THE MINUTES OF DISCUSSIONS ON THE BASIC DESIGN STUDY ON THE PROJECT FOR RECONSTRUCTING THE BEPOSO BRIDGE IN THE REPUBLIC OF GHANA

In response to the request of the Government of the Republic of Ghana, the Government of Japan decided to conduct a basic design study on the Project for reconstructing the Beposo Bridge (hereinafter referred to as "The Project"), and entrusted the study to the Japan International Cooperation Agency (hereinafter referred to as "JICA"). JICA sent the Basic Design Study Team headed by Mr. Masahiko MURASATO, Head of Structural Engineering Section, Nagoya Construction Bureau of Japan Highway Public Corporation, to carry out the study from September 24 to October 23, 1988.

The Japanese Team had a series of discussions on the Project with the officials concerned of Ghana, and conducted the field survey at the Project site.

Both parties agreed to recommend to their respective Government authorities that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

October 11, 1988.

Masahiko MURASATO
Leader
Basic Design Study Team
JICA

Eleanor Quist
Acting Chief Director
International Economic Relations Division
Ministry of Finance and Economic Planning

Witness:

H.O.A. Quaynor
Chief Executive
Ghana Highway Authority
Ministry of Roads and Highways

ATTACHMENT

1. Objective of the Project

The objective of the Project is to reconstruct the Beposo Bridge close to the existing old bridge in order to smoothen and improve the safety of the traffic flow on the Route 1 which is a part of the Trans West African Highway.

2. Implementing Body

Ghana Highway Authority of the Ministry of Roads and highways is responsible for the implementation of the Project.

3. Construction Site of the Project

The construction site of the Project is downstream side of the existing bridge located at Beposo over the Pra River, on the Route 1 as shown in ANNEX I.

4. Outline of the Project

(1) New Beposo Bridge:

Length	:	about 100m
Width of carriage way	:	2 x 3.75m
Effective width of pedestrian way	:	2 x 1.5m

(2) Approach Road: tentatively about 1200m (total length of both sides including some improvement work of existing roads), which will be finalized after the completion of basic design.

5. The Government of the Republic of Ghana will take the necessary measures listed in ANNEX II on condition that the Grant Aid by the Government of Japan is extended to the Project.

6. Both sides confirmed that the Japanese Study Team explained the Japanese Grant Aid Programme and the Ghana side understood it.

7. JICA will conduct phase II study in order to proceed with the bridge design after analysing the data obtained in this study.

TO ACCRA
Beposo village
APPROACH ROAD
EXISTING BRIDGE
NEW BRIDGE
About 100M
PRA RIVER
FLOW
APPROACH ROAD
TO TAKORADI
CROSS SECTION
About 23.0 M
EXISTING BRIDGE
NEW BRIDGE

ANNEX II

Necessary measures to be taken by the Government of the Republic of Ghana.

1. To secure land necessary for the execution of the Project and provide enough space for such construction as temporary offices, working area, stockyard and other utilities prior to the commencement of construction.

2. To demolish all existing buildings inside the Project site and clear the site prior to the commencement of construction.

3. To ensure that the river area necessary for construction of the facilities be freely accessible.

4. To provide information about necessary facilities for the construction such as electricity, water supply, telephone and other incidental facilities up to the project site.

5. To ensure prompt unloading, customs clearance at ports of disembarkation and, duties, taxes and levies exemption in Ghana of the goods purchased under the Grant Aid.

6. To ensure free internal movement of the goods imported under the Grant Aid handled by the contractor.

7. To exempt Japanese nationals from customs duties, internal taxes and other fiscal levies which may be imposed in Ghana with respect to the supply of the products and services under the verified contracts.

8. To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into Ghana and stay herein for the performance of their works.

9. To maintain properly and effectively the bridge and approach roads constructed under the Grant Aid.

THE MINUTES OF DISCUSSIONS ON THE BASIC DESIGN STUDY ON THE PROJECT FOR RECONSTRUCTION THE BEPOSO BRIDGE IN THE REPUBLIC OF GHANA

In response to the request of the Government of the Republic of Ghana, the Government of Japan decided to conduct a basic design study on the Project for reconstructing the Beposo Bridge (hereinafter referred to as "The Project"), and entrusted the study to the Japan International Cooperation Agency (hereinafter referred to as "JICA"). JICA sent the First and the Second Basic Design Study Teams headed by Mr. Masahiko MURASATO, Head of Structural Engineering Section, Nagoya Construction Bureau of Japan Highway Public Corporation, to carry out the study. The Second Basic Design Study during the period from December 3 to 23, 1988.

The Japanese team had a series of discussions on the Project with the Officials of Ghana concerned, and conducted the field survey at the Project Site.

Both parties agreed to recommend to their respective Government authorities that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

December 9, 1988.

Masahiko MURASATO
Leader
Basic Design Study Team
JICA

Eleanor Quist
Acting Chief Director
International Economic Relations Division
Ministry of Finance and Economic Planning

Witness:

H.O.A. Quaynor
Chief Executive
Ghana Highway Authority
Ministry of Roads and Highways

ATTACHMENT 1

1. Type of Bridge

The bridge proposed to be reconstructed will be of a single span prestressed concrete box girder with an opening width of about 100m between abutment faces. (See Figure 1).

2. Bridge Section

The bridge will have a two lane carriageway of 8.5m wide (curb to curb), 1.5m wide pedestrians walkways, 0.25m wide reinforced concrete wall parapets on both sides, giving an overall bridge width of 13.3m. (See Figure 1).

3. Approach Roads

Approach roads of about 600m long in total will be constructed. (See Figure 2).

4. Design Standard

The design standard to be applied to the bridge, road, and their ancillary structures will be, in principle, "Specifications for Highway bridges", "A policy on Geometric Design of highway" and their relevant design standards issued by the Japan Road Association, and "Design Guide for Bridges" issued by GHA.

5. Hydraulic Design Standard

The following design flood frequency and maximum flood level will be applied to the bridge design:-

Design flood Frequency	1:50 years
Maximum Flood Level	MSL + 5.5m

6. The necessary measures to be taken by the Government of the Republic of Ghana in addition to those agreed in the 1st Basic Design Study are as follows:-

(a) The Government of Ghana shall provide an area about 20,000m2 of flat ground within about two kilometres of either side of the construction site for the Contractor's office, stockyard, plantyard and other temporary facilities.

(b) The Government of Ghana shall demolish and clear all existing buildings inside the right of way of the proposed approach road and bridge before the start of construction.

(c) As far as possible, the Government of Ghana shall provide two international telephone lines (one for telephone and the other for telex) each to the Contractor's and Consultant's liaison offices in Accra City respectively and one telephone line each to the Contractor's and Consultant's staff houses in Takoradi respectively.

7. The Government of Ghana shall exempt the Consultant's and Contractor's personnel from customs duties, internal taxes and other fiscal levies which may be imposed in Ghana with respect to the supply of goods and services under the verified contract.

8. The cost of electricity supply, water supply and internal telephone lines required at the construction site will be covered within the Grant Aid Programme.

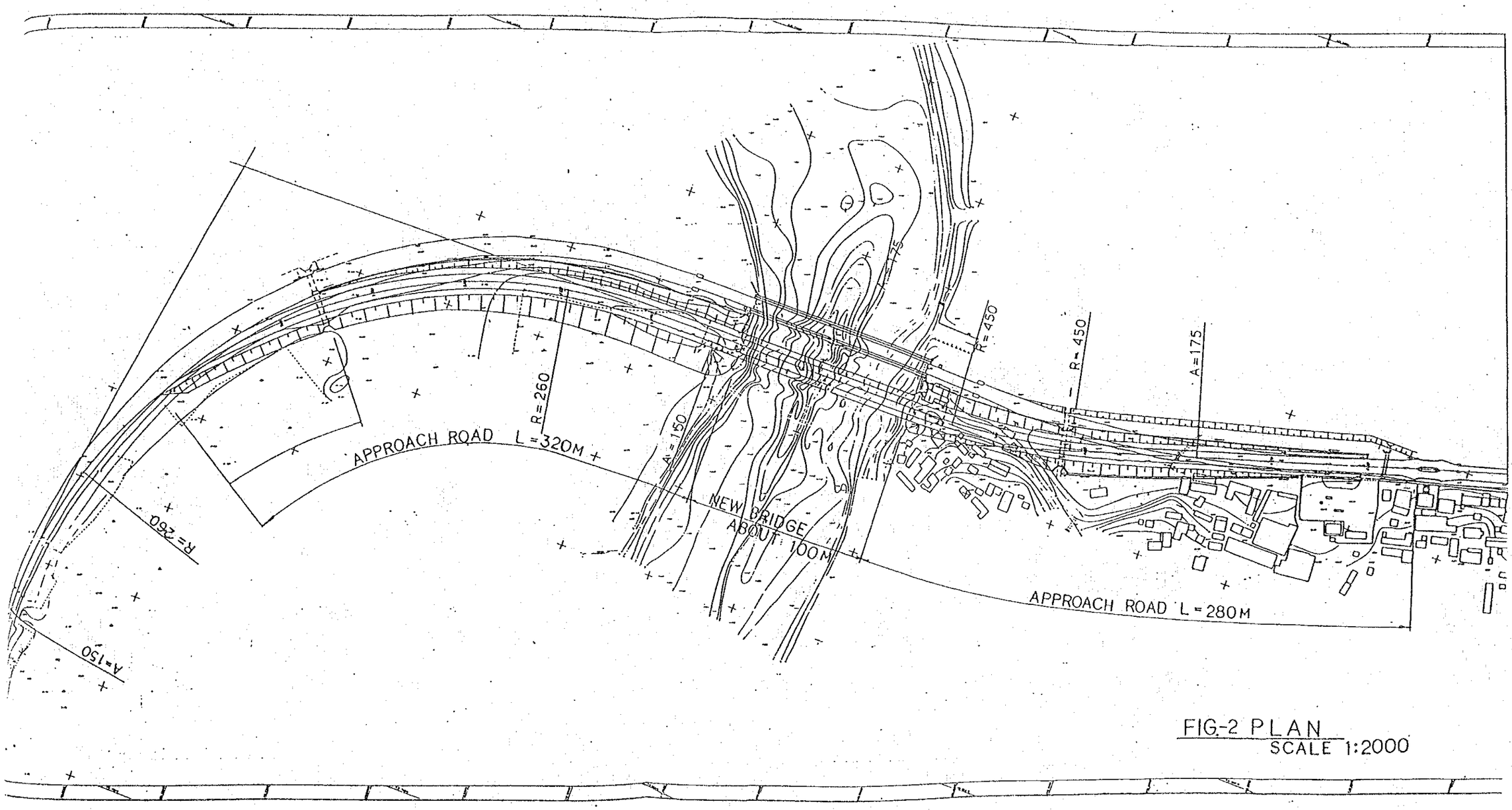
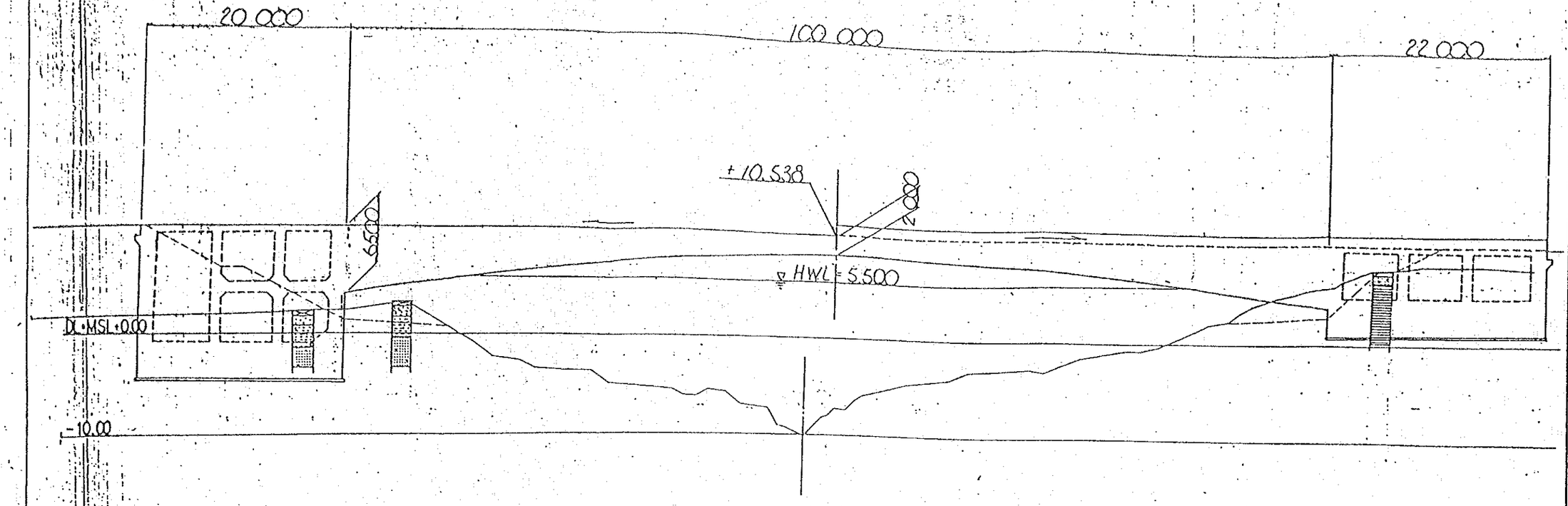
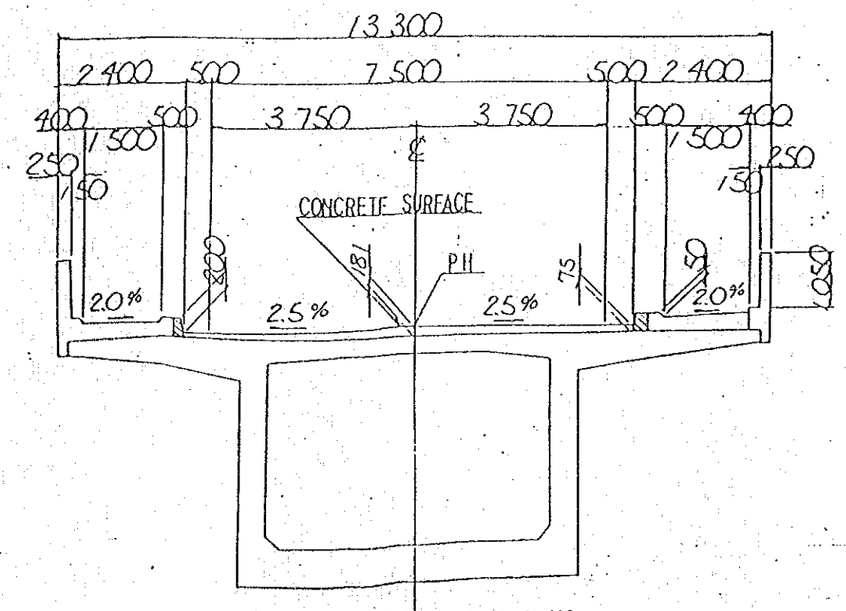


FIG-2 PLAN
SCALE 1:2000



ELEVATION ON BRIDGE SCALE 1:400



BRIDGE SECTION SCALE 1:100

FIG.-1 SINGLE-SPAN PRESTRESSED CONCRETE GIRDER BRIDGE

THE MINUTES OF DISCUSSION ON THE BASIC DESIGN STUDY ON THE PROJECT FOR RECONSTRUCTING THE BEPOSO BRIDGE IN GHANA

In response to the request of the Government of the Republic of Ghana, the Government of Japan decided to conduct a basic design study of the Project for reconstructing the Beposo Bridge (hereinafter referred to as 'the Project'), and entrusted the Japan International Cooperation Agency (hereinafter referred to as 'JICA'). JICA sent the Basic Design Study Team headed by Mr. Masahiko MURASATO, head of Structural Engineering Section, Nagoya Construction Bureau of Japan Highway Public Corporation, two times in the period from September 24 to December 23, 1988.

As a result of the Study, JICA prepared a draft report and despatched a team headed by Mr. Masahiko MURASATO to explain and discuss it from February 10 to 24, 1989.

Both parties had a series of discussions on the report and agreed to recommend to their respective Governments that the major points of understanding reached between them on February 17, 1989, attached herewith should be examined towards the realization of the Project.

February 17, 1989

Masahiko MURASATO
Leader
Basic Design Study Team
JICA

CHIEF DIRECTOR
INTERNATIONAL ECONOMIC RELATIONS DIVISION
MINISTRY OF FINANCE & ECONOMIC PLANNING

Eleanor Quist
Acting Chief Director
International Economic
Relations Division
Ministry of Finance and
Economic Planning

Witness:

H.O.A. Quaynor
Chief Executive
Ghana Highway Authority
Ministry of Roads and Highways

ATTACHMENT

1. The Government of Ghana agreed in principle to the basic design proposed in the Draft Final Report.

2. The Government of Ghana has reconfirmed the Minutes of Discussion signed on October 11 and December 9, 1988.

3. The Government of Ghana assured the provision of the right-of-way and site clearance thereof necessary for the execution of the project as shown in Annex 1.

4. The Government of Ghana has agreed to be responsible for the provision of site for temporary yards already levelled and borrow pits as contained in GHA report of January 1989 necessary for the execution of the project as shown in Annex 2 and 3.

5. The Government of Ghana has agreed to report on the situation of the preparations as mentioned in the article 3 and 4 above, particularly on land acquisition, to the Japanese side by the end of May, 1989.

