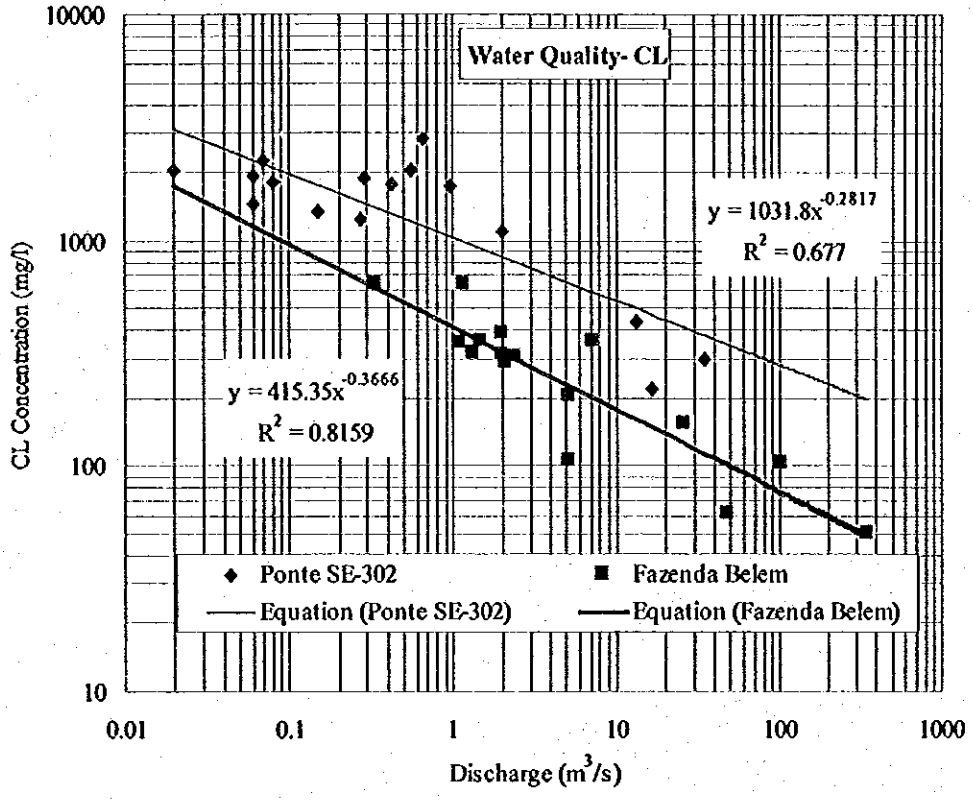
# CHAPTER 2 ANALYSIS OF CURRENT WATER QUALITY BEHAVIOR IN VAZA BARRIS RIVER

In the parameters that were observed in Vaza Barris River, Chlorine (Cl) concentration is high and critical for potable water, as well as Electric Conductivity (EC), Sodium (Na), Magnesium (Mg), Calcium (Ca), Carbonic Acid ($HCO_3$) and pH Value (pH) are important for irrigation planning. The relationship between river flow and the said water quality parameters were established at Ponte SE-302 and Fazenda Belem, showing Figure-2.1 and Figure-2.2. Besides, the correlation between EC and Na/Mg/Ca/Cl were studied, based on the water quality data at the both observation stations and are shown in Figure-2.4.

These figures characterize water quality in Vaza Barris River as follows:

1) The most important parameters of Cl and EC have strong relationship with river flow, presenting less concentration of Cl and EC while the larger river flow.
2) Na, Mg and Ca also present the same tendency of relationship with river flow as Cl and EC.
3) EC and Na/Mg/Ca/Cl are found to have good correlation.
4) It is found that $HCO_3$ has no relationship with river flow, while the range of $HCO_3$ is from 26 mg/l to 184 mg/l (average: 103 mg/l) at Ponte SE-302 and is from 51 mg/l to 146 mg/l (average: 109 mg/l). No differences are found between Ponte SE-302 and Fazenda Belem.
5) It is found that pH has no relationship with river flow, while the range of pH is from 6.9 to 8.3 (average: 7.5) at Ponte SE-302 and is from 7.2 to 8.4 (average: 7.6). No differences are found between Ponte SE-302 and Fazenda Belem.

However, it is noted that water quality data in Vaza Barris River is not yet enough to understand the water quality behavior. It is needed to continue observation of water quality such as the said parameters not only at the existing observation stations bat also at the proposed dam site and the check dam site.



