s, water current ratio is from 0.063 to 0.159l/sm. The water is transparent, non-smell, tasteless, temperature: 24,0-26^{o}C.

Caused by tectonic activity, rock at some places were fractured, destroyed, so these places can be seen as good water-bearing structures, as recorded in prospecting drifts 5-1, 6-2, 1-3, where water is running on the bottom of the drift with discharge of from 0.3 to 1.2l/s, especially >3.0l/s in the drift 5-1. At the survey point 470 the water runs out from fractures in quartzite with a discharge measured in July, 2008 being 0.9l/s, the quality of water is good which is using by the gold mine for life of its staffs.

The water of this formation is transparent, odorless, tasteless, good quality, its total mineralization is from 0.01-0.03g/l, pH from 6.95 to 7.0. Chemically, this water is bicarbornate chloride calcium magnesium.

3. Aquifer (water-bearing zone) in the intrusive magmatic formation γ^{t-3}_{4} *ts*

Early Mesozoic intrusive magmatic massifs γ^{t-3}_{4} *ts* of Truong Son Formation are distributed at the Southwest of the area, stretching from the market, across the West of managing headquarter and airport to the South with an area of about 0.0998 km^2. These massifs include melanocratic granodiorite, granite biotite in the form of dyke cutting through greenschist. This is consisted of quartz, feldspar, fine-grained biotite. The rocks are of massive structure, less fractured, weak water-bearing ability or bearing no water. Thus, these rocks have no significance for water supply purpose.

V.6. MINE DRAINAGE AND WATER SUPPLY FOR SOCIAL LIFE

1. Prevision of water volume to be necessarily drained

a. Surface water

- Dry season: It is nearly no surface water, so, the problem of drainage is out of consideration.

- Rainy season: Surface water - the precipitation directly dropping on the basin, which running to the mining pit is calculated by following formula:

$$Q = W.F \qquad (m^3/day)$$

In which:

Q- Volume of water running into mining pit (except for amount of water impregnated through the ground).

W- Maximum daily precipitation (m) according to meteorological data, giving by 170mm = 0.17m

F- Area of basin having surface water running into the mining pit (m^2), is about 291.400m^2

$$Q = 0.17 \times 291.400 = 49.538\ m^3$$

b. Underground water

The formula for the big well is used to calculate a volume of underground water running into mining pit from ore horizon and surrounding rocks.

$$Q_d = \frac{1{,}366K.(2H-S).S}{\lg Ro - \lg ro} = \frac{1{,}366K.H^2}{\lg R_o - \lg r_o}$$

Where:

K- Permeability coefficient of rock layer (k= 0.1m/day)

H- Height of water column which is necessary to be drained to 1010m equal 22.0m (height of drift 6-2 =1032m)

R- Influence radius calculated by formula (m) $R = 2S.\sqrt{K.H}$

$R = 2{,}0.22{,}0.\sqrt{0{,}1.22{,}0}$ = 65,26m

r_o- Radius of big well (m) $r_o = \sqrt{\frac{F}{\Pi}}$

F- Area of mining pit giving from drift 6-1 to drill hole LK1-T20 equal 140.630m^2

$r_o = \sqrt{\frac{140630}{3{,}14}} = 211{,}62$ m

Ro- Conversed radius: Ro = R + ro = 65.26 + 211.62 = 276.88m

Thus : $Q_d = \frac{1{,}366.0{,}1.22{,}0.22{,}0}{\lg 276{,}88 - \lg 211{,}62} =$ 550.95m^3/day

c. Volume of drained water

Under mining to a code height of 1010m, a water volume necessary to be drained is:

- Rainy season: QTK = QW + Qđ = 65.26 + 550.95 = 616.21m^3/day
- Dry season: QTK = Qđ = 550.95m^3/day