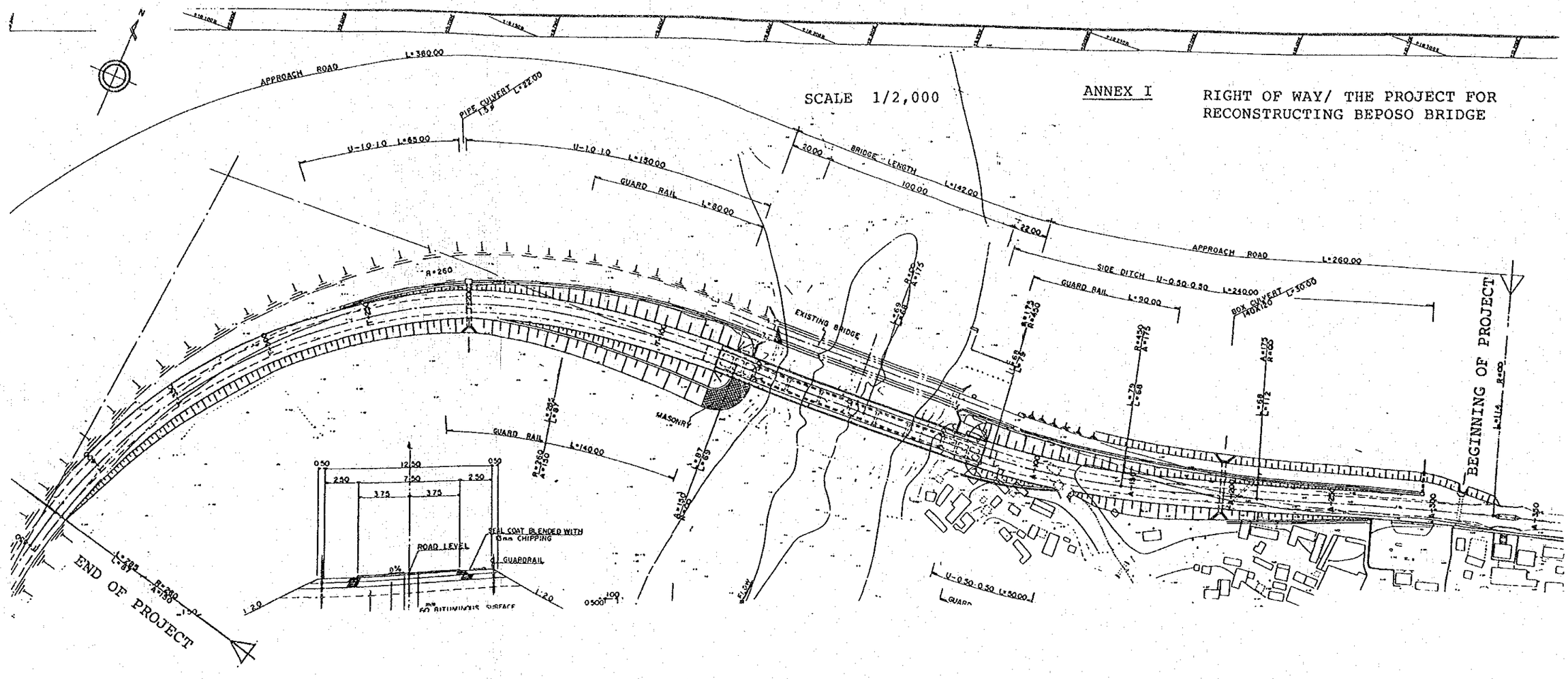
6. The JICA team agreed to the provision of ducts for Electricity, Water and Telephone in addition to ducts for lighting the bridge in the detailed design.

7. The Final Report (10 copies in English) will be submitted to the Government of Ghana in March, 1989.

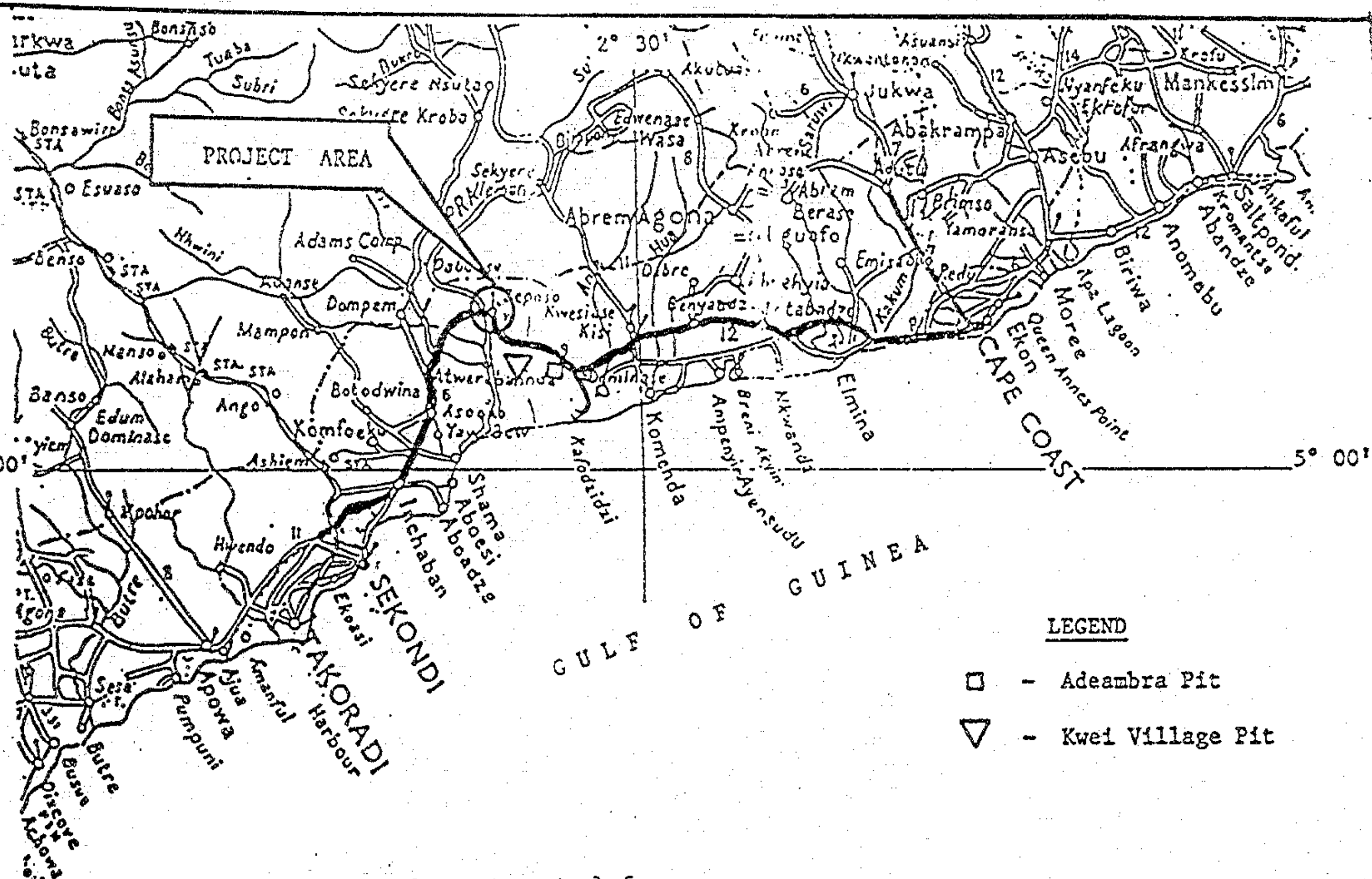
ANNEX I

RIGHT OF WAY/ THE PROJECT FOR RECONSTRUCTING BEPOSO BRIDGE

SCALE 1/2,000



ANNEX 2 TEMPORARY YARDS AND ANTICIPATED BORROW PIT



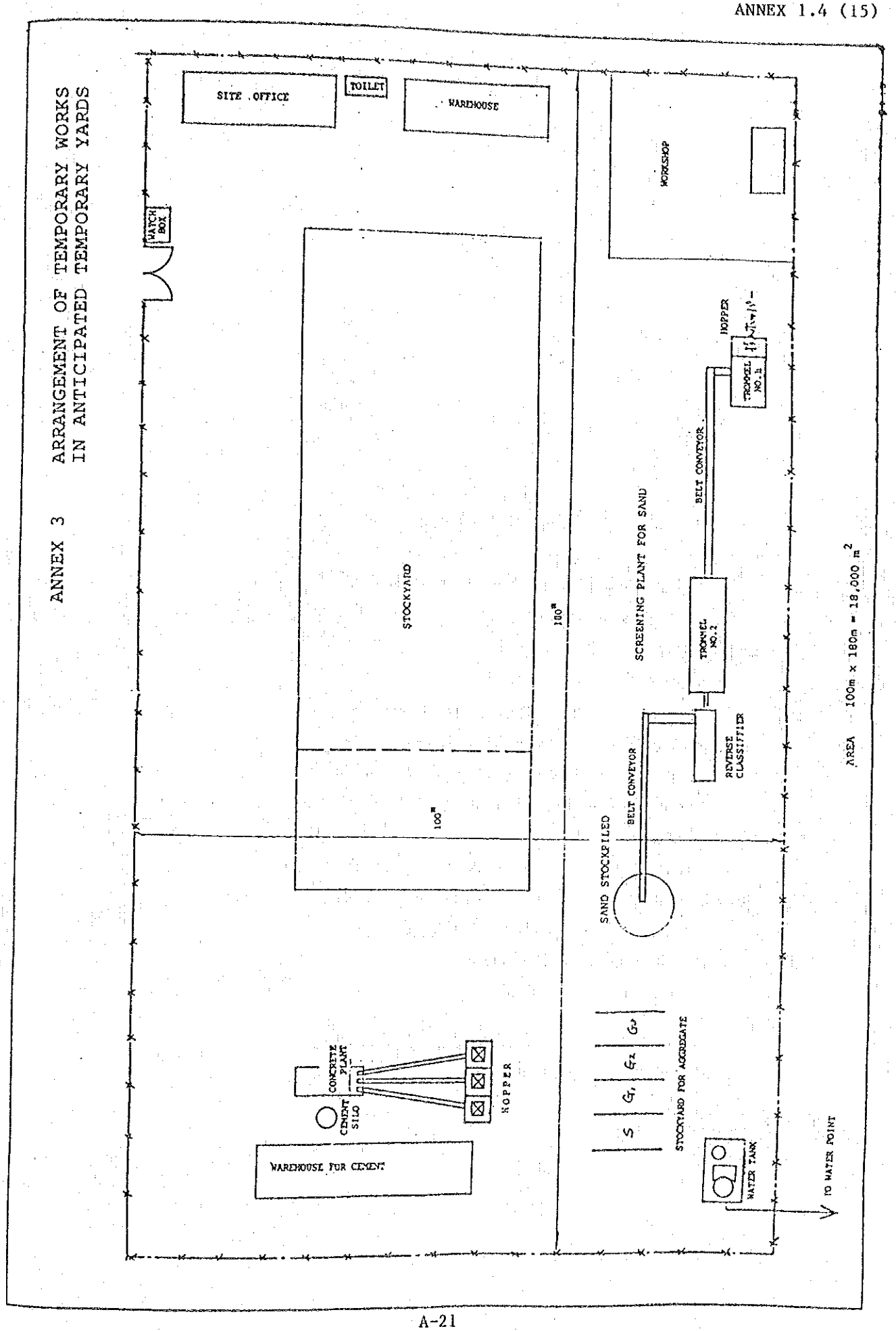
Appended to ANNEX 2, extracted from GHA Report of January 1989, "Materials Survey".

Scale. 1 : 500,000

SOURCES OF NATURAL MATERIALS

FIG. 1

ANNEX 3 ARRANGEMENT OF TEMPORARY WORKS IN ANTICIPATED TEMPORARY YARDS

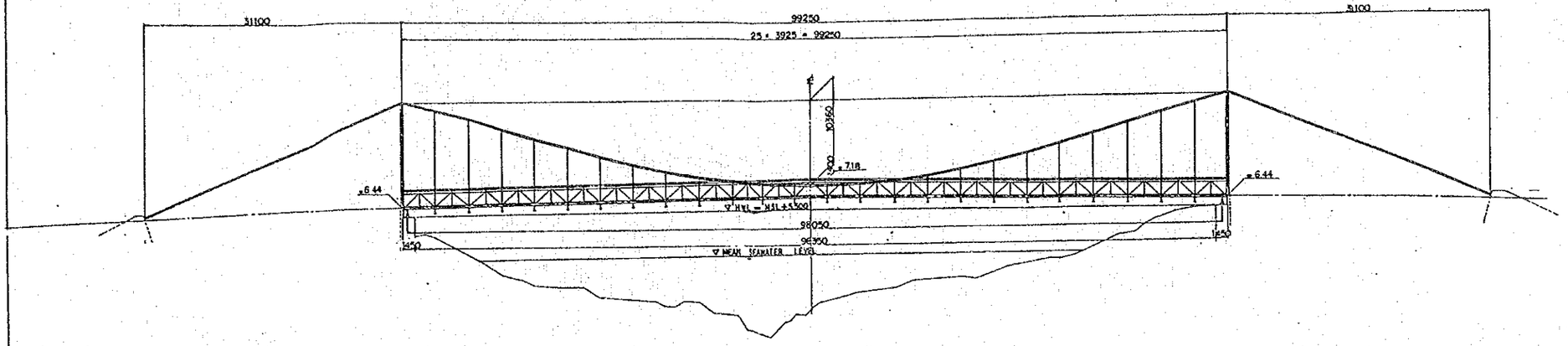


ANNEX 1.5 LIST OF COLLECTED DATA

1. Progress of The Economic Recovery Programme 1984-86 and Policy Framework 1986-88
   The Government of Ghana
2. Transport Rehabilitation Project October 29, 1987
   Document of The World Bank
3. Public Investment Programme 1988-90
   Volume 2.2 Project Profiles and Summary Tables
   Ministry of Finance and Economic Planning
4. Ghana Bridge Development Programme
   Feasibility Study of First Priority Bridges
   Tahal Consulting Engineers Ltd.
5. Ghana Bridge Development Programme
   Feasibility Study-Second Stage
   Tahal Consulting Engineers Ltd.
6. Hydrological Data Book Water Year Book
   Ministry of Works and Housing Public Works Department
7. Traffic Report (1983-1987)
   Ghana Highway Authority
8. Beposo Bridge Design Report and Scheme Drawings
   Cementation International Engineering Ltd.
9. Guide for Bridge Design Volume 1 Design Guide
   Tahal Consulting Engineers Ltd.
10. Ghana Building Code
    Building and Road Research Institute
11. Maximum Rainfall Intensity-Duration Frequencies in Ghana
    Ghana Meteorological Services Department
12. Mean Monthly and Annual Rainfall Maps
    Ghana Meteorological Services Department
13. River Basins of Ghana, Water year Book
    Ministry of Work and Housing, Public Works Department
14. Water year Report for 1971-1972
    AESC Hydrology Division
15. Organization Manual
    Ministry of Roads and Highways

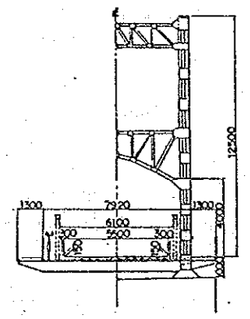
16. Quarterly Digest of Statistics, June 1988
Ghana Statistics Service Corporation
17. Ghana in Figures
Ghana Statistical Service Corporation
18. 1:50,000 Map
Ghana Survey Department
19. Ghana Quarry Industry
Lavalin International in Association with Saged Engineering Consultants
20. Tide Table
Ghana Ports and Harbours Authority
21. Bridge Maintenance Management Manual
Ghana Highway Authority
22. Economic Recovery Programme 1984-86
Government of Ghana, Accra November 1984
23. Ghana Fourth Highway Project
Preinvestment Study for Kumasi-Tamale-Bolgatanga-Paga Road
Ghana Highway Authority
24. Road Rehabilitation Programme
4th Highway Programme
Ghana Highway Authority
25. Quarterly Progress Report
Ghana Highway Authority
26. Road Rehabilitation And Maintenance Programme March 29, 1985
Document of The World Bank
27. A New Geography of Ghana
Logman
28. Basic Social Studies Atlas for GHANA
SEDCO Publishing Ltd.

