

No. 1

JAPAN INTERNATIONAL COOPERATION AGENCY

CENTRO DE REHABILITACION DE MANABI (CRM)
THE REPUBLIC OF EQUADOR

THE DETAILED DESIGN STUDY
ON
THE WATER TRANSBASIN SCHEMES
FOR
CHONE - PORTOVIEJO RIVER BASINS

FINAL REPORT
DATA BOOK NO.2

GEOLOGY
AND
CONSTRUCTION MATERIALS

MARCH 1995

NIPPON KOEI CO., LTD.

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**THE DETAILED DESIGN STUDY ON THE WATER
TRANSBASIN SCHEMES FOR CHONE-PORTOVIEJO
RIVER BASINS**

**GEOLOGICAL - GEOTECHNICAL
INVESTIGATIONS REPORT**

VOLUME I

FEBRUARY 1994



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JAPAN INTERNATIONAL COOPERATION AGENCY
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DETAILED DESIGN STUDY ON THE TRANSBASIN WATER
PROJECT FOR THE CHONE-PORTOVIEJO RIVER BASINS

REPORT ON GEOLOGICAL-GEOTECHNICAL RESEARCH

VOLUME I

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PROJECT FOR THE CHONE-PORTOVIEJO RIVER BASINS

REPORT ON GEOLOGICAL-GEOTECHNICAL RESEARCH

1. ANTECEDENTS

1.1 INTRODUCTION

The Japan International Cooperation Agency (JICA) hired the consulting company Hidrosueldos Cia. Ltda. to perform a Geological-Geotechnical Investigation for the detailed design study of the Transbasin Water Project for the Chone-Portoviejo River Basins.

The purpose of the project is to design a transbasin water system in order to, first, take the waters from the Daule Peripa reservoir to the La Esperanza Dam, then connect them to the Poza Honda reservoir, and, finally, connect them to the Mancha Grande River. This is achieved by connecting the current Daule Peripa reservoir on the Rio Duale through a tunnel on the La Esperanza Dam, currently under construction, sequentially connected via open channel from Severino to Caña Dulce and via tunnel from Caña Dulce to Poza Honda.

The Geological-Geotechnical research performed included the following works:

- Mechanical sounding using a rotary machine for continuous core recovery, standard penetration tests and "LUGEON" water pressure tests using "LEFRANC" infiltration, at tunnel portals and at the Severino intake site.
- Test pitting and manual sounding tests with continuous standard penetration tests along the open channel, the transmission line at the portal and crown of the tunnels at the Poza Honda reservoir.



- Mechanical Laboratory Rock Tests on samples obtained from mechanical sounding tests on the sections of interest for the tunnels.
- Mechanical Soil Tests on soil samples obtained from test pits, for the purpose of learning about their characteristics and deciding whether they may be utilized as building materials for the Open Channel and also to perform the foundation study for the towers along the Transmission Line.
- Geological Mapping along the sections of the Tunnels and the Open Channel.
- Sampling and laboratory tests on aggregates utilized in the preparation of different concrete mixtures and obtaining their resistances using a compressive strength test on cylinders.

Due to the large amount of information obtained from the investigation and for the maximum use of same, this Report has been structured as follows:

- Volume I Includes the results of the mechanical sounding and Laboratory Rock Tests.
- Volume II Includes the prospecting results using test pits and manual sounding and Soil Mechanics tests.
- Volume III Results of Geological Mapping.
- Volume IV Results of laboratory tests on concrete aggregates and resistance tests for the different mixtures prepared



2. CORE DRILLING WITH A HYDRAULIC DRIVEN ROTARY MACHINE FOR CONTINUOUS CORE RECOVERY

2.1 PURPOSE AND SCOPE OF THE INVESTIGATION

The purpose of the mechanical sounding tests with continuous core recovery and penetration and water pressure tests was to obtain relevant geotechnical information on the subsurface conditions at the sites for the most important structures of the Project.

As a result of the mechanical sounding and field tests, design parameters have been obtained starting with the quality of the soil (alluvial or colluvial) of the rock and its geomechanical characteristics and its permeability, permitting the design of the foundations for the Project's infrastructure such as the supports for the intake and exit portals of the tunnels, the Pumping Station and the Substation and Loading Tank.

2.2 WORKS PERFORMED

A total of 11 mechanical sounding tests were performed with their locations, approved by JICA, determined by the locations of the structures subject to this study, i. e. 3 sounding tests at the Daule Peripa-La Esperanza tunnel; 2 sounding tests at the La Esperanza-Poza Honda tunnel; 3 sounding tests at the Poza Honda-Mancha Grande tunnel; 1 sounding test at the Pumping Station; and 1 sounding test at the Loading Tank. The location of the sounding tests is shown in Appendix No. 4.5.

Sounding tests were performed using continuous core drilling and performing standard penetration tests on the soil and smooth rock, with the execution of "LEFRANC" water permeability tests on weathered soils or rocks and with "LUGEON" water permeability tests on sound rock. In addition, at determined depths, core drilling took place for laboratory tests. All the works performed followed the requirements of technical standards and specifications.

The different formations detected by the sounding tests, and their geotechnical characteristics have been described in detail and may be seen in the respective sounding test logs.