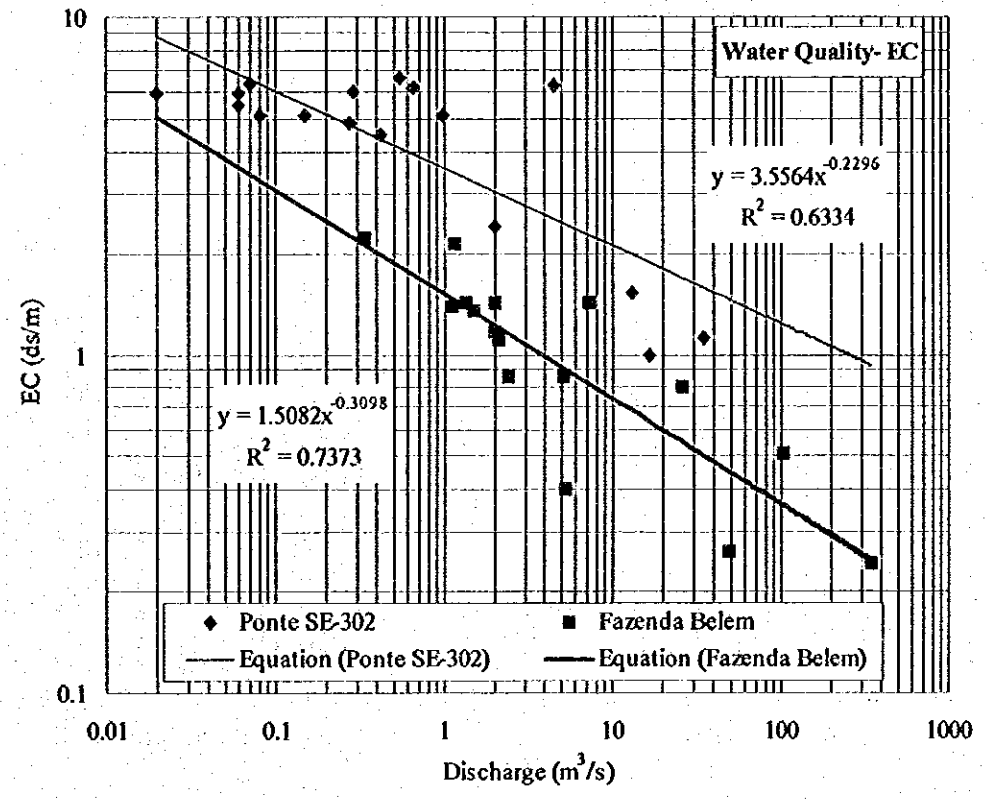




**Figure-2.1 Relationship between Cl Concentration / EC and River Flow**

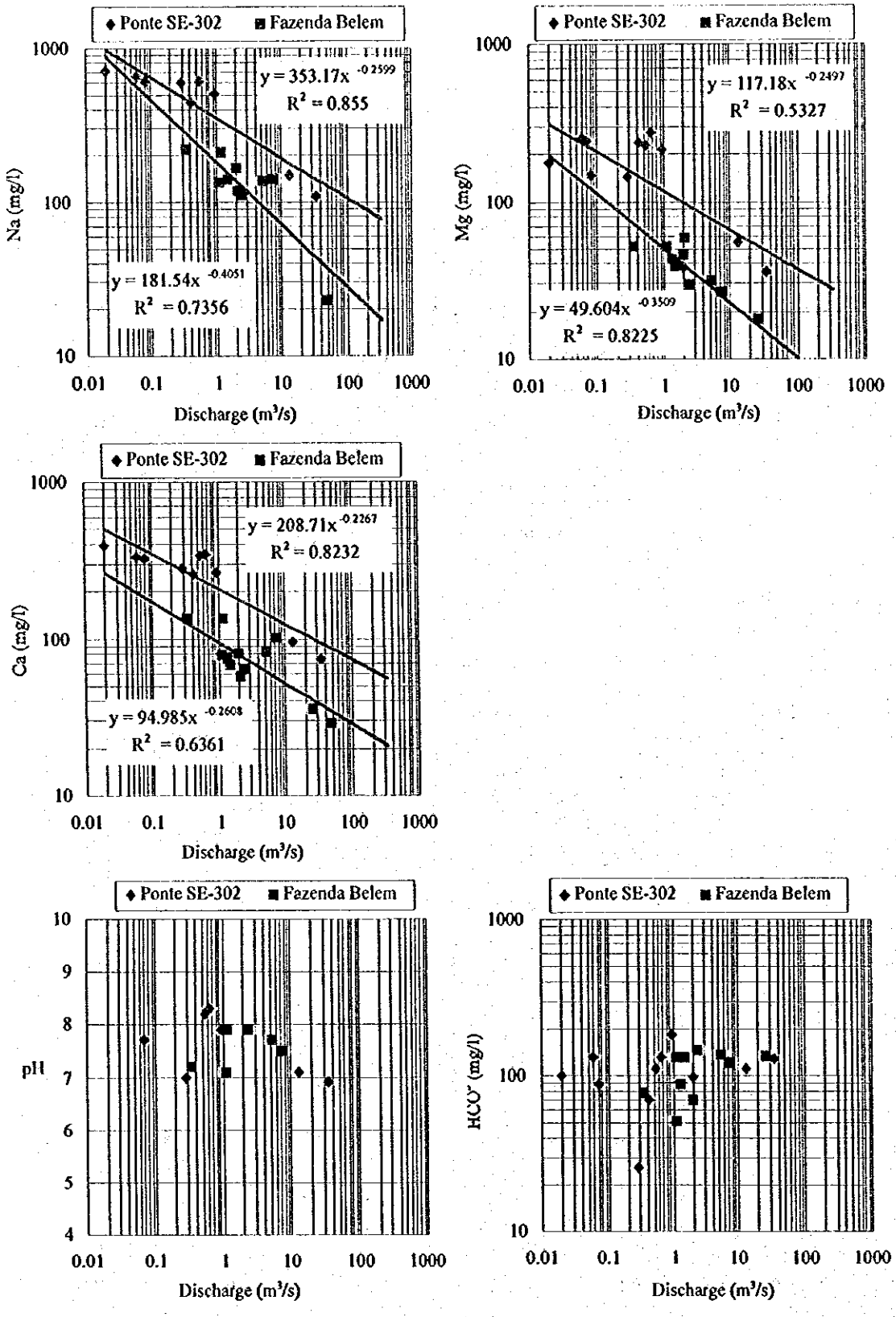



**Figure-2.2 Relationship between Na/Mg/Ca/$HCO_3$/pH and River Flow**

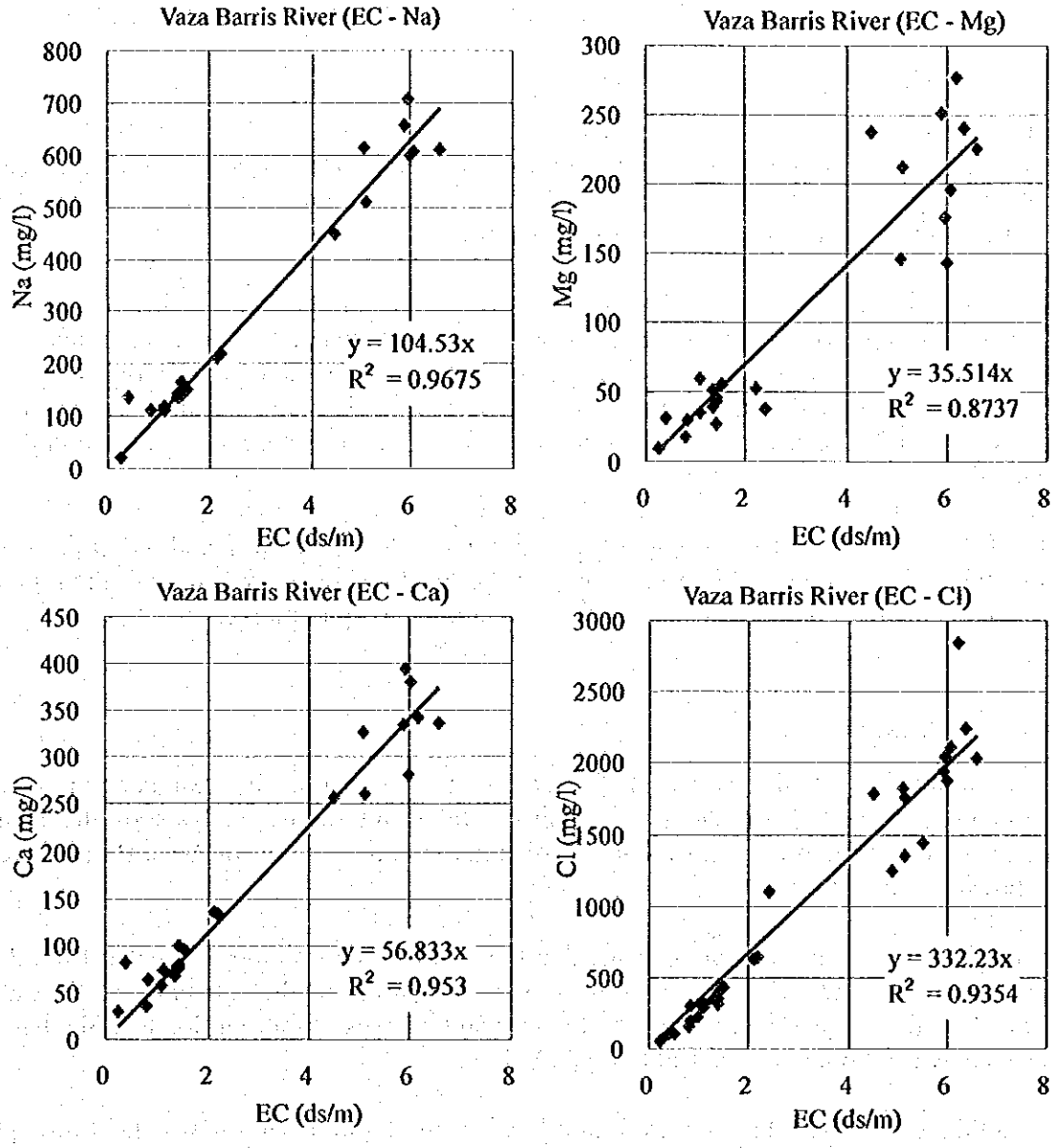



**Figure-2.4 Correlation between EC and Na/Mg/Ca/Cl**

# CHAPTER 3 ANALYSIS OF FUTURE WATER QUALITY BEHAVIOR IN VAZA BARRIS DAM RESERVOIR

## 3.1 Possible Impacts of Agrotoxics

Some irrigation projects have been developed at the region of Canudos in the upstream of Vaza Barris River in Bahia State, using water from Cocorobo Dam. Recent commercialized agrotoxics types present the tendency to use more and more property with lower toxicity and susceptibility for decomposition by solar energy.

There is not disposal any useful data at the present moment about the real applied types and quantity of agrotoxics at that region. However, in the viewpoint of long watercourse of Vaza Barris River as well as the bypass system that should be adopted to avoid the great part of water originated from the upper semi-arid region to discharge out of the reservoir, it is reasonable to consider that the agrotoxics effects on the future reservoir would be practically null.

It must be stood out that as one of the provision to prevention and control, it is recommendable to propose the discussion with the local authority, even though the region does not belong to Sergipe State, basing on the federal water pollution control laws.

## 3.2 Eutrophication

The accumulation of the water in the reservoir may cause the exaggerated algae proliferation, depending on the water quality. The result of the analysis of the main parameters regarding to nutrients (N and P) obtained at three stations on Vaza Barris River are shown in Table-3.1.

The results inserted in this table indicate that the nutrient contribution originated from the upper basin at Ponte SE-302 is very restricted, comparing to that obtained at Fazenda Belem. This fact suggests an existence of significant sources of nutrient loads in the basin situated between Ponte SE-302 and Fazenda Belem.

The simulation of eutrophication evolution level in the future reservoir was held through Vollenweider model that is known it is representatively of eutrophication phenomenon related as follow.

$$P_X = \frac{P_{IN}}{Z/T_W(1+2\cdot T_W)}$$

Where,

$P_X$: Total Phosphorous average concentration in reservoir (mg/l)
$P_{IN}$: Average concentration of total phosphorous in affluent (mg/l)
$Z$: Average depth (m)
$T_W$: Detention time (year)

$$CHL-a = 0.28\cdot P_X{}^{0.90}$$

Where,

*CHL-a*: Chlorophyll-a concentration (mg/m$^3$)
*PX*: Average Total Phosphorous concentration (mg/m$^3$)

**Table-3.1 Results of Nutrients Analyses in Vaza Barris River**

| Parameters \ Sampling Date | | April 7th | April 13th | April 20th |
|---|---|---|---|---|
| **Ponte SE-302 Station** | | | | |
| Org. N | mg/l | 0.5 | 0.3 | 0.2 |
| $NH_4$-N | mg/l | 0.019 | 0.009 | 0.055 |
| $NO_3$-N | mg/l | ND | ND | ND |
| $NO_2$-N | mg/l | 0.001 | trace | trace |
| Total P | mg/l | 0.052 | 0.06 | 0.05 |
| $PO_4$-P | mg/l | 0.002 | 0.005 | ND |
| Flow | $m^3/s$ | 0.06 | 0.07 | 0.06 |
| Total P flux | kg/d | 0.27 | 0.363 | 0.259 |
| Total N flux | kg/d | 2.592 | 1.814 | 1.21 |
| **Sao Domingos Station** | | | | |
| Org. N | mg/l | 0.4 | 0.2 | 0.5 |
| $NH_4$-N | mg/l | 0.03 | 0.008 | 0.048 |
| $NO_3$-N | mg/l | ND | ND | 0.03 |
| $NO_2$-N | mg/l | trace | 0.003 | trace |
| Total P | mg/l | 0.076 | 0.02 | 0.15 |
| $PO_4$-P | mg/l | 0.002 | ND | ND |
| **Fazenda Belem Station** | | | | |
| Org. N | mg/l | 0.5 | 0.4 | 0.3 |
| $NH_4$-N | mg/l | 0.018 | 0.011 | 0.046 |
| $NO_3$-N | mg/l | ND | ND | 0.02 |
| $NO_2$-N | mg/l | 0.004 | 0.001 | trace |
| Total P | mg/l | 0.043 | 0.1 | 0.039 |
| $PO_4$-P | mg/l | 0.014 | 0.005 | ND |
| Flow | $m^3/s$ | 1.5 | 1.3 | 1.2 |
| Total P flux | kg/d | 5.57 | 11.23 | 40.44 |
| Total N flux | kg/d | 64.8 | 44.93 | 33.18 |

According to simulation performed based on the data obtained at Fazenda Belem station and equations above referred, the trophic level predicted for Vaza Barris Dam reservoir would correspond to the range of oligotrophic stage as can be seen in Table-3.2 where shows comparison of trophic level criterion. This simulated trophic category would not constitute any problems to multiple use of future Vaza Barris Dam reservoir.

**Table-3.2 Proposed Criterion of Trophic Category (Vollenweider, 1983)**

| Trophic Category | Average TP (mg/l) | Average Chlorophyll-a ($mg/m^3$) |
|---|---|---|
| Ultra-oligotrophic | < 4.0 | 1.0- 2.5 |
| Oligotrophic | < 10.0 | 2.5- 8.5 |
| Mesotrophic | 10.0- 35.0 | 8.5- 25.0 |
| Eutrophic | 35.0- 100.0 | 25.0- 75.0 |
| Hipertrophic | > 100.0 | > 75.0 |
| Vaza Barris reservoir | 6.0 | 1.6 |

It must be pointed out, however, that the domestic sewage of municipalities as well as the diffuse pollution found in Vaza Barris drainage basin could constitute an important source of eutrophication, requiring the implantation of the adequate treatment plants for mitigation of these pollution loads.

The decree-law CONAMA 20 that establishes the classification of water system on the Brazilian territory prohibits discharge of any type of sewage into the water basin where exists drinking water facilities.