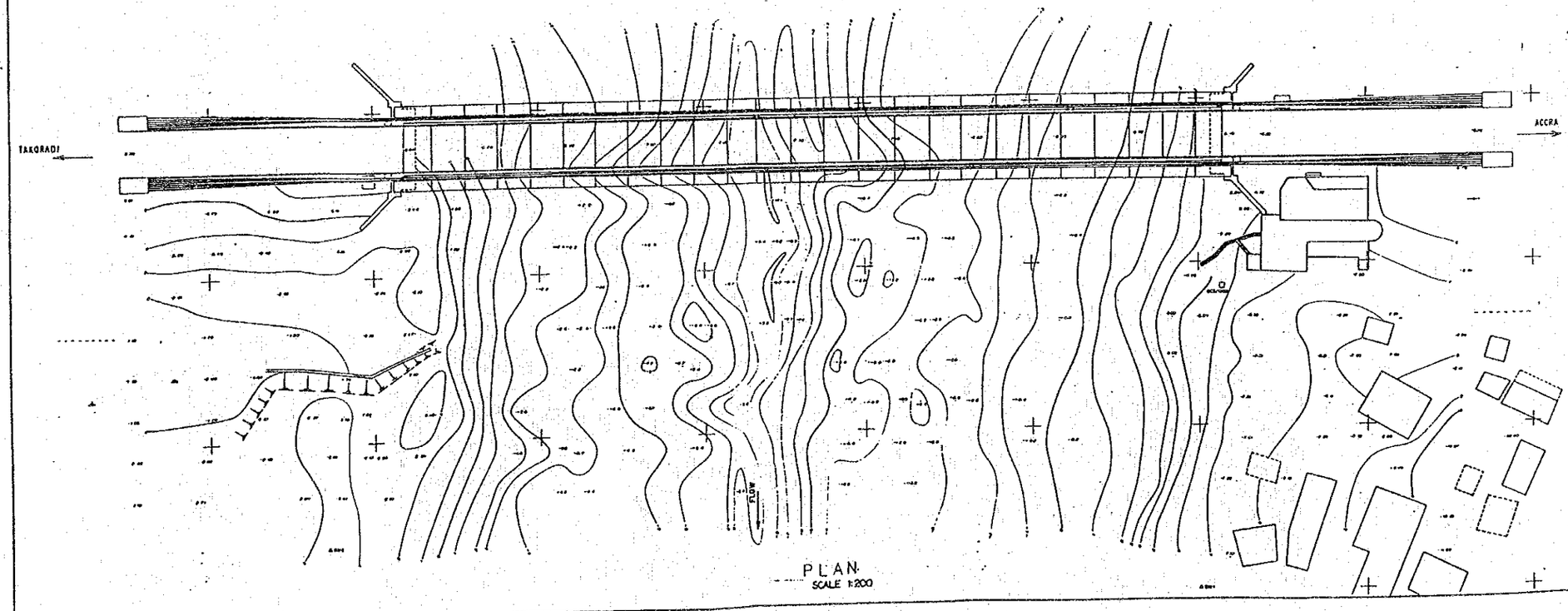
ANNEX 2



ELEVATION
SCALE 1:200

BRIDGE SECTION
SCALE 1:100



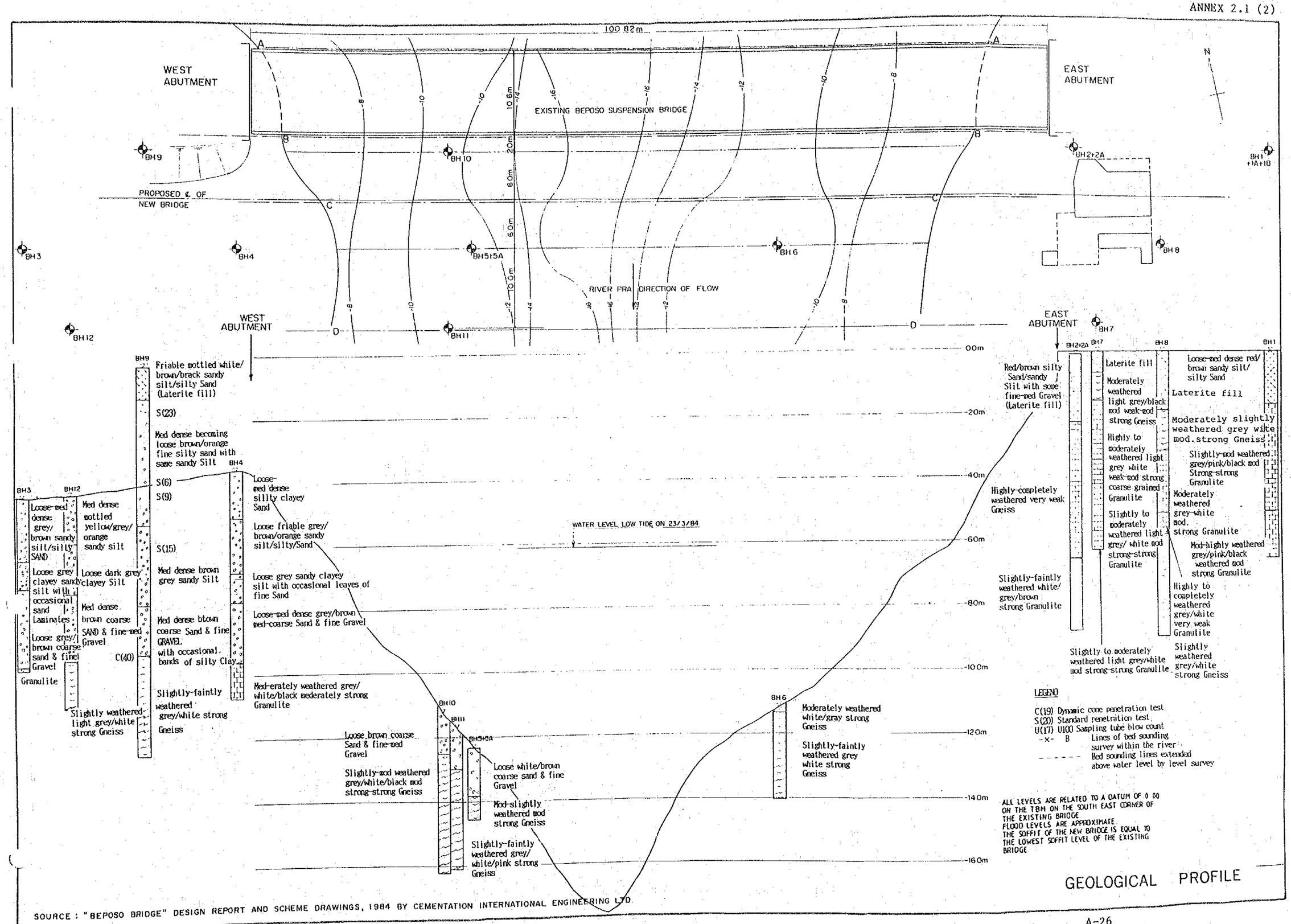


PLAN
SCALE 1:200

BASIC DESIGN STUDY ON
THE PROJECT FOR RECONSTUCTING
THE BEPOSO BRIDGE

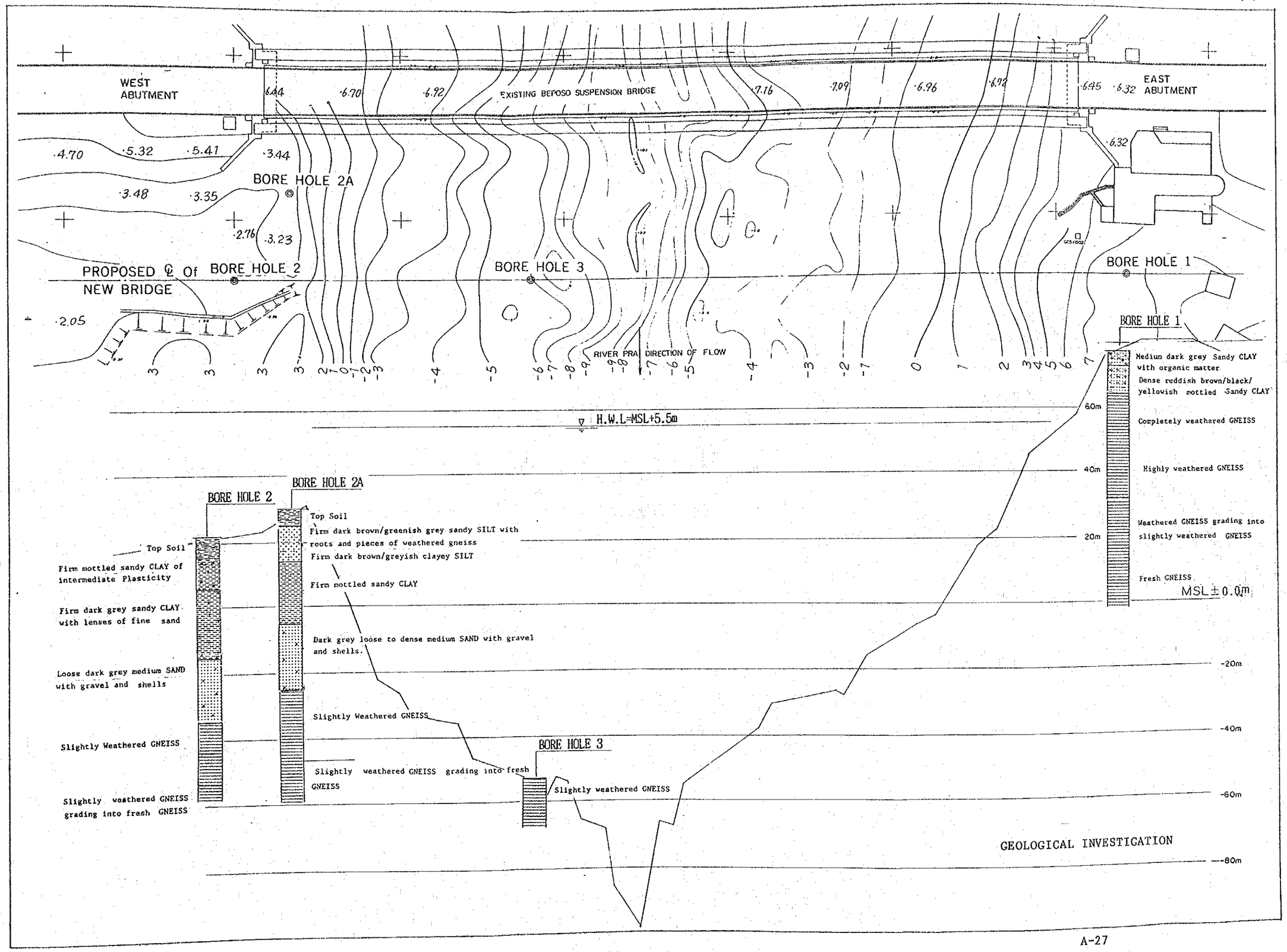
DESCRIPTION: GENERAL VIEW OF
THE EXISTING BRIDGE

DRAWN | CHECKED | APPROVED
SCALE: AS SHOWN | DRAWING NO. | DATE: 1 DEC 1988



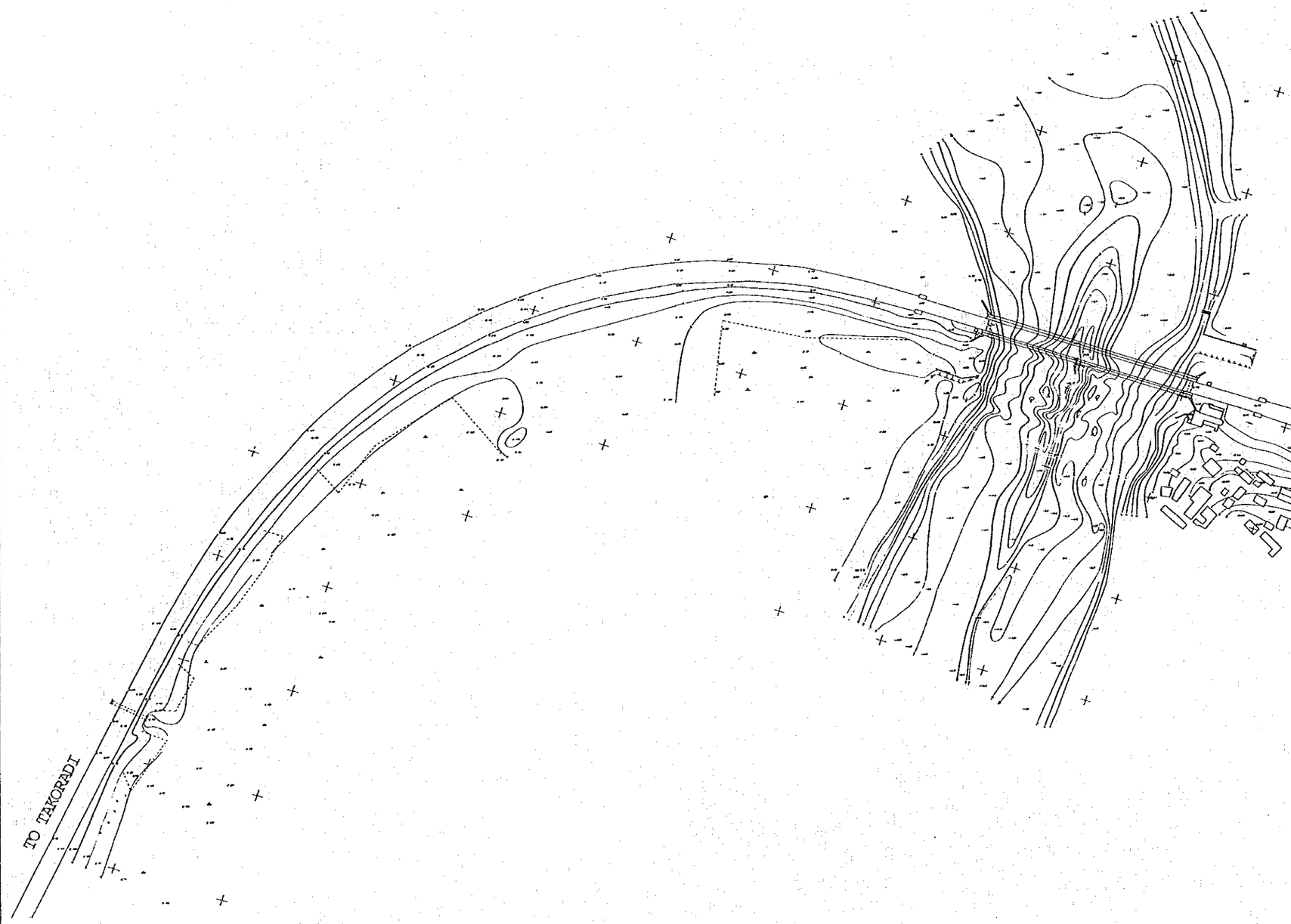
GEOLOGICAL PROFILE

SOURCE : "BEPOSO BRIDGE" DESIGN REPORT AND SCHEME DRAWINGS, 1984 BY CEMENTATION INTERNATIONAL ENGINEERING LTD.



GEOLOGICAL INVESTIGATION

TOPOGRAPHICAL MAP OF BEPOSO BRIDGE RECONSTRUCTION SITE



NOTES

1. Levels ar
   water lev

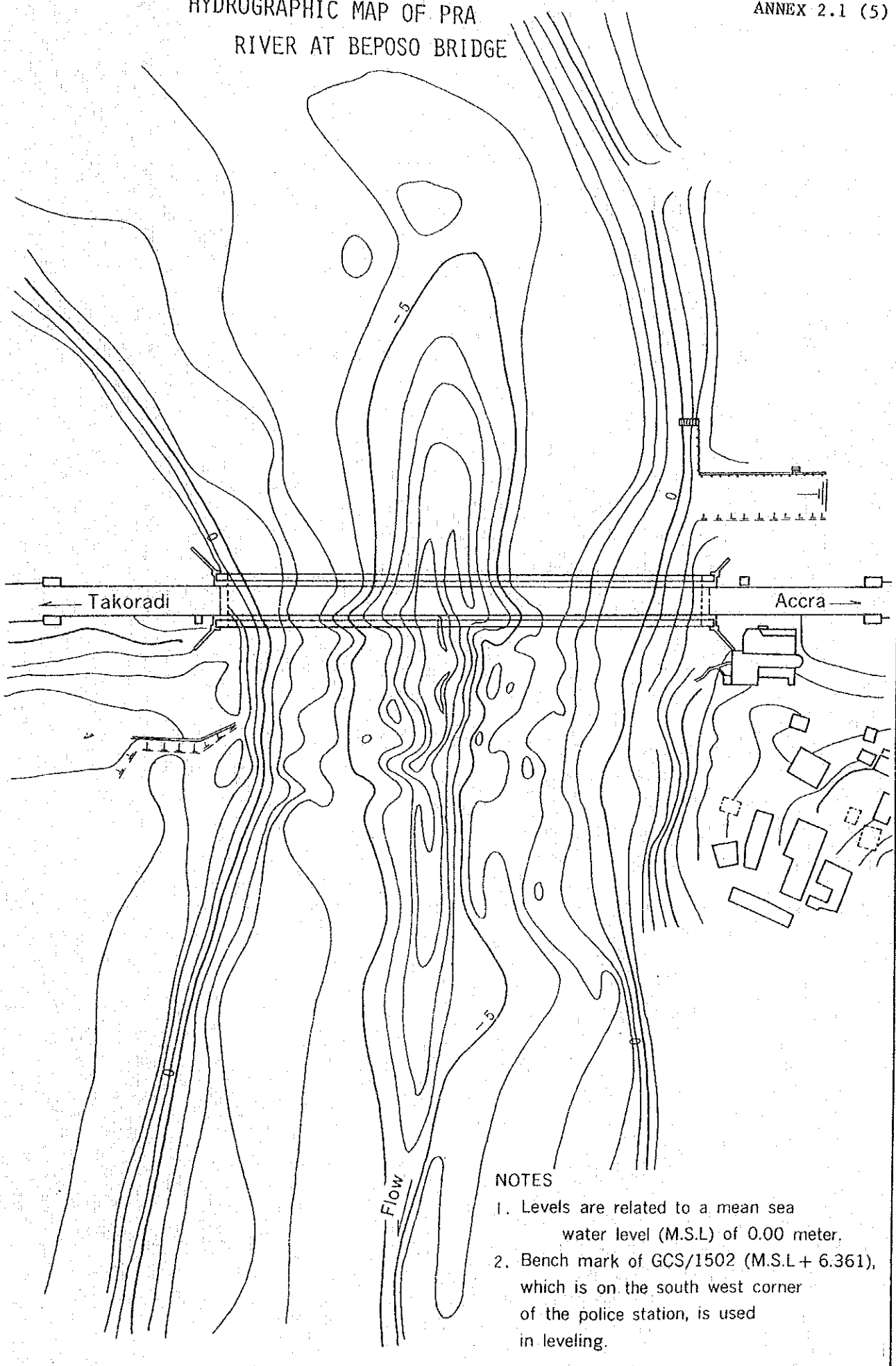
2. Bench mar
   which is
   of the pc
   in leveli

TOPOGRAPHICAL MAP OF BEPOSO BRIDGE RECONSTRUCTION SITE

NOTES

1. Levels are related to a mean sea water level (M.S.L) of 0.00 meter.
2. Bench mark of GCS/1502 (M.S.L+6.361), which is on the south west corner of the police station, was used in leveling.

