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No. 7

THE PEOPLE'S REPUBLIC OF BANGLADESH

FEASIBILITY STUDY
ON
MEGHNA, MEGHNA-GUMTI BRIDGES CONSTRUCTION PROJECT

FINAL REPORT

APPENDICES

MARCH, 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

THE PEOPLE'S REPUBLIC OF BANGLADESH

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AP. TABLE 2-1 : MONTHLY NORMAL TEMPERATURE AT DHAKA AND COMILLA STATIONS

(Unit : Centigrade)

Station		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Dhaka	Max.	25.5	28.1	32.5	35.1	36.2	31.8	30.7	31.0	31.2	30.9	28.7	26.3	30.5
	Min.	11.8	13.4	18.8	23.4	25.4	25.9	26.0	26.0	30.9	23.7	17.6	12.7	21.4
Comilla	Max.	26.4	28.3	32.5	33.6	32.9	31.3	30.9	31.0	31.6	31.2	29.2	26.9	30.5
	Min.	12.1	14.7	19.7	23.2	24.6	25.5	25.4	25.4	24.2	23.7	18.3	13.8	20.9

Note : Based on data for 1931 - 1960

Source : Bangladesh Bureau of Statistics

AP. TABLE 2-2 : RAINFALL AT DHAKA AND COMILLA CENTRES

(Unit : Millimetres)

Centre	1974	1975	1976	1977	1978	1979-80	1980-81	1981-82	1982-83	Average
Dhaka	2213	2044	2645	2112	1537	2458	2409	1034	1514	1996
Comilla	2118	2752	1885	2047	1878	2987	2663	1182	1610	2124

Note : From 1978 - 79 on wards data have been shown on July - June basis.

Source : Bangladesh Meteorological Department.

AP. TABLE 2-3 MONTHLY NORMAL RAINFALL AT DHAKA AND COMILLA STATIONS

(Unit : Millimetres)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dhaka	18	31	58	103	194	322	437	304	236	169	25	23
Comilla	10	44	53	158	316	479	404	417	337	226	45	2.5

Note : Based on data for 1931 - 1960

Source : Bangladesh Meteorological Department.

AP. TABLE 2-4 MONTHLY MAXIMUM WIND SPEED (IN KNOTS) AT DHAKA

Year \ Mon	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1953	9	14	24	53	60	35	11	19	25	15	13	9	23.9
54	9	13	20	18	60	16	17	14	15	24	5	7	18.1
55	10	12	78	71	60	15	16	13	40	16	10	7	29.0
56	12	9	60	52	25	26	35	16	22	12	9	9	23.9
57	27	14	14	35	43	30	16	14	12	14	7	9	19.6
58	10	40	16	30	71	35	18	20	18	12	7	9	24.4
59	9	16	35	22	87	18	22	15	12	19	7	9	22.6
60	10	16	26	60	40	18	25	18	16	28	9	7	22.8
61	7	13	39	52	60	35	18	16	16	14	10	10	24.1
62	14	17	48	52	43	19	19	14	35	9	10	13	24.4
63	12	17	25	45	40	36	21	20	22	-	-	-	-
64	9	45	50	43	65	70	19	19	25	25	13	9	32.7
65	9	9	39	31	79	25	19	19	13	9	40	13	25.4
66	9	9	14	28	30	30	13	10	10	30	5	5	16.0
67	9	9	35	15	50	36	13	13	13	9	9	5	18.0
68	9	9	52	52	65	30	35	13	13	13	5	5	27.6
69	17	9	30	17	9	13	9	13	17	13	5	5	13.1
70	15	28	60	65	40	20	28	18	24	90	40	10	36.5
71	14	13	-	-	50	25	25	20	13	20	20	-	-
72	12	22	35	60	45	29	42	26	20	18	15	10	27.8
73	9	60	20	60	40	13	10	9	9	9	13	25	21.4
74	6	5	35	55	31	9	10	14	19	5	5	5	16.6
75	14	27	25	50	44	35	9	9	5	5	-	-	-
76	17	5	35	48	17	42	13	19	19	15	5	5	20.3
77	20	30	35	50	52	37	13	20	13	5	5	9	24.1
78	9	43	40	55	45	10	12	13	19	13	9	9	23.1
79	5	9	25	65	40	25	19	25	9	13	13	5	21.1
80	5	45	52	74	95	38	38	15	9	15	5	5	33.0
81	15	13	19	19	19	20	13	13	13	9	9	44	17.2
82	10	9	13	19	19	13	18	19	9	9	5	9	12.7

Source : Bangladesh Meteorological Department

1 KNOT = 1.852 Km/Hr

100 KNOTS = 51.4 m/sec.

AP. TABLE 2-5 MONTHLY MAXIMUM WIND SPEED (IN KNOTS)

AT COMILLA

Year \ Mon	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1951	4	20	16	22	16	18	21	18	08	16	08	04	14.3
52	12	16	18	20	18	18	18	16	10	09	09	06	14.2
53	05	09	10	09	12	09	09	05	09	09	02	02	7.5
54	03	05	09	13	09	14	09	13	09	07	05	02	8.2
55	02	03	14	15	10	12	14	12	09	07	05	02	8.8
56	-	-	-	-	-	-	11	15	08	02	00	02	-
57	05	08	09	24	24	10	10	16	10	02	02	02	10.2
58	03	03	07	17	21	17	12	09	05	25	00	03	10.2
59	00	12	09	07	14	12	14	09	09	06	00	06	8.2
60	06	11	09	15	15	19	25	19	19	35	09	09	15.9
61	09	19	19	19	19	19	19	19	13	09	09	00	14.4
62	09	09	13	13	19	13	13	13	19	09	05	00	11.3
63	09	09	13	19	19	19	13	19	13	31	05	00	14.1
64	05	13	09	13	09	13	13	13	13	13	05	05	10.3
65	00	09	05	19	31	19	09	09	05	05	05	09	10.4
66	02	07	07	13	09	09	13	13	09	15	03	02	8.5
67	-	09	09	13	13	09	13	13	13	13	05	05	-
68	09	02	13	13	13	19	13	13	09	25	00	09	11.5
69	05	05	09	19	09	09	09	-	09	09	00	00	-
70	05	09	-	-	-	13	05	09	09	30	19	-	-
71	-	05	05	-	05	13	-	19	09	09	13	-	-
72	-	-	22	34	25	25	09	20	09	15	09	10	-
73	10	13	15	35	20	15	12	11	13	12	19	25	16.7
74	05	07	15	25	35	40	15	20	15	07	15	07	17.2
75	15	15	15	30	25	25	-	20	12	10	02	05	-
76	-	-	-	25	18	18	20	18	15	12	10	10	-
77	07	09	07	09	12	09	15	16	21	12	09	02	10.7
78	07	12	03	13	13	05	17	18	28	13	05	07	11.8
79	05	13	10	18	21	12	15	13	09	13	03	02	11.2
80	07	15	12	22	25	14	18	16	09	13	05	05	13.4
81	-	-	15	20	15	15	15	18	10	09	04	35	-
82	04	07	15	20	15	09	15	18	15	12	07	08	12.1

Source : Bangladesh Meteorological Department

1 KNOT = 1.852 km/Hr

100 KNOTS = 51.4 m/Sec

AP.TABLE 2-6 RECORD OF CYCLONIC STORMS WHICH AFFECTED VICINITY OF MEGHNA ESTURARY AND BRIDGE SITES

Date of Occurrance	Affected Area	Nature of the Phenomena	Approximate Loss/Damages
May 16-19, Oct. 21-24, both 1958	East Meghna esturary near 91 east of Barisal and Noakhali also West Meghna esturary	Cyclonic storm	Damage report not available
Oct. 9-10, 1960	Eastern Meghna estuary	Severe cyclonic storm 125 miles per hour, maximum storm wave 10 ft.	Caused considerable damage to Char Jabbar, Char Amina, Char Bhati, Ramgati, Hatya and Noakhali. 3,000 people reported killed.
May 9, 1961	West Meghna estuary, Comilla and Dhaka	Severe cyclonic storm speed 90-92 miles and wave 8-10 ft.	Rail track between Noakhali and Harinarayanpur damaged. Heavy loss of life in Char Allanda.
May 11-12, 1965	Barisal, Faridpur, Khulna, Jessore, Chittagong, Sylhet and Noakhali	Most severe cyclonic storm, maximum speed at Dhaka 100 miles per hour, with storm wave 12 ft.	Total loss of life 19,270. In Barisal 14,193 people were killed.
Nov. 12-13, 1970	Meghna estuary	Most severe cyclonic storm accompanied by moderate severe storm surge. Naval ship at Chittagong reported speed 138 miles per hour.	The entire belt from Khulna to Chittagong and offshore islands experienced hurricane winds for about 9 hours accompanied by storm surge of moderate to severe intensity which caused widespread damage to crop and properties. Innumerable human lives estimated to be about 200,000 were lost. A great number of animals were also killed.

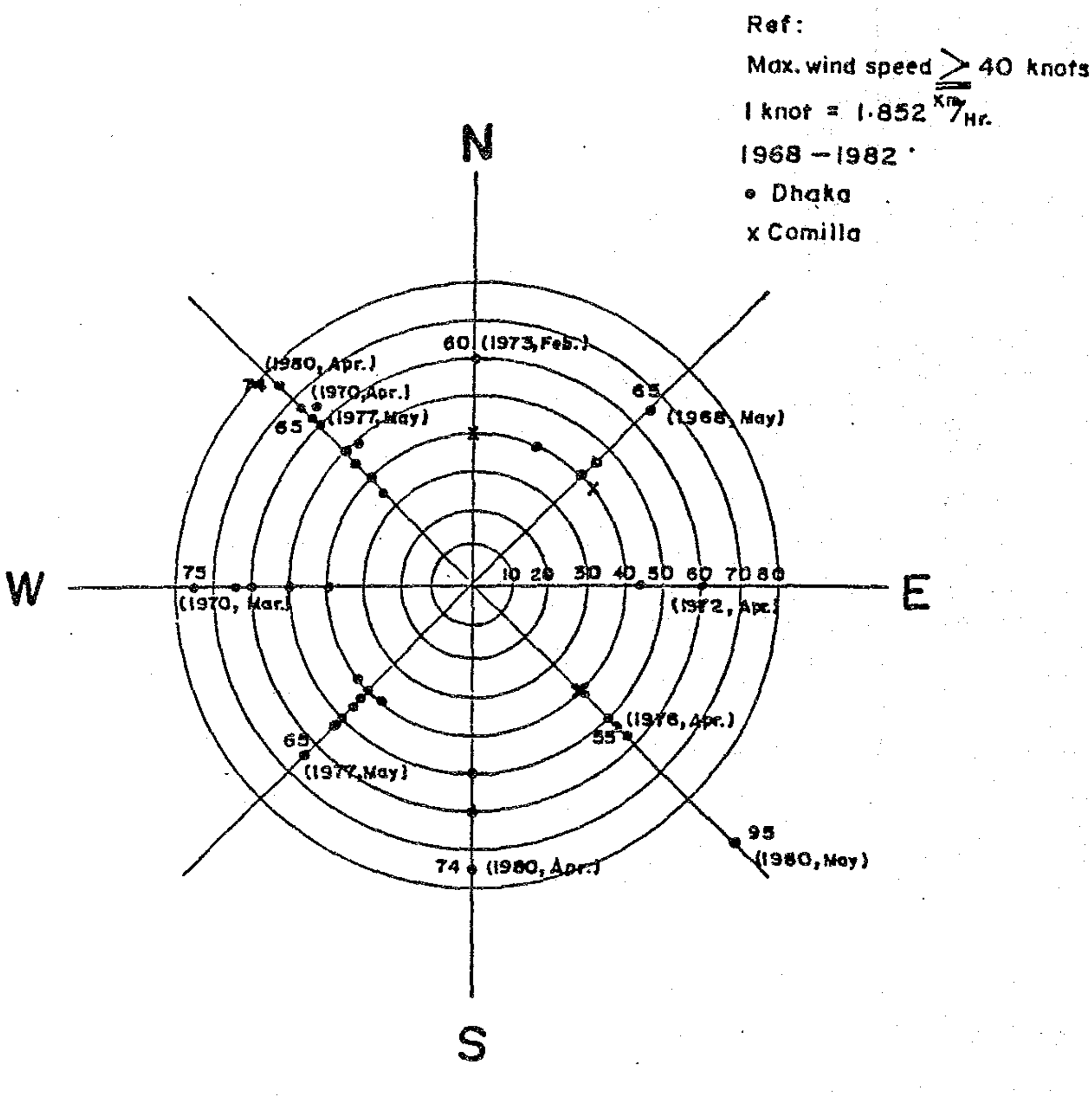
Source : The 1982 Statistical Yearbook of Bangladesh

AP. TABLE 2-7 MAXIMUM WIND SPEED IN KNOTS DIRECTION

Year Station / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1977												
Comilla	N/NW14	S15	S25	S35	S/SW25	SE25	S/SE19	S16	S17	NE10	N08	NW10
1978												
Comilla	SE07	N12	SE06	S09	SE19	S/SE5	S17	S18	S/SW12	SE13	S/SE5	N07
1979												
Comilla	NNW12	V13	S16	V13	S19	S18	S22	E20	S04	SE07	SE05	N03
Dhaka	V05	NW21	SW40	NW65	W50	E/SE25	SE/S19	SE25	SE/S09	SE/S13	N/NE13	NW05
1980												
Comilla	N08	NW15	NW12	S20	N25	SE14	SE18	SE16	E05	SE13	N05	NW05
Dhaka	NW05	NE/E45	SE/SW52	S/NW74	SE95	SE/S38	SE/S38	SE15	SE09	E15	N/NW05	NW05
1981												
Comilla	n.a.	n.a.	N15	S20	E15	SW15	S15	SE18	S10	S09	NE04	S35
Dhaka	N15	SW13	NW19	SE19	NW19	SE20	S13	SE13	SE13	N09	W09	SW44
1982												
Comilla	N04	N07	N15	S20	SE15	S09	S15	S18	SE15	W12	NW07	S08
Dhaka	NW10	W09	N13	W19	N19	SE13	S18	S19	S09	SW09	E05	W09

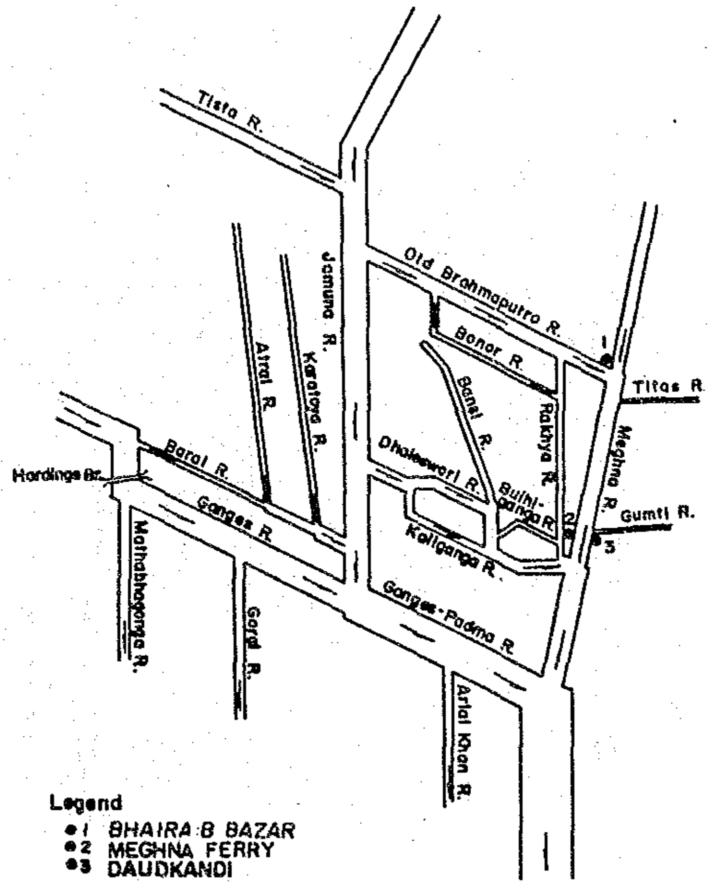
Note : V - Variable
n.a.-data not available

Source : Bangladesh Meterological Department



Source: Bangladesh Meteorological Department

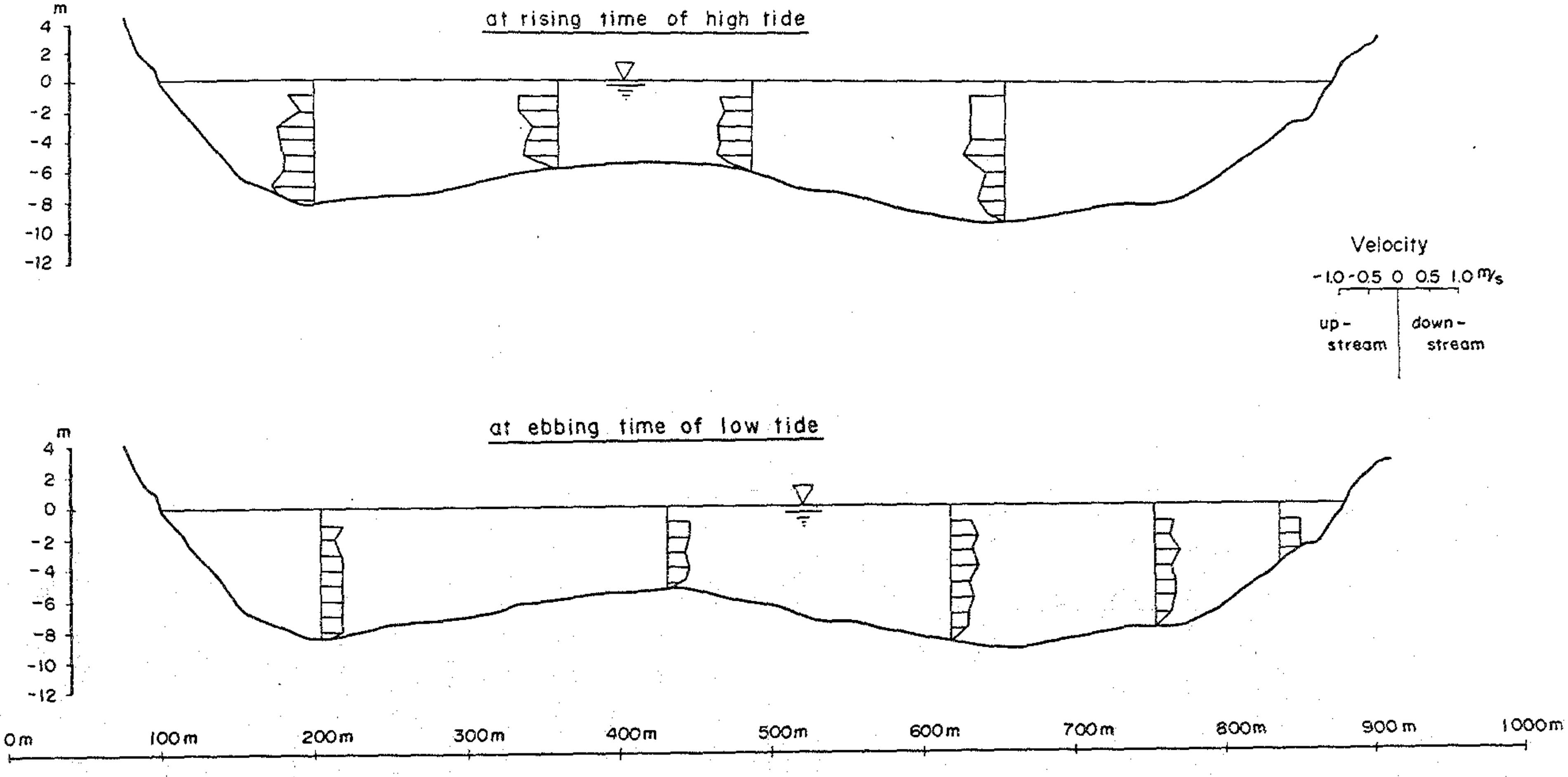
AP.FIG. 2-1 PAST MAXIMUM WIND SPEEDS AND DIRECTIONS