The depth of the sounding tests as well as the type and number of samples and field tests are shown in the following table:

HOLE NO (SITE)	DEPTH (m)	"SPT" TEST	ROCK TEST CORE SAMPLING DEPTH	PERMEABILITY TEST		PIEZOMETER	CORE BOXES
				LEFRANC (Interval)	LUCEON (Interval)		
DP-93-1 MULATOS	30,0	1	21,30-21,80		20,00-25,00 25,00-30,00	30	6
DP-93-2 CÁRALES	30,0	-	17,30-17,70		10,00-15,00 15,00-20,00 20,00-25,00	-	6
DP-93-3 CONSEJILLO	30,0	-	22,00-22,57		15,00-20,00 20,00-25,00 25,00-30,00	30	6
SR-93-1 PUMPING STATION	55,0	2	48,34-48,92				11
SR-93-2 SUB-STATION	25,0	3	18,26-18,84		5,00-10,00		5
SR-93-3 CARA DULCE	30,0	4	20,36-20,72		15,00-20,00 20,00-25,00 25,00-30,00		8
SR-93-4 PATA DE PAJARO	40,0	5	33,00-33,50		25,00-30,00 30,00-35,00 35,00-40,00	40	8
SR-93-5 HEAD TANK	25,0	4	8,79-9,00 9,38-9,77	2,00-5,00 5,00-7,80	10,00-15,00 15,00-20,00 20,00-25,00		5
MG-93-1 GUAJABITO	35,0	12	24,10-24,55		17,50-22,50 22,50-27,50 27,50-32,50		7
MG-93-2 MANCHA GRANDE	45,0	8	36,52-37,00		30,00-35,00 35,00-40,00 40,00-45,00		9
MG-93-3 MANCHA GRANDE	25,0	15	8,50- 8,80(*) 24,20-24,52	0,0- 3,0 3,0- 5,0 5,0- 8,0 8,0-12,0 12,0-15,0			5
TOTAL	370,0	54	11	7	24	100	76

(*): Soil



2.3 EQUIPMENT AND METHODS USED

The sounding tests used three complete sets of equipment as per the requirements of the technical specifications used, based on their capacity and the depths of the boreholes to be drilled as well as the conditions for access to the different sites.

Three hydraulic drive rotary type drilling machines were used with capable of drilling at more than 100 meters deep, with hole diameters of 98.8 to 75.3 mm or core diameters of 80.9 to 54.7 mm.

The brand names of the equipment are:

1. ACKER TELEDO
2. ACKER HILL BILLY
3. ACKER ACE

Each set of equipment was completed by a centrifugal driven pressure pump with a pumping capacity greater than 100 liters/minutes and pressures above 15 kg/cm². In addition, pressure and flow pumps for water storage at the drilling sites were used.

Core barrels of the single tube type were used for samplers with a borehole diameter of 72 mm, in formations of alluvial or colluvial soils and on completely weathered rocks which are very soft and must be drilled in dry conditions.

Core barrels of the double tube type with core diameters of 80.9 and 72.6 mm were used on rocky formations. A core barrel with a diameter of 54.7 mm from 10 meters down was used only for sounding test SD-93-2 due to the presence of a conglomerate level that forced the diameter of the sounding to be changed.

Basically, because of the soft sedimentary rocks metal drill bits were used and locally at sounding tests DP-1, DP-2 and DP-3 and diamond bits were used because of siliceous or conglomerate levels.

Permeability tests on highly weathered soil or rocks were performed using the infiltration method at a constant level (Lefranc).



Lugeon permeability tests were performed using mechanical packers with glycerine pressure gauges at a 20 kg/cm² pressure capacity and precision of 0.5 kg/cm with accumulated hydrometers and clean water. The steps of the charges were based on the rock properties in the sections tested. Also, a test for the loss of the charge due to friction which determined losses considered in the calculation of the permeability tests was performed and the results are attached to this report.

Standard penetration tests, "SPT" were performed according to the standards for said test, i. e.:

Mass weight	140 lbs.
Height of fall	76 cm
Split tube diameter	2"

They were performed every 1.5 m on 0.45 m. pipe lines, divided into three 15 cm parts. The strokes necessary to drive each 15 cm. line were counted and were considered as rejects when more than 30 strokes were required. For interpretation of the test, the strokes in the last two lines were added up obtaining the value of N_{30} . If N_{30} was more than 50 strokes, then it was considered a reject.

For rock mechanics laboratory tests, core lines between 40 and 60 cm were selected and were coated with paraffin immediately after removal in order to avoid the rock's losing its natural characteristics. These cores were duly labeled and sent to the laboratory.

2" diameter piezometric pipes were placed, with grooves in 10% of their peripheral area, on three of the sounding tests performed in order to measure the water level in the rocky mass or to take water samples.

A concrete slab (0.5 x 0.5 m) with its respective description and a tube with a screw top 2 1/2" in diameter were placed on each of the sounding tests at the termination of the sounding test.

Core recovery was measured at each step whether for soil or rock, reaching the following average recovery per sounding test.