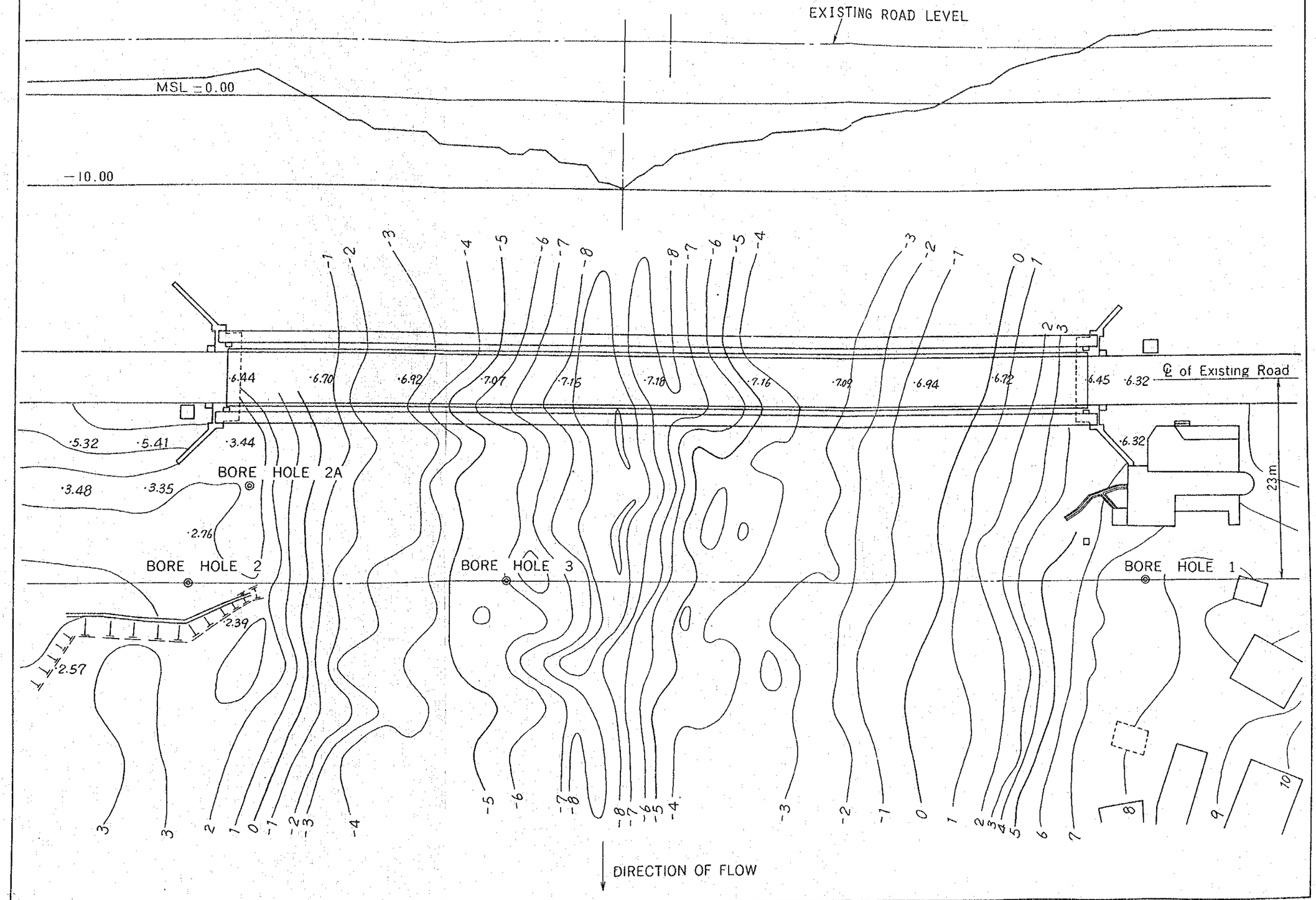
HYDROGRAPHIC MAP OF PRA RIVER AT BEPOSO BRIDGE

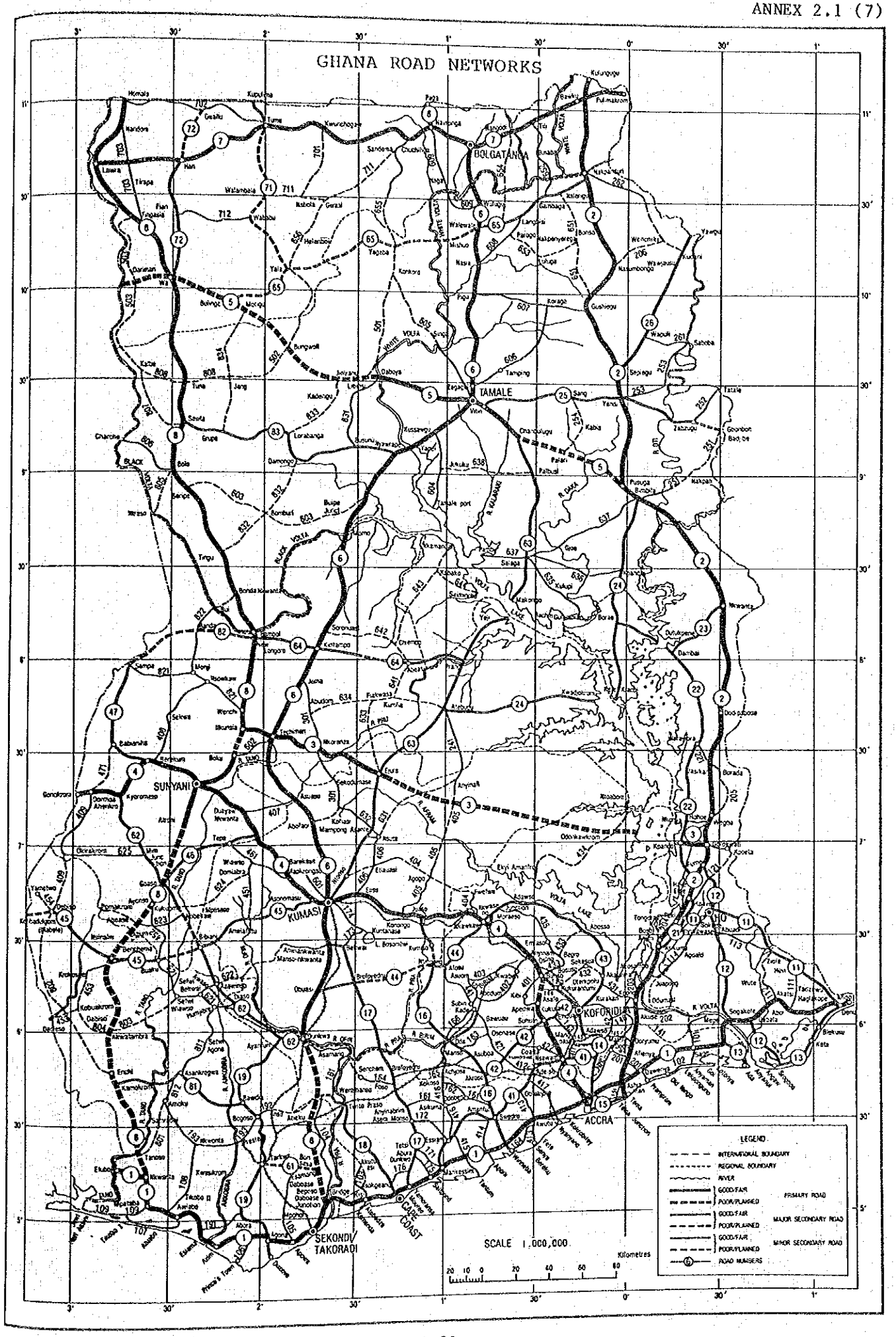


NOTES

1. Levels are related to a mean sea water level (M.S.L) of 0.00 meter.
2. Bench mark of GCS/1502 (M.S.L + 6.361), which is on the south west corner of the police station, is used in leveling.

PROFILE OF PRA RIVER AT BEPOSO BRIDGE RECONSTRUCTION SITE




GHANA ROAD NETWORKS
BOLGATANGA
TAMALE
SUNYANI
KUMASI
KOFORIDUA
ACCRA
HO
SEKONDI/
TAKORADI
CAPE
COAST
LEGEND
INTERNATIONAL BOUNDARY
REGIONAL BOUNDARY
RIVER
GOOD/FAIR
POOR/PLANNED
PRIMARY ROAD
GOOD/FAIR
POOR/PLANNED
MAJOR SECONDARY ROAD
GOOD/FAIR
POOR/PLANNED
MINOR SECONDARY ROAD
ROAD NUMBERS
SCALE 1:1,000,000
Kilometres
20 10 0 20 40 60 80

PLAN
SCALE 1:1,000

TYPICAL SECTION
SCALE 1:15

PROFILE
SCALE H=1:1,000
V=1:200

GRADIENT	
ROAD LEVEL	
GROUND LEVEL	
STATION	
HORIZONTAL ALIGNMENT	
SUPER-ELEVATION	

BASIC DESIGN STUDY ON THE PROJECT FOR RECONSTRUCTING THE BEDOSO BRIDGE

DESCRIPTION
GENERAL ARRANGEMENT OF THE PROJECT

DRAWN | CHECKED | APPROVED

SCALE AS SHOWN | DRAWING NO. | DATE DEC 1989

MONTHLY MEAN WATER LEVEL (FEET) DABOASI GAUGING STATION

Year	3	4	5	6	7	8	9	10	11	12	1	2
1971 -72	4.62	4.14	3.97	7.56	7.65	7.62	7.12	8.49	5.89	5.49	3.75	3.25
1972 -73	4.33	7.13	7.47	11.32	8.52	7.00	5.83	7.02	5.89	4.75	4.01	3.07
1973 -74	2.94	4.82	4.53	6.47	6.03	6.67	9.48	8.42	6.95	4.75	3.50	2.49
1975 -75	3.77	5.19	7.39	8.61	9.18	7.88	10.56	9.39	7.61	5.11	4.07	4.64
1975 -76	4.51	5.34	6.38	8.09	11.86	6.15	5.31	7.63	6.07	5.40	3.67	3.56
1976 -77	4.30	5.17	6.39	10.49	7.03	5.19	4.60	5.94	7.24	4.65	3.62	2.78

MONTHLY MEAN DISCHARGE (C.F.S) DABOASI GAUGING STATION

Year	3	4	5	6	7	8	9	10	11	12	1	2
1971 -72	2,423	1,743	1,596	8,116	8,311	8,219	7,213	10,091	4,624	2,871	1,264	648
1972 -73	1,808	6,732	7,826	16,673	10,189	6,802	4,264	6,835	4,436	2,317	1,495	619
1973 -74	624	2,346	1,987	5,728	4,892	6,252	12,217	9,888	6,663	2,275	942	327
1974 -75	1,286	3,017	7,679	10,361	11,684	8,836	14,752	11,882	8,100	2,833	1,532	2,408
1975 -76	1,864	3,281	5,377	9,144	18,370	4,950	3,262	8,242	4,761	3,533	1,083	995
1976 -77	1,861	3,018	5,516	14,664	6,801	3,052	2,044	4,496	7,495	2,218	1,020	460

SOURCE: ARCHITECTURAL AND ENGINEERING SERVICES CORPORATION

ANNEX 3

ANNEX 3.1 COUNTRY DATA

1.	Official Name of Country	Republic of Ghana
2.	Capital city	Accra
3.	Independence	1957
4.	Official Language	English
5.	Currency	
	Currency	Cedi
	Exchange rate	162.37 Cedi/dollar (1987)
6.	Area and Population	
	Area	238,533 Km^2
	Population	12,296,000 (1984)
	Growth rate of population	2.6% (1970 - 1984)
	Density of population	52 persons per sq. km
7.	Gross National Product	
	GNP (1987)	725,541 (¢ Millions)
	Per capita national Income	50,586 Cedi (311 US$)
	% change over previous year	+4.8
8.	Percentage Distribution of Economic Activity (At 1987 Price)	
	Agriculture	50.6%
	Industry	15.9%
	Transport, Storage, Governmental Service	33.5%
9.	Public Finance (1987 · Preliminary actuals)	
	Revenue	111,046 (¢ Million)
	Expenditure	102,135 "
	Recurrent expenditure	80,583 "
	Development expenditure	21,552 "
	Total budget deficit	8,911 "
10.	External Trade (1987 · Provisional)	
	Imports	145,319 ¢ Million
	Exports	147,275 "
	Balance of Trade	+1,956 "

Source: "Quartery Digest of Statistics" June 1988, Statistical Service, Accra, Ghana

ANNEX 3.2 SUMMARY OF TEST RESULTS

TABLE 1.

SUMMARY OF RESULTS OF TEST ON BOREHOLE SAMPLES - DEPOSO BRIDGE PROJECT

Sample No.	Pit No.	Depth (m)	% BY WEIGHT PASSING B.S. SIEVE												Liquid Limits	Plastic Limits	Natural Moisture Content(%)	Plasticity Index
			37.5 mm.	25 mm	19 mm	14 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 µm	300 µm	150 µm	75 µm	2µm				
1	1	0.5					100	99	96	91	83	75	69	64		47.5	24.4	18.1	23
2	1	0.6					100	97	94	86	78	67	59	56		38.5	20.5	22.4	18
3	2A	0.5			100	99	99	89	97	96	95	92	78	60		22.6	15.6	16.8	7
4	2A	1.0										100	94	83				35.4	
5	2A	1.6							100		95		95	69	30	29	17	20.0	12
6	2A	2.05-2.65										100	93	83				22.2	
7		3.05							100		85			50	12	26	18	30.7	8
8	2A	3.5-4.1			100		98	98	95	85	35	7	3	3		NON -	PLASTIC	15.6	
9	2A	4.1-4.3		100	95		79	74	71	59	23	5	2	2		NON -	PLASTIC	8.6	
9A	2A	4.7			100		94	87	81	64	38	15	8	6		NON -	PLASTIC	5.9	
10	2	0.6							100	99	99	93	67	46		27.9	16.7	22.6	11
11	2	0.92-1.52									100	99	90	74				13.1	
12	2	1.52								100	99	95	81	72		29.9	18.6	22.9	11
13	2	2.2-2.82							100	100	99	97	83	73				41.2	
14	2	3.65-4.25			100		93	88	81	61	34	14	5	3		NON -	PLASTIC	17.3	
15	2	5.4			100		94	88	81	63	37	14	6	4		NON -	PLASTIC	8.6	

TABLE II

UNCONFINED COMPRESSION TEST RESULTS

Borehole No.	Sample No.	Depth (m)	Unconfined Compressive Stength q_u KN/m²
2A	5	1.6	129.3
2A	7	3.05	*

* Too Soft to be tested

TABLE III

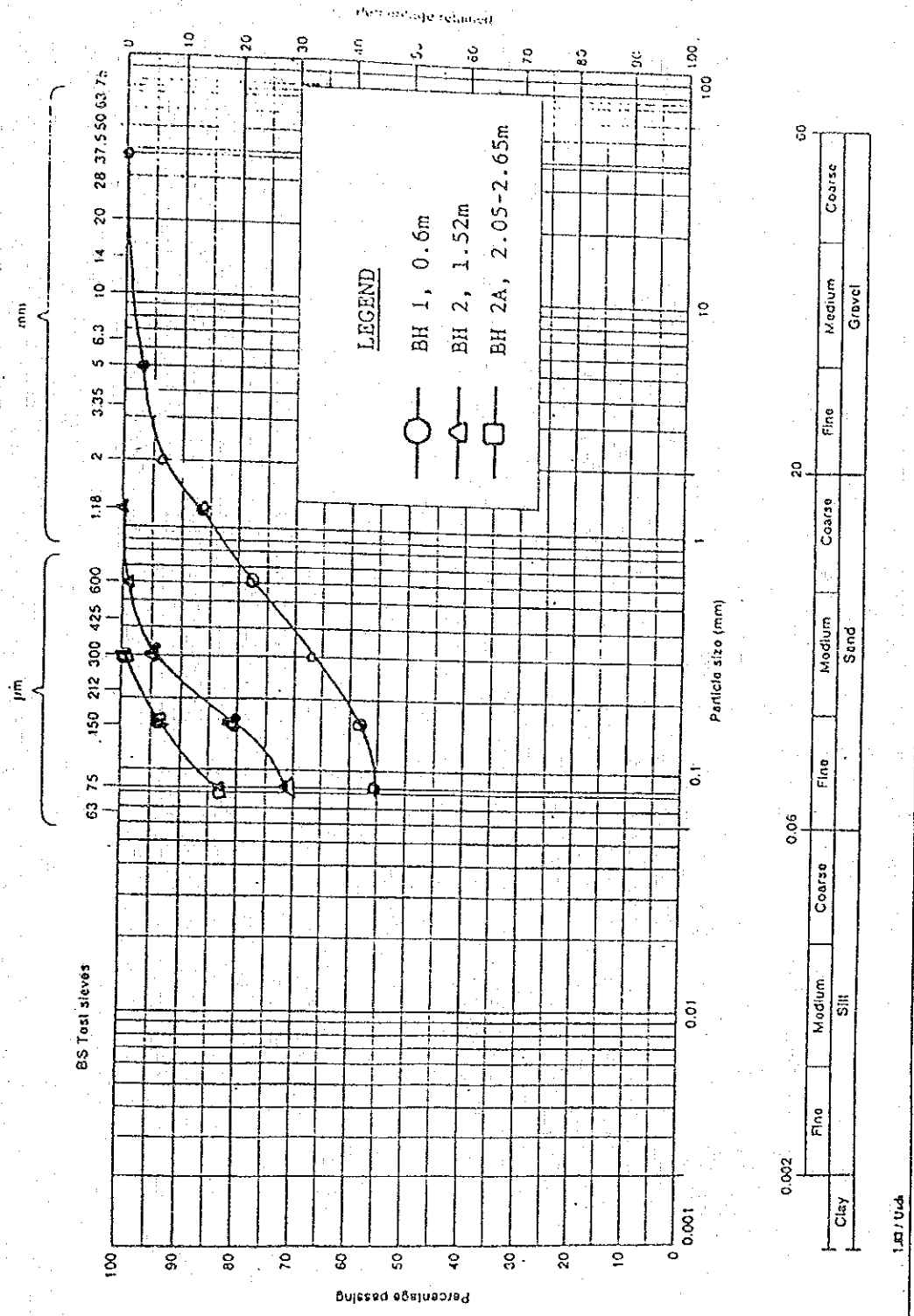
TRIAXIAL TEST RESULTS

Borehole No.	Samples No.	Depth (m)	C_{uu} KN/m²	Wet Density (kg/m³)	Dry Density (kg/m³)	ϕ_{uu} (deg.)	Moisture Content (%)
2A	5	1.6	112	2045	1700	5.1	20.1
2A	7	3.05	7	1950	1480	2.6	30.7