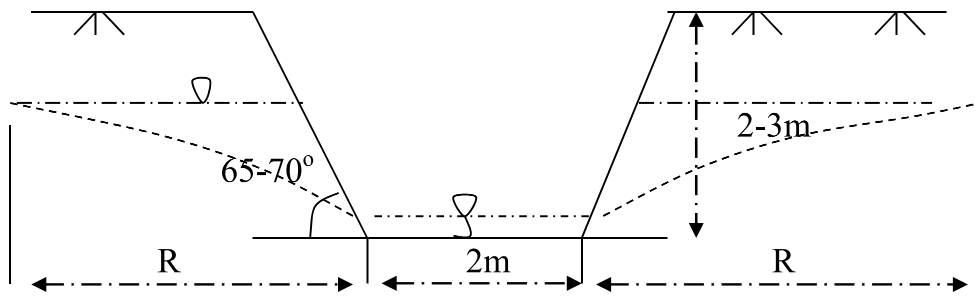
2. Drainage methods

Under mining at the height code of 1032m there require only drainage ditches because of that the stream bed is from 5.0m to 6.0m lower than mining pit, so water can run off freely, no need to pump .

a. System of drainage ditches

The whole volume of water run into the mining pit was led by subordinate system of drainage ditches to two main drainage ditches at the West which are tributaries from survey drifts 5 and 6. The dimension of the main drainage ditch is predicted so that it can drain maximum volume of water as it shown in the fig:

Fig. V-1: Section of the drainage ditch



b. System of pumps

In the future if mining will be developed from the height code of 1032m to 1020m then a system of suction pumps will be needed to drain mining pit, if a pump with capacity of 20-30m^3/h will be used, so such 02 to 03 pumps should be used to drain this calculated volume of water.

In short, because of the slop mountainous relief, the rainy water discharges very fast through depression places and then runs to streams. In other hand, the underground water level is deep (drill holes at the lines T.15, T.15^A, T.16 have not met the underground water level), so the drainage of the mine is favourable, requiring not much expenses for this problem.

Notice: It is necessary to let natural flows running freely.

3- Water supply for social demands

In the mine area, the underground water exists in fractures and fissures in metamorphic rocks, this is a main source of water supplying for daily life. The data of water withdrawing slug test the water discharge at drill holes is from 0.75 to 1.04l/s corresponding 64.8-89.8 m^3/day.

- Demands of water use in the gold mine

Recently, the working people at the mine are about 400 persons, in the future, a factory will be built and mining will further be developed from line 13 to the North of line 1 which belongs to the sheet 1 of the mine map, that can lead to increase of working people to 700-800 persons. According to the recent water consumption norm:100l/day/person, then the demand of water consumption is: 100 x 800 = 80,000 l/day, so that 02 drill holes can supply enough for the demand of the mine.

- The quality of water for social demand:

The analytical results of 16 water samples (include comprehensive and colliform samples) done by the Chemical Experimental laboratory of the Mien Trung Hydrogeological-Geoengineering Division and the Department of Science and Technology of Gia Lai province show that in comparison with the norms of drinking water hygiene issued by Decision No. 1329/2002/BYT/QĐ of the Vietnam Ministry of Public Health dated 18/4/2002, the underground water in the gold mine of Vang Tat Noi-Xan Xay-Attapu-Lao P.D.R is characterized by:

- *Phisical properties*: The underground water in the Vang Tat Noi Gold Mine is colourless, tastless, odorless, temperature varies from 19 to 26,5^{o}C.

- *pH values*: it varies from 6.87 to 7.4 that are in the range of allowed norms, of some samples pH = 6.06 (MS7- drift KS1-3).

- *Total iron content* (Fe^{2+} + Fe^{3+}): The total iron content in 14 samples varies from 0.1 to 0.4, lower than allowed.

- *Content of nitrogen:* The content of nitride (NO_2^-) varies from non to 0.01 mg/l and the content of nirtrate (NO_3^-) varies from 0.11 to 0.85 mg/l, All of them are in the allowed range.

- *Total Colliform and Fecal Colliform*: Two experiment samples show that the content of colliform in them is non or very little, that can guarantee a water quality for social life.