### 3.3 Water Color of the Reservoir

The water originated from the upstream of the basin presents normally good transparence without any objectionable color. Significant watercolor appears only after the rainfall that brings the soil erosion materials constituted mainly micro particles, colloidal form of soil and some part of the humic substances with brown color. The great part of these materials loose rapidly into the water body owning to precipitation process when water remains quiet in the reservoir even if some of dissolved substances stay for a long period. Although depending on the verification of the water characteristics, the color products in the future reservoir could not attain any harmful level for water use.

JAPAN INTERNATIONAL COOPERATION AGENCY

STATE SECRETARIAT OF PLANNING, SCIENCE AND TECHNOLOGY
THE STATE OF SERGIPE, THE FEDERATIVE REPUBLIC OF BRAZIL

# THE STUDY
# ON
# WATER RESOURCES DEVELOPMENT
# IN THE STATE OF SERGIPE
# IN
# THE FEDERATIVE REPUBLIC OF BRAZIL

## FINAL REPORT
## SUPPORTING
## (VOLUME II)
## FEASIBILITY STUDY

## [D] DAM GEOLOGY

MARCH 2000

YACHIYO ENGINEERING CO., LTD. (YEC)

THE STUDY ON WATER RESOURCES DEVELOPMENT
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SUPPORTING REPORT (D)
DAM GEOLOGY

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# CHAPTER 1 GEOLOGICAL SURVEY

The geological survey was carried out to obtain geological date for design of Vaza Barris Dam. The geological survey consists of two parts as listed below;

1) Preliminary geological survey to select sites for a dam and appurtenant facilities, and a site for dam materials.
2) Detailed geological survey to get geological data for design of a dam and appurtenant facilities.

The content of the geological survey and its result are described below.

## 1.1 Preliminary Geological Survey

### (1) Purpose of Preliminary Geological Survey

The purpose of this survey is to select sites for a dam and appurtenant facilities, and site for dam materials. Based on the preliminary geological survey, the locations of the detailed geological survey were decided. The preliminary geological survey area was located in the middle stream of Vaza Barris River. In the preliminary geological survey, locations listed below were examined.

- Vaza Barris dam site
- Spillway site
- Check dam site
- Dam material site

### (2) Content of Preliminary Geological Survey

Content of the preliminary geological survey is as follows,

- Aerial photograph interpretation
- Field geological reconnaissance

The Study area were investigated by aerial photograph interpretation. By this investigation, outline of landform and geology of the Study area were made clear. Field geological reconnaissance was also carried out. By this field survey, rock quality, weathering condition and geological stricture of the Study area were made clear.

### (3) Result of Preliminary Geological Survey

Based on the results of the preliminary geological survey, the suitable construction sites for a dam and its appurtenant facilities were selected. The process of the sites selection is explained in detail in Chapter 2 of this Report. Summary of the preliminary geological survey is described below.

#### (a) Topography of Vaza Barris Basin

The Vaza Barris river system has its source further upstream of the State of Bahia, and its lower section flows eastward to south-eastward through the State of Sergipe. At the west of

the city of Sao Domingo, two large tributaries of the Jacare river and the Salgado join the main stream of the Vaza Barris river which flows Northwest to south-east, one from the west and another from the north. As far as this confluence, drainage pattern shows reticular characteristics which reflects relatively soft geological features, on the other hand, down to the confluence, the river system shows a poor development. This is due to the existence of rigid rocks of the Itabaiana Dome and dominant deposits of Tertiary system. Thus, the Vaza Barris river flows in rather a narrow valley dissected within a peneplain. Several kilometres under the study area, the valley becomes wide, running through Tertiary or Quaternary deposits with some minor outcrops of underlying Mesozoic strata.

The Study area consists of a landform of peneplain, namely, flat tablelands and narrow valleys intersecting the tablelands with meanders controlled by pre-existing geological structures. In fact, several levels of peneplains are arranged like river terraces. Near the proposed dam site, peneplains with the levels of 120 m, 90 m and 70 m can be identified.

The valley of the Vaza Barris River shows typical rectangular intrenched meanders, of which, NW to SE sections coincide almost to structural lineaments and geological boundaries or schistosities, and NE to SW sections coincide almost to another fault system.

Hill slope of the future reservoir is rather steep forming a gorge with some widening formed at confluence points with its tributaries. The future reservoir will have, therefore, quite an elongated form.

### (b) Geology of Vaza Barris Basin

This area is mainly consisted of Precambrian metamorphic rocks. The Itabaiana Dome, located at the north to the Vaza Barris river, is one of the oldest rocks in the world, is gneiss to migmatite of Archaean system in the core, and metamorphic phyllitic rocks of Archaean system surrounding the core. Just above the core, a thick layer of quartzite forms a distinct dome or cuesta showing relative strength against erosion compared with gneiss. To the west and north of the above-mentioned confluence, arenaceous, pelitic to calcareous phyllitic rocks are dominant, and the bottom of the valley of the Vaza Barris river is in the same condition.

The course of the lower Vaza Barris river and the Jacare river coincides with the trace of the Vaza Barris Fault. This is a large-scale thrust fault, separating gneissose member and phyllitic member within the Brazil Craton.

The Tertiary deposits are mainly seen in the south of the Vaza Barris river. This is unconsolidated gravel to lateritic soils, covering the basement in a thin sub-horizontal layer.

The quaternary sediments are seen at the bottom of the valley of the Vaza Barris river in a form of unconsolidated mud and sand, and increasing its thickness toward the downstream, especially from the boundary of metamorphic rocks and Mesozoic deposits lying just near to the proposed dam site.

## 1.2 Detailed Geological Survey

### (1) Purpose of Detailed Geological Survey

The purpose of detailed geological survey was to obtain geological data for a dam design. This survey was carried out in the sites for the dam and its appurtenance facilities.

### (2) Content of Detailed Geological Survey

Based on the preliminary survey, eight (8) drilling along the proposed dam site (see Figure-1.2), one (1) at a tentative spillway site (see Figure-1.2) and one (1) at a check dam site, were executed as shown Table-1.1. The drilling equipment employed was the rotary boring machine. Also, Lugeon Test was executed to make clear of a permeability of rock foundations.

**Table-1.1 Content of Detailed Geological Survey**

| Location | Number of Drill hole | Elevation (m) | Total depth (m) | Lugeon test (num.) | Groundwater level obs. |
|---|---|---|---|---|---|
| Dam site | BR-1 | 67.95 | 45.00 | 7 | O |
| | BR-2 | 62.91 | 45.00 | 5 | O |
| | BR-3 | 61.02 | 50.00 | 7 | O |
| | BR-4 | 29.97 | 50.00 | 6 | × |
| | BR-5 | 62.86 | 55.00 | 9 | O |
| | BR-6 | 31.40 | 55.00 | 8 | × |
| | BR-7 | 30.30 | 55.00 | 8 | × |
| | BR-8 | 29.57 | 50.00 | 8 | × |
| Spillway | BR-9 | 67.70 | 20.00 | - | × |
| Check dam | BR-10 | 53.33 | 35.00 | 5 | × |
| Total | — | — | 460.00 | 63 | — |

Note: O Groundwater level observation was be installed.
× Groundwater level observation was not installed.