HOLE NO	DRILLED DEPTH (m)	RECOVERY LENGTH (m)	AVERAGE CORE RECOVERY (%)
SD-93-1	30,00	30,00	100
SD-93-2	30,00	26,20	87
SD-93-3	30,00	29,65	99
SR-93-1	55,00	54,60	99
SR-93-2	25,00	24,20	97
SR-93-3	30,00	29,85	99
SR-93-4	40,00	40,00	100
SR-93-5	25,00	25,00	100
MG-93-1	35,00	35,00	100
MG-93-2	45,00	42,30	94
MG-93-3	30,00	29,60	99

The samples obtained were duly placed in standard labeled wooden boxes which once registered and photographed were submitted to JICA.

The different formations detected in the sounding tests and their geotechnical characteristics have been described in detail. For soil samples a manual-visual description was given of the different materials, indicating their character, color, consistency or compactness and organic material content, following the standards listed in Table 1 of Appendix 4.1.

In addition to the bedding description of the rock samples, the different geotechnical parameters on each length sampled were evaluated, i. e. RQD, weathering, fracturing, resistance index, diacalse and status of same were evaluated.

Based on these parameters, which are listed in Appendix No. 41., the quality index for the rock was determined as per the Bieniawsky classification.



2.4 RESULTS OBTAINED

For a better analysis of the information obtained, the results are listed separately for each of the projected works.

2.4.1 DAULE PERIPA-LA ESPERANZA RESERVOIR

For the geotechnical study of the supports of the tunnel and especially on the intake (Conguillo) and exit (Membrillo) portals, DP-93-3 and DP-93-1 sounds, respectively, were performed. Also the DP-93-2 sounding was performed at the Estero Cañales.

Bedding profiles detected by each of the sounding tests and their geotechnical characteristics are listed herebelow. The correlation of the bedding cuts detected will be the object of the Geological study.

HOLE NO: DP-93-1
Elevation: 83,01 masl
Depth: 30,00 m

- From 0,00 to 1,30 m Colluvial soil constituted of blackish silty clay with weathered debris stiff.
- From 1,30 to 9,70 m. Fine grained sandstone with grayish brown levels of mudstone and gray muddy from 6,60 m with a Bieniawsky quality index of III and on the top IV.
- From 9,70 to 12,90 m Greenish gray fine and medium grained sandstone with a quality index III.
- From 12,90 to 17,20 m Gray fine grained sandstone, some soft, with a quality index III and with intercalated level of brown mudstone tufaceous.
- From 17,20 to 18,50 m Level of brown mudstone with a quality index III.
- From 18,50 to 23,20 m Greenish gray silty fine grained sandstone with a quality index III.



From 23,20 to 28,20 m Dark gray fine and medium grained sandstone, some soft, with a quality index III-IV, bedding horizontal.

From 28,20 to 29,70 m Medium and coarse grained sandstone, soft rock with a quality index IV.

From 29,70 to 30,00 m Conglomerat, soft rock, with a quality index IV.

The grade line of the tunnel is found at an elevation of 60.60 meters above sea level making the excavation of the tunnel at the level of fine grain mudstone with sandstone with a quality index of III.

HOLE NO: DP-93-2
Elevation: 84,85 masl
Depth: 30.00 m

From 0,00 to 0,40 m Alluvium constituted of sand and gravel.

From 0,40 to 2,75 m Greenish gray silty fine grained sandstone, some soft, quality index III - IV.

From 2,75 to 6,70 m Dark brown, medium and coarse grained sandstone, bedding horizontal, with a quality index IV.

From 6,70 to 8,50 m Greenish gray mudstone, some breach. From 7,60 m muddy sandstone with a quality index III.

From 8,50 to 12,00 m Bluish gray medium grained sandstone, some soft, with a quality index IV.

From 12,00 to 14,15 m Coarse grained conglomeratic, soft, with a quality index IV.

From 14,15 to 23,20 m Greenish gray silty fine and medium grained sandstone (from 16,70 to 20,80 m, medium and coarse grained), quality index III.



From 23,20 to 30,00 m : Greenish gray mudstone with some sandstone, with a quality index III, from 26,40 to 28,15 m level of fine and medium grained sandstone.

The grade line of the tunnel is found at an elevation of 64.70 meters above sea level meaning that the tunnel would involve sandstone of the fine grain type and somewhat like mudstone with a quality index of III.

HOLE NO: DP-93-3
Elevation: 89,67 masl
Depth: 30,00 m

From 0,00 to 1,20 m Brown mudstone with siliceous conglomeratic debris (breach) with a quality index IV.

From 1,20 to 3,00 m Brown fine grained sandstone, from 2,0 m medium and coarse grained, quality index III.

From 3,00 to 4,60 m Brown mudstone with conglomeratic debris (breach), with a quality index II.

From 4,60 to 10,20 m Greenish gray silty fine grained sandstone with traces of shell, from 8,10 m brown color, quality index II.

From 10,20 to 13,45 m Dark brown medium and coarse grained sandstone, some soft, with a quality index III - IV.

From 13,45 to 15,60 m Sandy and conglomeratic greenish mudstone, with a quality index III.

From 15,60 to 20,50 m Greenish gray silty fine grained sandstone, with a quality index II.

From 20,50 to 23,60 m Greenish gray mudstone with breach debris and some sandy with traces of shell from 21,90 m, quality index III.



(i)

From 23,60 to 27,90 m Greenish gray fine and medium grained sandstone, with traces of shell, muddy, microconglomeratic from 27,0 m, quality index II.

From 27,90 to 28,80 m Greenish gray mudstone with a quality index II.