Table V- 6 : Main content and norms for the water of the Vang Tat Gold Mine

No	Norms	Unit	Content in the water of Vang Tat gold Mine	Limit content in water according to Vietnam standards TCCP (1329/2002/BYT)
1	pH value		6.87 – 7.4	6.5 – 8.5
2	Total hardness	mg/l	7 - 50	300
3	Total mineralization	mg/l	12.7 – 57.0	1000
4	Total (Fe^{2+}+Fe^{3+})	mg/l	0.1 – 0.4	0.50
5	Nitrate NO_3^-	mg/l	0.11 – 0.85	50.0
6	Nitrite NO_2^-	mg/l	0.0 – 0.01	3.00
7	Content of NH_4^+	mg/l	0,01 - 0,06	1,5
8	Chloride	mg/l	4,6 - 6,03	250
9	Natrium	mg/l	0,49 - 2,3	200
10	Content of Sulphate	mg/l	0,32 - 1,52	250

11	Colliform	MPN/100ml	0-93	2,2
12	Fecal Colliform	MPN/100ml	0-43	0

Thus, The results of samples' analysis indicate that the basic norms of underground water in the Vang Tat Noi-Xan Xay-Attapu, Lao P.D.R are all lower than allowed for drinking (some norms are too lower than the allowed), that mean underground water here is of good quality.

- Quality of water for technical purposes

The results of comprehensive analysis of 14 samples show technical norms as follows:

(See table V-6)

Table V – 6 : Water quality for technical and construction purposes

No	Number of samples	Sampling site	H	Hh	Kh	Kk	F	Ka
1	MS1	Station QT 1	446.07	212.66	0.48	-25.81	182.72	8.41
2	MS2	Station QT 2	170,20	355,13	2,09	-7,94	182,72	9,03
3	MS3	Station QT 3	498,71	323,12	0,65	-25,84	209,64	9,55
4	MS4	Station QT 4	183,08	270,17	1,48	-7,86	118,24	12,49
5	MS5	Drift KS 6-1	377,27	391,46	1,04	-22,15	176,10	9,03
6	MS6	Drift KS 5-2	230,71	303,09	1,31	-11,05	57,68	12,49
7	MS7	Drift KS 1-3	107,48	323,21	2,98	-4,89	68,84	11,61
8	MS8	Point KS 11	855,26	324,47	0,38	-51,07	68,84	11,61
9	MS9	Point KS 478	844,54	291,05	0,34	-46,75	122,78	12,49
10	MS10	Point KS 412	922,49	309,01	0,33	-54,14	101,08	13,55
11	MS11	Point KS 170	474,15	287,83	0,61	-30,76	204,94	11,61
12	MS12	Point KS 773	177,12	309,89	1,75	-7,99	199,10	10,16
13	MS13	Drill hole LK1-T 18^A	327,71	244,25	0,75	-19,69	166,86	16,23
14	MS14	Drill hole LK1-T 22^A	1997,35	825,43	0,41	-133,52	387,84	8,12
Average			543.72	340.77	1.04	-32.10	160.53	11.17

Underground water in the Vang Tat Noi Gold Mine has high possibility of soaf obsorption, small accumulation (except for bore hole LK1-T22^A, point KS412, point KS478point KS11 has a high accumulation); small remain-forming coeffocient, incorrosive, foamless to semifoamless. Thus, underground water here, in general, is well serving for numerous technical branches.

V. 7. GEOENGINEERING CONDITIONS OF THE MINE

V. 7.1. Geoengineering characteristics of rock

Geoengineering characteristics of the mine are combination of natural geological factors affecting to design, construction and use of engineerings including following factors:

- Topographic, geomorphological factor: The Topographical, geomorphological characteristics of the mine are high mountains (absolute altitude is from 900 to 1200m in comparison with sea level), vertical slopes, conveso-concave relief, which much influence to the implementation of engineerings.