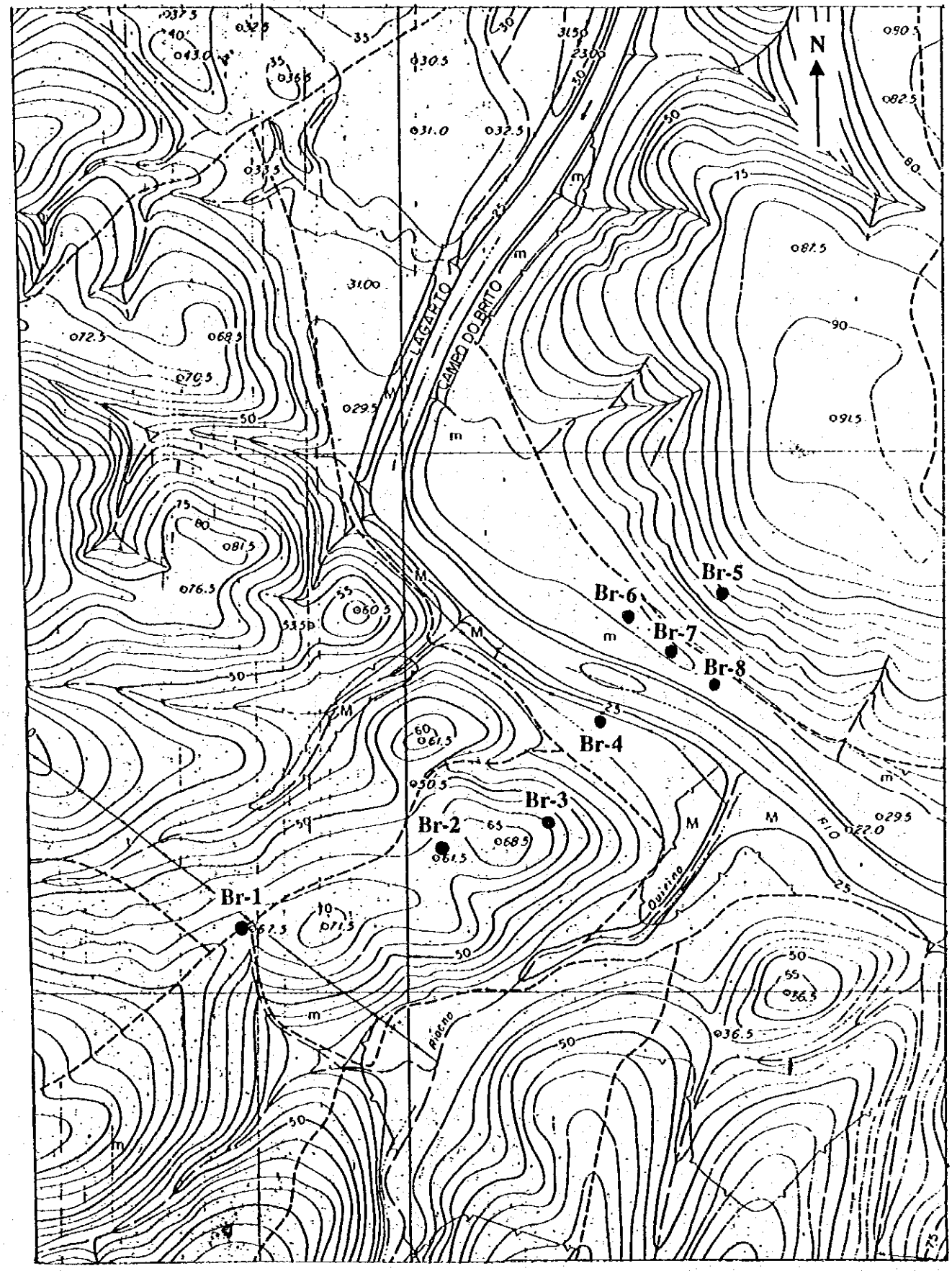



**Figure-1.1 Boring Point in Dam Site**

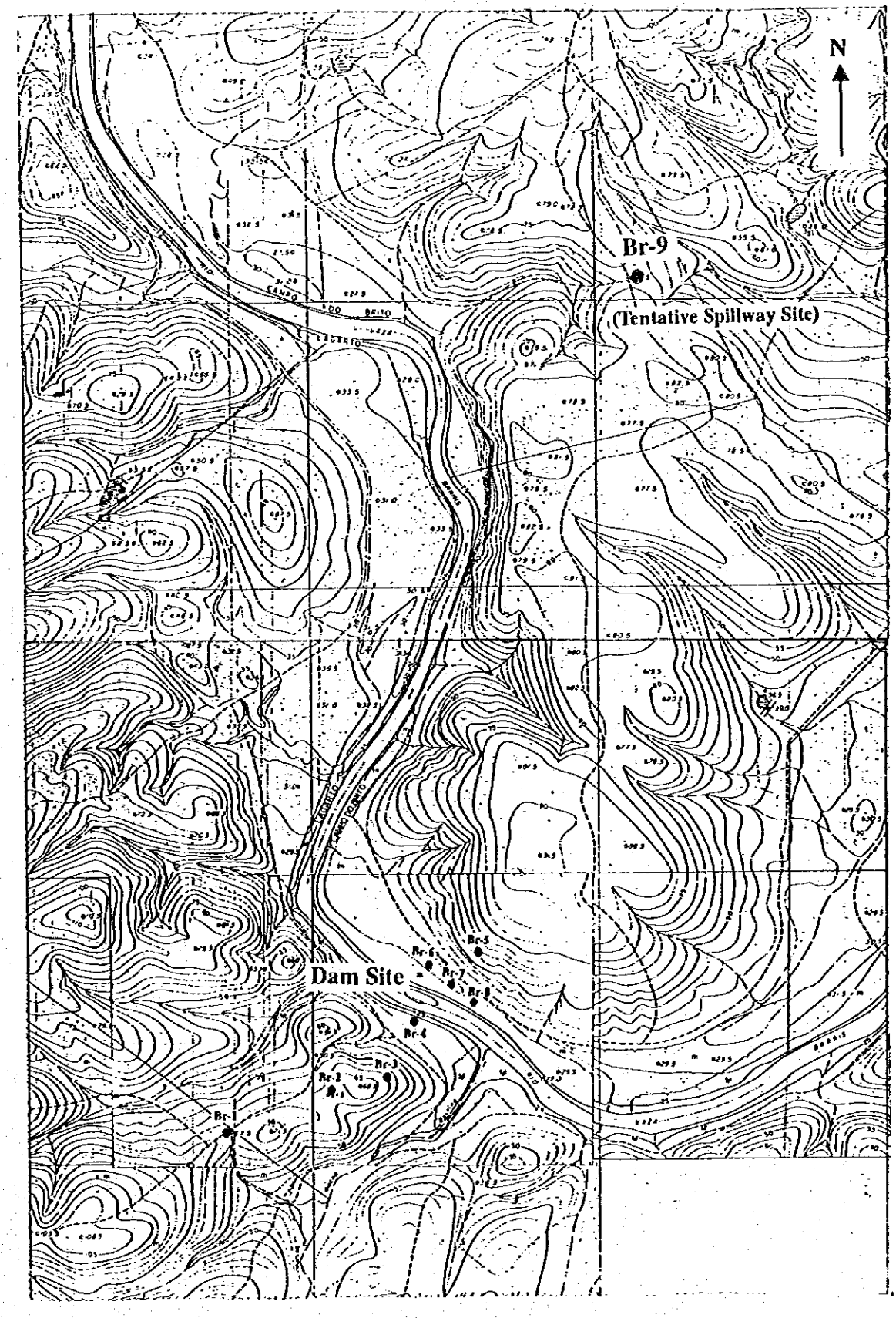



**Figure-1.2 Boring Point of Tentative Spillway Site**

## (3) Result of Detailed Geological Survey

### Result of boring

Results of the borings, Br-1 to Br-10, were shown in Figure-2.2 and 2.3.

In all the boring points, meta-phyllite of various weathering condition were taken as core samples. Other than meta-phyllite, alluvial sand, clay and gravel were taken as core samples where boring points were located in alluvial terraces. The geological condition made clear by the boring survey is explained in detail in Chapter 2 of this Report.

### Result of Lugeon Test

The Lugeon Tests were performed in the rock parts of boreholes every 5 m in the direction of the depth. In each borehole, the Lugeon Tests were commenced at the depth where rock was hard enough to perform the test. The results of the Lugeon Tests are shown in Figure-2.2 and 2.3. As shown in the figures, phyllite in the dam site is almost impermeable at the depth of more than 10 m. On the other hand, the phyllite is slightly permeable at the depth of less than 10 m.

### Groundwater level

Groundwater level was observed in the groundwater observation wells of Br-1,2,3,5. The result of the observation is shown in Figure-1.3. In this Figure, groundwater level of the other boreholes during the drilling period are also shown.

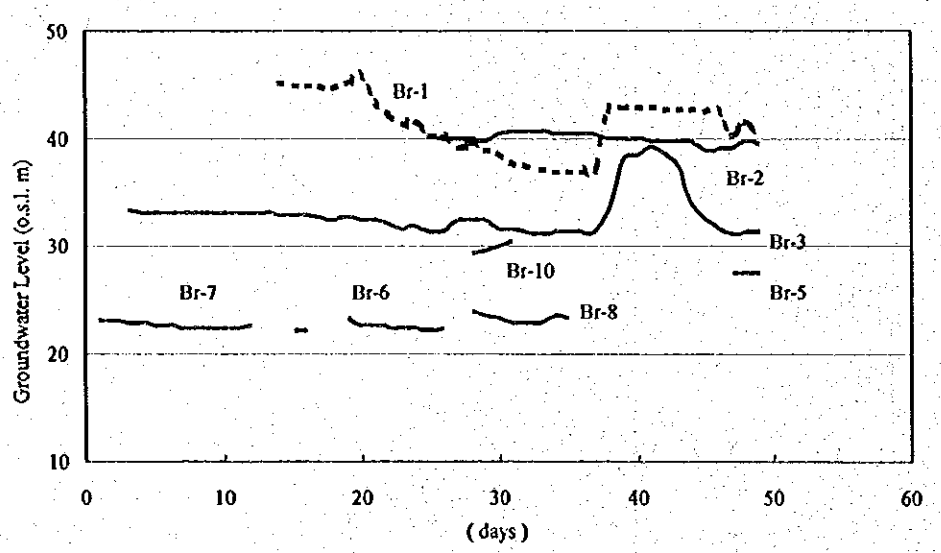



**Figure-1.3 Groundwater Level of Boreholes in Vaza Barris Dam Site**

# CHAPTER 2 Geotechnical Characteristics of Vaza Barris Dam Site

## 2.1 Topography and Geology of Vaza Barris Dam Area

### (1) Topography and Geology of Vaza Barris Dam Site

#### (a) Topography of Proposed Dam Site

The watercourse of the Vaza Barris River at the proposed dam site is located at a top of an arc, whose tangent coincides almost with a direction of NW to SE, this direction is in accordance with the general trend of this large area of western Sergipe. There can be seen some outcrops along the watercourse, but they are quite sporadic and hill slope is also covered with weathered materials. Although it is relatively thin and suggests an existence of rock body near to surface, rock scarcely appears in the ground surface. The altitude of the site is about 22 m at the river bed. Several lineaments parallel to this direction can be seen, e. g. cols existing southwestern of the proposed dam site and others. Small valleys dissecting almost perpendicular to the general direction exist on the right bank with an interval of 300 m. Whereas, the left valley is almost smooth in shape. There valleys running parallel each other at an interval of 300 m may act as a deep seepage conduit as commented below.

#### (b) Geology of Proposed Dam Site

Geology of projected dam site is summarized as explained below.

<u>Geological situation</u>

Geology of proposed dam site mainly consists of meta-phyllite (this naming is according to that of the Ministerio das Minas e Energia, and this report use the same expression, schist or phyllite may be sufficient as an ordinary nomination) of Proterozoic system, with the direction of around N45-60W and the dip of 70-80NE. These metamorphic rocks distribute surrounding a core of migmatite of the Itabaiana Dome, one of the oldest rocks of the Brazilian Craton, and incline towards the outer rim of the basin. Migmatites of the Itabaiana Dome is relatively suffered erosion, and relatively hard outer quartzite configures a landform like a caldera.

<u>Rock quality</u>

In the proposed dam site, the meta-phyllite is an alternance of psammitic schist and pelitic schist, severely weathered along slightly-opened planes of schistosity, which enables penetration of alteration into rock-forming minerals such as micas (muscovite) or feldspars (plagioclase).

<u>Geological structure</u>

The direction of schistosity is also parallel to the regional geological structure, which includes ordinary reverse faults and regional thrusts of large scale (called the Falha de Itaporanga, approximately a northeastward thrust upstream of the dam site and a simple reverse fault downstream). Though the precise structure has not been made clear, such important structures involving large fractured zone or altered zones are not found in the proposed dam site area. Nevertheless, weathering of the rock is very strong and deep at the area of meta-phyllite, due to its steep dip which enables water to penetrate or separate the rock into fragments along planes of schistosity.

**Tertiary**

On the higher peneplain, it was reported an existence of unconsolidated Tertiary sedimentary rocks, but in this area, it is a kind of loose conglomerate to gravel layer just alike a terrace deposit. Its thickness is estimated to have an order of 10 m .