From 28,80 to 30,00 m Greenish gray muddy fine grained sandstone, from 29,60 m microconglomeratic, quality index II.

The grade line of the tunnel is found at an elevation of 64.90 meters above sea level meaning that the tunnel would involve grayish green mudstone and sandstone with a quality index of III and the lower part of the sandstone bedding with fine sandstone and mudstone with a quality index of II.

PERMEABILITY

Results of the permeability tests are summarized in the following table:

LUGEON FIELD PERMEABILITY TEST					
HOLE NO	INTERVAL	COEFFICIENT OF PERMEABILITY K (cm/sec)	LUGEON UNIT	NET PRESSURE kg/cm ²	REMARKS
DP-93-1	20,00-25,00	$4,9 \times 10^{-5}$	4,75	9,9 kg/cm ²	
DP-93-1	25,00-30,00	$2,4 \times 10^{-4}$	23,26	7,3 kg/cm ²	
DP-93-2	10,00-15,00	$3,9 \times 10^{-4}$	35,35	5,1 kg/cm ²	
DP-93-2	15,00-20,00	$7,4 \times 10^{-6}$	0,66	5,1 kg/cm ²	
DP-93-2	20,00-25,00	$5,4 \times 10^{-5}$	4,82	6,1 kg/cm ²	
DP-93-3	15,00-20,00	$5,2 \times 10^{-4}$	50,55	4,83 kg/cm ²	
DP-93-3	20,00-25,00	$1,4 \times 10^{-4}$	13,59	6,9 kg/cm ²	
DP-93-3	25,00-30,00	$5,9 \times 10^{-6}$	0,57	10,8 kg/cm ²	



WATER LEVEL

The following are the stabilized water levels:

DP-93-1 = 19,00 m

DP-93-2 = 4,00 m

DP-93-2 = 9,15 m

2.4.2 LA ESPERANZA-POZA HONDA TUNNEL

For the study of the supports of the tunnel and especially the intake (Caña Dulce) and exit (Pata de Pájaro) portals, we drilled the SR-93-3 and SR-93-4 sounding tests respectively.

The bedding profiles detected by the sounding tests and their geotechnical characteristics are listed herebelow.

The correlation between the bedding profiles will be discussed in the Geological Report.

HOLE NO:	SR-93-3
Elevation:	130,00 masl
Depth:	30,00 m
From 0,00 to 3,00 m	Yellowish brown silty clay with weathered rock debris stiff.
From 3,00 to 6,20 m	Yellowish brown completely weathered mudstone with a quality index V (very poor).
From 6,20 to 8,90 m	Very weathered greenish gray mudstone with traces of shells, with a quality index IV (poor).
From 8,90 to 30,00 m	Greenish gray mudstone with traces of shells and levels of siltstone, some sandy bedding horizontal, quality index III, from 16,0 m some shells and sandy characters.



The grade line of the tunnel is at an elevation of 107.31 meters above sea level making the material involved in the tunnel of the grayish green mudstone type with a sandstone character and some shells with a quality index of III (medium).

HOLE NO:	SR-93-4
Elevation:	100,18 masl
Depth:	40,00 m
From 0,00 to 1,50 m	Weathered mudstone fragments in brown silty matrix, stiff.
From 1,50 to 8,30 m	Completely weathered yellowish brown mudstone (residual clay) with a quality index V.
From 8,30 to 13,80 m	Greenish gray mudstone, sound rock with traces of shells on silty levels, bedding horizontal, from 12,0 m some shells and sandy character, quality index III.
From 13,80 to 21,20 m	Greenish gray silty fine grained sandstone with traces of shells, with a quality index III - IV.
From 21,20 to 35,80 m	Greenish gray mudstone with traces of shells and silty levels, sound rock, bedding horizontal with a quality index III, from 28,0 m with sandy character and greenish dark gray color.
From 35,80 to 40,00 m	Greenish gray silty fine grained sandstone with traces of shells, bedding horizontal, quality index III.

Since the grade line of the tunnel is at an elevation of 100.18 meters above sea level, the material involved in the tunnel would be of the grayish green mudstone type with indexes of shells and a sandstone character with a quality index of III (medium).



PERMEABILITY

The results of the permeability tests are summarized in the following table:

LUGEON FIELD PERMEABILITY TEST					
HOLE #2	INTERVAL	COEFFICIENT PERMEABILITY (cm/sec.)	LUGEON UNIT	NET PRESSURE kg/cm ²	REMARKS
SR-93-3	15,00-20,00	$4,1 \times 10^{-4}$	40,00	4,77	
SR-93-3	20,00-25,00	$2,4 \times 10^{-4}$	19,90	6,81	
SR-93-3	25,00-30,00	$3,1 \times 10^{-4}$ $3,5 \times 10^{-4}$	0,25 28,50	7,84 8,78	Hidraulic Brocked
SR-93-4	25,00-30,00	$3,9 \times 10^{-4}$	31,90	11,29	Hidraulic Brocked
SR-93-4	30,00-35,00	$7,7 \times 10^{-4}$	62,90	4,40	Open Joints
SR-93-4	35,00-40,00	$5,2 \times 10^{-4}$	42,40	6,35	Open Joints

WATER LEVEL

Stabilized water levels are the following:

SR-93-3 = 17,50 m

SR-93-4 = 14,80 m

2.4.3 POZA HONDA-MANCHA GRANDE TUNNEL

A total of three sounding tests were performed and MG-93-A was drilled at the intake portal (Guajabito) at a depth of 35 meters and sounding tests MG-93-2 and MG-93-3 were drilled at the exit portal (Mancha Grande) at depths of 45 and 25 meters, respectively.