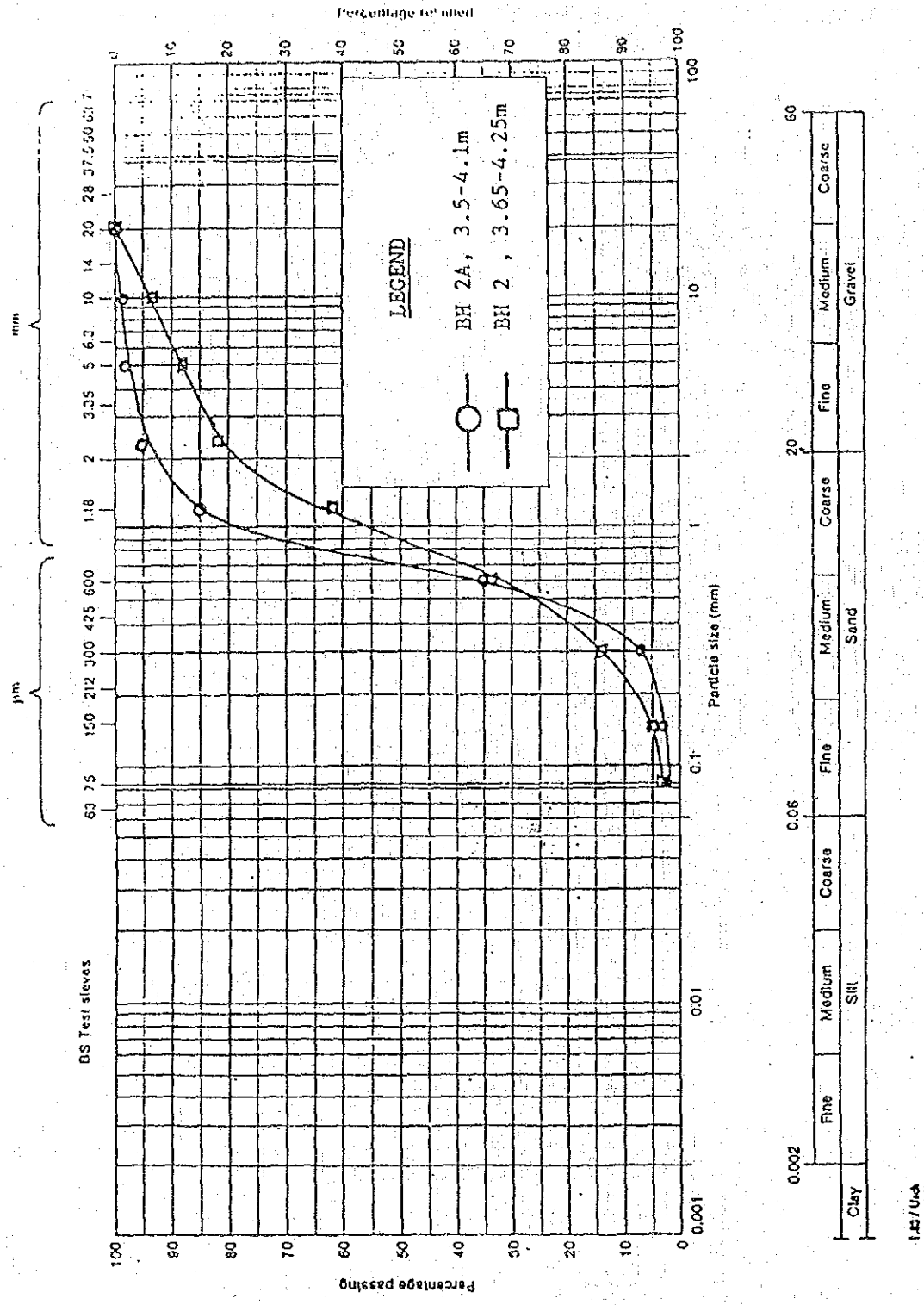
TABLE IV

RESULTS OF CHEMICAL ANALYSIS OF GROUNDWATER

Borehole No.	Depth (m)	Chloride as NaCl (ppm)	Sulphate as SO_3 (ppm)	Sulphate as $Na_2 SO_4$ (ppm)	Total Soluble Salts (ppm)	pH
2	1.03-1.06	702	9	15	242	7.0
3	0.62-2.10	2165	9	17	260	8.5
River Water	-	1112	5	9	138	8.5



TYPICAL PARTICLE SIZE DISTRIBUTION FOR ALLUVIAL DEPOSITS FIG.



TYPICAL PARTICLE SIZE DISTRIBUTION FOR SAND

FIG.

TABLE I

GHANA HIGHWAY AUTHORITY

SUMMARY OF LABORATORY TEST RESULTS

MATERIALS DIVISION

Beposo Bridge Project - Quarry Samples

% BY WEIGHT PASSING BS SEIVE

SAMPLE IDENTIFICATION	75 mm	50 mm	37.5 mm	25 mm	19 mm	14 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 um	300 um	150 um	75 um	63 um	FI	EI	AIV	LAAV
C.P.QUARRY																			
20 mm			100		79	6	1									29	6	-	25
14 mm					100	43	3									28	13	18	-
G.D.C.QUARRY																			
40 mm		100	89	47	8	1	1									44	21	-	-
20 mm			100	99	71	9	3	1								45	18	29	38
10 mm					100	95	48	3	1							38	20	-	-
Quarry dust							100	79	61	49	38	26	11	4					
SCC/DYWIDAG QUARRY																			
40 mm		100	93	31	3	0										37	22		
20 mm				100	81	34	18	1								50	21	28	39
6 mm							100	29	2	1	1	1	1	0					
CAPE COAST QUARRY																			
20 mm				100	98	30	6									37	20	25	35
14 mm						100	94	19	2							35	27	21	

LEGEND

FI = Flakiness Index AIV = Aggregate Impact Value

EI = Elongation Index LAAV = Los Angeles Abrasion Value

TABLE II

GHANA HIGHWAY AUTHORITY

SUMMARY OF LABORATORY TEST RESULTS

MATERIALS DIVISION

SAMPLE IDENTIFICATION	% BY WEIGHT PASSING BS SEIVE																
	75 mm	50 mm	37.5 mm	25 mm	19 mm	14 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 um	300 um	150 um	75 um	63 um	LL	PI
Asamasa sand pit (Sample 1)									100	84	32	11	2	1		NP	NP
Asamasa sand pit (Sample 2)								100	97	79	41	20	6	2		NP	NP

LEGEND

LL = Liquid Limit

PI = Plasticity Index

TABLE III

GHANA HIGHWAY AUTHORITY

SUMMARY OF LABORATORY TEST RESULTS

MATERIALS DIVISION

SAMPLE IDENTIFICATION	% BY WEIGHT PASSING BS SEIVE																		
	75 mm	50 mm	37.5 mm	25 mm	19 mm	14 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 um	300 um	150 um	75 um	63 um	LL	PI	MDD	OMC	CBR 96 HRS
Kafodzidzi gravel pit (Sample 1)				100		97	93	64	49	34	29	27	26	24				2180	8	
Kafodzidzi gravel pit (Sample 2)				100	100	99	94	57	40	30	26	25	24	23		41	12	2172	8	118

LEGEND

LL = Liquid Limit

PI = Plasticity Index

MDD = Maximum Dry Density

OMC = Optimum Moisture Content

A N N E X 3.3

BOREHOLE ROGS

PROJECT: PROPOSED BEPOSO BRIDGE			GROUND LEVEL: 7.64				COMMENCED: 7/10/88		
EQUIPMENT: ACKER TOREDOR MARK II			CO-ORDINATES:				COMPLETED: 13/10/88		
DESCRIPTION OF STRATA	REDUCED LEVEL (m)	SYMBOL	DEPTH & (THICKNESS)m	CASING DEPTH (m)	SAMPLE TYPE	SAMPLE NO.	FIELD TEST	FIELD RECORD	DAILY PROGRESS
Medium dark grey Sandy CLAY with organic matter	7.24		0.4		D	1			7/10/88
Dense reddish brown/black/yellowish mottled Sandy CLAY			(0.8			2	S	N28 70 blows/ 75mm	
							C		7/10/88

LEGEND

- U_{100} (Undisturbed Sample)
- U_{100} Sample not recovered
- Split spoon sample
- Disturbed (DCP) sample

- D - Bulk disturbed sample
- S - Standard Penetration Test
- S+ - Blow count includes seating blows
- C - Dynamic Cone Penetration test
- C+ - Blow count includes seating blows

- Groundwater first encountered
- Highest groundwater level encountered

RECORD OF BOREHOLE 1

FIG. C1/1

PROJECT: PROPOSED BEPOSO BRIDGE	GROUND LEVEL: 7.64	COMMENCED: 7/10/88
EQUIPMENT: ACKER TOREDO MARK II	CO-ORDINATES:	COMPLETED: 13/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH (m)	CASING DEPTH (m)	SAMPLE (NX)	CORE RUN	TOTAL CORE RECOVERY (%)	ROCK QUALITY DESIGNATION (%)	TIME TAKEN TO DRILL
	6.44		1.2	1.1					
Completely weathered GNEISS			2.0			1	0	0	46min
	4.59		3.0	1.1					
Highly weathered GNEISS						2	17	0	37min
	3.14		4.0						

RECORD OF BOREHOLE 1 FIG. C1/2

PROJECT: PROPOSED BEPOSO BRIDGE | GROUND LEVEL: 7.64 | COMMENCED: 7/10/88

EQUIPMENT: ACKER TOREDO MARK II | CO-ORDINATES: | COMPLETED: 13/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH (m)	CASING DEPTH (m)	SAMPLE (NX)	CORE RUN	TOTAL CORE RECOVERY (%)	ROCK QUALITY DESIGNATION (%)	TIME TAKEN TO DRILL
Weathered GNEISS grading into slightly weathered GNEISS			4.6						
			5.0			3*	48	23	73min
Weathered GNEISS grading into slightly weathered GNEISS	1.64		6.0	1.1					
						4	88	68	30min
	1.24			1.1					
Fresh GNEISS			7.0			5	95	95	150min
	-0.24								
END OF HOLE									

Remarks

* Excessive loss of drilling fluid encountered during run

RECORD OF BOREHOLE 1 FIG. C1/3

PROJECT: PROPOSED BEPOSO BRIDGE | GROUND LEVEL: 2.27 | COMMENCED: 12/10/88

EQUIPMENT: PILCON WAYFARER 1500 | CO-ORDINATES: | COMPLETED: 17/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH & (THICKNESS) (m)	CASING DEPTH (m)	SAMPLE TYPE	SAMPLE NO.	FIELD TEST	FIELD RECORD	DAILY PROGRESS
Top Soil			(0.6)	0.0					12/10/88
	1.67			0.6	D	10			
Firm mottled sandy CLAY of intermediate Plasticity			1.0 (0.9)			11	S	N5	
	0.77					12		31 blows	
Firm dark grey sandy CLAY with lenses of fine sand			2.0 (2.1)	2.1		13	S	N7	
			3.0	2.1					12/10/88

LEGEND

- U_{100} (Undisturbed Sample)
- U_{100} Sample not recovered
- Split spoon sample
- Disturbed (DCP) sample
- D - Bulk disturbed sample
- S - Standard Penetration Test
- S‡ - Blow count includes seating blows
- C - Dynamic Cone Penetration test
- C‡ - Blow count includes seating blows
- Groundwater first encountered
- Highest groundwater level encountered

RECORD OF BORHEOLE 2

FIG. C2/1

PROJECT: PROPOSED BEPOSO BRIDGE | GROUND LEVEL: 2.27 | COMMENCED: 12/10/88

EQUIPMENT: PILCON WAYFARER 1500 | CO-ORDINATES: | COMPLETED: 17/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH & (THICKNESS) (m)	CASING DEPTH (m)	SAMPLE TYPE	SAMPLE NO.	FIELD TEST	FIELD RECORD	DAILY PROGRESS
Firm dark grey sandy CLAY	-1.33			3.05		14	S	N6	12/10/88
			4.0						
Loose dark grey medium SAND with gravel and shells				4.2					
			(1.9)			15	S	N6	
			5.0						
				5.4			S‡	195 blows/ 225mm	
	-3.23								12/10/88

LEGEND

- U_{100} (Undisturbed Sample)
- U_{100} Sample not recovered
- Split spoon sample
- Disturbed (DCP) sample
- D - Bulk disturbed sample
- S - Standard Penetration Test
- S‡ - Blow count includes seating blows
- C - Dynamic Cone Penetration test
- C‡ - Blow count includes seating blows
- Groundwater first encountered
- Highest groundwater level encountered

RECORD OF BOREHOLE 2

FIG. C2/2

PROJECT: PROPOSED BEPOSO BRIDGE	GROUND LEVEL: 2.27	COMMENCED: 11/10/88
EQUIPMENT: PILCON WAYFARER 1500	CO-ORDINATES:	COMPLETED: 12/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH (m)	CASING DEPTH (m)	SAMPLE (NX)	CORE RUN	TOTAL CORE RECOVERY (%)	ROCK QUALITY DESIGNATION (%)	TIME TAKEN TO DRILL
			5.4						
	-3.23			5.43					
Slightly Weathered GNEISS						1	87	0	50min.
	-3.46			5.43					
						2	37	0	135min.
	-3.73		6.0	5.43					
Slightly Weathered GNEISS						3*1	15	0	166min.
			7.0						
	-5.38			5.43					
Slightly weathered GNEISS grading into fresh GNEISS			8.0			4*2	24	16	129min.
	-5.63								
END OF HOLE									

Remarks

*1 Core lifter broken (there were indications that TRC/RQD > 90%)

*2 Rotary head unable to break core from rock mass (there were indications that RQD > 90%)

RECORD OF BOREHOLE 2 FIG. C2/3

PROJECT: PROPOSED BEPOSO BRIDGE | GROUND LEVEL: 3.040 | COMMENCED: 11/10/88

EQUIPMENT: PILCON WAYFARER 1500 | CO-ORDINATES: | COMPLETED: 11/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL (m)	SYMBOL	DEPTH & (THICKNESS) (m)	CASING DEPTH (m)	SAMPLE TYPE	SAMPLE NO.	FIELD TEST	FIELD RECORD	DAILY PROGRESS
Top Soil			(0.5)						11/10/88
	2.54		0.5	0.0	D	3			
Firm dark brown/greenish grey sandy SILT with roots and pieces of weathered gneiss			(0.5)						
	2.04		1.0 ▽ ▼	0.0					
Firm dark brown/greyish clayey SILT			(0.5)			4	S	N7	
	1.44			1.06					
				1.5		5		56 blows	
			2.0						
Firm mottled sandy CLAY			(0.98)	2.4		6	S	N6	
			3.0						
				3.0		7		80 blows	
	-0.46								11/10/88

LEGEND

- U_{100} (Undisturbed Sample)
- U_{100} Sample not recovered
- Split spoon sample
- Disturbed (DCP) sample
- D - Bulk disturbed sample
- S - Standard Penetration Test
- S‡ - Blow count includes seating blows
- C - Dynamic Cone Penetration test
- C‡ - Blow count includes seating blows
- ▽ - Groundwater first encountered
- ▼ - Highest groundwater level encountered

RECORD OF BOREHOLE 2A

FIG. C3/1

PROJECT: PROPOSED BEPOSO BRIDGE			GROUND LEVEL: 3.040				COMMENCED: 11/10/88		
EQUIPMENT: PILCON WAYFARER 1500			CO-ORDINATES:				COMPLETED: 11/10/88		
DESCRIPTION OF STRATA	REDUCED LEVEL (m)	SYMBOL	DEPTH & (THICKNESS) (m)	CASING DEPTH (m)	SAMPLE TYPE	SAMPLE NO.	FIELD TEST	FIELD RECORD	DAILY PROGRESS
	-0.46			3.4					11/10/88
			4.0			8	S	N7	
Dark grey loose to dense medium SAND with gravel and shells.			(3.0)	6.4					
			5.0			9	S	N31	
	-2.46								

LEGEND

- U_{100} (Undisturbed Sample)
- U_{100} Sample not recovered
- Split spoon sample
- Disturbed (DCP) sample
- D - Bulk disturbed sample
- S - Standard Penetration Test
- S+ - Blow count includes seating blows
- C - Dynamic Cone Penetration test
- C+ - Blow count includes seating blows
- Groundwater first encountered
- Highest groundwater level encountered

RECORD OF BOREHOLE 2A

FIG. C3/2

PROJECT: PROPOSED BEPOSO BRIDGE	GROUND LEVEL: 3.040	COMMENCED: 11/10/88
EQUIPMENT: PILCON WAYFARER 1500	CO-ORDINATES:	COMPLETED: 12/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH (m)	CASING DEPTH (m)	SAMPLE (NX)	CORE RUN	TOTAL CORE RECOVERY (%)	ROCK QUALITY DESIGNATION (%)	TIME TAKEN TO DRILL
			5.4	5.43					
Slightly Weathered GNEISS	-2.46					1	87	0	50min.
	-2.69			5.43					
	-2.96		6.0	5.43		2	37	0	135min.
Slightly Weathered GNEISS						3 *1	15	0	106min.
			7.0						
	-4.61			5.43					
Slightly weathered GNEISS grading into fresh GNEISS			8.0			4 *2	24	16	120min.
	-5.86								
END OF HOLE									

Remarks

*1 Core lifter broken (there were indications that TRC/RQD > 90%)

*2 Rotary head unable to break core from rock mass (there were indications that RQD > 90%)

RECORD OF BOREHOLE 2A

FIG. C3/3

PROJECT: PROPOSED BEPOSO BRIDGE | WATER LEVEL: ? | COMMENCED: 27/10/88

EQUIPMENT: ACKER TOREDO MARK II | CO-ORDINATES: | COMPLETED: 28/10/88

DESCRIPTION OF STRATA	REDUCED LEVEL	SYMBOL	DEPTH (m) **	CASING DEPTH (m)	SAMPLE (NX)	CORE RUN	TOTAL CORE RECOVERY (%)	ROCK QUALITY DESIGNATION (%)	TIME TAKEN TO DRILL
			8.3						
				8.38					
Slightly weathered GNEISS						1	86	0	35min.
				8.38					
Slightly weathered GNEISS						2*	100	0	25min.
			9.1						
Fresh GNEISS				8.38		3	100	0	90min.