- Stratigraphic factor and physic mechanic features of rock and soil play a determination role in the formational features of regional relief, related to forming and developing conditions of process and phenomena of dynamic geoengineering, distribution characteristics and ability of bearing underground water as well as characteristics of mineral resources of the mine area.

- Geostructural factor and tectonic characteristics effect directly to stability of the basement ground and permeability of the ground and rock as well. The geostructural factor can push the development of some dynamic geological processes and phenomena of engineering: weathering, landslide, etc.

- Hydrogeological factor: Underground water much effects to the stability of the engineering as well as construction conditions. Underground water can make a durability of the rock to be changed, forming a floating pressure under the basement of engineering, causing corrosion of gold and runs into mining pit.

- Factor on process and phenomena of dynamic geoengineering: Activity of process and phenomena of dynamic geoengineering can make composition and features of rock to be changed, causing impossible of engineering and loss of water in the reservoir by permeability.

- Factor on natural mineral materials plays a considerable role in reducing building cost price of engineerings.

Hydrogeological phenomena can occur in the mine area:

+ Very popular weathering phenomena in the prospecting area are under the action of different weathering factors such as variability of temperature, effect of water and plants which are seen in almost all types of rocks in the area. Many properties of rocks are changed such as their composition, colour, physic – mechanic properties (at the mining pit, the thickness of weathered schist bed is 70-80m, partly thicker). Rocks were weathered to be friable, weakly cemented with bad loading capacity, that easily lead to slide of walls of mining pit.

+ Landslide, erosion are popularly observed at mountain slopes, road talus, mining pit edges, etc under the acting of rainy water.

+ Sand flow phenomenon can be seen in the stratum of tectonic activity, faulting that make rocks to be fractured, crushed leading to bad cementation under the action of underground water running into mining pit.

On the basis of geoengineering data, physic-mechanic properties of rocks, rocks and grounds (soil) in the mine area can be divided into 2 groups: group of weakly cemented rocks and grounds, and group of hardly consolidated rocks and grounds.

A- Group of weakly cemented rocks and grounds

Those are mainly in-situ weathering products derived from quartzite, quartz-sericite schist, intrusive magmatic rocks, forming sandy ground, loamy (light) sand, loamy clay, clay, etc which are concretely described through drill holes as follows:

1- Sandy ground, loamy sand bed

This is a weathering product of quartzite rock. The ground is light ash, yellow brown, partly violet. Its composition consists of fine-grained sand mixed with clayey powder, its cementation is weak, somewhere is desultory, it is easy to collapse and to wash out in water. The ground is relatively dry, average humidity is 12.90%; its specific gravity is 2.66 g/cm^3. its thickness measured at the bore hole LK1-T13 is from 0 to 23.2m; at the bore hole LK2-T16^A is from 0 to 39.5. Furthermore, at mountain ridge areas its thickness may be bigger, however, these sites have not been subjected to the survey and exploration, so the thickness then should be predicted to be of some tens metres to more than a hundred metres.

Two samples have been taken from this bed for determination of norms on grain composition, natural humidity and specific gravity of the ground. The results of analysis are as follows:

+ Grains of sizes 0.5 - 5mm occupy: 8.0-38.0% (average: 23%)

+ Grains of sizes 0.05-0.5mm occupy: 55.0-68.0% (average: 61.5%)

+ Grains of sizes 0.05-0.005mm occupy: 4.0-17.0% (average: 10.5%)

+ Grains of sizes <0,00mm occupy: 3.0-7.0% (average : 5%)

+ Average humidity: 12,9%

+ Average specific gravity: 2.66 g/cm^3

2. Loamy clay bed

This is a weathering product of quartz biotite schist. The rock is brown ash, yellow brown, violet brown, consisted of a group of clayey grains mixed with sandy powder. The rock is relatively dry, average humidity is 15.0%;

Natural density is 1.96 g/cm^3. Porosity is 38.69%, Plasticity index is 9.6%. Internal friction angle is 22^{o}23'. Adhesive power is 0.114. Weak cementation, in water it is easy to be swollen and caused strong collapse and slide.