Item \ River	MEGHNA. R	BRAHMAPUTRA R.	GANGES. R.
Total stream length (km)	880	2 800	2 560
Stream length in Bangladesh (km)	560	275	400
Catchment area (km²)	77 000	580 000	900 000
Catchment area in Bangladesh (km²)	46 500	31 000	39 000
Maximum experienced discharge (km²)	19 500	70 000	85 000
Minimum experienced discharge (m³/s)	370	3 300	1 200
Annual mean discharge (m³/s)	3500	12 900	11 700
Water surface slope	1 : 8 800	1 : 16 000	1 : 20000

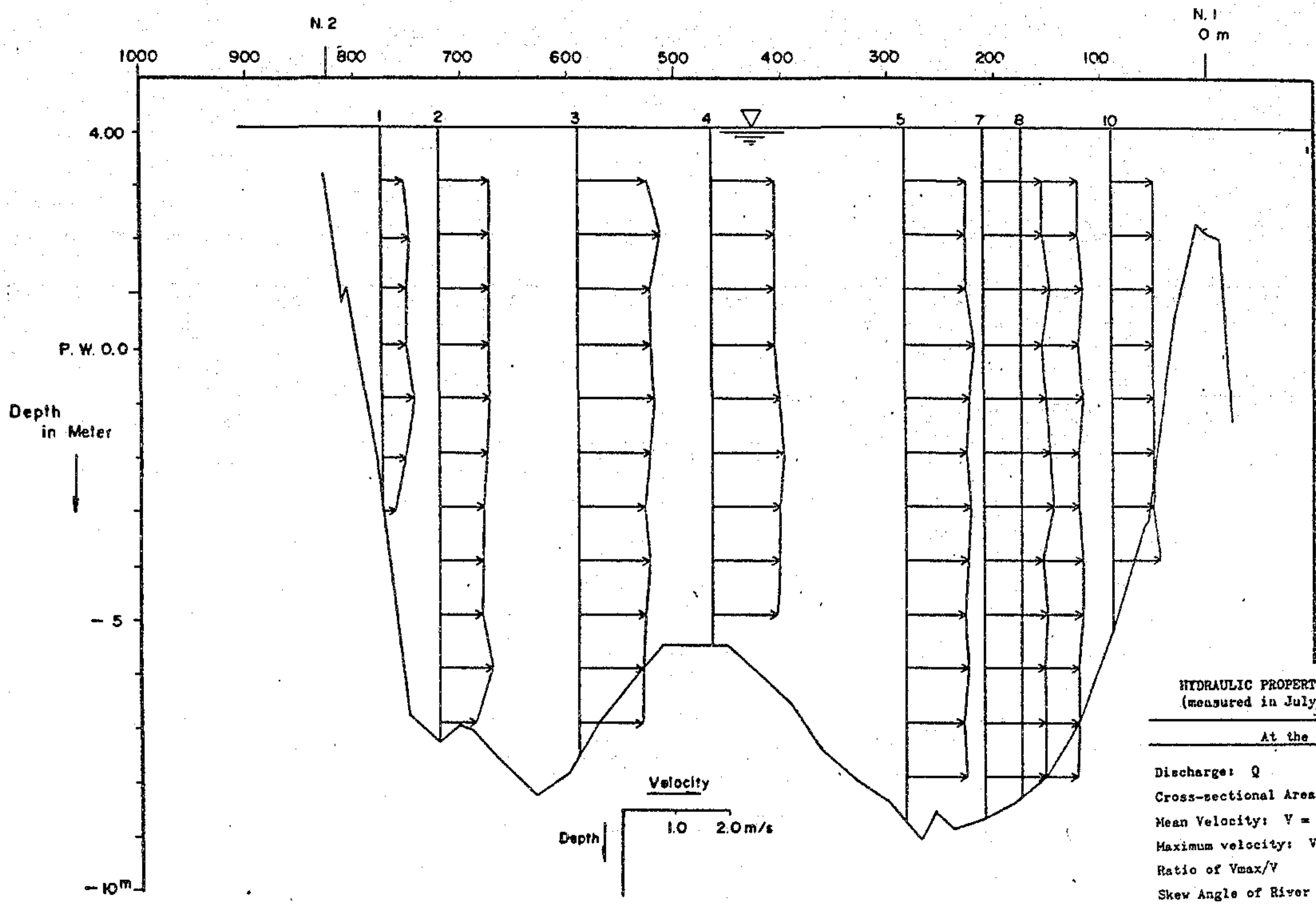
Source: Report "Flood Control in Bangladesh" by DR. MD SAYEEDUL ISLAM KHAN, 1977

AP. FIG. 2-2 RIVER SYSTEM AROUND THE MEGHNA RIVER AND GENERAL FEATURE OF THE MAIN RIVERS IN BANGLADESH



Source: The Study Team

AP. FIG. 2-3 VELOCITY OF RIVER FLOW AT THE PROPOSED MEGHNA BRIDGE SITE, MEASURED IN APRIL, 1984

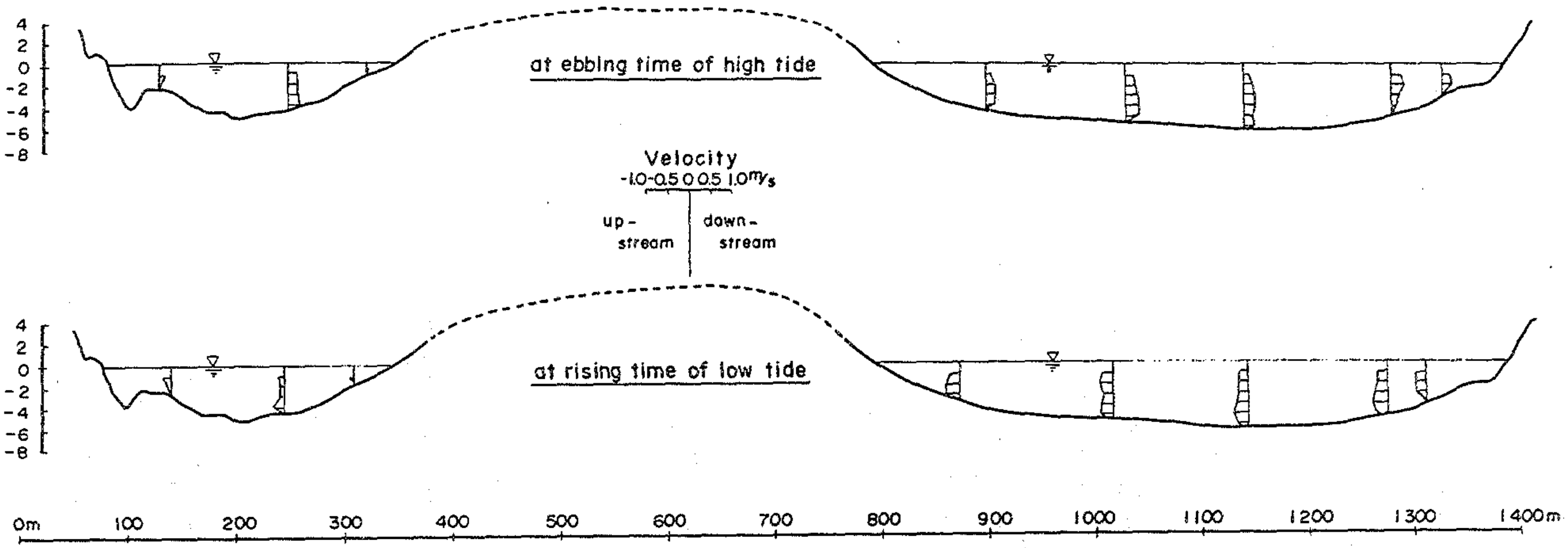


HYDRAULIC PROPERTIES OF MEGHNA RIVER
(measured in July 1984)

	At the proposed site of Meghna Br.
Discharge: Q	9,020 m^3/s
Cross-sectional Area: A	8,181 m^2
Mean Velocity: V = Q/A	1.10 m/s
Maximum velocity: Vmax	1.54 m/s
Ratio of Vmax/V	1.40
Skew Angle of River Flow	29 degrees

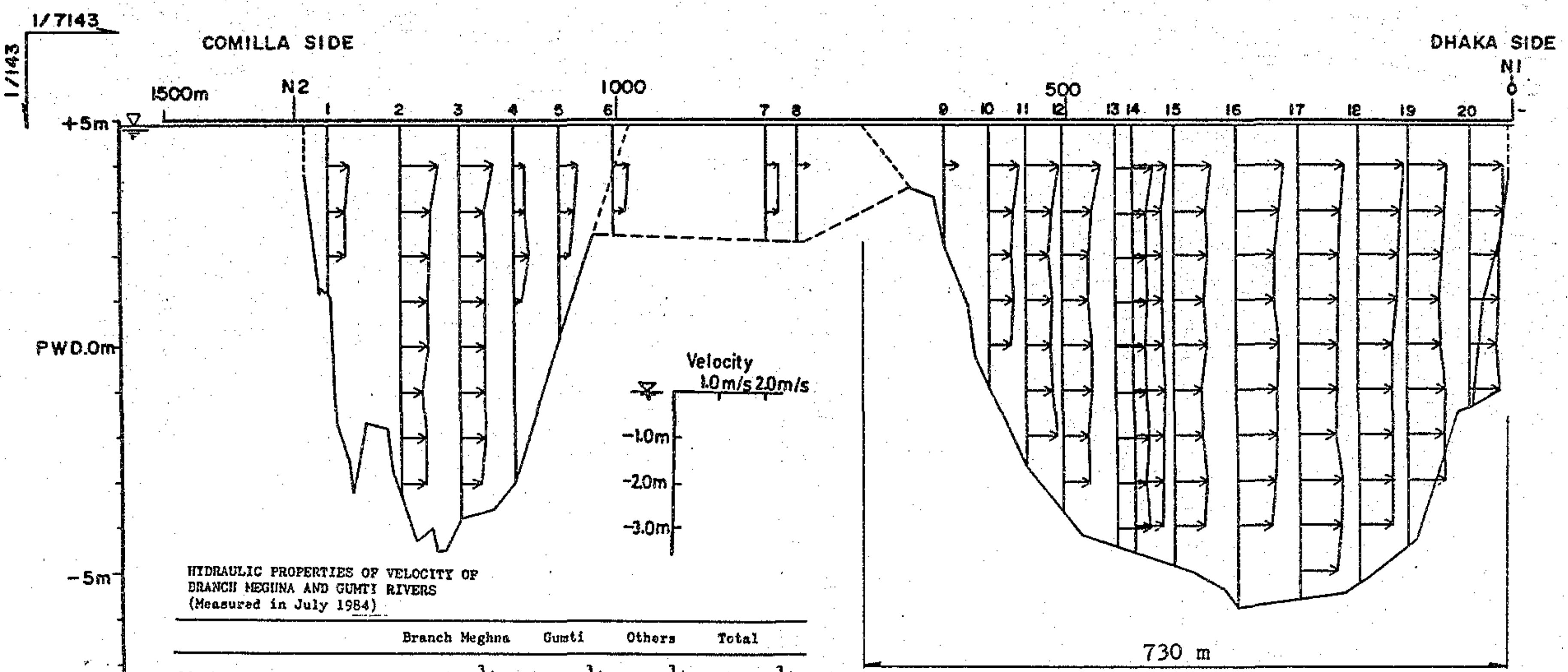
Source: The Study Team

AP. FIG. 2-4 VELOCITY OF RIVER FLOW AT THE PROPOSED MEGHNA BRIDGE SITE, MEASURED IN JULY, 1984



Source: The Study Team

AP. FIG. 2-5 VELOCITY OF RIVER FLOW AT THE PROPOSED MEGHNA-GUMTI BRIDGE SITE, MEASURED IN APRIL, 1984

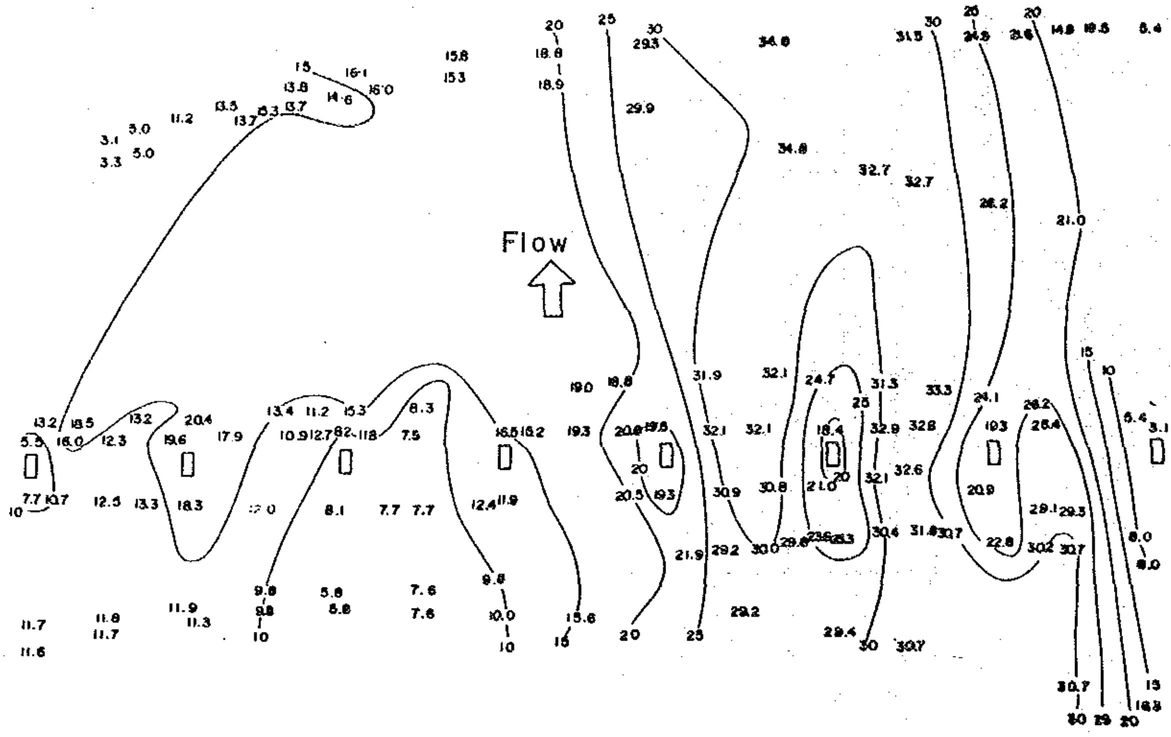


HYDRAULIC PROPERTIES OF VELOCITY OF BRANCH MEGHNA AND GUMTI RIVERS (Measured in July 1984)

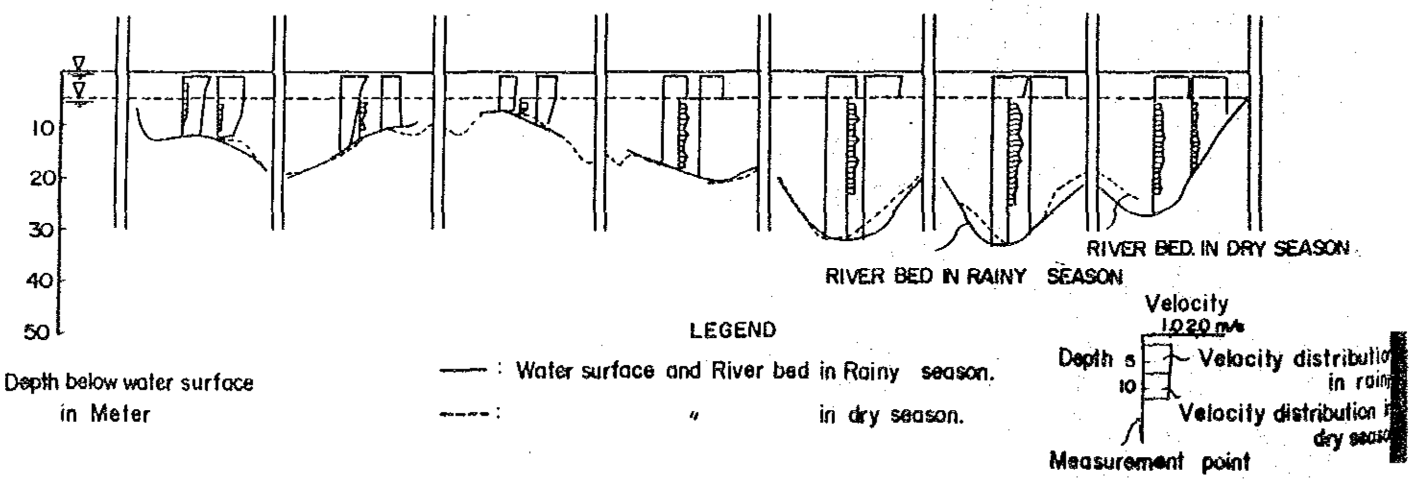
	Branch Meghna	Gumti	Others	Total
Discharge: Q	3,784 m^3/s	961 m^3/s	95 m^3/s	4,840 m^3/s
Cross Sectional Area: A	5,535 m^2	2,240 m^2	775 m^2	8,550 m^2
Mean Velocity: V = Q/A	0.68 m/s	0.43 m/s	-	0.57 m/s
Maximum Velocity: Vmax	1.05 m/s	0.86 m/s	-	1.05 m/s
Ratio of Vmax/V	1.54	2.00	-	1.84
Skew Angle of Riverflow	32 degrees	-	-	-