Bedding profiles detected by the sounding tests and their geotechnical characteristics are listed herebelow.



The correlation of the bedding cuts will be discussed in the Geological Study.

HOLE NO: MG-93-1
Elevation: 117,420 masl
Depth: 35,0 m

- From 0,00 to 3,00 m Weathered and oxidited debris of brown silty fine grained sandstone in sandy silty matrix Stiff.
- From 3,00 to 7,50 m Completely weathered yellowish brown silty fine grained sandstone with a quality index V.
- From 7,50 to 13,40 m Completely wathered yellowish brown mudstone, from 12,80 m sandy character, quality index V.
- From 13,40 to 17,50 m Very weathered greenish gray mudstone with traces of shells, with a quality index IV.
- From 17,50 to 24,00 m Sound greenish gray mudstone with silty levels, bedding horizontal, from 20 to 21 m sandy character quality index IV - III.
- From 24,00 to 27,30 m Sound gray sandy fine grained sandstone with a quality index IV III.
- From 27,30 to 30,20 m Greenish gray mudstone with traces of shells some sandy, bedding horizontal, quality index III.
- From 30,20 to 35,00 m Grrenish gray muddy fine grained sandstone, bedding horizontal with a quality index III.

Since the grade line of the tunnel is at an elevation of 91.25 meters above sea level it means that the material involved in the excavation of the tunnel would consist of sandstones with very fine gray mudstones with the same quality index as that of sandstones.



HOLE NO: HG-93-2
Elevation: 128,10 masl
Depth: 45,00 m

From 0,00 to 5,60 m Colluvial soil constituted of yellowish gray clayey silt with some fine grained sand and numerous weathered rock debris, Stiff.

From 5,60 to 7,80 m Completely weathered brown silty fine grained sandstone with a quality index V.

From 7,80 to 11,80 m Completely weathered grayish brown mudstone with sandy levels with a quality index V.

From 11,80 to 17,80 m Highly weathered grayish brown mudstone with a quality index IV.

From 17,80 to 27,50 m Highly weathered yellowish brown silty fine grained sandstone with a quality index IV, from 25,0 m muddy.

From 27,50 to 30,10 m Yellowish brown mudstone weathered, with oxidated joints, quality index IV.

From 30,10 to 33,70 m Greenish gray mudstone with yellowish oxidated levels, quality index IV - III.

From 33,70 to 45,00 m Sound greenish gray mudstone with traces of shells and sandy levels, bedding horizontal, quality index III - IV.

The grade line of the tunnel is at an elevation of 88.62 meters above sea level meaning that the rock involved in the line of the tunnel will be of the grayish green mudstone type with indexes of shells and sandy levels with a quality index of III to IV (medium to bad).



HOLE NO: MG-93-3
Elevation: 97,75 masl
Depth: 25,00 m

From 0,00 to 5,00 m Alluvial soil constituted of sandy silt level to 2,20 m and silty fine grained sand with weathered rock debris, Stiff.

From 5,00 to 18,80 m Colluvial soil constituted of weathered rock debris and fragments of fine grained sandstone and siltstone in yellowish brown silty sand matrix with a levels of dark gray soft silt.

From 18,80 to 23,80 m Completely weathered yellowish brown silty fine grained sandstone, from 23,00 m greenish gray color, quality index V.

From 23,80 to 25,00 m Greenish gray silty fine grained sandstone, soft rock with a quality index IV.

The grade line of the tunnel is at an elevation of 88,55 meters above sea level meaning that the rock involved silty fine grained sands and levels of soft siltstone.

PERMEABILITY

Lugeon permeability tests were performed with sound tests MG-93-1 and MG-93-2 while at sounding test MG-93-3 five Lefranc infiltration tests were performed due to the strength of the alluvial deposits.



Results were as follows:

LUGEON FIELD PERMEABILITY TEST					
HOLE NO	INTERVAL	COEFFICIENT OF PERMEABILITY K (cm/sec.)	LUGEON UNIT	NEXT PRESSURE kg/cm ²	REMARKS
MG-93-1	17,50-22,50	$3,7 \times 10^{-4}$	35,6	6,75	
MG-93-1	22,50-27,50	$5,18 \times 10^{-4}$	49,8	5,70	
MG-93-1	27,50-32,50	$4,03 \times 10^{-4}$	38,7	6,69	
MG-93-2	30,00-35,00	$3,6 \times 10^{-4}$	34,9	5,73	
MG-93-2	35,00-40,00	$1,66 \times 10^{-4}$	15,9	8,09	
MG-93-2	40,00-45,00	$1,61 \times 10^{-4}$	15,5	12,66	