The determined depth of this bed at bore hole LK1-T22 is from 5.6 to 15.1m; at bore hole LK1-T25^A is from 9.8 to 20.0m; at bore hole LK1-T26 is from 13.6 to 27.3m and from 28.1 to 43.3m. Furthermore, at unexplored places, the thickness is predicted to be of some tens metres to more than a hundred metres.

Table.5.7 – 1 : Physic mechanical norms of the loam layer

No	Physic mechanical norms	Index	Unit	Loam layer
I	**Values of standards**			
1	Natural humidity	W	%	□□□□
2	Natural density	□$_W$	g/cm^3	□□□□
3	Dry density	□$_c$	g/cm^3	□□□□
4	Specific gravity	□	g/cm^3	□□□□
5	Natural porosity ratio	□		□□□□□
6	Porosity	n	%	□□□□□
7	Saturation	G	%	□□□□□
8	Limit of viscosity	W_T	%	□□□□□
9	Limit of plasticity	W_P	%	□□□□□
10	Plasticity index	W_n	%	□□□□
11	Degree of pasty	B		□□
12	Internal friction angle	□$^□$	degree, minute	□□□□□□
13	Adhesive power	C		□□□□□
14	Coefficient of settlement compression	a	kg/cm^2	
	Level P 0-0,5 kg/cm^2		-----------	□□□□□
	Level P 0,5-1 kg/cm^2		-----------	□□□□□
	Level P 1-2 kg/cm^2		-----------	□□□□□
	Level P 2-3 kg/cm^2		-----------	□□□□□
	Level P 3-4 kg/cm^2		-----------	□□□□□
15	Modulus of total deformation	E	kg/cm^2	
	Level P 0-0,5 kg/cm^2		-----------	□□□
	Level P 0,5-1 kg/cm^2		-----------	□□□
	Level P 1-2 kg/cm^2		-----------	□□□
	Level P 2-3 kg/cm^2		-----------	□□□
	Level P 3-4 kg/cm^2		-----------	□□□

Only one infinitive sample was taken from this bed for determining all physic-mechanic properties (norms) of ground (rock). The results of analysis are as follows:

- ***Grain size portions***

+ Grains of sizes >5mm occupy: 21.0%
+ Grains of sizes 0.5 - 5mm occupy: 28.0%
+ Grains of sizes 0.05 -0.5mm occupy: 20,0%
+ Grains of sizes 0.05 -0.005mm occupy: 18,0%
+ Grains of sizes <0,00mm occupy: 13,0%

- Physic-mechanic norms *(See table **V.**10 -1)*

3- Gold-bearing loamy clay bed

This is a weathering product of quartz-sericite schist. There are some gold-bearing quartz veins intersected in this rock. The rock is brown ash, yellow brown, violet brown, consisting of a group of clayey grains mixed with sandy powder, quartz grit and gravel, etc. The rock is relatively dry, average humidity is 21.45%; Natural density is 1.92g/cm^3. Porosity is 42.13%, Plasticity index is 11.72%. Internal friction angle is 18^{o}02'. Adhesive power is 0.181. Weak cementation, in water it is easy to be swollen and caused strong collapse and slide.

Its thickness measured at the bore hole LK1-T18 is from 6.9 to 15.0m and from 15.8 to 25.8m. Furthermore, at the sites which have not been subjected to the survey and exploration, the thickness then should be predicted to be of some tens metres to more than a hundred metres.