Source: The Study Team

AP. FIG. 2-6 VELOCITY OF RIVER FLOW AT THE PROPOSED MEGHNA-GUMTI BRIDGE SITE, MEASURED IN JULY, 1984

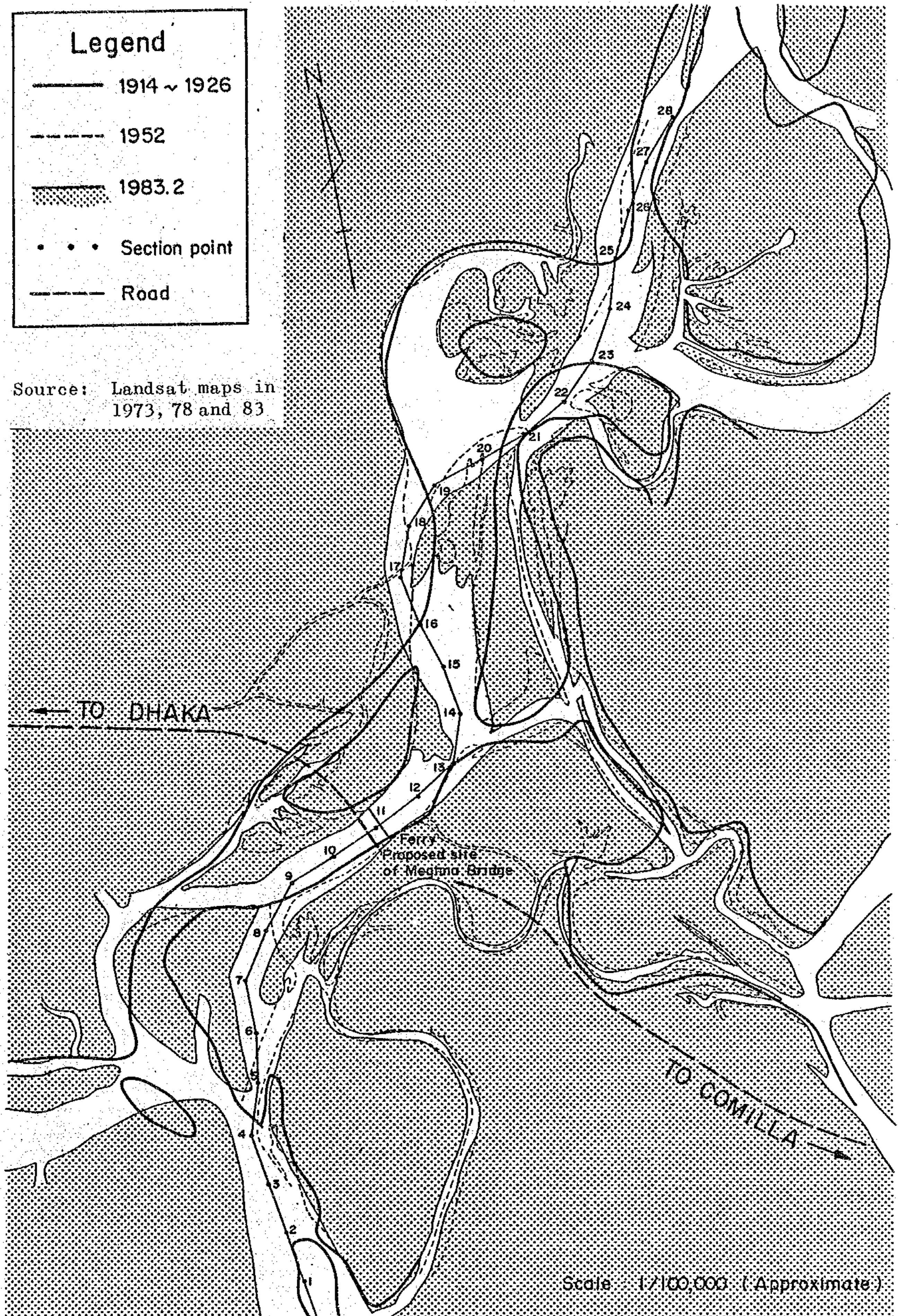


AP.FIG. 2-7 (a) RESULT OF SOUNDING INVESTIGATIONS DURING RAINY SEASON MEASURED AT BHAIRAB BAZAR BRIDGE IN 1984 JULY

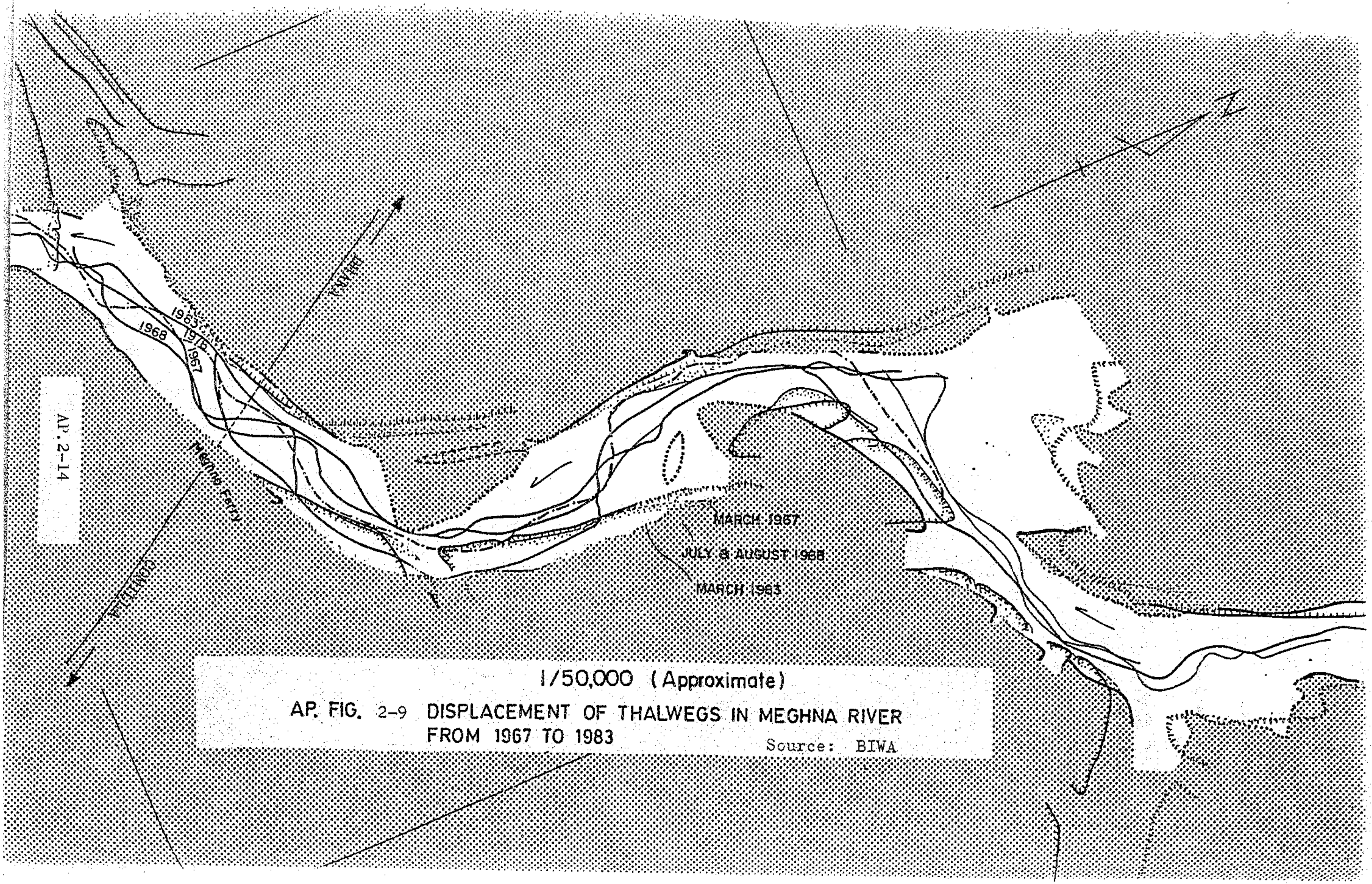


AP.FIG. 2-7 (b) PROFILE OF DRY SEASON IN 1984 APRIL AND RAINY SEASON IN 1984 JULY (At Bhairab Bazar)

Source: The Study Team



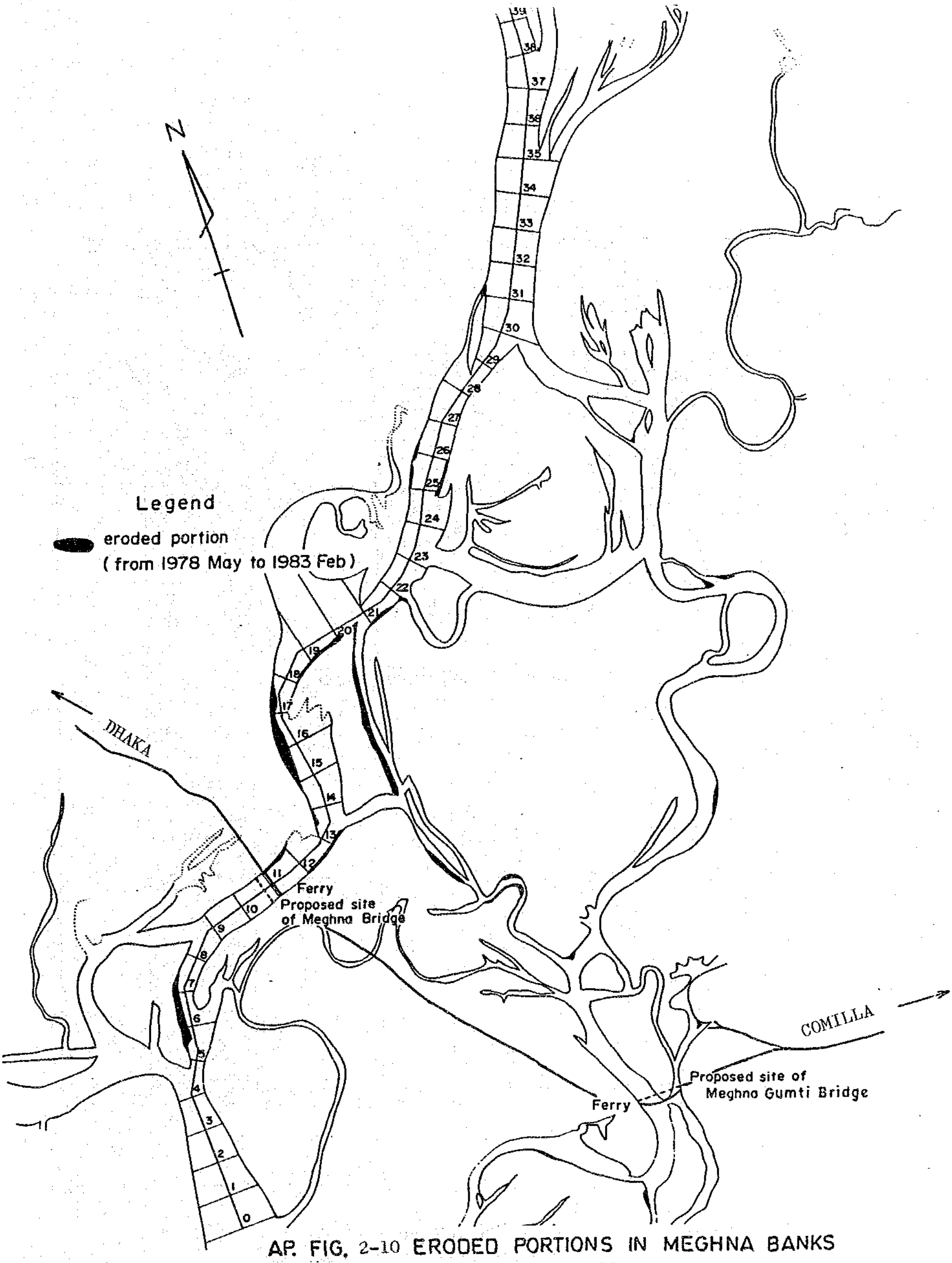
AP. FIG. 2-8 RIVER COURSE SHIFTING OF MEGHNA RIVER (FOR THE PAST 7 DECADES)



1/50,000 (Approximate)

AP. FIG. 2-9 DISPLACEMENT OF THALWEGS IN MEGHNA RIVER FROM 1967 TO 1983

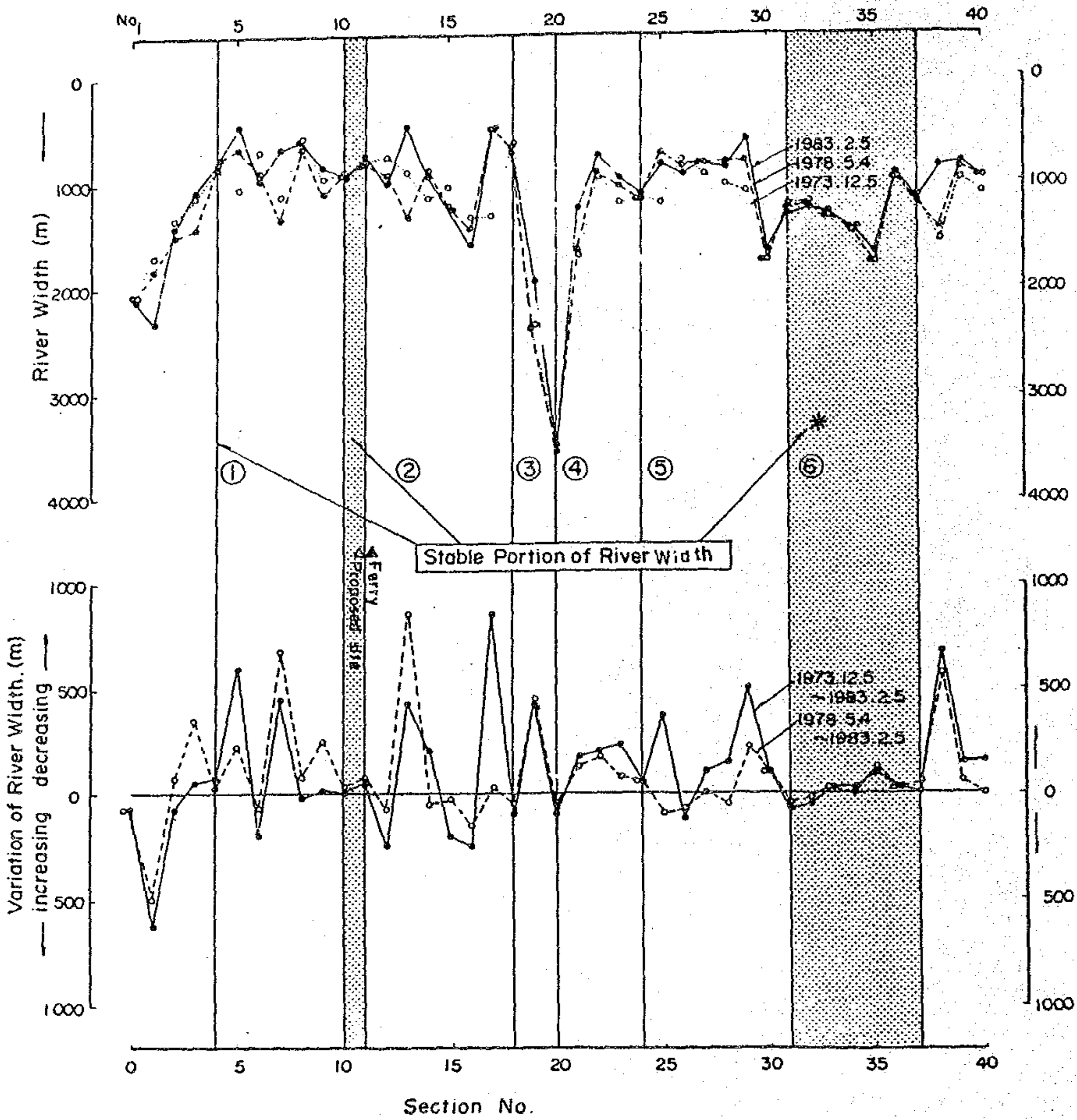
Source: BIWA



AP. FIG. 2-10 ERODED PORTIONS IN MEGHNA BANKS FROM 1978 TO 1983

Scale : 1 / 143,000 (Approximate)