END OF HOLE

Remarks

* Coring bit partially displaced by waves resulting in fracture of the core sample with an accompanying low RQD

** Depth below water level

RECORD OF BOREHOLE 3 FIG. C4

ANNEX 3.4 FLOOD ANALYSIS

1. Peak Discharge

The peak discharges for different return periods at Daboasi gauge station, about 4.5 km upstream of existing bridge, have been derived by Gumbel method from the annual flood records for past 30 years. The result are given as follows. (See Annex 3.4 (1)

Return Period (year)	10	20	50	100	200
Discharge (m^3/sec)	1,180	1,350	1,560	1,810	1,880

The discharge observed at Daboasi gauge station will be taken to represent the discharge at proposed bridge site, because the distance between them is short.

2. Flood Level

2.1 Flood Level from Discharge Data

The flood level associated with the 5-year return period peak discharge was obtained from the stage-discharge relations (Annex 3.4 (3) which was prepared from the annual floods data described above.

As flood level at the Daboasi gauge station of 5-year return period peak discharge has been MSL + 24.5 feet (7.35 m), the flood level at proposed bridge site, 4.5 km down stream from Daboasi, will be estimated as MSL + 5.5m considering the water surface drop between the proposed bridge site and the Daboasi gauge station. (See Fig. 3-6)

2.2 Flood Level from Inquiry

Interviews with local villagers revealed that the highest flood level has been about 0.3 m above the road surface in front of GHA traffic regulation office;- MSL + 5.4 m (surrounding road surface) - 0.2 m (depression of the place) = MSL + 5.4-0.2 + 0.3 = MSL 5.5 m

This value coincides well with that estimated above.

3. **Water Flow Capacity**

Water flow capacity at proposed bridge site will be calculated as water level MSL + 5.5 metre.

Manning's roughness "n" is determined from the measurement of water data as follow:-

Velocity of water flow	V = 1.13 m/sec
Water level	MSL + 1.4 m
Flow area	A = 420 m^2
Wetted perimetre	P = 87 m
Hydraulic radius	R = 4.84 m
Water surface gradient	I = 0.017%

(See Annex 3.4 (4) for the above)
From Manning's formula,

$$n = \frac{R^{2/3} \times I^{1/2}}{V} = \frac{4.83^{2/3} \times 0.00017^{1/2}}{1.13} = 0.033$$

Water flow velocity at water level MSL + 5.5m,

$$v = \frac{1}{n} \times R^{2/3} \times I^{1/2} = \frac{1}{0.033} \times 7.0^{2.3} \times 0.0004^{1/2} = 2.2 \text{ m/sec}$$

thus,

$Q = A \times V = 770 \times 2.2 = 1{,}690\ M^3/sec$ $\quad 1{,}560\ m^3/sec$

Thus, the river has enough capacity to pass, the 50-year return period flood.

The normal river section is not wide enough to accommodate the full flow, and so, the river inundate the floodplain on the west bank as shown in the attached Figure.

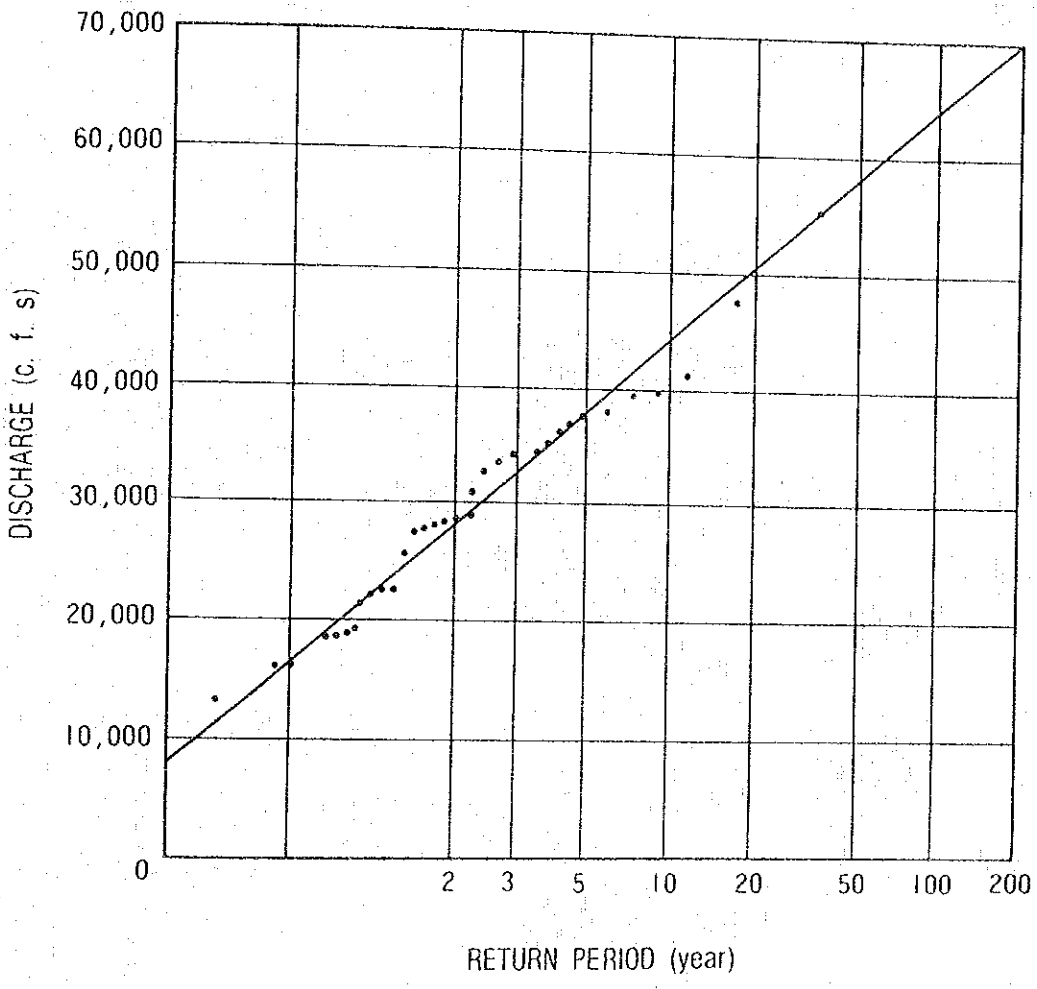
The embankment of existing approach road is constructed on this floodplain at MSL + 5.4m; this level is 0.1 m less than the 50-year return period flood level. The flood water, therefore overlows on the road surface. Thus, the side Ditch of 1.0 m wide will be provided at the upstream side of the embankment of the new approach road to enable flood water to drain away.

ANNUAL FLOODS DATA (DABOASI GAUGING STATION)

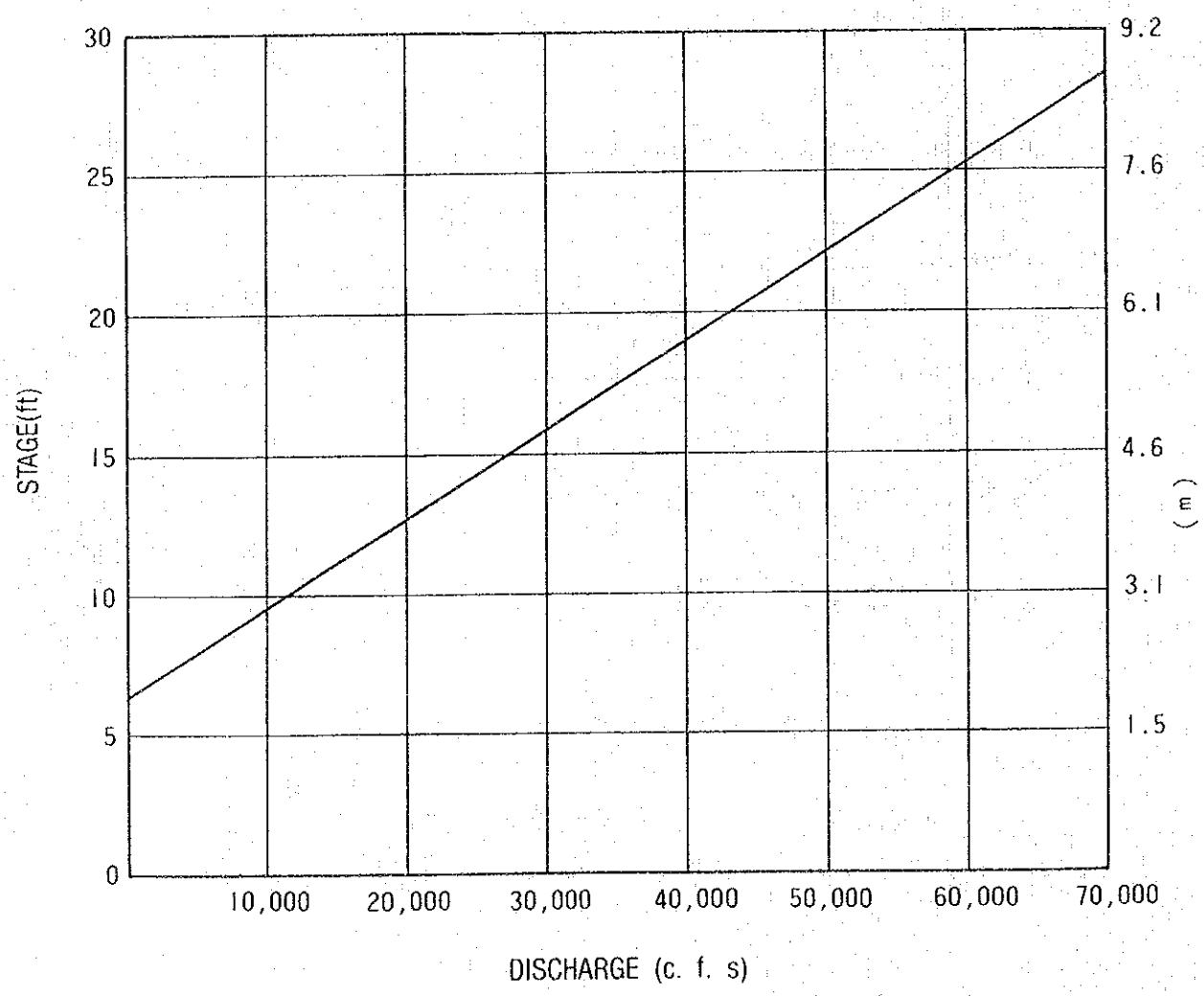
No.	Year	Maximum Gauge Reading (ft)	Maximum Discharge (c.f.s)
1.	1954	13.40	22,600
2.	1955	14.50	25,560
3.	1956	15.60	28,600
4.	1957	18.50	37,555
5.	1958	15.30	27,870
6.	1959	18.15	36,470
7.	1960	17.50	34,455
8.	1961-62	19.60	40,965
9.	1962-63	19.00	39,105
10.	1963-64	21.60	47,207
11.	1964-65	15.05	27,040
12.	1965-66	18.40	37,245
13.	1966-67	16.85	32,440
14.	1967-68	15.65	28,804
15.	1968-69	23.85	55,021
16.	1969-70	13.10	21,421
17.	1970-71	12.20	18,928
18.	1971-72	11.10	16,027
19.	1972-73	15.40	27,770
20.	1973-74	12.30	18,845
21.	1974-75	16.30	30,625
22.	1975-76	15.50	28,080
23.	1976-77	13.70	22,695
24.	1977-78	17.40	34,270
25.	1978-79	17.35	34,100
26.	1979-80	19.00	39,890
27.	1980-81	12.00 +	18,060 +
28.	1981-82	12.00 +	18,060 +
29.	1982-83	17.10	33,255
30.	1983-84	11.20	16,030
31.	1984-85	17.80	35,640
32.	1985-86	13.50	22,125
33.	1986-87	9.90	12,955

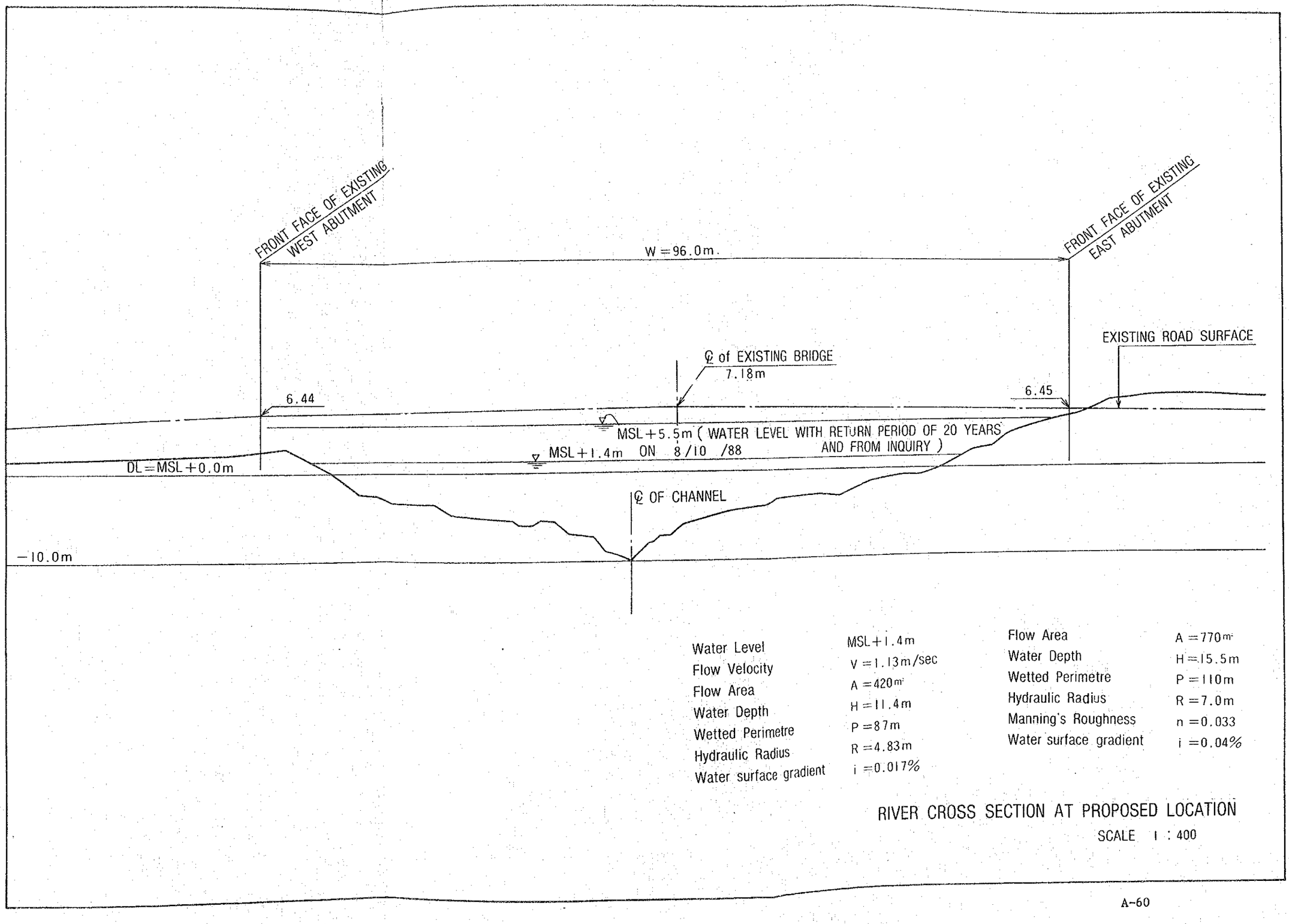
Note: Gauge zero elevation = MSL

GUMBEL DISTRIBUTION
(DABOASI GAUGING STATION)



STAGE-DISCHARGE RELATION
(DABOASI GAUGING STATION)