## 2.2 Dam Site Selection

In the survey area of the Vaza Barris Valley, the general trend of geology is approximately NW to EW, and there is no distinct difference of trend within the site. The possible dam sites must be chosen under some criteria (narrow river valley, appropriate steep of valley slope, not lying over large lineament or fault line, etc.), from technological point of view. To minimize the dam volume while maintaining the required storage volume, site selection must be based on a comparison of storage volume – dam height relation diagram (H-V curve). Figure-2.1 shows the proposed dam site and the alternatives.

As for position of a dam site, the necessary reservoir capacity must be secured at the minimum height and volume of the dam body. That is, in short, dam site selection is a matter of reservoir site hunting. From this view of point, there are two constraints, namely, i) up to about a dozen km northwest of Itaporanga, the Vaza Barris River has a wide valley and a thick alluvial deposit; ii) on the upstream of the confluence with a straight valley coming down from an adjacent of the town of Sao Domingo, the valley of the Vaza Barris River is quite narrow with steep valley walls and is having no wide portion suitable for the reservoir. After the consideration above, finally four sites were selected as mentioned below (see Figure-2.1) :

**Alternative A**

Alternative A is located near the lowest part of the area above mentioned, on a section of meridional direction, is considered to be overlying an supposed prolongation of a distinct sheared zone on a geological document, and needs precise survey previous to any reservoir planning. The survey, however, seems somehow time-consuming, and this site is judged to be insufficient for this project.

**Alternative B**

Alternative B is located at about 2 km upstream of the proposed dam site, this site also has a fair landform, but it overlies an distinct lineament which suggests also an large structural accident nothing but a existence of fracturation. Thus, this site must be avoided.

**Alternative C**

Alternative C is on the almost same circumstance as the alternative B.

**Proposed Dam site**

The proposed dam site has rather narrow ridge in its right slope, but this site can avoid a clear lineament, and can choose some little modifications of its final setting. Near the river bed, the recent river deposit has rather thickness to conceal almost all the features of geological conditions, especially just under the watercourse and adjacent lowest terrace. Nonetheless, some rock outcrops are still visible here and there at a brink, this suggests an irregularity of underground rock surface.

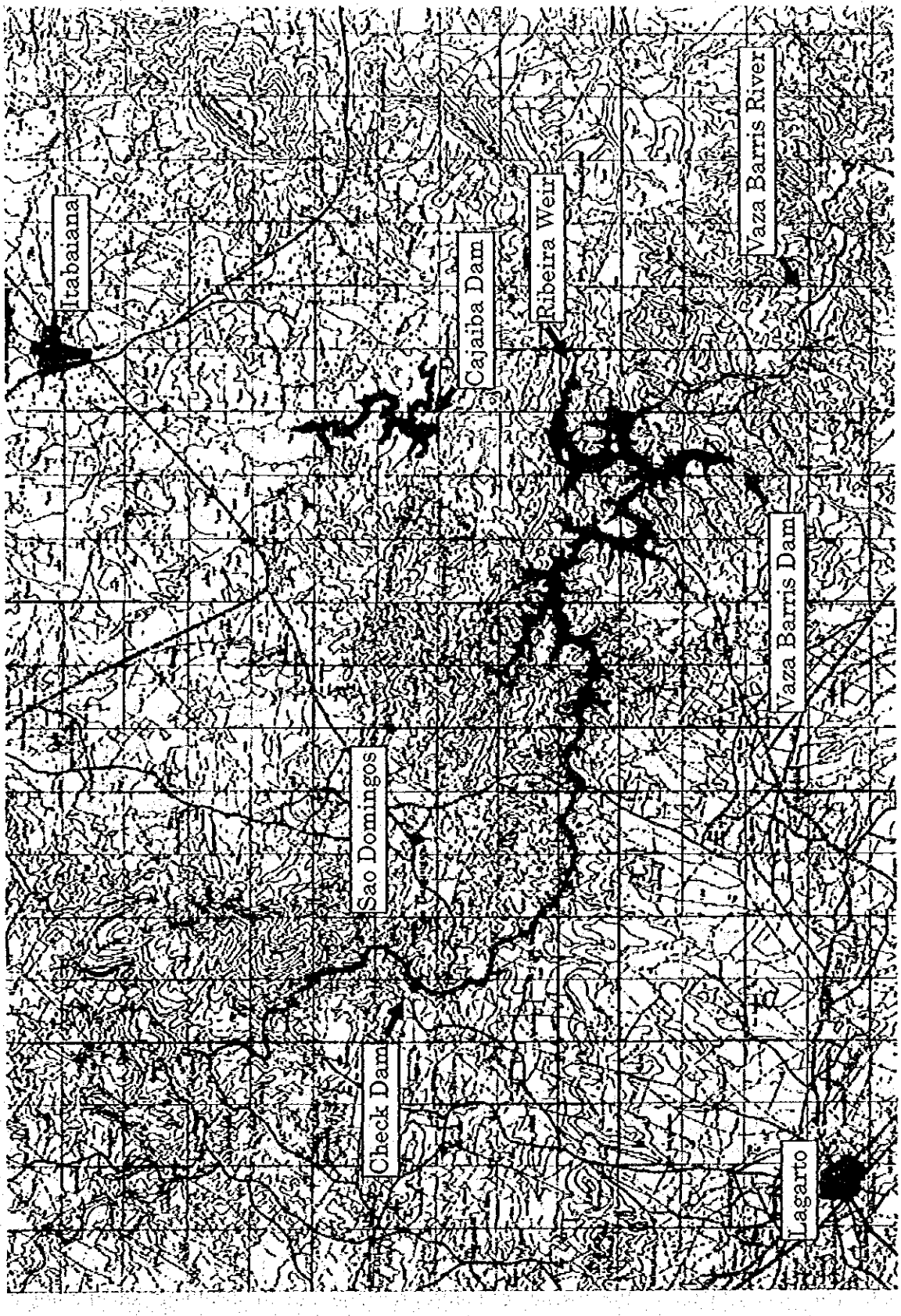



Figure-2.1 Possible Dam Sites and Its Selection

## 2.3 Dam Site

Based on the result of the boring survey, rock classification was carried out. The result of rock classification for all the boring points are shown in Figure-2.2 and 2.3, and rock classification section map for the dam site is shown in Figure-2.4. The rock classification is necessary for the evaluation of foundation of the dam. The evaluation of foundation of the dam is based on the criterion adopted by the Ministry of Construction of the Japanese Government, and the detail is shown in APPENDIX of this Report.

According to the field excursion and the borings, the main geological features of the dam site are as follows:

### (1) Rock quality and rock mass classification

Rock quality and rock mass classification of rock foundation of the Vaza Barris Dam are summarized as listed below;

- This site consists of highly weathered rocks at the surface part.
- Assumed rock surface may have an irregular form.
- Rock itself is quite hard and stiff if sound, its deterioration is caused mainly by weathering and shearing (maybe faults sub-parallel to bedding plane and schistosity). Whereas the former is universal along its surface, the latter is quite restricted along sporadic zones.
- Rock body at the dam site consists of deeply-penetrated weathered rocks. But the weathered zone is somehow shallow at the river floor (see Figure-2.4), and extends flat or in a lower gradient than that of hill slope into the ground (see Figure-2.4), namely, the boundary between weathered / sound rocks does not rise proportionally to the hill slope (see Figure-2.4).
- On the valley wall, the weathered zone is rather thin compared with hill-slope, therefore, sound rock ($C_M$ or $C_H$) can be found just under the river bed sediments with a intervention of thin layer of rock of low grade ($C_L$).
- On both hill slopes, rock of low grade extends into the abutments in a low gradient corresponding to the lower boundary of weathered zone. This means that rock of low grade ($C_L$) is relatively thick at the abutments, and sound rock cannot be found until at the depth of about 20 m. This tendency is more remarkable in the right bank than in the left bank.

### (2) Pervious Zone

Pervious zone is limited to the ground surface and mainly at less than 10 m of depth, and any highly pervious zone at more than 10 m of depth has not been encountered, this means that any deep conduits can not exist.

### (3) Groundwater Level

Groundwater level is considerably low on both abutments, this is considered to show the deepness of weathering front (that is, the surface of intact rock is fairly flat compared with the relief of dam site).

### (4) Groundwater Recharge

As mentioned above, groundwater level is low and flat compared with the relief of the dam site. This is considered as the absence of natural recharge due to absolutely small amount of effective precipitation (= precipitation – evapo·transpiration) and small mountain bodies in size to receive underground supply from region of higher hydraulic potential.