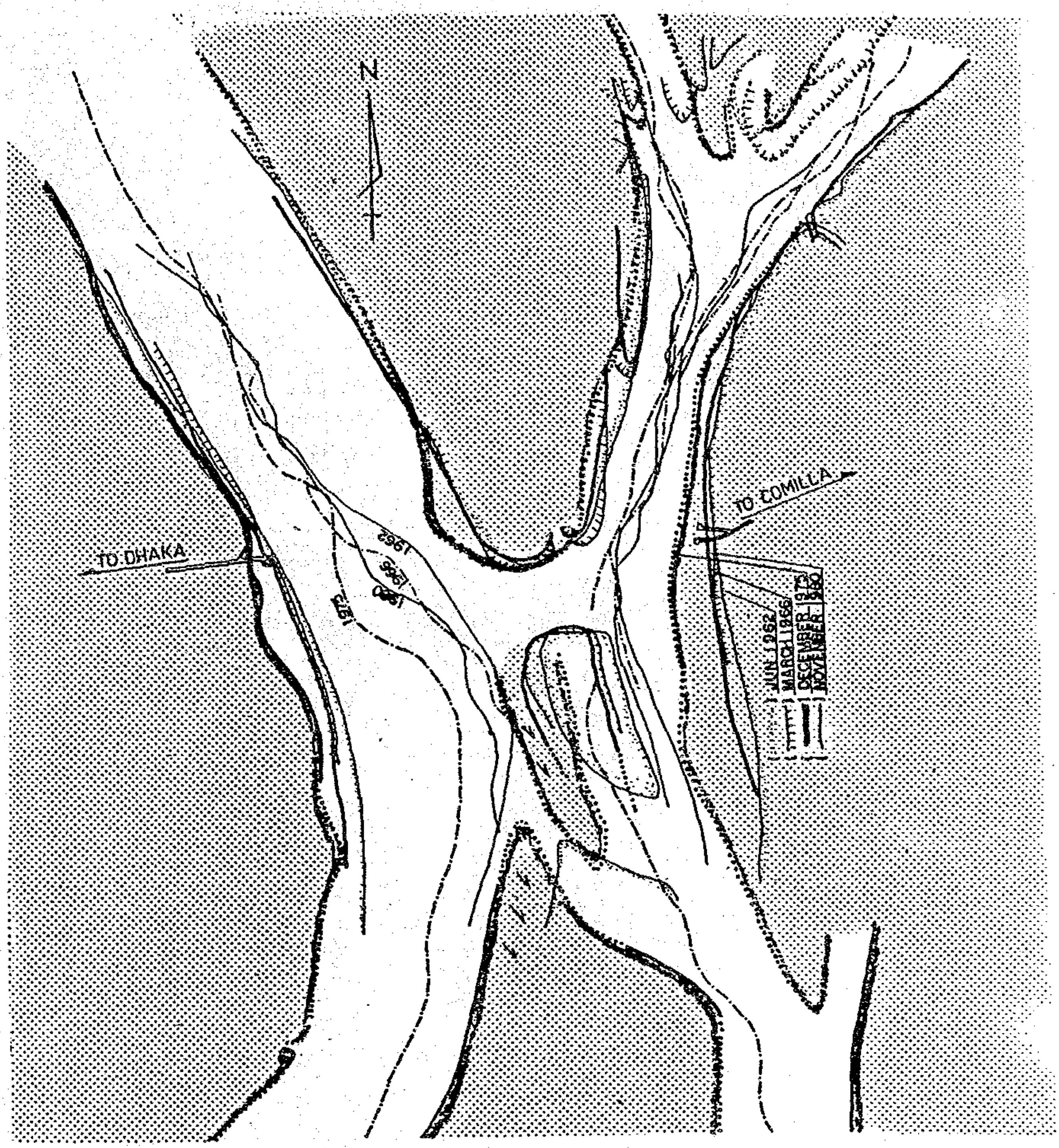
Source: Landsat mpas



Note: * The portion denoted by * is not preferable because it is far from the proposed bridge site.

Source: Landsat maps in 1973, 78 and 83.

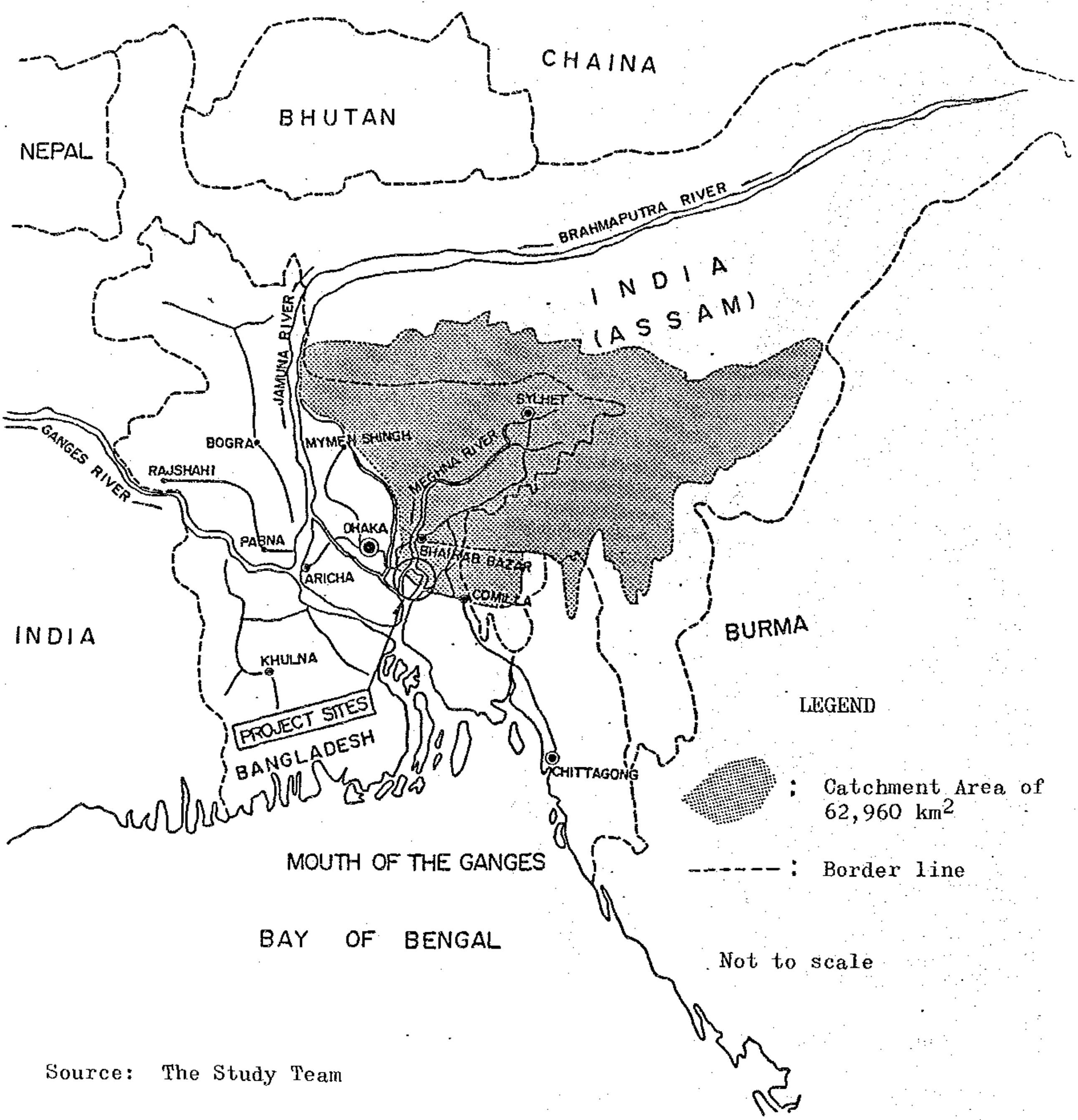
AP. FIG. 2-11 VARIATIONS OF MEGHNA RIVER WIDTH



Source: BIWA

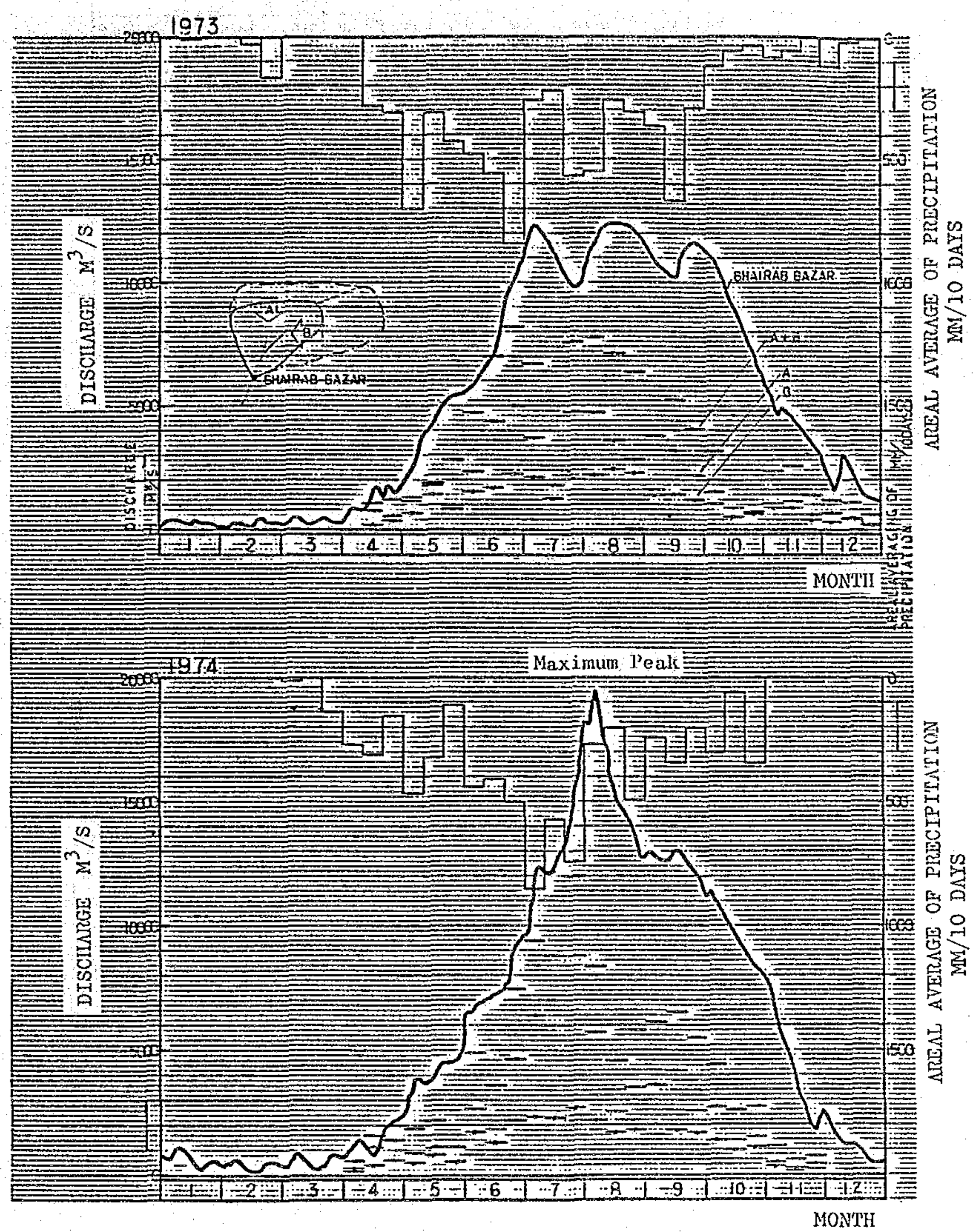
SCALE: 1/16.600

AP. FIG. 2-12 DISPLACEMENT OF THALWEGS AND BANKS OF MEGHNA-GUMTI RIVER



Source: The Study Team

AP. FIG. 2-13 CATCHMENT AREA OF THE MEGHNA RIVER



Source: The Study Team

AP. FIG. 2-14 TYPICAL TYPES OF RAINFALL AND RUNOFF

AP. TABLE 2-8 RAINFALL-RUNOFF RELATION
(at Bhairab Bazar)

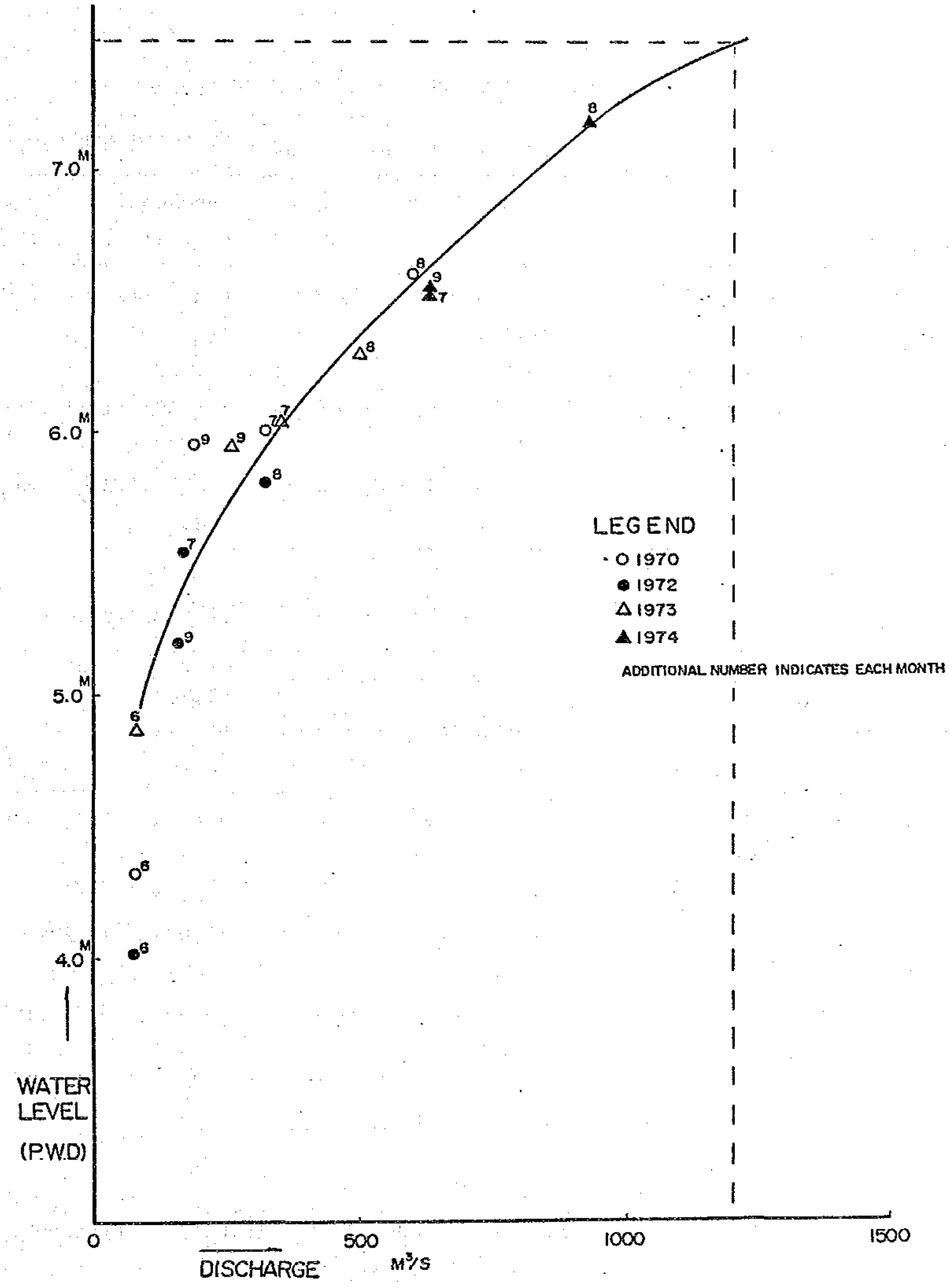
Unit	Rainfall Intensity for Return Period: 100 year mm/hr	Inflow from Out side of Bangla-desh m³/s	Runoff Volume by Unit Hy-drograph m³/s	Total Discharge m³/s
1974, 4 (1)	0.697	336	182	518
(2)	0.795	672	711	1,383
(3)	0.403	1,637	1,588	3,225
5 (1)	1.206	2,031	2,755	4,786
(2)	0.812	1,960	3,141	5,101
(3)	0.278	2,225	3,118	5,343
6 (1)	1.115	1,167	3,262	4,429
(2)	1.052	4,853	2,102	6,955
(3)	1.286	3,582	2,588	6,170
7 (1)	2.153	7,458	4,433	11,891
(2)	1.462	9,464	5,285	14,749
(3)	1.873	8,769	7,962	16,731
8 (1)	0.703	11,951	9,189	21,140
(2)	0.521	8,303	7,715	16,018
(3)	1.253	4,616	7,031	11,645
9 (1)	0.612	5,810	4,979	10,789
(2)	0.880	6,076	4,067	10,143
(3)	0.496	6,503	5,104	11,607
10 (1)	0.700	4,538	5,400	9,938
(2)	0.148	4,399	7,267	11,666
(3)	0.885	2,567	6,383	8,950
11 (1)	0	2,703	6,719	9,422
(2)	0	1,137	6,094	7,231
(3)	0.097	644	4,150	4,794
12 (1)	0	-	2,763	
(2)	0	-	667	
(3)	0	-	798	

Source: The Study Team

AP. TABLE 2-9 MAXIMUM DAILY DISCHARGE
(at Bhairab Bazar)

Year	Discharge
1964	12,300 m³/s
65	12,080
66	14,400
67	12,700
68	13,300
69	11,500
70	16,400
71	-
72	11,500
73	12,400
74	19,500
75	12,700
76	16,700

Source: The Study Team



AP. FIG. 2-15 WATERLEVEL-DISCHARGE DIAGRAM AT BHAIRAB BAZAR RAILWAY BRIDGE

Source: The Study Team & Hydrological Year Book of Bangladesh

AP. TABLE 2-10 (a) DISCHARGE DISTRIBUTION IN CASE OF PWD = 6.99 m

	Proposed Meghna Bridge	Proposed Meghna-Gumti Bridge
Water Level (PWD) at P_{t-1}	Meghna Ferry: 6.99 m	Daudkandi: 6.99 m
at P_{t-2}	Saitnal : 6.41 m	Saitnal : 6.41 m
Distance between P_{t-1} & P_{t-2}	Approximately 15,000 m	Approximately 13,000 m
Hydraulic Gradient: I	1/25,424	1/22,034
Hydraulic Roughness: n*	0.02	0.02
Hydraulic Mean Depth: R=A/W	$10,656m^2/825m = 12.92m$	$11,230m^2/1,340m = 8.38m$
Velocity: $V = 1/n \times R^{2/3} \times I^{\frac{1}{2}}$	1.73 m/s	1.39 m/s
Discharge: Q = A x V	$10,656 \times 1.73 = 18,435 m^3/s$	$11,230 \times 1.39 = 15,610 m^2/s$
Discharge Distribution (%)	54.1 %	45.9 %