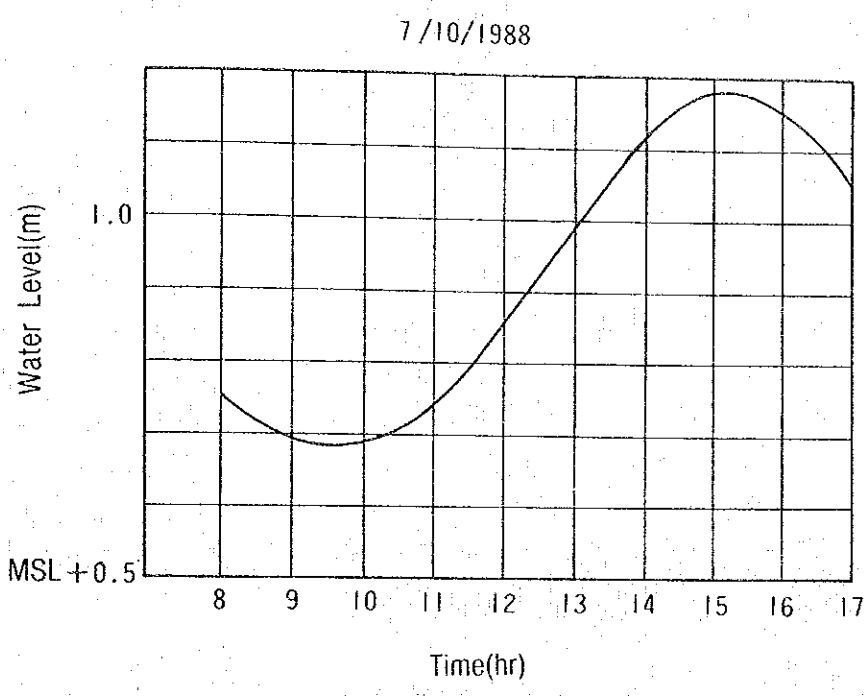


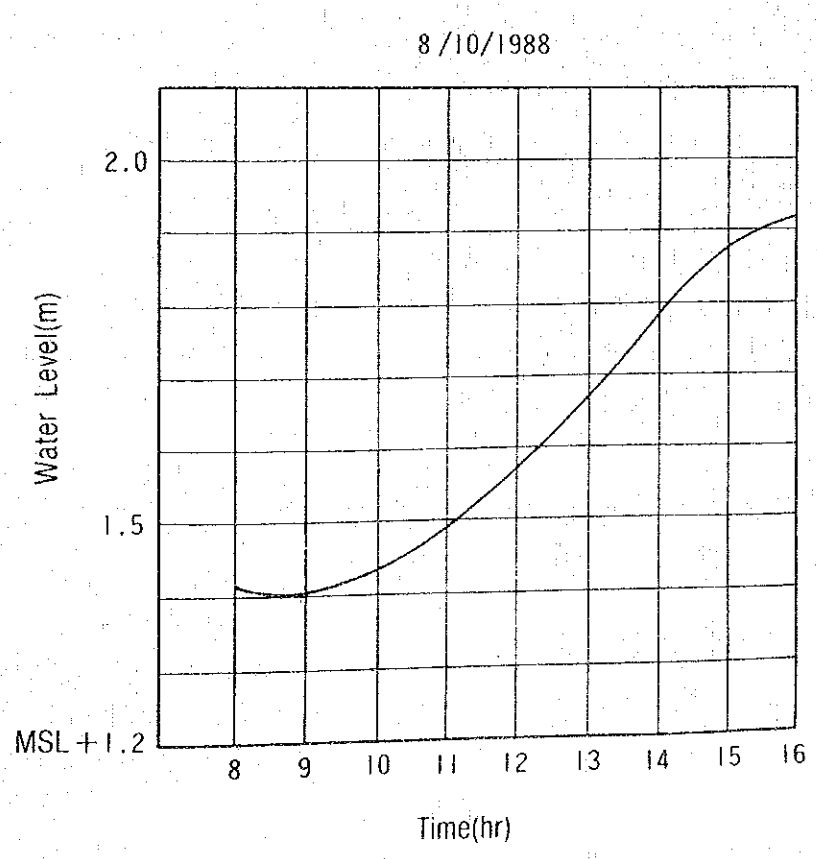
Water Level	MSL+1.4m	Flow Area	A = 770m²
Flow Velocity	V = 1.13m/sec	Water Depth	H = 15.5m
Flow Area	A = 420m²	Wetted Perimetre	P = 110m
Water Depth	H = 11.4m	Hydraulic Radius	R = 7.0m
Wetted Perimetre	P = 87m	Manning's Roughness	n = 0.033
Hydraulic Radius	R = 4.83m	Water surface gradient	i = 0.04%
Water surface gradient	i = 0.017%		

RIVER CROSS SECTION AT PROPOSED LOCATION

SCALE 1 : 400

WATER SURFACE VARIATION





ANNEX 3.5 Computation of Vehicle Operation Cost

Source: Ghana Highway Authority, road Rehabilitation Programme, 4th Highway Programme, supplementary Report for Reconstruction Studies, Scott Wilson Kirkpatric & Partners, Accra, Ghana, August 1984.

1. General

A report on road vehicle operating costs in Ghana was prepared as part of the consultancy services under the preconstruction phase of the Fourth Highway Programme.

That report had two objectives, the first was to provide a general updating of previous estimates of vehicle operating costs in Ghana and the second more specific objective was to provide the basis for assessing the vehicle operating costs benefits of road investments being considered by Highway Authority and IBRD for conclusion in the Fourth Highway Programme. In particular, the rehabilitation of the Accra-Takoradi road and Accra-Kumasi corridor.

New operating cost formulae were derived for the latter purpose. These were explained in full in Chapter 6 of the vehicle operating cost report and more briefly in Chapter 4 of the 1982 draft final report containing the economic analysis.

The vehicle operating cost formulae derived in 1981 incorporate surface roughness as defined by the TRRL as the prime operating costs parameter. The estimation of vehicle operating costs using the formulae is a three stage process. There are five vehicle classes. For each of these, vehicle speed is first deduced as a function of road surface, road geometry and traffic.

Individual cost components are then defined in physical terms as functions of speed and surface roughness. These equations are indendent of price, fuel consumption, for instance, is measured in litres per 1000 kms. specific price data are added in at the last stage and the component cost formulae summed to give total operating costs. This method of working, with prices incorporated only at the final stage, allows new prices to be inserted without going back to the beginning.

For east of reference the speed and component cost formulae are summarized below, in advance of the discussion of prices and the updating thereof. We have seen no cause to review or revise the speed or cost fomulae which are precisely as in the 1981 and 1982 reports.

2. VEHICLE SPEED FORMULAR

The TRRL equation for speed on paved roads in relation to the engineering aspects of the road is in the form:

$$V = a - bRs \pm cF - dC - eA$$

V = speed in km per hour

where R_S = rate of rise in m per km

F = rate of fall in m per km

C = horizontal curvature (degrees/km)

A = altitude in metres

a,b,c,d and e are positive coefficients.

There are four equations for paved roads for cars, Light goods, buses and medium and heavy vehicles. In the last, power to weight cation (PW bhp/tounes) is an extra variable. Road width is also a variable but applies only at widths less than 5 metres.

Rise and fall may normally be equated with the average for the two directions and combined into a single parameter, RF = RS + F.

Altitude is relatively unimportant since the range in variation in the project roads (up to about 250 m) is small compared with that found in Kenya (up to 2500 m) and implies, on the basis of the TRRL coefficients, a maximum variation of only about one kph. In this case an average value of A + 100 may therefore be used as a first approximation.

As compare with the TRRL equations there are two parameters which demonstratively affect vehicle speeds and which we have incorporated in the speed equations. These are surface condition and traffic flow.

As a guide to the variation of speed with roughness on deteriorating bitumen roads we adopted coefficients and multiple regression coefficients obtained by TRRL for unpaved roads. The coefficients, by vehicle type are:-

Cars	0.0020
Light goods (or commercial vehicles (LCV)	0.0019
Medium and heavy goods vehicles (MGV & HGV)	0.0014
Buses (or passenger commercial vehicle PCV)	0.0018

In incorporating the additional term in the speed equations the constant was adjusted so that speed is as predicted din the TRRL equations for a value of R = 2500 mm/km (i.e. a typical relatively new well maintained surface dressed road).

The modified equations applying to lightly trafficked road (i.e. assuming negligible impact of traffic on speeds) are as follows:-

CAR V = 107.6 - 0.224 RF - 0.111 C - 0.0049A - 0.0020 R
LCV V = 92.7 - 0.234 RF - 0.074 C - 0.0028A - 0.0019 R
PCV V = 77.0 - 0.230 RF - 0.066 C - 0.0042A - 0.0018 R
MGV V = 66.7 - 0.245 RF - 0.058 C - 0.0042A - 0.0014 R
HGV V = 60.7 - 0.245 RF - 0.058 C - 0.0042A - 0.0014 R

On a typical bitumen road in Ghana it is probably safe to ignore the interaction of traffic and the effect on speed with an average daily traffic (ADT) up to at least 1000 vehicles per day (VPD).

The effect of traffic on speed is in fact a complex one dependant both on traffic composition and distribution and on road alignment and condition. As a first approximation a linear relation nevertheless serves. A term - fT is therefore added to the equations already specified, T being ADT in VPD. The coefficient f represents the slope of the speed flow relationship and is calculated from the free flow speed and an assumed speed of 40 kph at a flow of 1000 vpd.

The free flow speeds are calculated with the following typical geometrical values:-

RF=20, C=50, A=100, R=3000. This gives values of f in the range 5.1 to 0.8 x 10^{-3} kph for the different vehicle types. Using these values and assuming that in the absence of more detailed information

the geometrical values quoted above are typical of existing paved roads, the speed equations reduce to the following functions of R and T. (Roughness and traffic).

CAR V = 97.1 - 0.0020 R - 0.0051 T
LCV V = 83.0 - 0.0019 R - 0.0037 T
PCV V = 68.7 - 0.0018 R - 0.0023 T
MGV V = 58.5 - 0.0014 R - 0.0013 T
HGV V = 52.5 - 0.0014 R - 0.0008 T

The equations given above indicate the following traffic from speeds for T = 0 and R = 2400

Vehicle	Typical Traffic Free Speed New Bitmen
CAR	92
LCV	78
PCV	64
MGV	55
HGV	49

These speeds conform with previous estimates of the 1975 vehicle operating cost manual.

3. OPERATING COST FORMULAE

For the purposes of vehicle operating cost analysis we consider the components listed below. Equations are based primarily on the TRRL studies but take account also of previous estimates made in Ghana.

Fuel consumption
Tyre consumption
Lubricating oil consumption
Maintenance and depreciation
Accident costs
Crew and overheads

The accepted form of the fuel consumption equation is:

$$F = a + \frac{b}{v} + cv^2$$

where F = Fuel Consumption (litres per 1000 km)
V = Average/speed (kph)

a, b & c are coefficients varying with vehicle classification.

Adopting as base data points, fuel consumption at a speed appropriate for lightly trafficked roads in relatively good condition (from the 1975 manual) the following equations for fuel consumption were derived.

$$\text{CAN } F = 20.15 + \frac{3365}{V} + 0.00612\ V^2$$

$$\text{LCV } F = -9.12 + \frac{4542}{V} + 0.01365\ V^2$$

$$\text{PCV } F = -101.12 + \frac{4542}{V} + 0.0464\ V^2$$

$$\text{MGV } F = -49.13 + \frac{8546}{V} + 0.0464\ V^2$$

$$\text{HGV } F = 154.91 + \frac{8546}{V} + 0.0464\ V^2$$

The TRRL equations give tyre consumption as the number of tyres per killometre run. We converted this to tyre life and examined implied average lives for the type of operating conditions found in Ghana. After comparing with estimates obtained from road user surveys in Ghana, the following equation for tyre wear were derived.

$$\text{CAR TC} = 0.0435\ R \times 10^{-6}$$

$$\text{LCV TC} = 0.0435\ R \times 10^{-6}$$

$$\text{PCV TC} = (83+0.0112R) \times 10^{-6}$$

$$\text{MGV TC} = (100+0.013R) \times 10^{-6}$$

$$\text{HGV TC} = (200+0.027R) \times 10^{-6}$$

where Tc is the number of tyres per kilometre and R is the surface roughness in mm/km.

The TRRL study makes no attempt to differentiate lubricating oil consumption except between gravel and unpaved roads. The cost of oil replanishment is a small item, around 5% of fuel cost. For the sake of simplicity oil consumption is held constant for all bituminous surfaced roads at the following values:

CAR	1.4 Litre per 1000 km
LCV	1.4
PCV	4.8
MGC	5.1
HGV	8.3

The values were derived from the 1975 manual and are generally + 20% of the TRRL's Kenyan results.

The TRRL study relates vehicle maintenance costs to new vehicle price and expresses this as a function of roughness. The maintenance cost formulae in the form given by the TRRL can be used to derive economic vehicle life, also as a function of average road roughness. Vehicle maintenance and depreciation may then be combined into a single equation. Costs per kilometre are average over the economic life of the vehicle and expressed as a function of the price of a replacement vehicle (V_p). Related to roughness (R), the combined maintenance and depreciation costs are as follows:

$$\text{CAR} = (-50.75 + 0.0045R)^{\frac{1}{2}} V_p \, 10^{-6}$$

$$\text{LCV} = (-30.75 + 0.0045R)^{\frac{1}{2}} V_p \, 10^{-6}$$

$$\text{PCV} = (12 + 0.00925R)^{\frac{1}{2}} V_p \, 10^{-6}$$

$$\text{MCV} = (12 + 0.00925R)^{\frac{1}{2}} V_p \, 10^{-6}$$

$$\text{HGV} = (12 + 0.00925R)^{\frac{1}{2}} V_p \, 10^{-6}$$

To conform with previous practice in Ghana, we included in our 1981 estimates of vehicle operating costs an estimate of additional costs arising from accidents. The poor state of much of the road network in Ghana is considered a factor in high accident rates and costs. It is accordingly appropriate to relate accident costs per kilometer (A) to surface roughness (R) as the measure of road condition.

The same equation is used for all vehicle types:

$$A = (35 + 0.01R)V_p \times 10^{-8}$$

for crew and overhead costs, the annual cost of a crew for one vehicle is considered as the price parameter. The crew consists of driver plus assistants or conductor as appropriate. Costs include wages, allowances and other direct labour items. Overheads for fleet

operators are also largely labour costs and it seemed appropriate to estimate as multiple of crew costs. The multiples for the three heavier types of vehicle are as follows:

passenger commercial	1.5
medium goods	0.8
heavy goods	2.75

Fleet overheads for cars and light commercial vehicles are considered negligible.

Crew and overheads are treated as standing costs. To convert to a cost per kilometre annual utilization is required. Annual utilization may be expected to vary directly with running speed but because vehicles do not spend all their time running the change in utilization will be less than proportionate to the change in speed. The following relationships were derived for the inverse of annual utilization expressed in kilometres ($1/K_a$). To obtain standing costs per kilometre, the annual cost is divided by annual utilization, and thus multiplied by its inverse.

$$\text{CAR} \quad \left(\frac{53.6}{V} + 0.179\right) .10^{-5}$$

$$\text{LCV} \quad \left(\frac{66.1}{V} + 0.333\right) .10^{-5}$$

$$\text{PCV} \quad 2.5 \times \left(\frac{53.5}{V} + 0.238\right) .10^{-5}$$

$$\text{MGV} \quad 1.8 \times \left(\frac{48.8}{V} + 0.500\right) .10^{-5}$$

$$\text{HGV} \quad 3.75 \times \left(\frac{45.3}{V} + 0.353\right) .10^{-5}$$

Total costs per km. The component cost may be summarized by vehicle type in the form

$$a + \frac{b}{v} + cv^2 + d\,R + (e + fR)^{\frac{1}{2}}$$

where a, b, c, d, e & f are all price dependent coefficients.

4. PRICES AND UPDATING

The base date for pricing in the previous report was July 1981. Local and foreign components were given separately, in cedis and US$, respectively. With five vehicle classes and five cost components, there is a maximum of fifty price inputs. With only one price pair required for lube oil and two discrete prices is reduced to 31.

Although the price matrix contains 31 different items, these do not all require to be individually estimated for updating purposes. The hope and intention at the time of preparing the previous report was that the GHA would update the VOC estimates on a regular basis by preparing price indices for the four main categories of component is fuel and oil, tyre, vehicles and crew. This has not happened. The discontinuity is unfortunate. Had the VOC estimates been regularly updated the price data would have been under continuous review. Updating and revision could have progressed in parallel. It would then have been appropriate three years after the initial work to have produced at this stage a completely revised base matrix. In the event we have had to work partly on the basis of revised price estimates and partly be means of index numbers. The price information on which the various estimates are based is given in Appendix 9. The revised price matrix is shown below.

Price Input Matrix: May 1984

Local Costs ¢		CAN	LCV	PCV	MGV	HGV
Vehicle*	unit	6,000	6,000	75,000	85,000	215,000
Tyre	unit	60	78	211	326	477
Fuel	litre	1.4	1.4	1.4	1.4	1.4
Lube oil	litre	3.3	3.3	3.3	3.3	3.3
Crew	annual	101,500	45,000	75,000	84,000	91,000
Foreign Costs $						
Vehicle*	unit	7,100	6,900	42,500	261,500	50,000
Tyre	unit	34	45	120	186	273
Fuel	litre	0.30	0.30	0.26	0.26	0.26
Lube oil	litre	0.7	0.7	0.7	0.7	0.7

* Net of cost of original set of tyres; note also that local content of maintenance cost is different from that for replacement cost; coefficients e and f are adjusted for this.

EXTRACT FROM "GHANA BRIDGE DEVELOPMENT PROGRAMME, F/S, SECOND STAGE"

1. SCOPE OF THE FEASIBILITY STUDY

According to the bridge inventory carried out in 1982, there are 437 bridges and ferries on the national road network maintained by the GHA. Out of these bridges, 80 were in a deteriorate state, requiring a feasibility study for their rehabilitation.

Not included are an unknown number of town bridges and bridges on feeder roads which only recently have come under the responsibility of GHA but are beyond the scope of this project.

At the beginning of 1986, talks were held between the representatives of the World Bank, GHA and the Consultant, in order to update the tasks of the Second Stage of the Project. As a result of the bridge inventory, it was reevaluated that the bridges to be rehabilitated and thus included in both F.S. stages would have a total length of about 2,500 m instead of the initial estimate in the 1981 Terms of Reference of 2,000 m.

The first stage of the F.S. was conducted in 1982/83 and covered 28 bridges. The second stage of the Feasibility Study, comprises 56 bridges inspected in this stage and 13 bridges carried over from the first stage of the F.S. for reevaluation and updating.

The inspection of the bridges in May 19086 was conducted in cooperation with the Regional GHA offices, and it was at their request that eight bridges in deteriorated condition were added to the list. Other bridges included in the 2nd and 3rd priority lists were deleted.

The locations of the resulting comprehensive 69 bridges are shown in Fig. 1.