LEFRANC FIELD PERMEABILITY TEST					
HOLE NO	INTERVAL	COEFFICIENT OF PERMEABILITY K (cm/sec.)	LUGEON UNIT	WITHOUT PRESSURE	LEFRANC FIELD TEST
MG-93-3	0,00-3,00	$1,02 \times 10^{-3}$	-	H	
MG-93-3	3,00-5,00	$1,05 \times 10^{-4}$	-	H	
MG-93-3	3,00-8,00	$6,13 \times 10^{-5}$	-	H	
MG-93-3	9,00-12,00	$6,26 \times 10^{-5}$	-	H	
MG-93-3	12,00-15,00	$6,27 \times 10^{-5}$	-	H	

WATER LEVEL

Stabilized water levels at the holes were as follows:

MG-93-1 = 9,50 m
MG-93-2 = 39,80 m
MG-93-3 = 4,00 m



2.4.4 PUMPING STATION

For the foundation study of the Pumping Station sounding SR-93-1 was performed at a depth of 55.0 meters, detecting the following bedding profile:

- From 0,00 to 1,50 m Colluvial soil constitute of stiff blaxkish clayey silt with organic material.
- From 1,50 to 7,00 m Greenish gray fine grained sandstone, moderately cemented with a quality index III.
- From 7,00 to 10,50 m Weathered yellowish green fine and medium grained sandstone with sells and oxidated joints, quality index III.
- From 10,50 to 14,00 m Bluish gray medium and coarse grained sandstone mode rately cemented, from 12,20 m coarse grained some soft rock, quality index III - IV.
- From 14,00 to 19,30 m Gray medium grained sandstone with conglomeratic levels, quality index III.
- From 19,30 to 22,00 m Gray medium an coarse grained sandstone with microconglomeratic levels, moderately cemented with a quality index III.
- From 22,00 to 25,10 m Light gray silty fine grained sandstone, stiff rock with a quality index II.
- From 25,10 to 33,90 m Yellowish green fine and medium grained sandstone with microconglomeratic levels, quality index III, from 29,40 m levels of mudstone bluishgray color and a quality index II.
- From 33,90 to 38,10 m Gray medium grained sandstone, from 36,0 m bluish gray color, quality index II.
- From 38,10 to 43,60 m Gray fine and medium grained sandstone, triable with a quality index III.



From 43,60 to 45,00 m Levels of mudstone alternating fine grained sandstone stiff rock, quality index II.

From 45,00 to 49,20 m Gray siltstone with levels of light gray silty fine grained sandstone, compact massive with a quality index II - III.

From 49,20 to 55,00 m Greenish gray mudstone massive, stiff rock with levels of shells, quality index II - III.

Permeability tests were not performed during this sounding test.

The stabilized water level is at a depth of 35.50 meters.

2.4.5 SUBSTATION

Sounding test SR-93-2 was performed for the foundation study at a depth of 25.00 m.

The bedding profile detected is as follows:

From 0,00 to 2,30 m Colluvial soil constituted of weathered debris in grayish brown silty clay, stiff.

From 2,30 to 4,00 m Yellowish brown very weathered mudstone with a quality index IV.

From 4,00 to 6,60 m Greenish yellow very weathered siltstone with sandy layers with a quality index IV.

From 6,60 to 7,30 m Conglomeratic sandstone with a quality index III.

From 7,30 to 8,90 m Weathered light brown fine grained sandstone with a quality index III.

From 8,90 to 11,70 m Greenish yellow fine to medium grained sandstone some soft rock, bedding horizontal, quality index IV.



- (D)
- From 11,70 to 18,90 m Greenish gray fine grained sandstone with medium and coarse grained levels, stiff rock with cross beddings and a quality index II.
 - From 18,90 to 21,20 m Yellowish green fine grained sandstone with oxidated joints, quality index III - IV.
 - From 21,20 to 25,00 m Bluish gray medium and coarse grained sandstone with microconglomeratic levels, compact quality index III.

2.4.6 LOADING TANK

Sounding test SR-93-5 was drilled to study the foundation of the Loading Tank at a depth of 25.00 m.

The bedding profile detected is as follows:

- (D)
- From 0,00 to 3,50 m Colluvial soil constituted of yellowish brown clayey silt with plant roots and weathered rock debris, stiff.
 - From 3,50 to 6,20 m Completely weathered brown mudstone, residual soil with shells, quality index V.
 - From 6,20 to 7,80 m Greenish gray fine grained sandstone with shells with a quality index IV - III.
 - From 7,80 to 9,30 m Light brown mudstone with shells, from 8,60 m dark gray color, quality index III.
 - From 9,30 to 14,85 m Dark gray fine grained with shells and levels of mudstone, moderately cemented with a quality index III.
 - From 14,85 to 17,85 m Dark gray siltstone with levels of sandstone, with shells moderately cemented, quality index III.
 - From 17,85 to 19,85 m Greenish gray muddy fine grained sandstone with some of shells, stiff rock, quality index II.
- (D)



From 19,85 to 25,00 m Dark gray fine and medium grained sandstone moderately cemented, from 24,00 some soft, quality index III - IV.

PERMEABILITY

The following table provides a summary of the results of the Lugeon permeability tests performed at sounding tests SR-93-2 and SR-93-5.