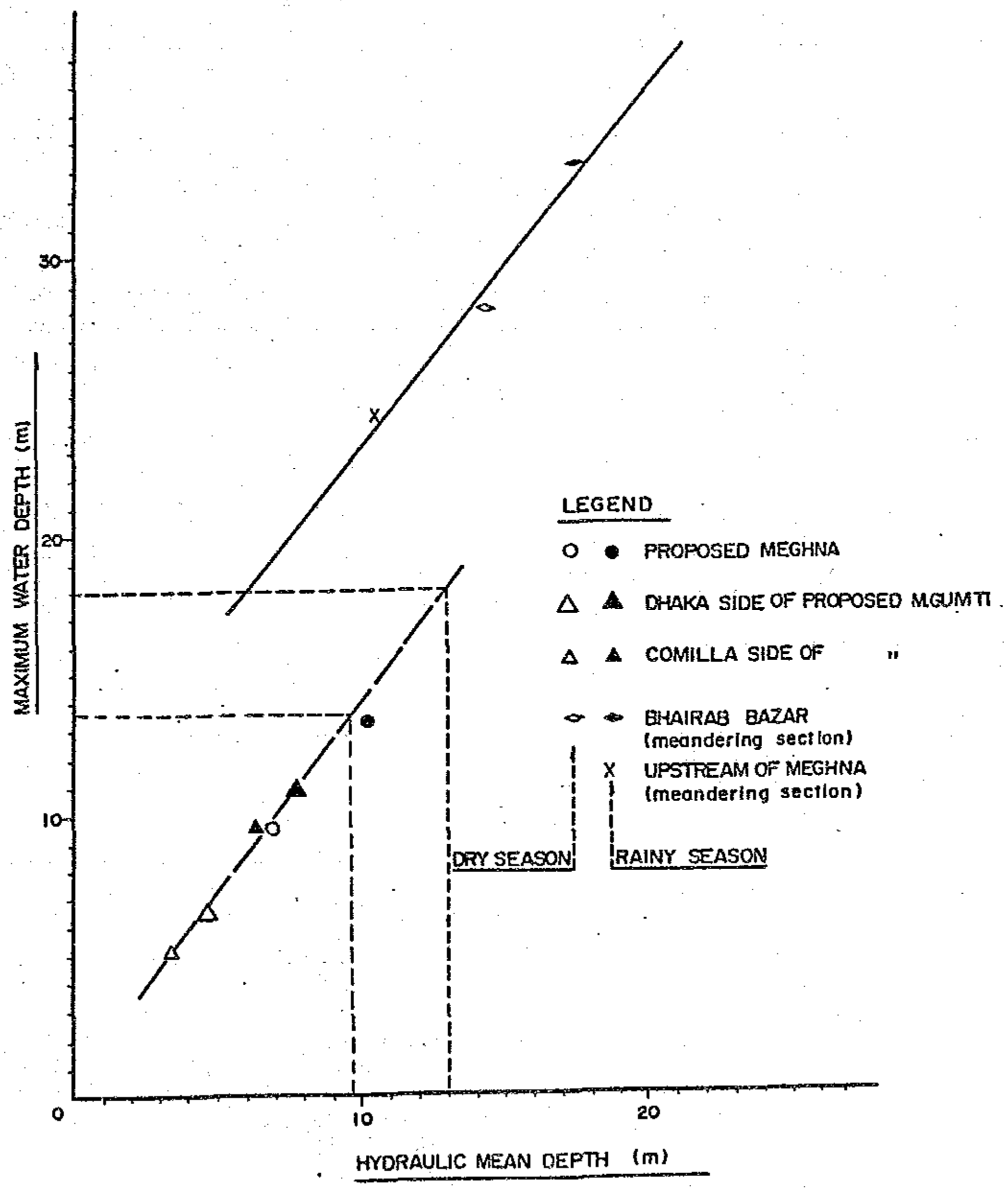
TABLE 2-10 (b) DISCHARGE DISTRIBUTION IN CASE OF PWD = 6.60 m**

	Proposed Meghna Bridge	Proposed Meghna-Gumti Bridge
Water Level (PWD) at P_{t-1}	Meghna Ferry: 6.60 m	Daudkandi: 6.60 m
at P_{t-2}	Saitnal : 6.41 m	Saitnal : 6.41 m
Distance between P_{t-1} & P_{t-2}	Approximately 15,000 m	Approximately 13,000 m
Hydraulic Gradient: I	1/78,947	1/68,421
Hydraulic Roughness: n	0.02	0.02
Hydraulic Mean Depth: R=A/W	$10,326m^2/825m = 12.52m$	$10,694m^2/1,340m = 7.98m$
Velocity: $V = 1/n \times R^{2/3} \times I^{\frac{1}{2}}$	0.959 m/s	0.763 m/s
Discharge: Q = A x V	$10,326 \times 0.959 = 9,903 m^3/s$	$10,694 \times 0.763 = 8,160 m^3/s$
Discharge Distribution (%)	54.8 %	45.2 %

Source: The Study Team

Note: * Coefficient of roughness 0.02 was same, as a result, with that of the JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT FEASIBILITY STUDY REPORT LOT II. RIVER CONTROL. AUGUST 1976 (JICA)

** The value of 6.60 m is the water level at Meghna-Gumti River, with the return period of 100 years, which is analyzed based on the existing water level records at Daudkandi.



AP. FIG. 2-16 RELATION BETWEEN HYDRAULIC MEAN DEPTH & MAXIMUM WATER DEPTH

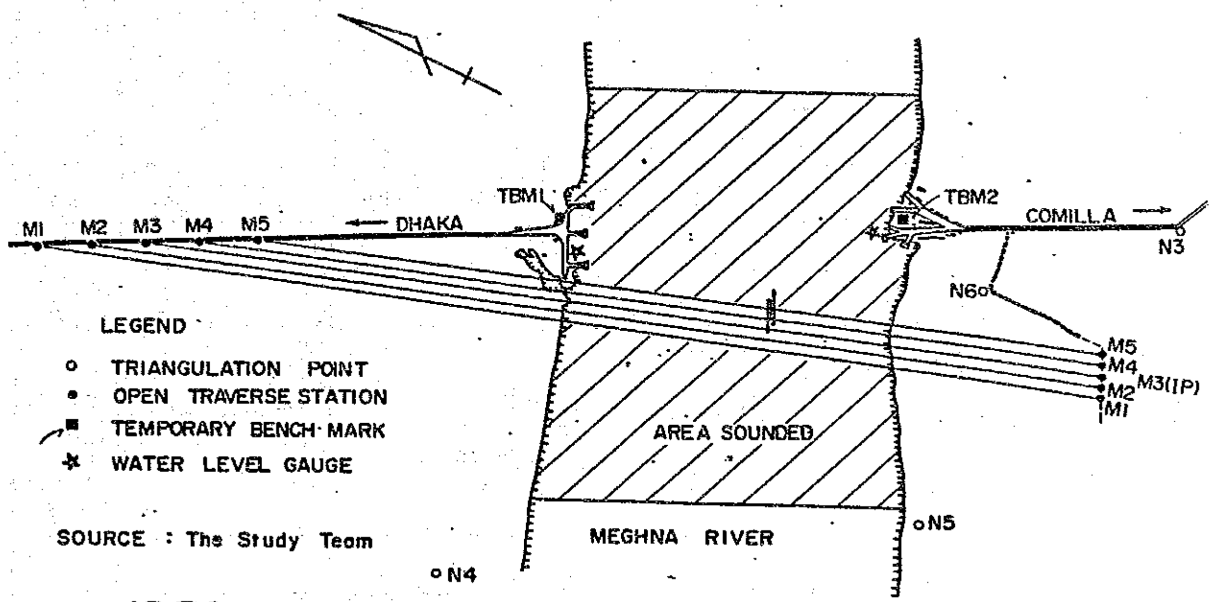
Source: The Study Team

AP. TABLE 2-11 COMPARISON OF THE SCOURING LEVELS CALCULATED BY DIFFERENT FORMULAS

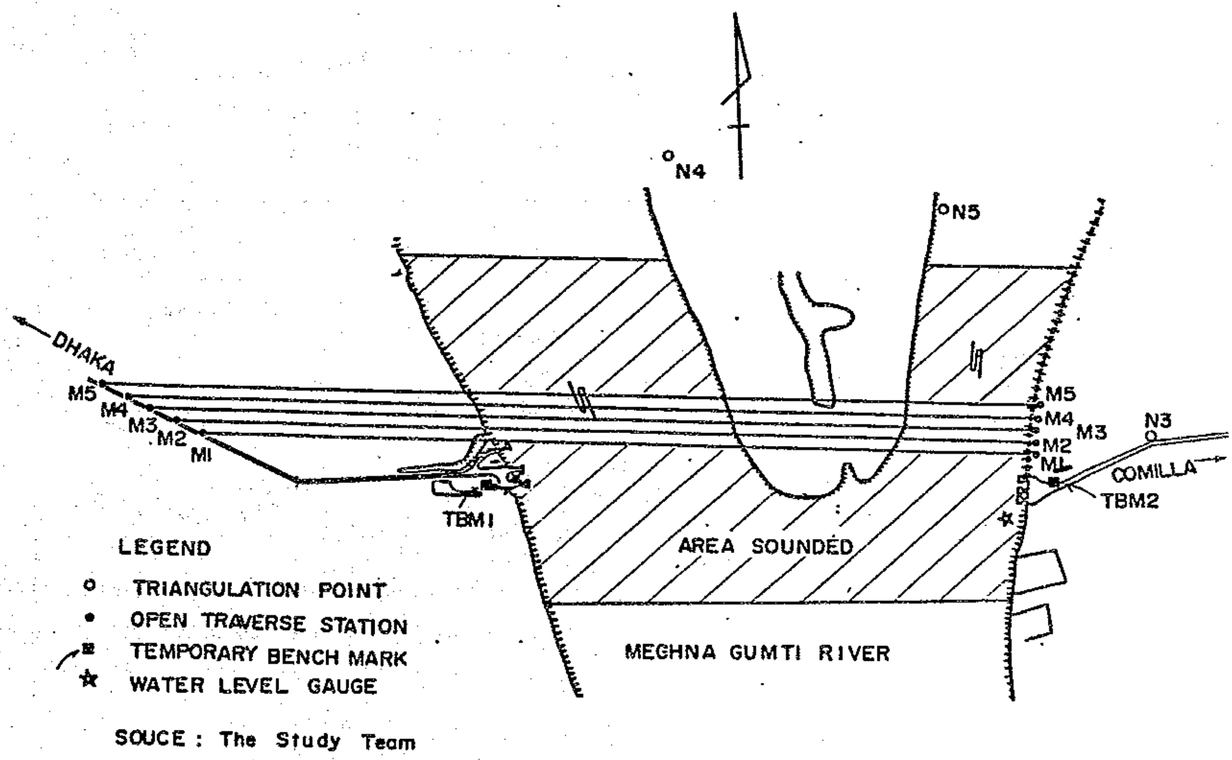
Proposers	Type of Equation	Calculated Values Meghna Bridge	Calculated Values Meghan-Gumti Bridge	Notes
Andru	$Z/D = 0.8 \times ho/D$ ho: Water Depth D: Width of Piers	—	—	ho: 18m $0 < ho/D < 1.5$ *
Tarapore	$Z/D = 1.35$	3.4	3.4	$(ho/D) > 1.15$
Larras Breusers	$Z = 1.42\ K \cdot D^{0.75}$ $Z = 1.4D$	4.0 3.5	4.0 3.5	
Moza and Sanchex	$Z/D = ho/D(K_1 \cdot K_2 \cdot U_0^2 - 3100\text{cm}/D)$	2.7	1.9	
Neil Qureshi	$Z/D = K \cdot (ho/D)^{0.3}$ $Z/D = 1.8(ho/D)^{0.75} - ho/D$	10.9 2.9	10.2 4.0	
Carstens	$Z/D = 0.546\left(\frac{N_s^2 - N_{s1}^2}{N_s^2 - N_{s2}^2}\right)^{3/4}$ $N_s = \frac{U_0}{\sqrt{(\sigma/\rho - 1) g\, d_m}}$ $N_{s2} = 2.24$ $N_{s1} = \frac{1}{2} N_{s2}$	2.1	2.2	$U_0 = 1.73$m/s
Shen	$Z = 0.0222 R_p^{0.619}$ (cm) $R_p = \frac{D \cdot U_0}{\nu}$	-	-	$U_0 = 1.73$cm/S * $\nu = 0.01\text{cm}^2/\text{s}$
Japan National Railways	$Z/D = 1.6$	4.0	4.0	
Public Works Research Institute, Ministry of Construction	Z/D - ho/D: Design Curve	9.2	8.6	$ho/D \leq 3.50$
Laursen	Z/D - ho/D: Design Curve	11.0	10.2	
Poona	$D_s = 1.70\ D \cdot (q^{2/3}/D)^{0.78}$ D_s: the depth of Scour below water level q: unit discharge per foot	4.5	4.1	
Lacy	$D' = 0.473(Q/f)^{1/3}$ $D = 2 \times \delta'$ Q: maximum discharge in cusec f: silt factor $1.76\sqrt{m}$ m: mean diameter of sand in mm D: maximum scouring depth below HFL	9.7	12.3	

Note: * Equations are not applicable to the proposed bridges and rivers.