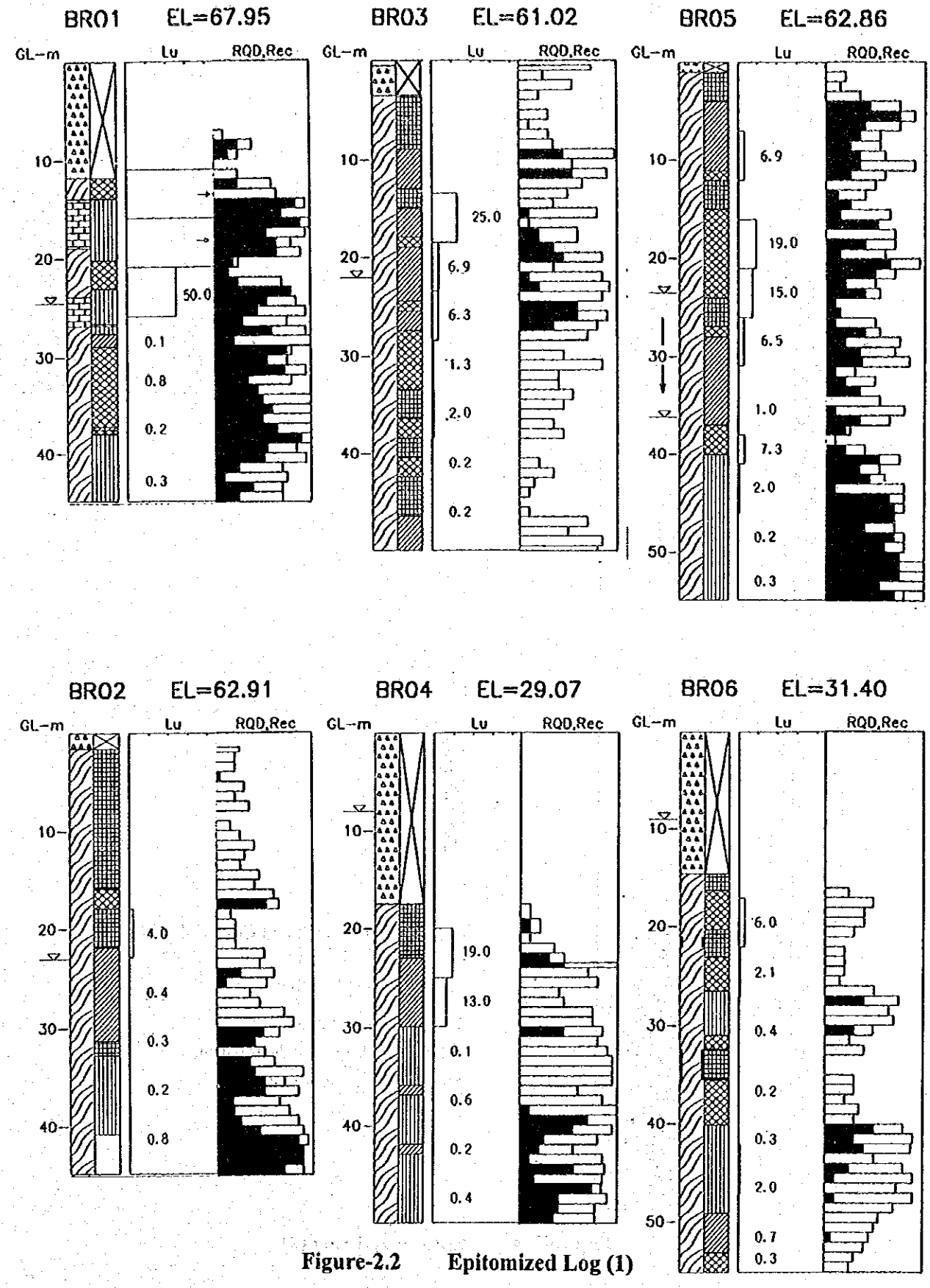



**Figure-2.2 Epitomized Log (1)**

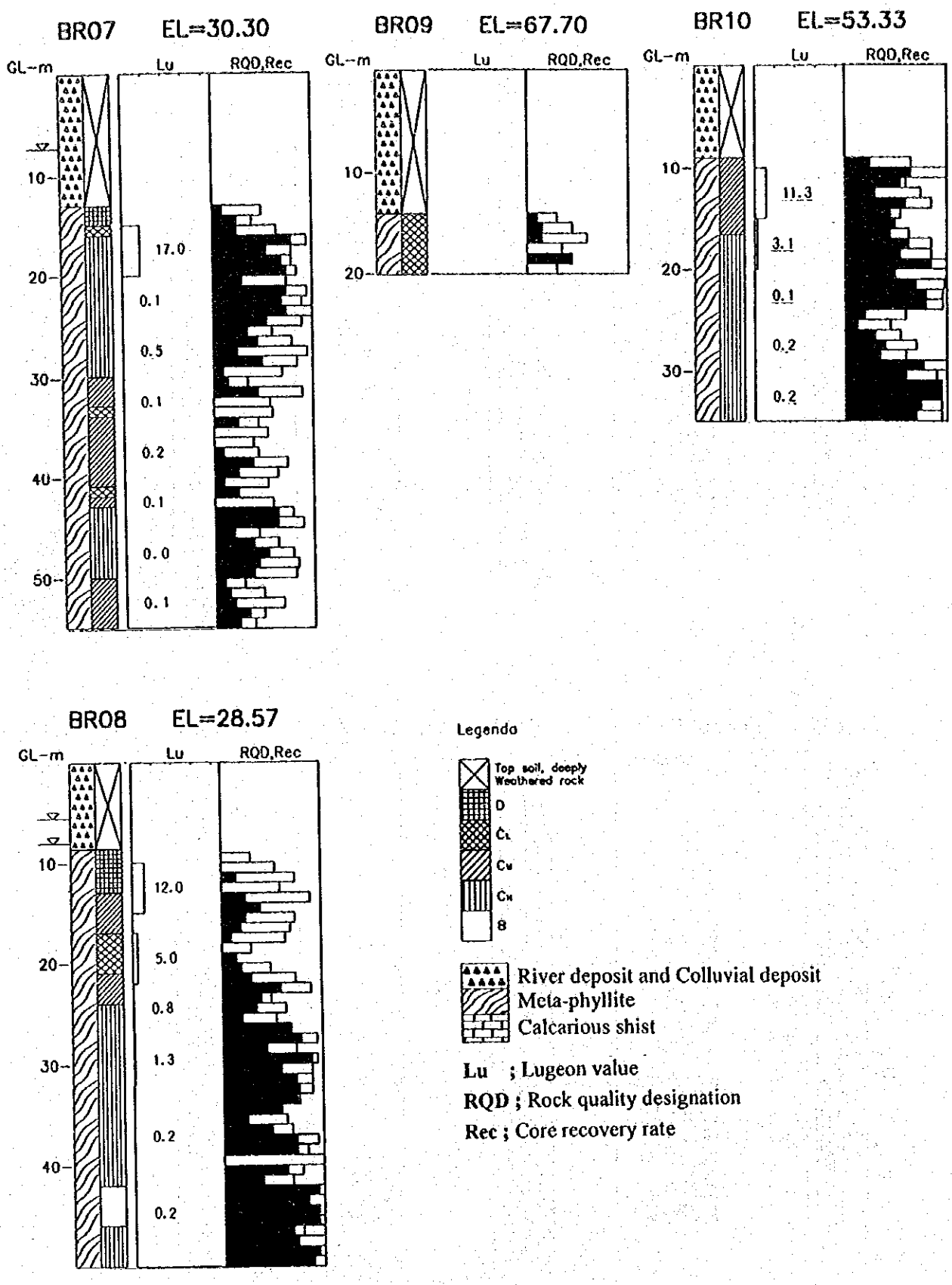
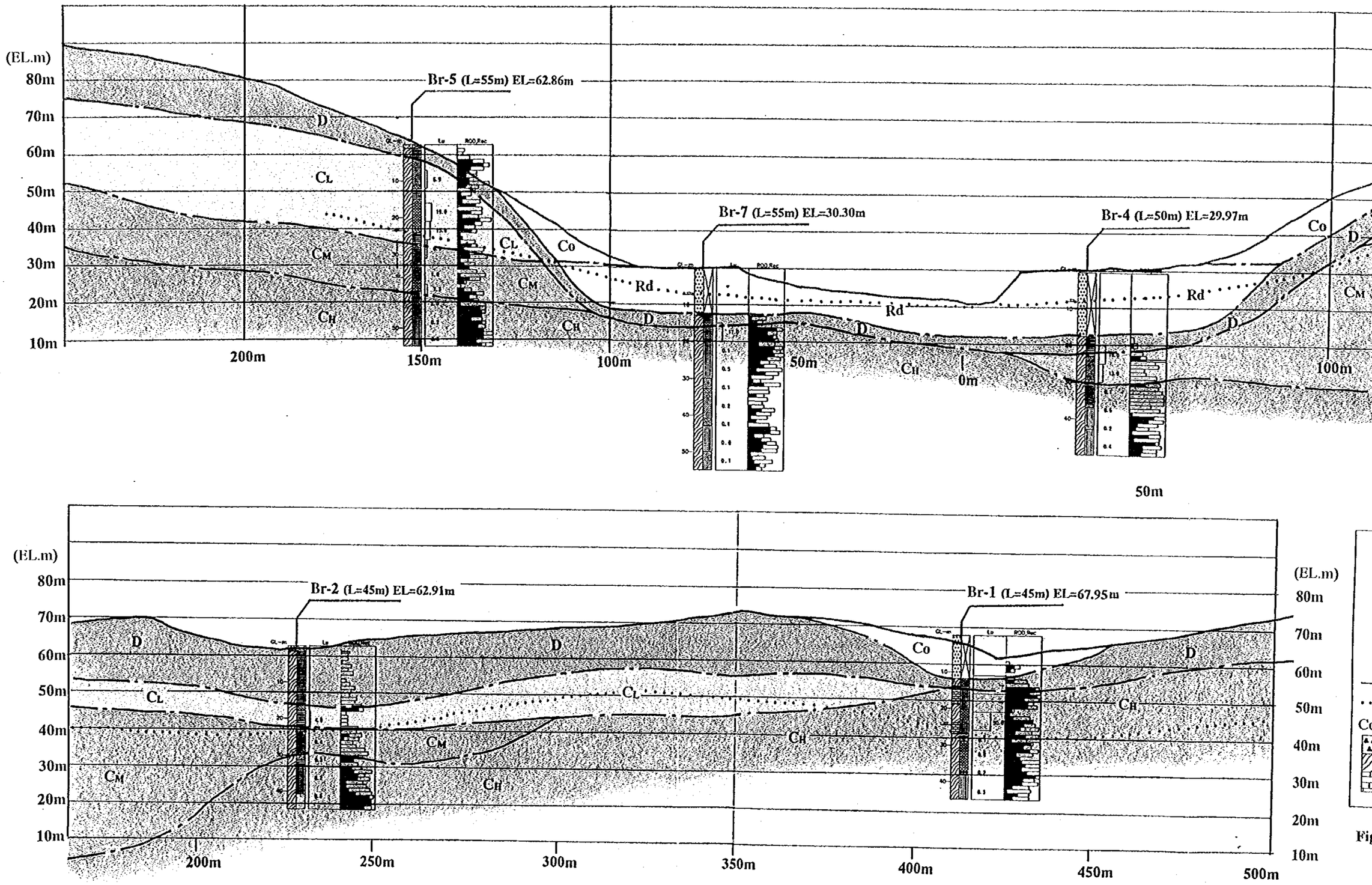
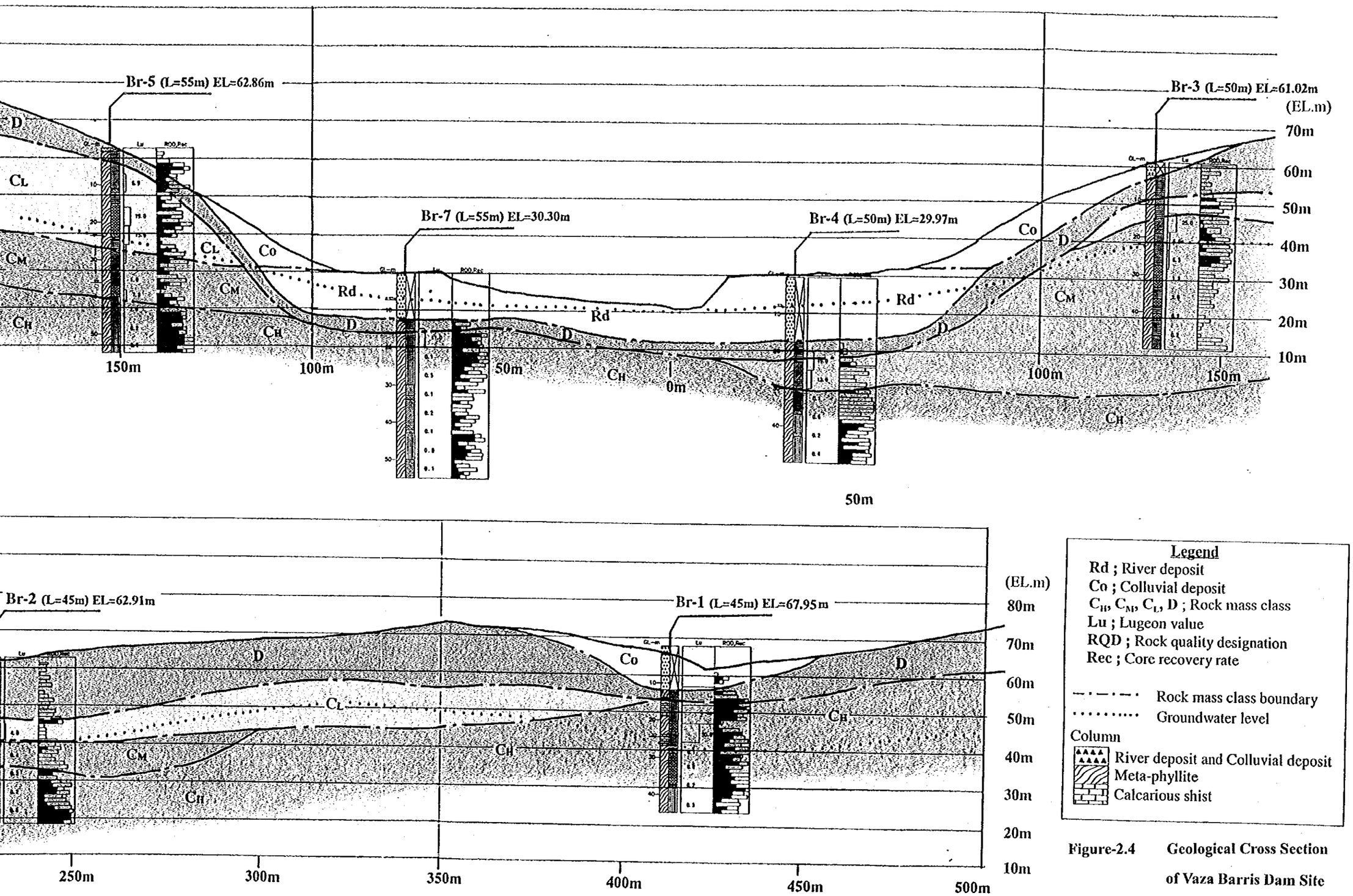