6 infinitive samples have been taken from this bed for determining allround physic-mechanic properties (norms) of rock. The results of analysis are as follows:

- Grain size portions

+ Grains of sizes >5mm occupy: 0-14.0% (average: 5.5%)
+ Grains of sizes 0.5 - 5mm occupy: 14.0-77.0% (average: 28.83%)
+ Grains of sizes 0.05 -0.5mm occupy: 15.0-35.0% (average: 25.2%)
+ Grains of sizes 0.05 -0.005mm occupy: 3.0-30.0% (average: 20.2%)
+ Grains of sizes <0,00mm occupy: 1.0-30.0% (average: 20.3%)

- Physic-mechanic norms *(See table **V.**7 **- 2**)*

Table V.7 - 2: Physic mechanic norms of gold-bearing loam layer

No	Physic mechanical norms	Index	Unit	Gold-bearing Loam layer
I	**Values of standards**			
1	Natural humidity	W	%	□□□□□
2	Natural density	□$_W$	g/cm^3	□□□□
3	Dry density	□$_c$	g/cm^3	□□□□
4	Specific gravity	□	g/cm^3	□□□□
5	Natural porosity ratio	□		□□□□□
6	Porosity	n	%	□□□□□
7	Saturation	G	%	□□□□□
8	Limit of viscosity	W_T	%	□□□□□
9	Limit of plasticity	W_P	%	□□□□□
10	Plasticity index	W_n	%	□□□□□
11	Degree of pasty	B		□□□□
12	Internal friction angle	□$^□$	degree, minute	□□□□□
13	Adhesive power	C		□□□□□
14	Coefficient of settlement compression	a	kG/cm^2	
	Level P 0-0,5 kg/cm^2		-----------	□□□□□
	Level 0,5-1 kg/cm^2		-----------	□□□□□
	Level P 1-2 kg/cm^2		-----------	□□□□□
	Level P 2-3 kg/cm^2		-----------	□□□□□
	Level P 3-4 kg/cm^2		-----------	□□□□□
15	Modulus of total deformation	E	kG/cm^2	
	Level P 0-0,5 kg/cm^2		-----------	□□
	Level P 0,5-1 kg/cm^2		-----------	□□
	Level P 1-2 kg/cm^2		-----------	□□□
	Level P 2-3 kg/cm^2		-----------	□□□
	Level P 3-4 kg/cm^2		-----------	□□□
II	**Calculation values**			
16	***Bearing status***			
	Density	γ_1	G/cm^3	□□□□
	Internal friction angle	□$^□_□$	degree, minute	□□□□□□
	Adhesive power	C_1	kG/cm^2	□□□□□
17	***Deformational status***			
	Density	γ_2	G/cm^3	□□□□
	Internal friction angle	□$^□_□$	degree, minute	□□□□□□
	Adhesive power	C_2	kG/cm^2	□□□□□

4. Clayey bed

This is a weathering product of quartz-sericite schist. The rock is brown ash, yellow brown, violet brown, consisting of a group of clayey grains mixed with sandy powder. The rock is relatively dry, average humidity is 28.9%; Natural density is 1.94g/cm^3. Porosity is 44.84%, Plasticity index is 19.3%. Internal friction angle is 14^{o}38'. Adhesive power is 0.268. Weak cementation, in water it is easy to be swollen and caused strong collapse and slide.

Its thickness measured at the bore hole LK1-T26 is from 43.3 to 64.6m. Furthermore, at the sites which have not been subjected to the survey and exploration, the thickness then should be predicted to be of some tens metres to more than a hundred metres.

Only an infinitive sample has been taken from this bed for determining all physic-mechanic properties (norms) of rock. The results of analysis are as follows:

- ***Grain size portions***

+ Grains of sizes >5mm occupy: 43.0%

+ Grains of sizes 0.5 - 5mm occupy: 25.0%

+ Grains of sizes 0.05 -0.005mm occupy: 22.0%

+ Grains of sizes <0,00mm occupy: 10.0%

- ***Physic-mechanic norms*** *(See table **V.7 - 3**)*

Table V.7 – 3 : Physic-mechanical norms of clay layer

No	Physic mechanical norms	Index	Unit	Clay layer
I	**Values of standards**			
1	Natural humidity	W	%	□□□□□
2	Natural density	□$_W$	g/cm^3	□□□□
3	Dry density	□$_c$	g/cm^3	□□□□
4	Specific gravity	□	g/cm^3	□□□□
5	Natural porosity ratio	□		□□□□□
6	Porosity	n	%	□□□□□
7	Saturation	G	%	□□□□□
8	Limit of viscosity	W_T	%	□□□□□
9	Limit of plasticity	W_P	%	□□□□□
10	Plasticity index	W_n	%	□□□□□
11	Degree of pasty	B		□□□□
12	Internal friction angle	□$^□$	Degree, minute	□□□□□□□
13	Adhesive power	C		□□□□□
14	Coefficient of settlement compression	a	kG/cm^2	
	Level P 0-0.5 kg/cm^2		-----------	□□□□□
	Level P 0.5-1 kg/cm^2		-----------	□□□□□
	Level P 1-2 kg/cm^2		-----------	□□□□□
	Level P 2-3 kg/cm^2		-----------	□□□□□
	Level P 3-4 kg/cm^2		-----------	□□□□□
15	Modulus of total deformation	E	kG/cm^2	
	Level P 0-0,5 kg/cm^2		-----------	□□
	Level P 0,5-1 kg/cm^2		-----------	□□□
	Level P 1-2 kg/cm^2		-----------	□□□
	Level P 2-3 kg/cm^2		-----------	□□□
	Level P 3-4 kg/cm^2		-----------	□□□

B- Hard consolidate group

This group includes hard, thick-bedded quartzite rocks; thin-bedded, laminated clayey aleurolite, forming thick member, which was horny metamorphosed to form, in some places, quartz horn, biotitic horn. Sulfidic minerals such as fine-grained pyrite, pyrrhotine were contaminated in these horny formations; clayey schist, black thin-bedded schist bearing little graphite. This member was metamorphosed to form a member of greenized rocks consisting mainly of quartz and biotite. The rock is hard, melanocratic to brown black. Granite, granodiorite intrusive formations compose mainly of quartz, feldspar and a little of mica (biotite), the rock is melanocratic, fine-grained texture in the form of shallow intrusive, compact.

These rocks were described through exploration bore holes as follows:

1- Quartzite, horny schist and a member of greenized rocks

These rocks are mainly distributed in the central part and at the East of the area, forming a belt of sub-meridional direction. Absolute altitude of these rocks is from 1080 to 1267m. The relief is twisted, strongly dissected, vertical slopes, at some places the rocks were strongly weathered, forming cross and parallel fissures, with water, these rocks are easy to collapse and to slide along slopes. Unsteady standing large rocks are very dangerous for people, who work near these places (talus slopes at the mining pits and 5 points in the mine area). Petrographic composition is composed of quartzite, horny clayey schist, sandy gritstone, etc. Normal-to-fine-grained texture, fine-bedded massive structure.

11 samples (total 65 pieces) have been taken from the exploration bore holes. Samples were arranged to be taken at the depth of 20-100m in the hard rock layers intersected in between weathered quartz biotite schist. Their thickness varies from 0.1 to some metres. It was unknown at the more deeper parts, but their thickness may be of about some tens metres to some hundreds metres as well.

Please, see the analytical results of physic-mechanic norms in the table V.7 – 4.

Table V.7 – 4 : Physic mechanical norms of rocks

Physic mechanical norms	Unit	Schist	Quartzite
Saturated humidity W_H	%	0,42	0,401
Dry humidity W_o	%	0,326	0,308
Specific gravity P	g/cm^3	2,754	2,615
Saturated density Y_h	g/cm^3	2,695	2,553
Dry density Y_o	g/cm^3	2,706	2,563
Porosity r	%	1,738	1,984
Coefficient of softening K_m	%	1,002	1,014
Coefficient of quality K_{pc}	kG/cm^2	249,9	284,0
Saturated compressive strength σ_h	daN/cm^2	672,4	734,2
Dry compressive strength σ_o	daN/cm^2	671,5	724,9

Tensile strength	daN/cm^2	321,8	318,1
Degree of corrosion P (LosAngeles)	%	35,68	36,74

2. *Intrusive magmatic rocks*

Those rocks are distributed at the West, SW parts of the mine area, occupying an area of about 0.0998 km^2. The surface part was weathered to become clay, powder of brown, red brown, yellow ash colour, soft and friable structure with bad loading capacity. Weathering thickness is 13.0-20.0m (recorded at the geoengineering survey bore holes for plant construction). The lower part is consisted of hard rocks of white ash, spotted black colour ie, mainly granite and granodiorite. Petrographic composition includes mainly quartz, feldspar and a little of mica (biotite). The rocks are melanocratic, massive structure, fine-grained texture of shallow intrusion type. Their thickness has not been realized yet.