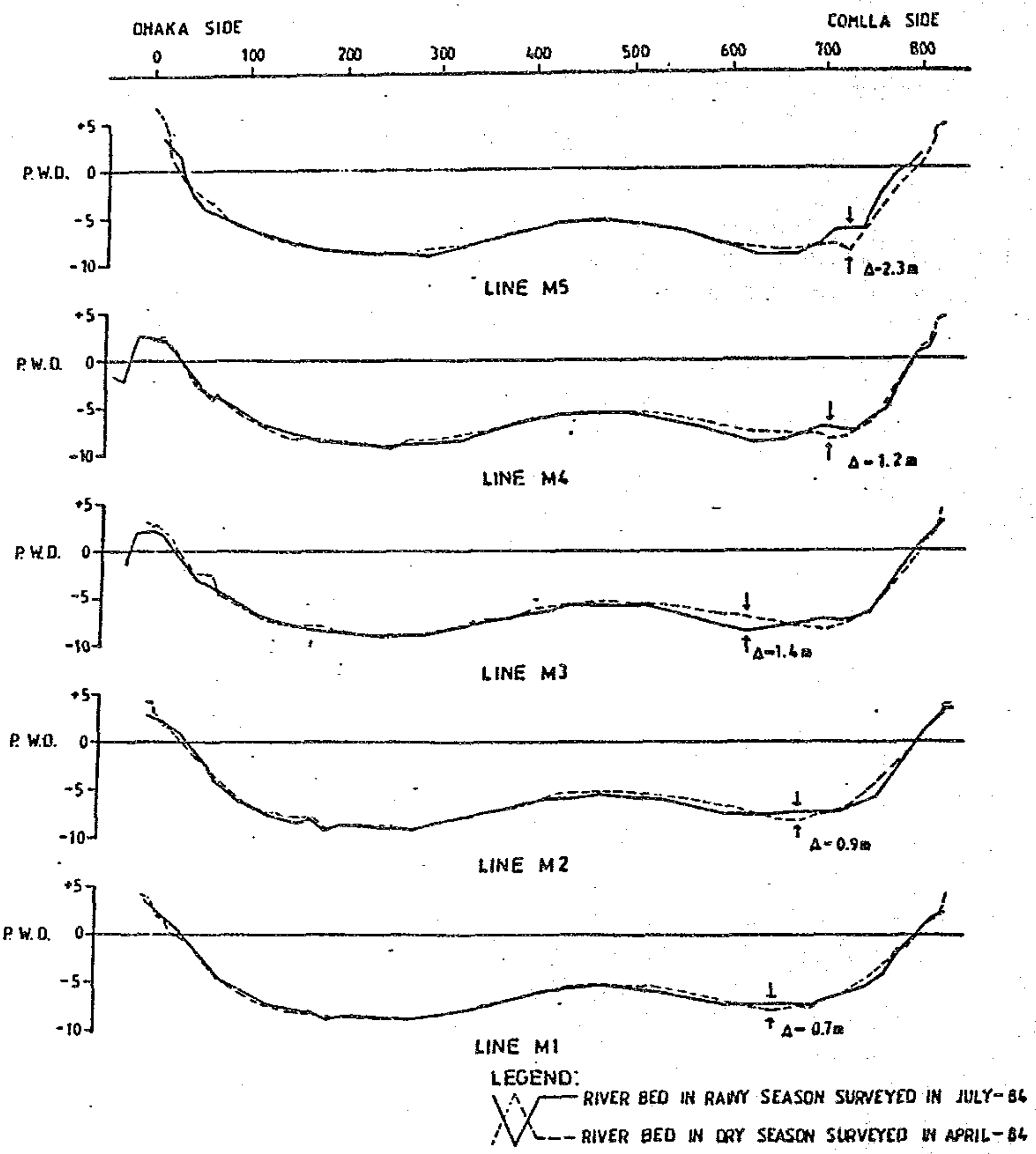
Source: The Study Team



AP. FIG. 3-1 LOCATION OF SURVEY POINTS AND AREA SOUNDED FOR MEGHNA BRIDGE SITE

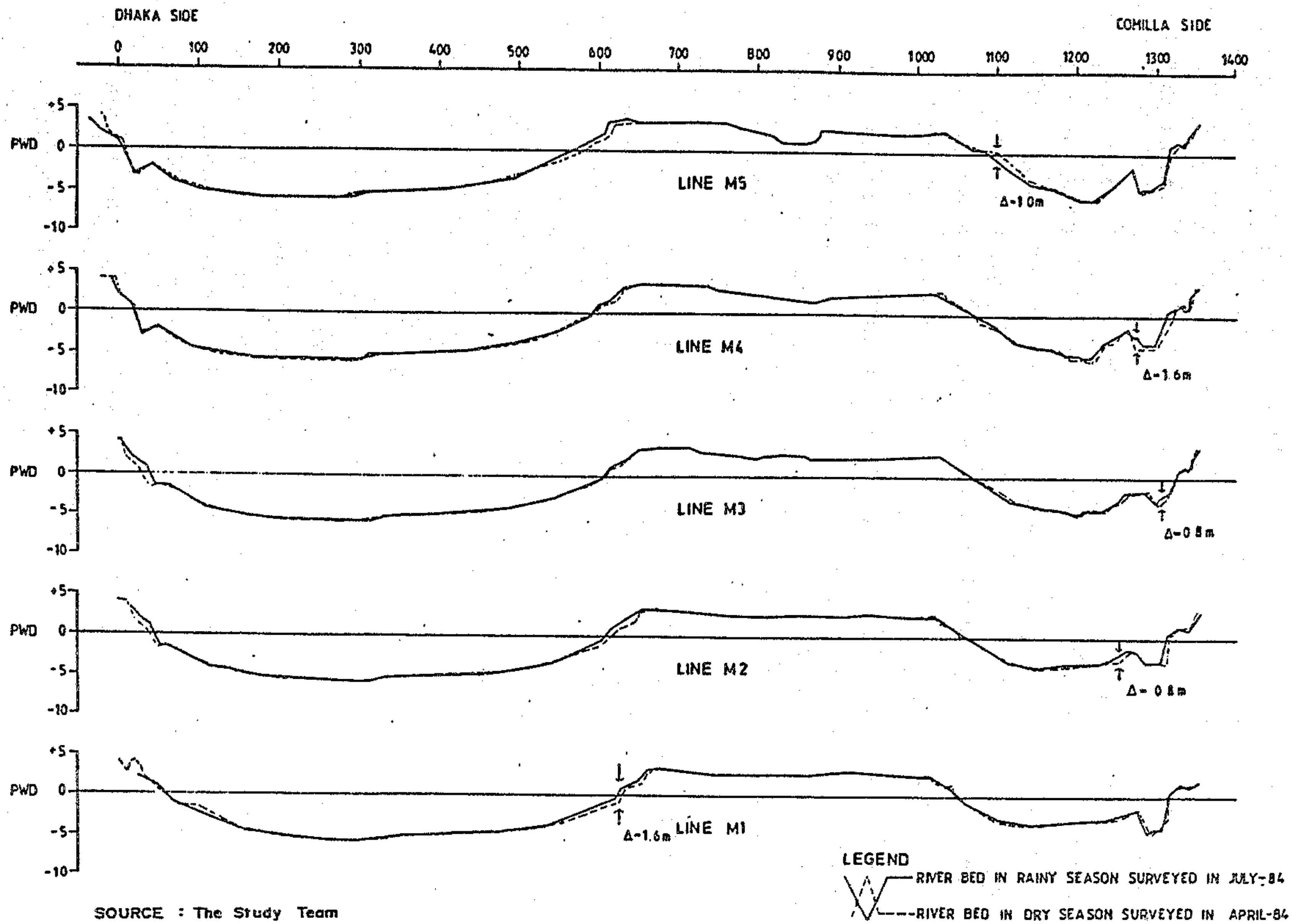


AP. FIG. 3-2 LOCATION OF SURVEY POINTS AND AREA SOUNDED FOR MEGHNA-GUMTI BRIDGE SITE



SOUCE : The Study Team

AP.FIG. 3-3 CROSS SECTIONS OF MEGHNA RIVER IN RAINY AND DRY SEASONS



SOURCE : The Study Team

AP.FIG. 3-4 CROSS SECTIONS OF MEGHNA-GUMTI RIVER IN RAINY AND DRY SEASONS

AP. NOTE 4–1 GEOLOGY AND SOILS OF BANGLADESH

* GEOLOGY:

With about half the surface of the country below the 7.5 metre contour line, Bangladesh is generally described as a delta or as a flat alluvial plain. Geologically speaking the land can be divided into three broad categories of physiographic regions. These are the Tertiary Hills, the Pleistocene Uplands and the Recent Plains. This tripartite division also coincides with a division of the country based on altitude or relief. The Recent Plains can be further subdivided into Piedmont Plain, Flood Plain, Deltaic Plain, Tidal Plain and Coastal Plain.

The Tertiary Hills can be found in the Chittagong Hill Tracts region in the southeast, the only region in the country that experienced upheaval contemporaneously with the Himalayan Orogeny. Formed mainly of sandstones and shales, the average height of the hills is around 300 metres, the highest peak being Mowduk Mual (1,003 m) on the Bangladesh-Burma Border.

The Pleistocene Uplands comprise the Madhupur Tract, north of the city of Dhaka and the Barind to the northwest of the country. The altitude of the Madhupur Tract, a continuous block of about 3,800 sq.km varies between 9 m and 18 m. The tract rises as an island above the flood plains all around, its elevation being due, perhaps, to regional uplift. The Barind, although discontinuous, at present extends over a much larger area. It attains a height of about 40 m in places. One notable outlier of Pleistocene formation is the Lalmai Hills near Comilla.

Besides the above, other areas of the country are plain lands. The Piedmont Plain to the northwest rolls down sharply from north to south with an average gradient of 56.6 cm/kilometre. Flood plains made up of continental deposits, deltaic plains built up by both marine and continental deposits, and the tidal plain composed predominantly of marine deposits are all of very low elevation with considerable areas lying below the 3 metre contour line. All together they occupy about 90% of the area of Bangladesh. A narrow strip along the coast of Chittagong represents a coastal plain.

Marshes are fairly numerous in Bangladesh and are strewn over wide areas. There are, however, three areas of major concentration: to the southwest, to the northeast and to the northwest of the country.

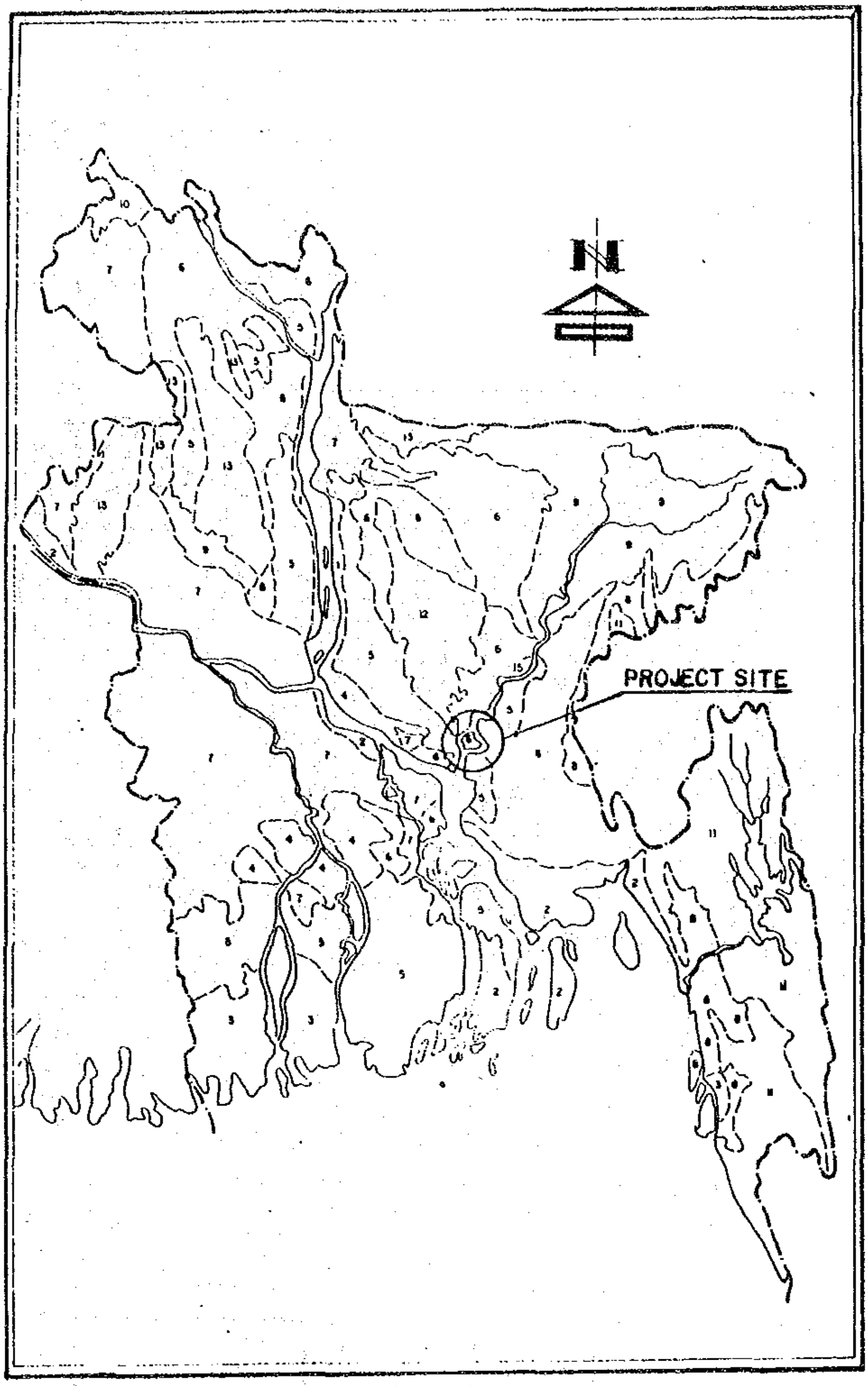
* SOILS:

Different types of soils in Bangladesh are attributed to three major rivers, viz., the Ganges, the Brahmaputra (Jamuna) and the Meghna along with their tributaries and distributaries. However, most of the soils are zonal with little or no profile development. They have been derived from alluvial deposits, forming flood plains and piedmont plains and deltas; and in most cases they are some type of loam. On the basis of texture, these can be divided into various categories, such as sands, sandy-loams, clays, clay-loams or silt-loams. It is, however, only in the regions of Pleistocene uplands and saline soils that their boundaries could be drawn satisfactorily.

Soils vary widely with topographic features, as well as with differences between levels of land. The soil associations vary depending upon the river that laid them down. Thus, the micro-regional differences in lands as well as in their soil textures between adjacent sites, i.e. between levees, flood plains, slopes and marshy areas influence the cropping pattern.

Ap. Fig. 4–1 shows the soil types of Bangladesh and Ap. Fig. 4–2 the outline of the Quarternary geology of the Bengal Basin after J.P. Morgan and W.G. McIntive (1959).

* Source: Bangladesh in Maps, University of Dacca



AP. FIG. 4-1 SOIL TYPES
SOURCE: BANGLADESH IN MAPS

A. FLOODPLAIN AND PIEDMONT SOIL:

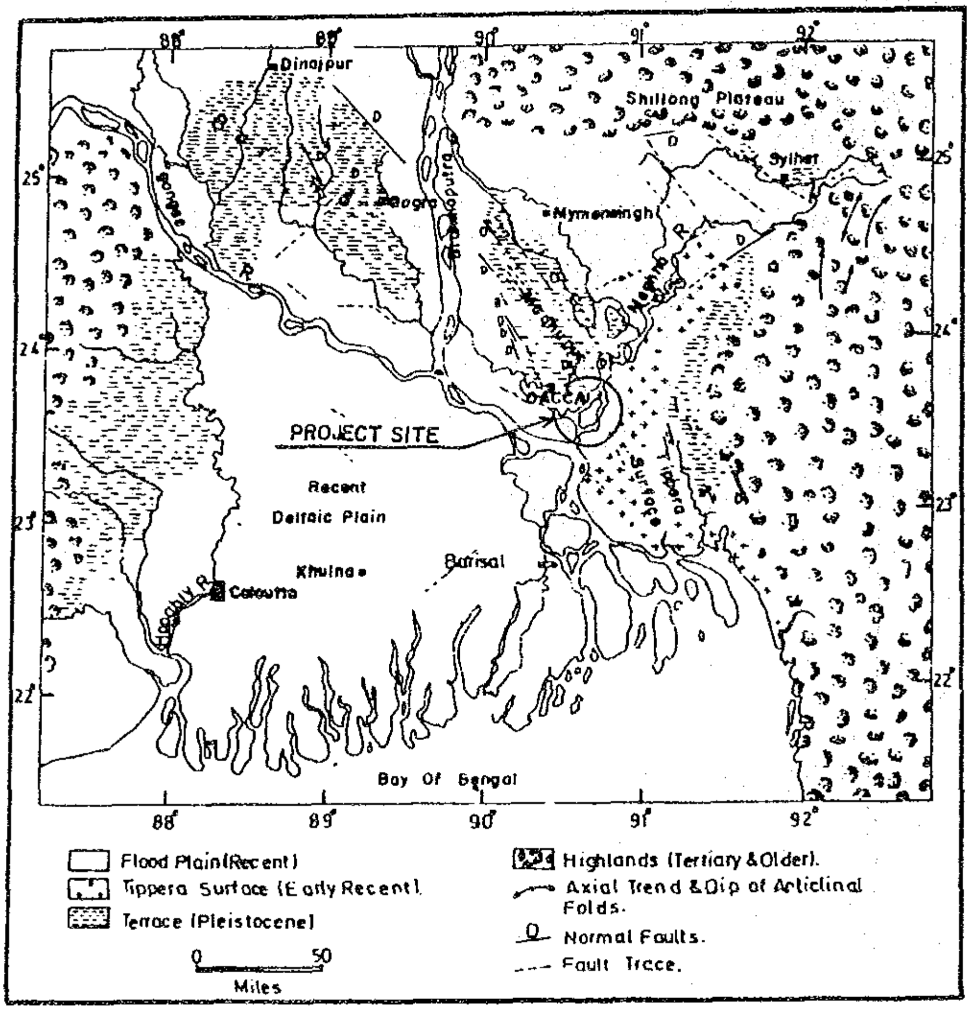
1. NON-CALCAREOUS ALLUVIUM.
2. CALCAREOUS ALLUVIUM.
3. ACID SULPHATE SOILS.
4. PEAT.
5. GREY FLOOD PLAIN SOIL.
6. NON-CALCAREOUS DARK GREY AND BROWN FLOOD PLAIN SOILS.
7. CALCAREOUS DARK GREY AND BROWN FLOOD PLAIN SOIL.
8. GREY PIEDMONT SOIL.
9. GREY FLOOD PLAIN SOIL AND ACID BASIN CLAYS.
10. BLACTERAI SOIL.

B. HILL SOIL:

11. BROWN HILL SOIL.

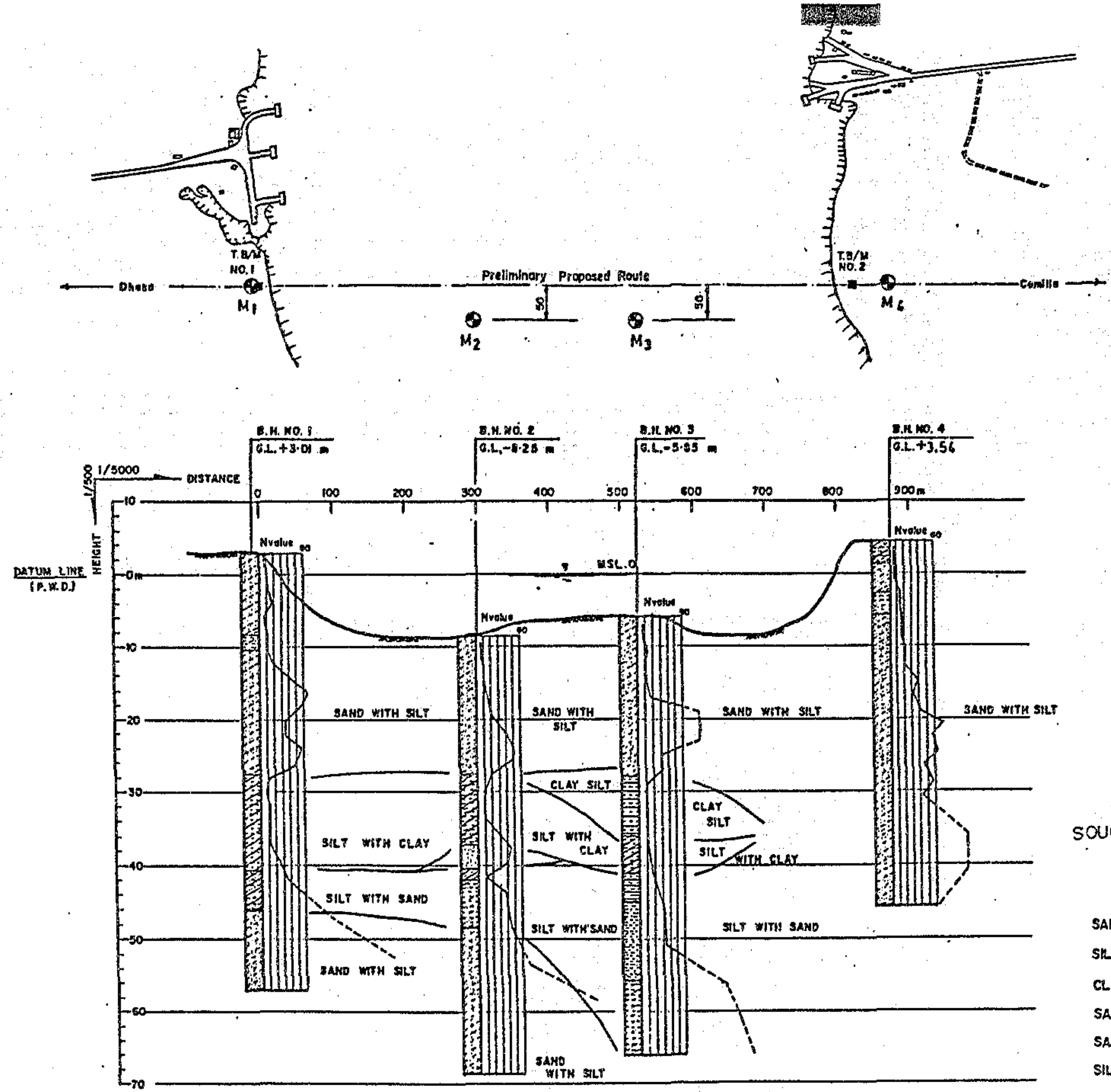
C. TERRACE AND OLD PIEDMONT SOIL:

12. RED BROWN TERRACE SOILS.
13. GREY TERRACE SOILS.



SOURCE: AFTER MOGAN AN Mc INTIVE 1959

AP. FIG. 4-2
THE OUTLINE OF THE QUARTERNARY GEOLOGY OF THE BENGAL BASIN



AP. FIG. 4-3 BORING LOGS (M1, M2, M3 & M4) FOR MEGHNA RIVER

SOUCE : The Study Team

LEGEND (VISUAL)

SAND..........
SILT..........
CLAY..........
SAND WITH SILT.......
SAND WITH CLAY....
SILTY SAND..........
CLAY SILT..........