LUGEON FIELD PERMEABILITY TEST					
HOLE NO	INTERVAL	COEFFICIENT OF PERMEABILITY K (cm/sec.)	LUGEON UNIT	NET PRESSURE	REMARKS
SR-93-2	5,00-10,00	$9,6 \times 10^{-4}$	92,13	1,89	LUGEON
SR-93-5	10,00-15,00	$3,9 \times 10^{-4}$	31,88	11,29	
SR-93-5	15,00-20,00	$7,7 \times 10^{-4}$	62,87	4,39	
SR-93-5	20,00-25,00	$5,2 \times 10^{-4}$	42,36	6,35	

LEFRANC FIELD PERMEABILITY TEST					
HOLE NO	INTERVAL	COEFFICIENT OF PERMEABILITY K (cm/sec.)	LUGEON UNIT	NET PRESSURE	REMARKS
*SR-93-5	2,00-5,00	$3,3 \times 10^{-3}$	-	-	LEFRANC
SR-93-5	5,00-7,80	$1,7 \times 10^{-5}$	-	-	-

The Lefranc test at depths of 2.00 to 5.00 meters for sounding test SR-93-5 did not manage to stabilize the flow which always increases due to the possible dissolution of salts or washes of cracks in the colluvial.

The greatest flow measured at 60 minutes is calculated.



(1)

3. LABORATORY ROCK TEST

3.1 PURPOSE AND SCOPE

For the purpose of learning the bedding and geomechanical characteristics of the rock bed to be involved in the performance of the project works, representative core lines have been selected at the depths we are interested in for the work of each one of the sounding tests. A broad laboratory testing program of Rock Mechanics has been performed.

3.2 TYPE AND AMOUNT OF TESTS PERFORMED

The type and number of rock testing performed is as follows:

DESCRIPTION	QUANTITY
- Mineralogic Analysis by X-Ray	11
- Specific gravity and water absorption	11
- Natural Density	11
- Uniaxial Compression	11
- Static deformation modulus	11
- Poisson's ratio	11
- Tensile strength	11
- Swelling	11
- Slaking tendency	11

An identification test was performed on the soil sample from sounding test MG-93-3 of the line at a depth of 8.50 - 8.80 m.

Tests were performed at the laboratories of the Polytechnic University of Quito, in strict compliance with the standards established for each one of them.



3.3 RESULTS OBTAINED

Results of the laboratory rock tests are provided herebelow in the summaries for each one of the works.

Complete results are provided in Appendix No. 4.3.



3.3.1 TUNEL DAULE PERIPA - LA ESPERANZA / DAULE PERIPA - LA ESPERANZA TUNNEL

HIDROSUELOS CIA. LTDA.		PROYECTO TRASVASES MANABI		
MUESTRA Y PROFUNDIDAD (m) SAMPLE AND DEPTH		DP-93-1 (21.30 - 21.80)	DP-93-2 (23.95 - 23.75)	DP-93-3 (22.00 - 22.57)
TIPOS DE ENSAYOS NAME OF TEST				
1. ANALISIS MINERALOGICO POR RAYOS X MINERALOGIC ANALYSIS BY X-RAY (%)	> 30% 10-30% < 10% < 1%	Plagiocasa - Esmectita / Illita Hombienda, cuarzo, clorita, pirita	Plagiocasa Esmectita / Illita - Cuarzo Hombienda, clorita pirita	Plagiocasa Esmectita / Illita - Cuarzo Hombienda, clorita
2. GRAVEDAD ESPECIFICA Y ABSORCION DE AGUA (gr/cm ³) SPECIFIC GRAVITY AND WATER ABSORPTION (%)	G _s Ab	2.758 46.16	2.704 41.48	2.696 46.97
3. DENSIDAD NATURAL NATURAL DENSITY (gr/cm ³)	γ_m	1.787	1.824	1.856
4. COMPRESION UNIAxIAL UNIAxIAL COMPRESSION (kg/cm ²)	q _u	48.91	103.28	60.15
5. MODULO DE DEFORMACION ESTATICA STATIC DEFORMATION MODULUS (kg/cm ²)	E	12.920	12.690	21.100
6. RELACION DE POISSON POISSON'S RATIO	ν	0.11	0.20	0.26
7. RESISTENCIA A LA TENSION TENSILE STRENGTH (kg/cm ²)	σ_b	13.16	6.47	13.73
8. HINCHAMIENTO SWELLING (kg/cm ²)	S _{pl}	0.00	6.47	1.23
9. TENDENCIA AL FRACCIONAMIENTO SLAKING TENDENCY (%)	kd	85.8	kd = 0.1	72.7