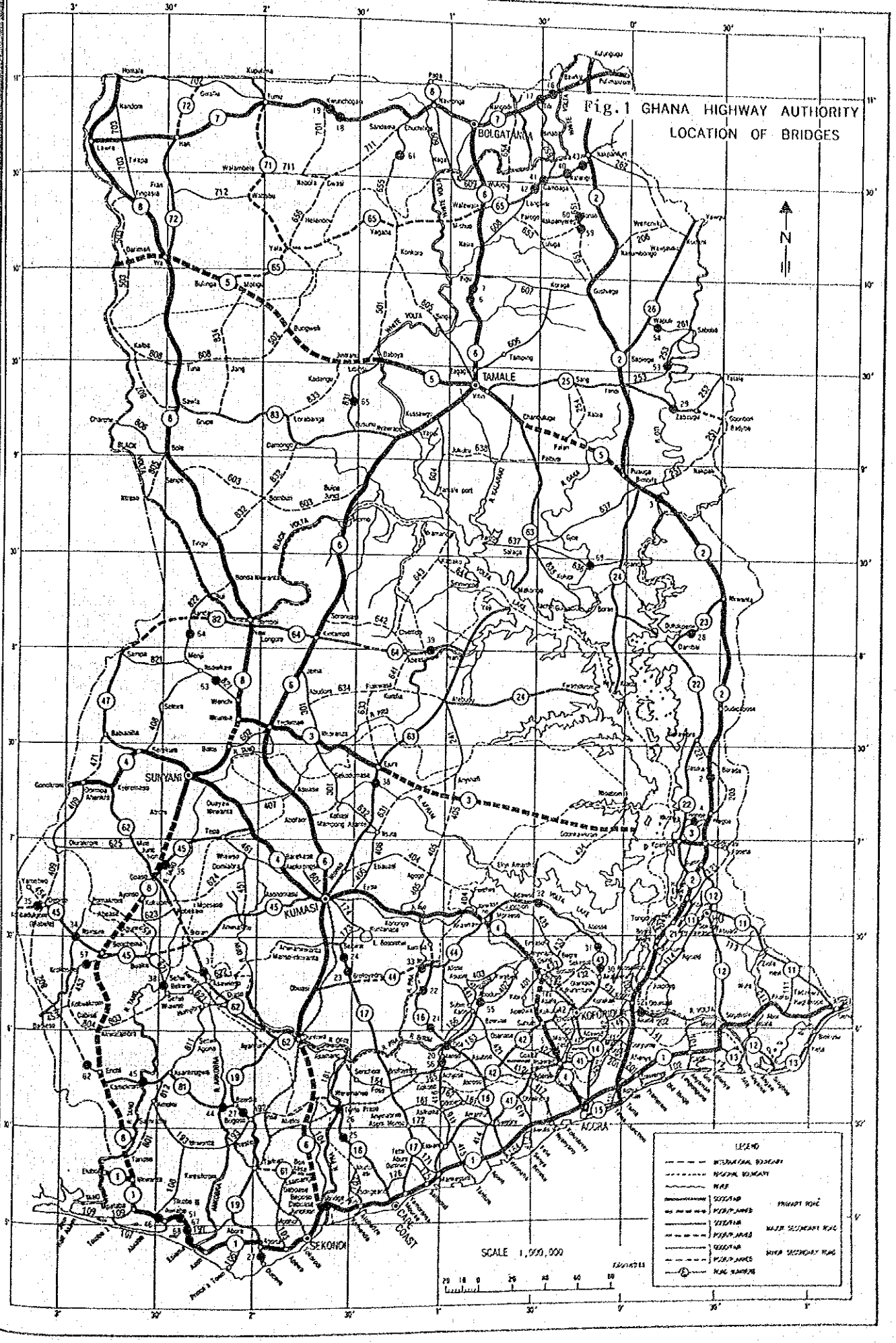


Fig.1 GHANA HIGHWAY AUTHORITY
LOCATION OF BRIDGES

1. BRIDGE NO. 1/26

2. Particulars:
   Region: Western
   Road Section: Cape Coast-Daboase Jct.
   River: Pra
   Coordinates: 5°05'N, 1°37'W
   Locality: Beposo
   Nearby bridges needing repair: None

3. Economic Significance: Road No. 1 is part of the West African Highway linking Abidjan to Accra and Lome. Bridge 1/26 has consequently national and international importance and is given priority in the National and Road Development Plan.

4. Road Network:

Road No.	Road Section	Length (km)	Existing Road: Surface Type	Existing Road: Surface Quality	ADT 1984	Improved Detour: Upgrading Category	Improved Detour: Road Type
	Direct Route:						
1	Cape Coast-Daboase Jct.	52.0	Bitumen	V.Good	953 (1981=3099)	-	-
	Detour Routes: None (166 km)						

5. State of Existing Bridge:
   Superstructure: 125 m long suspended bridge with RC slab on steel girders. 5.70 m wide carriageway. Built 1924. Fair condition but displacement of vertical tie cables and cracks in the concrete deck were observed. Accommodate only one lane (enforced reversible traffic by flag-men).
   Substructure: Good condition.
   Life expectancy: Approx. 50 years, but pending needed maintenance.

6. Foundation Conditions: Granite bedrock at 10-15 m depth, covered by clay, silt and gravel.

7. Hydrology and Hydraulics (see Feasibility Study by L. Berger, 1970):
   Discharge:
   Velocity:
   Depth of flow:
   Recommended bridge length:
   Expected scour:

8. Proposed Solution:
   Construct immediately a new 2-lane, 125 m long bridge. Details see Appendix A in this study.

9. Cost Estimate:

	New Bridge: year	New Bridge: thous. $	New Bridge: thous. ₵	Repaired Bridge: year	Repaired Bridge: thous. $	Repaired Bridge: thous. ₵
Construction	1989	3,768	142,000	-	-	
Yearly maintenance	-	19	710	-	-	

Appendix A

A-1

Bridge 1/26 at Beposo

The existing one-lane suspension bridge, built in 1934, spans the Pra River on the important and busy Road No. 1 (a section of the West African Highway linking Abidjan-Accra-Lomé). It is 100 m long and 5.5 m wide.

ADT figures, computed from data recorded on adjacent road sections are as follows:

1969 - approx. 1,000 (L. Berger)	1981 - 1,134
1977 - 1,607	1982 - 1,609
1978 - 1,588	1983 - 559 (?)
1980 - 1,463	1984 - 491 (?)

In 1970 - as part of the plans for the possible realignment of Road No. 1 with the purpose of shortening the route - Messrs. Louis Berger were commissioned to undertake a feasibility study for a new bridge. Three possible solutions were investigated in the study:

Alternate I	A new 164-m long two-lane bridge 7.2 km downstream of the existing bridge, with a 15 km long new access road.
Alternate II	A new 318-m long two-lane bridge, 2.4 km downstream of the existing bridge, with a 6-km long new access road.
Alternate III	A new 123-m long one-lane bridge, 30 m upstream of the existing bridge, with a 1-km new access road.

Alternate I was discarded, as cost-benefit studies showed it to be more expensive than Alternate II for about the same saving of road distance. Alternate II was recommended, having been found preferable to Alternate III when traffic savings are considered.

During the period 1982-1986 the existing bridge was repeatedly inspected by GHA and TAHAL engineers, who concluded that the bridge is still serviceable and in a fair condition. However, a number of flaws were discovered and it became clear that a thoroughgoing, highly specialized inspection (including field and laboratory tests) must be urgently undertaken, followed by proper maintenance works. Some of the defects observed include: displacement of the upper connections of vertical ties and cracks in the concrete deck. Fatigue and corrosion of the main cables must also be checked.

At a meeting held on 27th August 1986, with the participation of the Chief Engineer (Bridges) and Chief Engineer (Planning) of the GHA and Messrs. Manor and Warshavski of TAHAL, the alternates proposed in the 1970 Feasibility Study by Louis Berger were discussed in detail in the light of the present development plans for Road No. 1.

It was decided that within the framework of the present Feasibility Study, TAHAL would compare two alternatives:

Alternative IIIA - A new 2-lane bridge near the existing one (located at Berger's Alternate III, but with a different structure).

Alternative IIA - A new 2-lane bridge, about 2.4 km downstream, which would shorten the travel distance by about 5 km (located at Berger's Alternate II, but with different structure).

Economic evaluation of the two alternatives, including capital investments and O &M of costs, is presented in the table on the next page. It shows that Alternative IIIA requires much smaller capital outlay and less annual expenditures, and it is therefore the recommended alternative.

The budget estimate in the F.S. will include also the cost of a detailed inspection and testing of the existing suspension bridge. Based on the results of this inspection, it will be possible to decide whether it would be preferable to repair and retain the existing bridge and to build a new one-lane bridge, rather than adopting one of the two-lane alternatives.

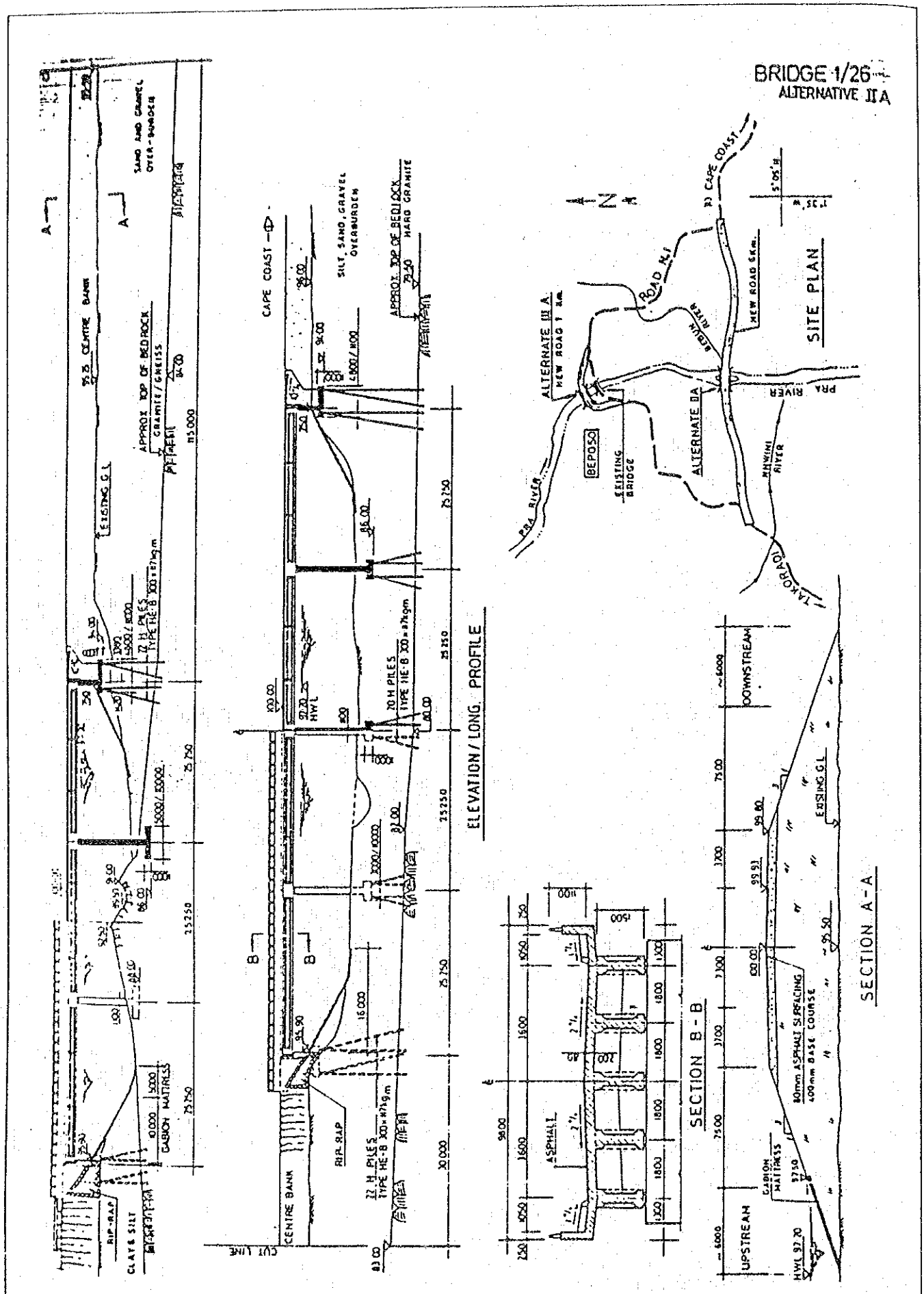
Appendix A

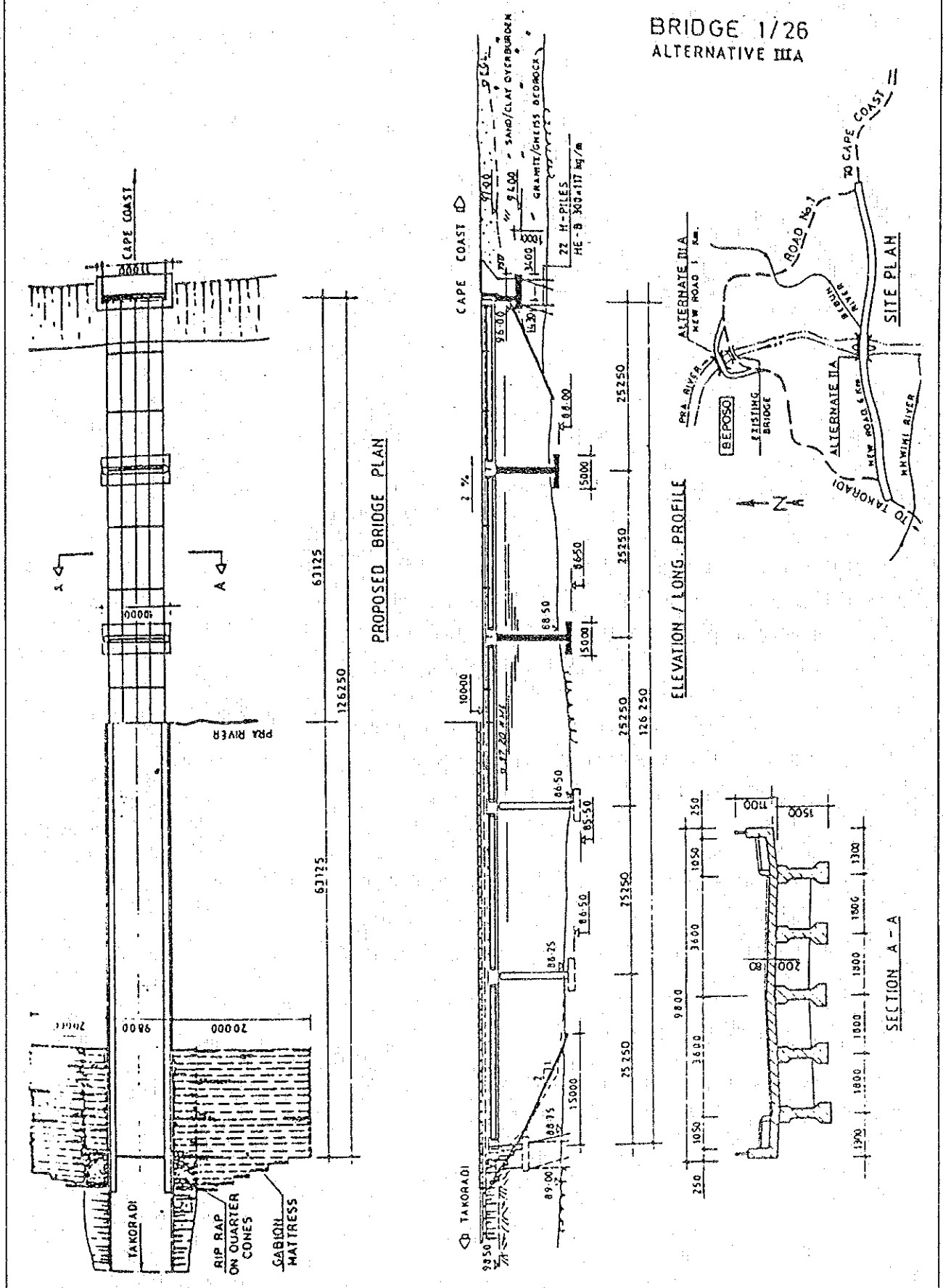
A-3

ECONOMIC EVALUATION OF ALTERNATIVES FOR RECONSTRUCTION OF BRIDGE 1/26

		Alternative IIA	Alternative IIIA
I.	**Capital Investments**		
I.1	Bridge		
	Local currency (₡ millions)	127.4	142.0
	Foreign currency ($ millions)	4.4	3.7
	Subtotal I.1 ($ millions)*	5.2	4.6
I.2	Approach Road		
	Local currency (₡ millions)	782.0	-
	Foreign currency ($ millions)	11.3	-
	Subtotal I.2 ($ millions)*	16.5	-
	Total Investments ($ millions)	21.7	4.6
II.	**Annual Costs**		
II.1	Operation and Maintenance		
	Local currency (₡ millions)	45.5	7.1
	Foreign currency ($ millions)	0.8	0.2
	Subtotal II.1 ($ millions)*	1.1	0.25
II.2	Road Shortening		
	Transportation savings ($ millions)**	-0.5	-
II.3	Annual capital costs ($ millions)***	3.5	0.85
	Total annual costs ($ millions)	4.1	1.1

* Expressed in US$ at an exchange rate of US$1 = ₡150.
** Saving accruing from shortening of the detour by 4.2 km, given the current ADT and its composition.
*** Calculated at 12% interest rate for 20 years.


BRIDGE 1/26
ALTERNATIVE IIA
SITE PLAN
ELEVATION / LONG. PROFILE
SECTION A-A
SECTION B-B
CAPE COAST
ALTERNATE IIIA
NEW ROAD 1 km
ALTERNATE IIA
BEPOSO
EXISTING BRIDGE
PRA RIVER
ANWINI RIVER
TAKORADI
NEW ROAD 6 km
ROAD No 1
SAND AND GRAVEL OVER-BURDEN
APPROX TOP OF BEDROCK
GRANITE/GNEISS
SILT, SAND, GRAVEL OVERBURDEN
HARD GRANITE
CENTRE BANK
EXISTING G.L
RIP-RAP
CLAYS & SILT
GABION MATTRESS
ASPHALT
UPSTREAM
DOWNSTREAM
80mm ASPHALT SURFACING
400mm BASE COURSE
HWL 97.20


BRIDGE 1/26
ALTERNATIVE IIIA
PROPOSED BRIDGE PLAN
CAPE COAST
TAKORADI
PRA RIVER
RIP RAP ON QUARTER CONES
GABION MATTRESS
ELEVATION / LONG. PROFILE
SAND/CLAY OVERBURDEN
GRANITE/GNEISS BEDROCK
22 H-PILES
SITE PLAN
ALTERNATE IIA
ALTERNATE IIIA
NEW ROAD 1 Km
NEW ROAD 6 Km
ROAD No.1
BEPOSO
EXISTING BRIDGE
BIBIANI RIVER
MMWIRI RIVER
TO TAKORADI
TO CAPE COAST
SECTION A-A