AP. TABLE 4-1 CORRECTED SPT VALUES BY RIVER SITE

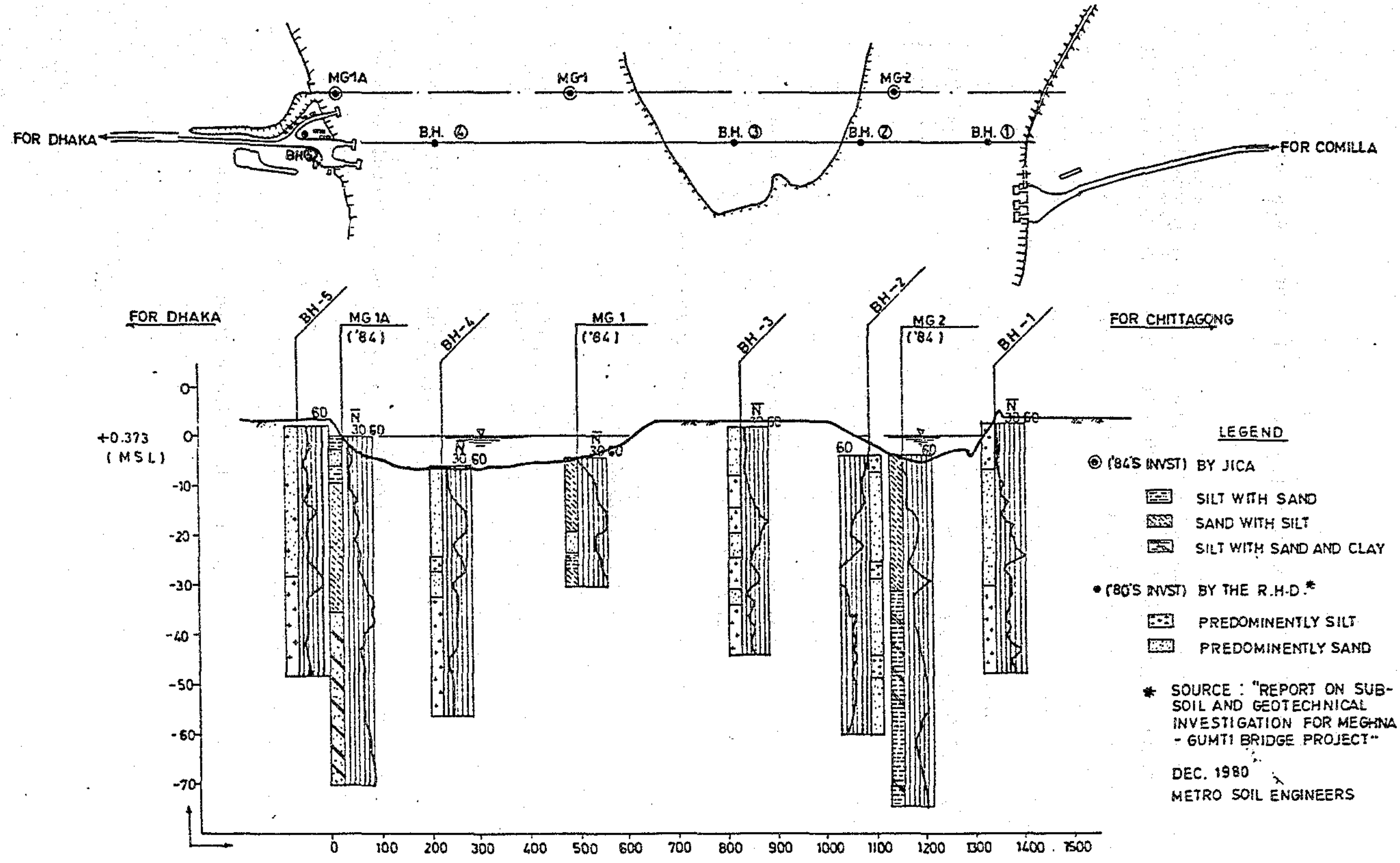
MEGHNA RIVER

Depth in metres below G.L.	Value of Corrected SPT at Different Bore Holes			
	M 1	M 2	M 3	M 4
0.85	7	5	5	5
2.85	10	6	7	5
4.85	11	10	12	4
6.85	15	10	10	12
8.85	6	14	11	13
10.85	10	17	15	15
12.85	10	26	48	15
14.85	16	34	50	18
16.85	26	33	49	17
18.85	41	16	22	26
20.85	35	10	23	23
22.85	25	8	9	27
24.85	24	9	10	42
26.85	36	20	8	35
28.85	32	30	7	39
30.85	12	27	11	29
32.85	8	8	12	35
34.85	12	25	15	28
39.85	12	29	23	58
44.85	25	44	23	82
49.85	54	88	66	39
54.85	72	100	75	-
59.85	68	120	78	-

MEGHNA-GUMTI RIVER

Depth in metres below in G.L.	Value of Corrected SPT a Different Bore Holes		
	M -G1/A	M - G 1	M - G 2
0.85	3	3	2
2.85	8	17	3
4.85	14	22	13
6.85	3	24	8
8.85	9	26	7
10.85	8	35	9
12.85	19	38	22
14.85	15	21	24
16.85	20	22	22
18.85	19	25	18
20.85	17	27	11
22.85	23	33	20
24.85	23	36	46
26.85	20	-	19
28.85	26	-	18
30.85	30	-	17
32.85	39	-	19
34.85	34	-	20
36.85	38	-	24
38.85	27	-	26
40.85	27	-	29
42.85	22	-	30
44.85	26	-	33
46.85	27	-	33
48.85	25	-	32
50.85	26	-	34
52.85	26	-	27
54.85	28	-	25
56.85	28	-	21
58.85	33	-	19
60.85	40	-	23
62.85	35	-	27
64.85	41	-	29
66.85	42	-	30
69.85	45	-	33

Source: Soil Investigation Report on Meghna, Meghna-Gumti Bridges Construction Project, 1984 by the Study Team



AP. FIG. 4-4 BORING LOGS (MG1 MG1A AND MG2) FOR MEGHNA-GUMTI BRIDGE PROJECT.

AP. NOTE 4–2 CALCULATION OF PILE BEARING CAPACITIES

Bearing capacities of the pile foundations of the proposed bridges were estimated based on the "SPECIFICATION FOR HIGHWAY BRIDGES" (PART IV: Specification for Substructures) issued by the Japan Road Association.

1. Formula Used

The following formula was used.

$$Ra = \frac{1}{n} Ru = \frac{1}{n}(qd \cdot A + U \Sigma \ell i \cdot fi)$$

where Ra = allowable bearing capacity of a pile (tons)

Ru = total ultimate bearing capacity (tons)

qd = ultimate bearing strength ($tons/m^2$), generally 300 $tons/m^2$ in case of a cast-in-situ pile in sandy soils which have SPT values of more than 30.

A = considering a 1.5 m diametre pile, an area of pile cross section (1.767 m^2)

U = perimetre of a pile (4.712 m)

ℓi = layer depth around pile (m)

fi = maximum skin friction around a pile in sandy soil: 0.5 x N $tons/m^2$, but not exceeding 20 $tons/m^2$ for a cast-in-situ pile

N = corrected SPT value of the stratum

n = safety factor: 3 for normal condition and 2 for seismic condition

In the preliminary calculation the weight of the concrete pile was not included because it is a minor factor.

2. Bearing Capacity of Foundation Piles of Meghna Briege

The following data were applied to the calculation of the bearing capacity of the foundation piles:

a) Data from Borings M–2 and M–3

b) Piling

Diametre of piles : 1.5 metres;
Length of piles : 43.5 metres; and
Elevation of pile tip : -55.0 metres (PWD)

c) Scouring Level of Foundation : -22.0 metres (PWD)

(1) Calculation on Boring M–2 Data

PWD (m)	Boring Depth	ℓi (m)	Soil Condition	N_{max}-N_{min}	$\bar{N}$	f_i (tons/m^2)	$U \cdot \ell i \cdot f_i$ (tons)
-22	14						
-27	19	5	Sand	50 - 36	43	20	471
-36	28	9	Clayey silt	25 - 9	17	15	636
-40	32	4	Sand	45 - 40	42	20	377
-48	40	8	Sand	39 - 9	24	12	452
-50	42	2	Sand	42 -	42	20	188
-55	47	5	Sand	60 -	60	20	471

$U\Sigma\ell_i \cdot f_i$ = 2,595 tons

$$Ru = qd \cdot A + U\Sigma\ell i \cdot fi = 530 + 2{,}595 = 3{,}125 \text{ tons}$$

Ra of (1)

$$\begin{cases} \text{Normal: } \frac{1}{3} Ru = 1{,}040 \text{ tons} \\ \text{Seismic: } \frac{1}{2} Ru = 1{,}562 \text{ tons} \end{cases}$$

(2) Calculation on Boring M–3 Data

PWD (m)	Boring Depth	ℓi (m)	Soil Condition	N_{max}-N_{min}	$\bar{N}$	f_i (tons/m^2)	$U \cdot \ell i \cdot f_i$ (tons)
-22	16						
-29	23	7	Sand	31 - 22	26	13	428
-37	31	8	Clayey silt	11 - 7	7	9	339
-50	44	13	Silt	27 - 11	19	9	551
-51	45	1	Silt	30 -	30	15	70
-55	49	4	Sand	60 -	60	20	377

$U\Sigma\ell_i \cdot f_i$ = 1,765 tons

$Ru = qd \cdot A + U\Sigma\ell i \cdot fi = 530 + 1{,}765 = 2{,}295$ tons

Ra of (2)
- Normal: $\frac{1}{3}Ru$ = 765 tons
- Seismic: $\frac{1}{2}Ru$ = 1,147 tons

3. Bearing Capacity of Foundation Piles of Meghna-Gumti Bridge

The following data were applied:

a) Data from Borings MG–1/A and MG–2

b) Piling:

Diametre of piles	:	1.5 metres;
Length of piles	:	51 to 67 metres: and
Elevation of pile tip	:	-70 metres (PWD)

c) Scouring Level of Foundation: -19.0 metres (PWD)

(1) Calculation on Boring MG–1/A Data

PWD (m)	Boring Depth	ℓi (m)	Soil Condition	N_{max}-N_{min}	$\bar{N}$	f_i (tons/m^2)	$U \cdot \ell i \cdot f_i$ (tons)
-19	19.3						
-32.7	33	13.7	Sand	38 - 16	27	13	839
-60.0	60.3	27.3	Silty sand	30 - 21	25	12	1,543

$U\Sigma\ell_i \cdot f_i$ = 2,382 tons

$$Ru = qd \cdot A + U\Sigma \ell i \cdot fi = 530 + 2,382 = 2,912 \text{ tons}$$

$$Ra \text{ of } (1) \quad \begin{cases} \text{Normal: } \frac{1}{3} Ru = 970 \text{ tons} \\ \text{Seismic: } \frac{1}{2} Ru = 1,456 \text{ tons} \end{cases}$$

(2) Calculation on Boring MG–2 Data

PWD (m)	Boring Depth	ℓi (m)	Soil Condition	$N_{max}-N_{min}$	$\bar{N}$	f_i (tons/m^2)	$U \cdot \ell i \cdot f_i$ (tons)
-19	22						
-23	26	4	Sand	42 - 17	30	15	283
-48	51	25	Silty	31 - 17	24	12	1,413
-70	63	12	Silt	31 - 17	24	12	678

$U\Sigma\ell_i \cdot f_i = 2,374$ tons

$$Ru = qd \cdot A + U\Sigma \ell i \cdot fi = 530 + 2,374 = 2,904 \text{ tons}$$

$$Ra \text{ of } (1) \quad \begin{cases} \text{Normal: } \frac{1}{3} Ru = 968 \text{ tons} \\ \text{Seismic: } \frac{1}{2} Ru = 1,452 \text{ tons} \end{cases}$$

Based on the above calculations, the allowable bearing capacities were considered as follows:

	Meghna Bridge	Meghna-Gumti Bridge
Normal:	700 tons	900 tons
Seismic:	1,100	1,400

4. Number of Piles Required

The total forces transmitted to the foundation by the superstructure and pier are as follows:

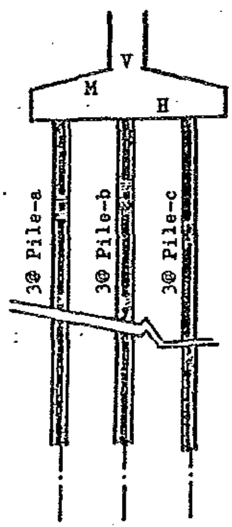
Forces at the Bottom of the Centre Footing

		Normal Conditions: Vertical Forces (t)	Earthquake Loadings		
			Vertical (t)	Horizontal (t)	Moment (t-m)
Live Load		240	-	-	-
Dead Load of Superst.		2,165	2,165	108	3,995
Dead Load of Pier		1,740	1,740	87	945
Buoyancy		-415	-415	-	-
Total	Max.	4,145	3,905	195	4,940
	Min.	3,730	3,490	195	4,940

Nine (9) piles per foundation are estimated to be necessary taking into consideration the following two points:

a) Pile reaction induced at the junction of piles with the footing:

Pile Reaction



External Forces

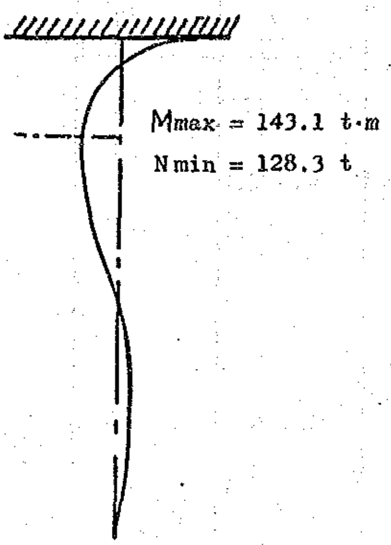
V = 3,490 t
H = 195 t
M = 4,941 t.m

	Reaction: Vertical (t)	Reaction: Horizontal (t)	Reaction: Moment (t.m)
Pile-a	647.3	21.7	143.1
Pile-b	387.8	21.7	143.1
Pile-c		21.7	143.1

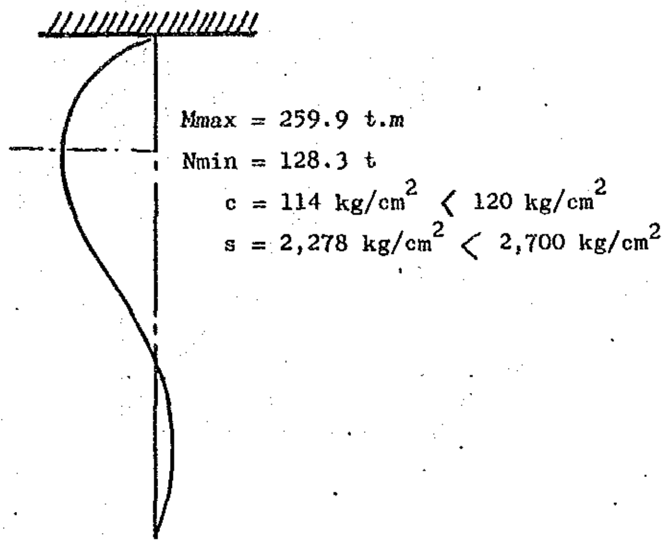
647.3 tons < allowable capacity = 700 tons.