One sample (MS8) was taken from bore hole LK1-T.25 at the depth of 49-50m; other sample (MS15) including 4 pieces was taken from bore hole LK1-T27^A at the depth of 30-40m.

Please, see the analytical results of physic-mechanic norms in the table V.7 – 5.

Table V.7 – 5 : Physic mechanical norms of rocks

Physic mechanical norms	Unit	Granodiorite	Remarks
Saturated humidity W_H	%	0,485	
Dry humidity W_o	%	0,398	
Specific gravity P	g/cm^3	2,647	
Saturated density Y_h	g/cm^3	2,593	
Dry density Y_o	g/cm^3	2,604	
Porosity r	%	1,59	
Coefficient of softening K_m	%	1,018	
Coefficient of quality K_{pc}	kg/cm^2	235,1	
Saturated compressive strength σ_h	daN/cm^2	620,4	
Dry compressive strength σ_o	daN/cm^2	609,1	
Tensile strength	daN/cm^2	307,6	
Degree of corrosion P (LosAngeles)	%	34,83	

V.8. Dipping angle estimation of the mining pit edge

The mining pit is mainly made of weathering product of the quartzite, quartz sericite schist. These rocks are bad in homogenous petrographic composition, weak in mechanic strength, fracture zones are disorderly developed. So far, during the mining activity, local landslide can be occurred to make mining pit edge unstable.

On the basis of analytical results of rock physic-mechanic properties, the dipping angle of mining pit edge can be calculated by the formula:

$$tg\,\alpha = \frac{tg\,\varphi}{\eta} + \frac{\lambda.c}{\gamma.H}$$

Where:

α - Predicted dipping angle of the mining pit edge

φ - Internal friction angle

C- Adhesive power (T/m^2)

γ - Natural density (T/m^3)

H- Height of slope, given 50.0m

η - Safety coefficient given 1.2

λ - Softness coefficient of rock given 0.5

Table V.8 – 1 :Results of calculating dipping angles of mining pit edge for layers of weakly consolidated group

Parameters for calculation	Loam layer	Gold-bearing loam layer	Clay layer
Natural density γ (T/m^3)	1.96	1.92	1.94
Adhesive power C (T/m^2)	1.14	1.81	2.68
Internal friction angle φ	22°23'	18°02'	14°38'
Height of slope H (m)	50	50	50
Coefficient of safety	1.2	1.2	1.2
Coefficient of softness of rock	0.5	0.5	0.5
Dipping angle of mining pit edge α	**19°14'**	**15°39'**	**12°57'**

In short:

+ Basically, the results of hydrogeological-geoengineering study have satisfied requirements of the mining design.

+ Mining pit with calculated dipping angle of (mining) pit edge as above-mentioned.

+ Pit edge should be opened at the West with favourable water discharge system and good dumping ground.

+ It is necessary to get additional investment in exploration on possibility of water supply for social needs in the mine.

* ***During the mining operation, attention should be paid to:***

- Landslide, which occurs easily at the on-going mining pit edge caused by that the pit edge is vertical, high, consisting of soft and unstable ground layers.

- Landslide, which occurs easily at the dumping ground (the mine under operation) caused by dip mountain slopes, great volume of waste ground, soft, badly cemented and unstable ground. Do not allow people going or working under hill feed, where on the hill locates dumping ground in order to avoid serious consequences, especially under hard raining, etc.

- Stone running down or landslide from vertical rocky crags in some places in the exploration area.