3.3.2 TUNEL LA ESPERANZA - POZA HONDA / LA ESPERANZA - POZA HONDA TUNNEL

HIDROSUELOS CIA. LTDA.		PROYECTO TRASVASES MANABI			
TIPOS DE ENSAYOS NAME OF TEST		MUESTRA Y PROFUNDIDAD (m) SAMPLE AND DEPTH		SR-93-3 (20,98-20,72)	SR-93-4 (33,00-33,50)
1. ANALISIS MINERALOGICO POR RAYOS X MINERALOGIC ANALYSIS BY X-RAY (%)	> 30% 10-30% < 10% < 1%	Esmeoita / Illita	Esmeoita / Illita		
		Plagioclasa, cuarzo clorita	Plagioclasa, Illita		
		Muscovita, pirlita calcita	Hornblenda, clorita pirlita, calcita		
2. GRAVEDAD ESPECIFICA Y ABSORCION DE AGUA SPECIFIC GRAVITY AND WATER ABSORPTION (%)	G _s A _b	2.736 98.47	2.768 89.20		
3. DENSIDAD NATURAL NATURAL DENSITY (g/cm ³)	γ'_m	2.074	2.038		
4. COMPRESION UNIAIXAL UNIAIXAL COMPRESSION (kg/cm ²)	q _u	62.8	63.72		
6. MODULO DE DEFORMACION ESTATICA STATIC DEFORMATION MODULUS (kg/cm ²)	E	22.60	12.695		
8. RELACION DE POISSON POISSON'S RATIO	ν	0.21	0.18		
7. RESISTENCIA A LA TENSION TENSILE STRENGTH (kg/cm ²)	σ_b	16.34	14.49		
8. HINCHAMIENTO SWELLING (kg/cm ²)	Sp _i	1.75	0.64		
9. TENDENCIA AL FRACCIONAMIENTO SLAKING TENDENCY (%)	k ₂	79.1	96.2		



3.3.3 TUNEL POZA HONDA MANCHA GRANDE / POZA HONDA MANCHA GRANDE TUNNEL

HIDROSUELOS CIA. LTDA.		PROYECTO TRASVASES MANABI		
MUESTRA Y PROFUNDIDAD (m) SAMPLE AND DEPTH		MG-93-1 (24.10-24.65)	MG-93-2 (36.62-37.00)	MG-93-3 (24.24-24.62)
TIPOS DE ENSAYOS NAME OF TEST				
1. ANALISIS MINERALOGICO POR RAYOS X MINERALOGIC ANALYSIS BY X-RAY (%)	> 90% 10-30% < 10% < 1%	Plagioclasa Esmectita / Illita Cuarzo Hornblenda, clorita, pirita	Plagioclasa, esmeo- rita / Illita - Cuarzo Hornblenda, clorita, pirita, mica	Plagioclasa, esmeo- rita / Illita - Cuarzo Hornblenda, clorita, pirita, mica
2. GRAVEDAD ESPECIFICA Y ABSORCION DE AGUA (gr/cm ³) SPECIFIC GRAVITY AND WATER ABSORPTION (%)	G _s A _b	2.608 32.83	2.661 34.91	2.735 39.73
3. DENSIDAD NATURAL (gr/cm ³) NATURAL DENSITY	ρ_m	2.062	2.068	2.000
4. COMPRESION UNIAxIAL (kg/cm ²) UNIAxIAL COMPRESSION	q _u	37.59	60.29	6.65
5. MODULO DE DEFORMACION ESTATICA (kg/cm ²) STATIC DEFORMATION MODULUS	E	7.73	6.10	1.90
6. RELACION DE POISSON POISSON'S RATIO	ν	0.22	0.21	0.20
7. RESISTENCIA A LA TENSION (kg/cm ²) TENSILE STRENGTH	σ_b	10.70	12.39	1.80
8. HINCHAMIENTO (kg/cm ²) SWELLING	S _{pl}	0.39	0.16	0.22
9. TENDENCIA AL FRACCIONAMIENTO (%) SLAKING TENDENCY	k ₂	63.4	12.6	0.40



3.3.4 ESTACION DE BOMBEO - SUBESTACION Y TANQUE DE CARGA
PUMP STATION - SUBSTATION AND HEAD TANK

HIDROSUELOS CIA. LTDA.		PROYECTO TRASVASES MANABI		
MUESTRA Y PROFUNDIDAD (m) SAMPLE AND DEPTH		SR-93-1 (48,84-49,92)	SR-93-2 (18,26-18,84)	SR-93-5 (9,79-9,00) (9,98-9,77)
TIPOS DE ENSAYOS NAME OF TEST				
1. ANALISIS MINERALOGICO POR RAYOS X MINERALOGIC ANALYSIS BY X-RAY (%)	> 90% 10-30% < 10% < 1%	Plagioclasa Esmectita / Illita - Homblanda, cuarzo, clorita, pirita	Plagioclasa Esmectita / Illita - Homblanda, cuarzo, clorita, pirita	Plagioclasa Esmectita / Illita - Homblanda, cuarzo, clorita, pirita
2. GRAVEDAD ESPECIFICA Y ABSORCION DE AGUA (g/cm ³) SPECIFIC GRAVITY AND WATER ABSORPTION (%)	G _s A _b	2.726 4.38	2.667 34.75	2.733 39.01
3. DENSIDAD NATURAL (g/cm ³) NATURAL DENSITY	γ_m	2.006	2.071	2.042
4. COMPRESION UNIAxIAL (kg/cm ²) UNIAxIAL COMPRESSION	q _u	92.00	128.5	134.69
5. MODULO DE DEFORMACION ESTATICA (kg/cm ²) STATIC DEFORMATION MODULUS	E	37.60	56.00	16.60
6. RELACION DE POISSON POISSON'S RATIO	ν	0.24	0.19	0.16
7. RESISTENCIA A LA TENSION (kg/cm ²) TENSILE STRENGTH	σ_b	18.38	29.64	21.07
8. HINCHAMIENTO (kg/cm ²) SWELLING	S _{pl}	0.26	0.08	0.10
9. TENDENCIA AL FRACCIONAMIENTO (%) SLAKING TENDENCY	Id ₂	77.1	95.2	68.40