**Figure-2.3 Epitomized Log (2)**

## Geological Cross Section



## Geological Cross Section



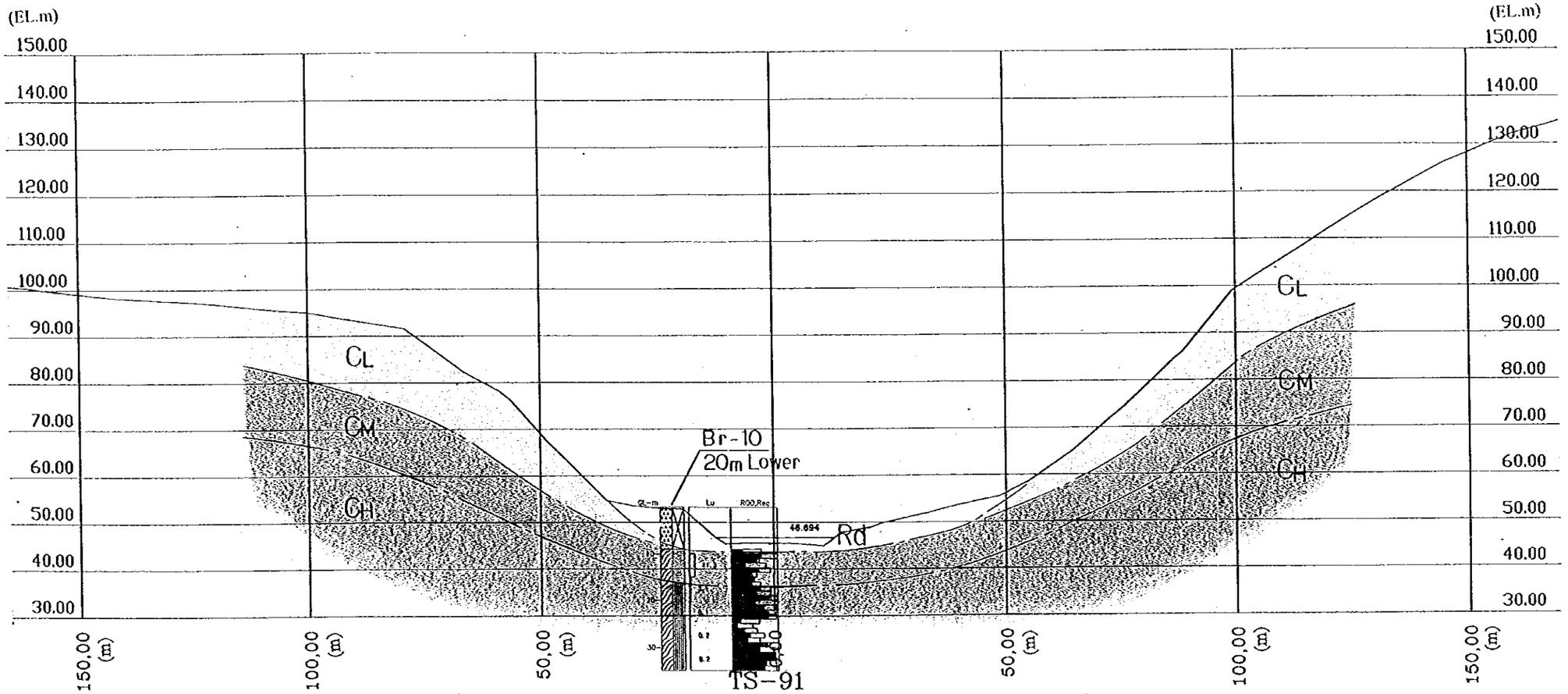

**Legend**

Rd ; River deposit
Co ; Colluvial deposit
$C_H$, $C_M$, $C_L$, D ; Rock mass class
Lu ; Lugeon value
RQD ; Rock quality designation
Rec ; Core recovery rate

Rock mass class boundary
Groundwater level

Column
River deposit and Colluvial deposit
Meta-phyllite
Calcarious shist

**Figure-2.4 Geological Cross Section of Vaza Barris Dam Site**




**Legend**

Rd ; River deposit
$C_H$, $C_M$, $C_L$, D ; Rock mass class
Lu ; Lugeon value
RQD ; Rock quality designation
Rec ; Core recovery rate

Rock mass class boundary

Column
River deposit and Colluvial deposit
Meta-phyllite

Top soil, deeply Weathered rock
D
$C_L$
$C_M$
$C_H$

**Figure-2.5 Geological Cross Section of Check Dam Site**

### (5) Groundwater Seepage

Characteristics of groundwater seepage of rock foundation of Vaza Barris Dam is summarized as listed below;

- Small valleys dissecting the right bank exist parallel in the direction of NE-SW and in the distance of about 300 m, and fairly deep. These valleys must be filled up to the height of storage water level to avoid any occurrences of seepage flow through the ground (this seepage flow may cause piping which gradually widens underground conduit and may eventually cause a failure of foundation).
- Small cols exist on a ridge line between these small valleys. These cols overlie just on the lineament that causes a fractured zone, this is assumed from the result of the drilling. There is a possibility that this zone may act as a drainage conduit, and must not be neglected.

## 2.4 Spillway Site

Generally speaking, a concrete type dam has a spillway on its body, on the other hand, a fill type dam has a spillway separate from the dam body. In this Study, a spillway site for a fill type dam was examined in the process of dam type selection. In the Vaza Barris dam site, the spillway for a fill type dam has three proposed positions, two for the spillway located in the left or the right bank of the dam body, and the one for the spillway separated from the dam body. Geological conditions of each position are as follows:

### (1) Spillway site of Separated Plan

Spillway site of the separated plan is weathered to the considerable depth (see Figure-2.3, Br-9), but it has sufficient bearing capacity for hydraulic structure.

### (2) Spillway site of Left or Right Bank Plan

Spillway site of the left or the right bank plan has fundamentally the same features as the dam site itself, and may cause an increase of excavation volume.

## 2.5 Check Dam Site

Positioning of the check dam must be given from the altitude of the reservoir, to diverse necessary volume of water at necessary season. As for a diversion weir, its structure may be of low height. But the gradient of the Vaza Barris river is quite low; then, an ideal position of a check dam may go up as far as the end of reservoir, and consequently very long by-pass channel must be needed. To avoid this problem, a rather higher check dam and a shorter channel may be sufficient. As far as the proposed site, both slopes of the valley are relatively gentle, whereas they become steep at the upstream. This site has an appropriate width to set check dam and accessory structures with a small scale, on a sound rocky ground.

One (1) drilling was executed at the supposed check dam site. The result is shown in Figure-2.3 (Br-10) and Figure-2.5. The rock condition was that of slightly weathered rock. The rock is considered to have a appropriate bearing capacity for concrete dam and sufficient impermeability.

## 2.6 Site for Dam Construction Material

As for the dam construction materials, the following two items were considered.

### (1) Earth Materials

It seems to be difficult to find earth materials such as soils for embankment dams in the proposed dam area, partly because of unsuitable properties of highly weathered meta-phyllites which mainly consists of flat particles of altered micas (vermiculite, phlogopite, etc.), partly because of thinness of weathered portion of massive rocks such as granites or massive metamorphic rocks around this area.

Another earthy material conventionally used in this region is laterite or saponite, but these are contained as matrices of tertiary conglomerate, showing quite irregular grain size distribution curve. This layer containing this earth seems to be rather thin (under several m) around the proposed Vaza Barris dam site, and separation of gravel or cobble from the layer is not effective. From a rough survey, this stratum may not exceed a thickness of 20 m, therefore a vast surface must be excavated if a quarry site is chosen near to the proposed dam site. A cutting of separated type spillway in case of fill type dam may produce a volume of earth, but it is a material of above type and weathered rock, and inappropriate for a dam.

### (2) Rocky Materials

Rocky materials for aggregates of concrete or shell of embankment dams also have to comply with some standards. Meta-phyllite or other metamorphic rocks near the dam site area are difficult to fulfil the standard demand, because of its flatness in shape and poor abrasion resistance. This series outcropping near the dam site or the future reservoir have suffered tectonic movement and weathering, and its quality is judged to be quite unsuitable for construction material. On the other hand, Granites or Migmatites in the basin of the Itabaiana Dome are sound and stiff, and sufficient for construction materials in quality and occurrence volume. They are free from other adverse effects, such as alkali-aggregate reaction or abrasion during concrete mixing etc.. Graywacke (hard sandstone) in the west of Jenipapo may be hopeful, especially for its larger specific weight.

## 2.7 Consideration on the Dam Site and Dam Type

The Vaza Barris river has quite a large catchment area at the proposed dam site, it means that a huge diversion tunnel must be prepared if a dam of fill type is chosen. The gradient of this section of watercourse is very gentle and alluvial sediment is rather thick, cofferdams either up or downstream of the river may become extremely large and uneconomic. At the proposed dam site, presence of a sound rock mass can be expected from the result of preliminary geological survey, a concrete gravity dam with a construction method of multiple-staged diversion can be recommended.

# CHAPTER 3 RECOMMENDATION

Geotechnical characteristics of the Vaza Barris Dam Site was made clear in this Feasibility Study. However, more detailed engineering geological information is necessary to set up a precise plotting and final design. Geological survey listed below is recommended to carry out in the next stage of Vaza Barris dam design. A proposed geological survey is shown in Table-3.1 and the location of the survey is shown in Figure-3.1.

**Table-3.1 Proposed Geological Survey**

| Item | Number | Depth (m) | Angle of Drill hole | Lugeon Test | Purpose |
|---|---|---|---|---|---|
| Boring | Br-11 | 60 | 45 | 11 | Rock condition of river floor, fault distribution |
| | Br-12 | 80 | 45 | 15 | Rock condition of river floor, fault distribution |
| | Br-13 | 50 | 90 | 9 | Rock condition of the middle part of the slope and abutment of the dam in the right bank. |
| | Br-14 | 50 | 90 | 9 | Rock condition of dam toe |
| | Br-15 | 50 | 90 | 9 | Rock condition of the middle part of the slope and abutment of the dam in the left bank. |
| | Br-16 | 40 | 90 | 7 | Permeability and groundwater level of the upper slope in right bank. |
| | Br-17 | 50 | 90 | 9 | Permeability and groundwater level of the upper slope in left bank. |
| total | | 380 | - | 60 | |
| Adit (Tunnel) | T-1 | 50 | - | - | Observation of depth of sound rock and condition of foundation rock. |
| | T-2 | 50 | - | - | Observation of depth of sound rock and condition of foundation rock. |
| total | | 100 | - | - | |
| Seismic Prospecting | I | 550 | - | - | Survey line should be set along Dam axis direction |
| | II | 450 | - | - | As the same as above |
| | III | 200 | - | - | Survey line should be set along river course direction |
| | IV | 200 | - | - | As the same as above |
| | V | 200 | - | - | As the same as above |
| | VI | 180 | - | - | Survey line along dam axis and sealing line |
| | VII | 450 | - | - | |
| total | | 2230 | - | - | |
| Boring (Quarry site) | Br-A | 50 | 90 | - | Lithology, rock volume |
| | Br-B | 50 | 90 | - | Lithology, rock volume |
| | Br-C | 50 | 90 | - | Lithology, rock volume |
| total | | 150 | - | - | |

Concerning check dam site, geological condition of the check site has already been made clear enough for the detail design, hence further geological survey is not necessary.

Survey Plan

| | Number | Depth(m) | Drill hole Angle | LugeonTest |
|---|---|---|---|---|
| Boring | Br-11 | 60 | 45 | 11 |
| | Br-12 | 80 | 45 | 15 |
| | Br-13 | 50 | 90 | 9 |
| | Br-14 | 50 | 90 | 9 |
| | Br-15 | 50 | 90 | 9 |
| | Br-16 | 40 | 90 | 7 |
| | Br-17 | 50 | 90 | 9 |
| total | | 380 | - | 60 |
| Adit(Tunnel) | T-1 | 50 | - | - |
| | T-2 | 50 | - | - |
| total | | 100 | - | - |
| SeismicProspecting | Ⅰ | 550 | - | - |
| | Ⅱ | 450 | - | - |
| | Ⅲ | 200 | - | - |
| | Ⅳ | 200 | - | - |
| | Ⅴ | 200 | - | - |
| | Ⅵ | 180 | - | - |
| | Ⅶ | 450 | - | - |
| total | | 2230 | - | - |
| Boring (Quarry site) | Br-A | 50 | 90 | - |
| | Br-B | 50 | 90 | - |
| | Br-C | 50 | 90 | - |
| total | | 150 | - | - |

Figure-3.1 Proposed Geological Survey for Vaza Barris Dam Site

# APPENDIX-1

# Rock Mass Classification Established for the Vaza Barris Dam

# Rock mass classification and its elements for the Vaza Barris Dam

## 1. Hardness of Rock

| Symbol | Description |
|---|---|
| A | Very hard; metallic sound with hammer blow, hard to break |
| B | Hard; light metallic sound with hammer blow, broken by hammer blow |
| C | Moderately hard; dim sound with hammer blow, easily broken |
| D | Soft; crumbled with hammer blow or hand |
| E | Very soft; mainly sandy of clayey |

## 2. Core Shape

| Symbol | Description |
|---|---|
| I | Cylindrical core with a length more than 30 cm |
| II | Cylindrical core with a length of 10 to 30 cm |
| III | Cylindrical core with a length of 5 to 10 cm |
| IV | Cylindrical to fragmentary core with a length less than 5 cm |
| V | Mainly brecciated core |
| VI | Mainly fragmental core |
| VII | Mainly sandy core |
| VIII | Clayey core, or impossible to recover, or cuttings |

## 3. Condition of Cracks

| Symbol | Description |
|---|---|
| a | Tightly closed, fresh and no weathering/alteration on its surface |
| b | Lightly oxidized on its surface and no softening of on its surface |
| c | Massively oxidized, or intercalating softened material or softened along its surface |
| d | Finely fractured or not to be identified as cracks |

## 4. Criterion of Rock mass classification – Combination of classification elements

This criterion must be separately prepared for this dam site, to emphasize important features characteristic to each rock foundations of each single dam site; considering with; rock species, and their vulnerabilities to deformation of decomposition of tissues or fabrics to drilling works or other subordinate deterioration; dimension and function of the proposed structures; problematic points concerning to construction works; etc.

| | | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| A | a | B | $C_H$ | $C_H$ | $C_M$ | $C_L$ | D | | |
| | b | $C_H$ | $C_H$ | $C_H$ | $C_M$ | $C_L$ | | | |
| | c | $C_M$ | $C_M$ | $C_M$ | $C_L$ | D | | | |
| | d | D | D | D | D | D | | | |
| B | a | $C_H$ | $C_H$ | $C_M$ | $C_L$ | $C_L$ | D | | |
| | b | $C_H$ | $C_H$ | $C_M$ | $C_L$ | $C_L$ | | | |
| | c | $C_M$ | $C_M$ | $C_L$ | $C_L$ | $C_L$ | | | |
| | d | D | D | D | D | D | | | |
| C | a | $C_M$ | $C_M$ | $C_L$ | $C_L$ | D | D | | |
| | b | $C_M$ | $C_L$ | $C_L$ | $C_L$ | D | | | |
| | c | $C_L$ | $C_L$ | $C_L$ | $C_L$ | C | | | |
| | d | D | D | D | D | D | | | |
| D | a | $C_L$ | $C_L$ | D | D | D | D | | |
| | b | $C_L$ | $C_L$ | D | D | D | | | |
| | c | D | D | D | D | D | | | |
| | d | D | D | D | D | D | | | |
| E | a | D | | | | | | | |
| | b | | | | | | | | |
| | c | | | | | | | | |
| | d | | | | | | | | |

Class B : Excellent for rock foundation
Class $C_H$ : Fair
Class $C_M$ : Rather fair with some problem (s)
Class $C_L$ : Rather improper and having severe problem (s),and requires some improvements.
Class D : Improper to foundation

Nota Bene: This rock mass designation of the proposed dam site, has been executed under the following assumptions:-

a. As penetration rate (drilling length per unit time) is quite large, a greater part of fractured rocks are recovered as sludge which is completely eliminated.
b. The rock species forming this district is has a distinct schistosity, collected samples are split during drilling or subsequent handling processes.
c. Rock itself is rather fresh and not suffered from weathering beneath a certain horizon, then a rank on weathering can be appreciated higher than usual.
d. From an observation at some outcrops, thickness of weathering is not so large (under several m).

The adjustment thus carried out is:-

i. For the hardness rank:
   A, B to A
   C to B
ii. For sections of no core recovery:
   core shape of IV to I to III of the adjacent section,
   core shape of V to VI of the adjacent section.
iii. For core recovery:
   As this designation is for recovered core, more than 60% of core recovery is necessary for the designation rank, otherwise the rank is down by one, e. g. a section of 55% of $C_M$ is finally ranked to $C_L$.