b) *Internal forces of a pile induced under the external forces:*

Internal Forces and Stresses

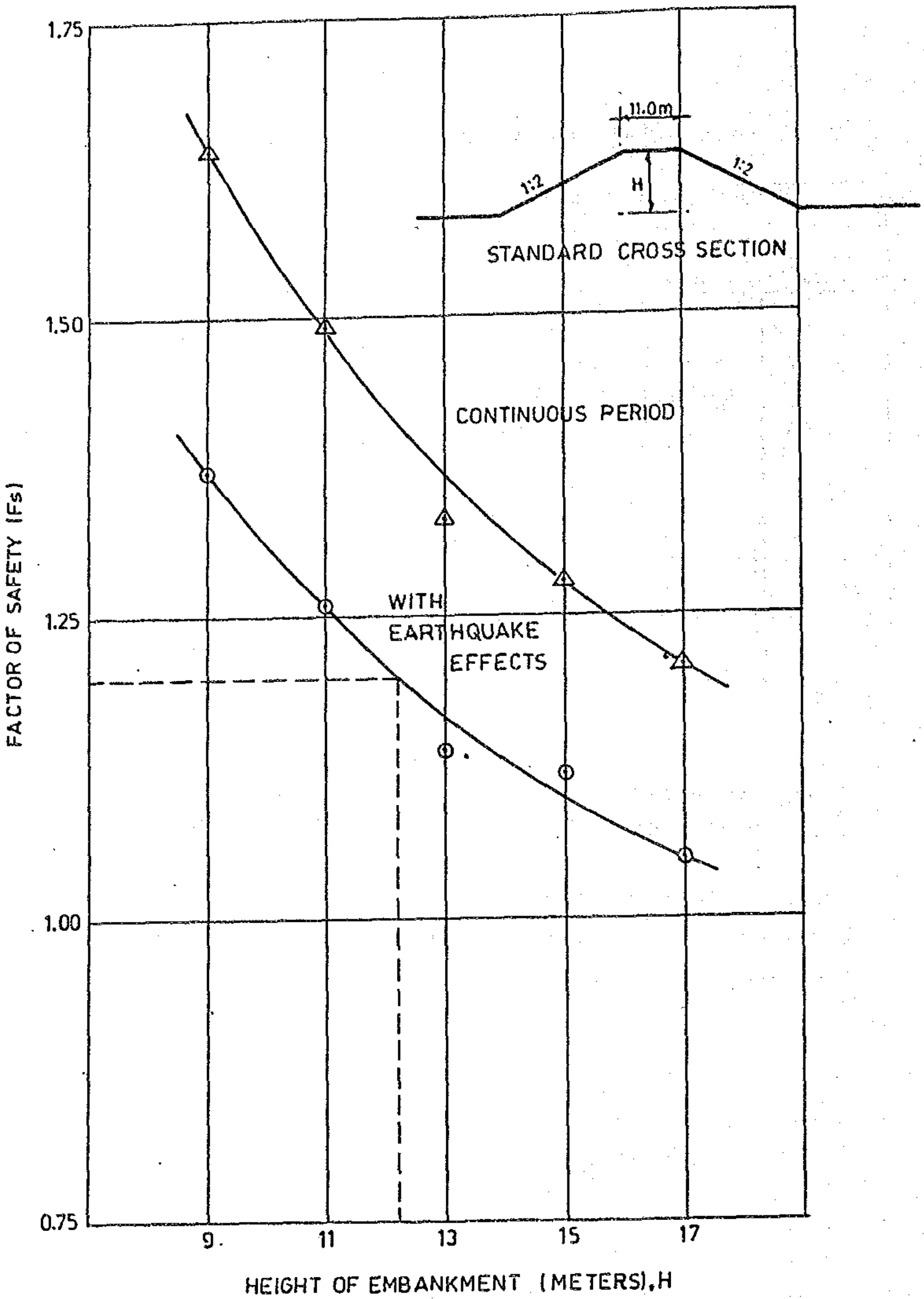


(1) Bending Moment Diagram
in case of Rigid Connection



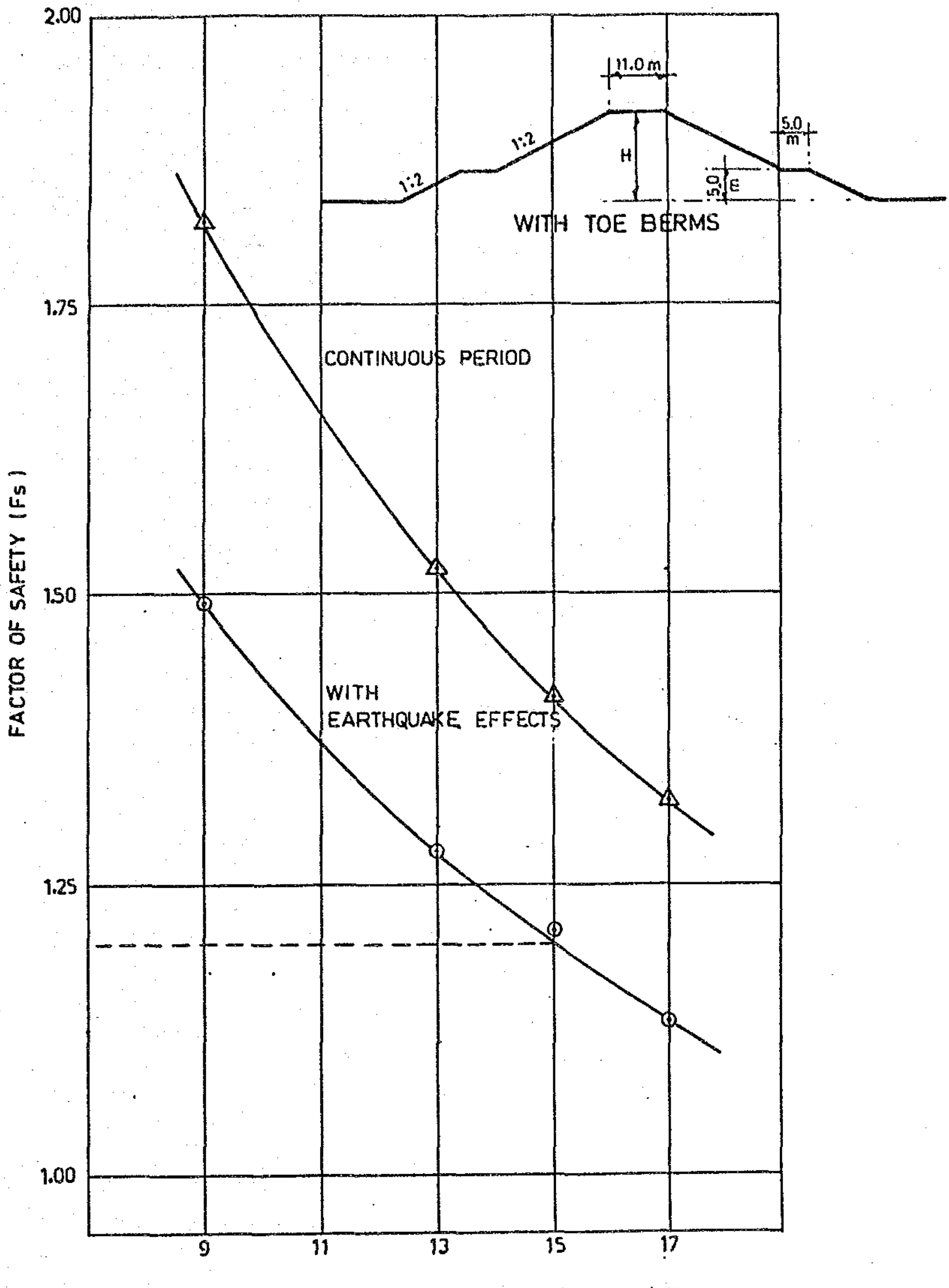
(2) Bending Moment Diagram
in case of Hinge Connection

Both conditions (a) and (b) were calculated on the basis of the structural theory for a beam-column member on an elastic foundation. The maximum concrete stress will not exceed the allowable stress of 120 kg/cm^2.



Source: The Study Team

AP.FIG. 4-5 EMBANKMENT HEIGHT AND FACTOR OF SAFETY
(STANDARD CROSS SECTION)



Source: The Study Team

AP. FIG. 4-6 EMBANKMENT HEIGHT AND FACTOR OF SAFETY (WITH TOE BERMS)

AP. TABLE 5-1 CONSTRUCTION MATERIALS OF MEGHNA BRIDGE (1)

Item No.	Work Item	Volume	Materials required	Quantities required	Remarks
402	Site Reclamation	110,000 m^3	(L/C=1.35)	457,920m^3	
101	Road Filling	229,200 m^3	Sandy Soil		
102	Sub-base Course	4,100 m^3	Sand	2,870m^3	
			Pea gravel	2,870m^3	
			Pea gravel	920m^3	
103	Base Course	2,300 m^3	Shingle	1,610m^3	
			Pit sand	690m^3	
	Asphalt Concrete	(4,520 ton)	Pea gravel	1,260m^3	
104	Asphalt Surface	2,560 ton	Sand	1,240m^3	
105	Bridge Surface	810 ton	Pit sand	560m^3	
600	Traffic Maintenance	1,150 ton	Cement	140 ton	
			Asphalt	340 ton	
	Concrete Class A	(9,650 m^3)			
108	Box Culvert	707 m^3	Cement	3,250 ton	
110	Slope Protection	385 m^3	Sand	2,230 m^3	
111	Back Abutment Slab	52 m^3	Pit sand	2,230 m^3	
112	Drainage, etc.	200 m^3	Shingle	3,790 m^3	
204 & 302	Footing Concrete	3,010 m^3	Crushed stone	3,790 m^3	
205 &303	Pier Concrete	4,500 m^3			
212	Footpath and Kerb	233 m^3	Plasticiser	9.7 ton	
301	Precast Concrete Pile	522 m^3			
504	Pier Protection	40 m^3			
	Concrete, Class X	(3,390 m^3)	Cement	1,320 ton	
201	Reverse Circulation Pile	2,040 m^3	Sand	800 m^3	
203	Seal Concrete	1,350 m^3	Pit sand	800 m^3	
			Shingle	1,190 m^3	
			Crushed stone	1,190 m^3	
			Plasticiser	3.4 ton	
	Concrete Class P	(7,290 m^3)	Cement	2,990 ton	
207	PC Box Concrete	7,070 m^3	Sand	1,530 m^3	
304	PC Girder Concrete	220 m^3	Pit sand	1,530 m^3	
			Shingle	2,770 m^3	
			Crushed stone	2,770 m^3	
			Plasticiser	7.3 ton	
	Remarks :		Cement	7,700 ton	
	Total of cement & aggregate for Approach Road and Bridge		Sand	8,670 m^3	
			Pea gravel	5,050 m^3	
			Shingle	9,360 m^3	
			Pit sand	5,810 m^3	
			Crushed stone	7,750 m^3	

AP. TABLE 5-1 CONSTRUCTION MATERIALS OF MEGHNA BRIDGE (2)

Item No.	Work Item	Volumes	Materials required	Quantities required	Remarks
	TORSTEEL	(2040 ton)			
108	Box Culvert	78 ton			
111	Back Abutment Slab	6 ton			
201	Reverse Circulation Pile	1100 ton	TORSTEEL Bar	2,040 ton	
206	TORSTEEL Bar	692 ton			
210	Railing	65 ton			
212	Footpath & Kerb	12 ton			
301	Precast Concrete Pile	83 ton			
	Deformed Bar	(840 ton)			
208	Deformed Bar of PC Box	810 ton	* Deformed Bar	840 ton	
305	Deformed Bar of PC Beam	27 ton			
	High Tensile Bar				
209	PC Cable Stressing	420 ton	* High Tensile Bar	420 ton	
	High Tensile Wire		* High Tensile Wire		
306	PC Cable Stressing	9 ton		9 ton	
	Fabricated Steel Goods	(106 ton)			
211	Expansion Joint	36 ton	* Fabricated Steel or Cast Iron	106 ton	
213	Centre Hinge	20 ton			
214	Bearing Shoe	2 ton			
307	Bearing Shoe	6 ton			
109	Guard Rail	42 ton			
	Shape Steels	(6,910ton)			
201	Reverse Circulation Pile	914 ton			
202	Excavation in River	2,130 ton			
401	Temporary Staging	2,230 ton	* Shaped Steels	6,910 ton	
403	Temporary Quay	920 ton			
502	Sheet Piling	490 ton			
504	Pier Protection	35 ton			
600	Traffic Maintenance	191 ton			

* Note : Imported Material

Source: The Study Team

AP. TABLE 5-2 CONSTRUCTION MATERIALS OF MEGHNA-GUMTI BRIDGE (1)

Item No.	Work Item	Volume	Materials required	Quantities required	Remarks
402 (G)	Site Reclamation	270,000 m^3	(L/C = 1.35)		
101 (G)	Road Filling	85,700 m^3	Sandy soil	480,200 m^3	
102	Sub-base Course	2,850 m^3	Sand	2,000 m^3	
			Pea gravel	2,000 m^3	
103	Base Course	1,560 m^3	Pea gravel	630 m^3	
			Shingle	1,100 m^3	
			Pit sand	470 m^3	
	Asphalt Concrete	(4,880 ton)	Pea gravel	1,360 m^3	
104 (G)	Asphalt Surface	2,210 ton	Sand	1,340 m^3	
105	Bridge Surface	1,290 ton	Pit sand	610 m^3	
600 (G)	Traffic Maintenance	1,380 ton	Cement	150 ton	
			Asphalt	370 ton	
	Concrete Class A	(9,320 m^3)			
108	Box Culvert	280 m^3	Cement	3,140 ton	
110	Slope Protection	390 m^3	Sand	2,160 m^3	
111	Back Abutment slab	52 m^3	Pit sand	2,160 m^3	
112 (G)	Drainage, etc.	120 m^3	Shingle	3,660 m^3	
202 (G) 302	Footing Concrete	5,520 m^3	Crushed Stone	3,660 m^3	
205 (G) 303	Pier & Abutment Concrete	2,460 m^3			
301	Precast Concrete Pile	410 m^3	Plasticiser	9.3 ton	
504	Pier Protection	80 m^3			
	Concrete Class X	(20,450 m^3)			
201 (G)	Reverse Circulation Pile	18,270 m^3	Cement	7,950 ton	
203 (G)	Seal Concrete	2,180 m^3	Sand	4,790 m^3	
			Pit sand	4,790 m^3	
			Shingle	7,180 m^3	
			Crushed stone	7,180 m^3	
			Plasticiser	20.5 ton	
	Concrete Class P		Cement	5,300 ton	
207 (G)	PC Box Concrete	12,930 m^3	Sand	2,710 m^3	
			Pit sand	2,710 m^3	
			Shingle	4,900 m^3	
			Crushed stone	4,900 m^3	
			Plasticiser	12.9 ton	

Remarks :

Total Cement & Aggregate for Approach Road and Bridge

Cement	16,540 ton
Sand	13,000 m^3
Pea gravel	3,990 m^3
Shingle	16,840 m^3
Pit sand	10,740 m^3
Crushed stone	15,740 m3

AP. TABLE 5-2 CONSTRUCTION MATERIALS OF MEGHNA-GUMTI BRIDGE (2)

Item No.	Work Item	(Volume)	Materials required	Quantities required	Remarks
	TORSTEEL	(3,680 ton)			
108	Box Culvert	30 ton			
111	Back Abutment Slab	6 ton			
201 (G)	Reverse Circulation pile	2,750 ton	TORSTEEL Bar	3,680 ton	
206 (G)	TORSTEEL Bar	700 ton			
210	Railing	108 ton			
212	Footpath & Kerb	20 ton			
301	Precast Concrete Pile	65 ton			
	Deformed Bar				
208 (G)	Deformed Bar of PC Box	1,480 ton	* Deformed Bar	1,480 ton	
	High Tensile Bar				
209 (G)	PC Cable Stressing	760 ton	* High Tensile Bar	760 ton	
	Fabricated Steel Goods	(100 ton)			
211	Expansion Joint	50 ton			
213	Centre Hinge	36 ton	* Fabricated Steel and Cast Iron	100 ton	
214	Bearing Shoe	2 ton			
109	Guard Rail	12 ton			
	Shape Steels	(10,810 ton)			
201 (G)	Reverse Circulation Pile	1,950 ton			
202 (G)	Excavation in River	4,260 ton	* Shaped Steels	10,810 ton	
401 (G)	Temporary Staging	3,130 ton			
403	Temporary Quay	1,230 ton			
504	Pier Protection	70 ton			
600 (G)	Traffic Maintenance	170 ton			

* Note : Imported Material
(G): Items for Meghna-Gumti Bridge only

Source: The Study Team

AP. NOTE 6–1 PCE: PASSENGER CAR EQUIVALENT

Bangladesh has been using the same coefficients of PCE (Passenger Car Equivalent) conversion as suggested by ESCAP (Economic and Social Council of Asia and the Pacific) to express the figures of traffic counts as shown below:

Type of Vehicles	PCE Factor
1. Trucks	3.0
2. Buses and coaches	3.0
3. Other medium and heavy commercial vehicles	3.0
4. Cars, jeeps, pick-ups, station wagons, microbuses, etc.	1.0
5. Light commercial vehicles	1.0
6. Auto-rickshaws	1.0
7. Motorcycles	0.5
8. Animal drawn or push carts	3.0
9. Rickshaws	0.5
10. Bicycles	0.25

Source: Roads & Highways Department

AP. TABLE 6-1 COMPARISON OF LOADING SPECIFICATIONS FOR HIGHWAY BRIDGES

DESCRIPTION	AASHTO (American Association of State Highway and Transportation Officials)	IRC (Indian Road Congress)	J.R.A (Japan Road Association)	Adopted to Meghna & Meghna-Gumti Bridge Project	Remarks
Live Load	HS 20 - 44 (MS 18)	90% of CLASS "A" (For 2-Lane Bridge)	TL - 20	HS 20 - 44 (MS 18)	
Impact Fraction	$i = \frac{15.24}{L + 30} \leq 30\%$	$i = \frac{4.5}{6 + L} \leq 50\%$	$i = \frac{20}{50 + L}$ (For T-Load.) $i = \frac{10}{25 + L}$ (For L-Load.)	$i = \frac{15.24}{L + 30} \leq 30\%$	L: Span Length in Meters
Sidewalk Loading	415 kg/m^2	400 kg/m^2	350 kg/m^2 (For $L \leq 80$) 430-L (For $80 < L \leq 130$) 300 (For $L > 130$)	415 kg/m^2	L: Span Length in Meters
Kerb Loading	744 kg/m	750 kg/m	--	744 kg/m	Lateral Force
Railing Loading	74.4 kg/m	150 kg/m	250 kg/m	74.4 kg/m	Lateral Force
Longitudinal Forces	5% of Live Load	20% of the first train load plus 10% of the succeeding train load		5% of Live Load	
Wind Load	V = 100 m.p/h (160.9 km/h) W = 244 kg/m^2 (For Girder and Beam) W = 195 kg/m^2 (For Sub-structure)	V_h = 20. = 2 x 136 km/h = 272 km/h	V = 55 m/s (198 km/h) W = 300 kg/m^2 (For PC Girder and Beam) W = 300 kg/m^2 (For Sub-structure)	V = 140 m.p.h (225.3 km/h) W = 479 kg/m^2 (For Girder and Beam) W = 383 kg/m^2 (For Sub-structure)	
Earthquake Load	- Equivalent Static Force Method - Response Spectrum Method	E = 0.05 W W: Dead Load (t)	- Modified Static Force Method - Response Spectrum Method	E = 0.05 W W: Dead Load (t)	
Thermal Forces	Rise 16.7°C Fall 22.2°C	± 17°C	± 15°C	26°C ± 17°C	
Stream Current Forces	$P = 515\ k \cdot V^2$ V: Velocity of Water $K = 1 \cdot \frac{3}{8}$ (For Square End) $K = \frac{1}{2}$ (For Angle End, ≤ 30°) $K = \frac{2}{3}$ (For Circular Pier)	$P = 52\ k \cdot V^2$ V: Velocity of Water K = 1.5 (For Square End) K = 0.66 (For Circular Pier) K = 0.5 (For Triangular cut, Angle ≤ 30°)	$P = k \cdot v^2$ v: Maximum Water Velocity k = 0.07 (For Square End) k = 0.04 (For Circular Pier) k = 0.02 (For Streamline Pier)	As specified in the IRC standard	
Centrifugal Forces	$C = \frac{0.79}{R} \cdot S^2$ S: Design Speed (km/h) R: Radius of Curve (m)	$C = \frac{WV^2}{127\ R}$ V: Design Speed (km/h) R: Radius of Curve (m) W: Vehicle Weight (t)	C = 0.08 x W W: Vehicle Weight (t)	$C = \frac{0.79}{R} \cdot S^2$ S: Design Speed (km/h) R: Radius of Curve (m)	
Earth Pressure	Rankine's Formula	Coulomb's Formula	Coulomb's Formula	Coulomb's Formula	

AP. NOTE 6–2 SEISMIC LOAD

1. Introduction

Seismic effects, which should be taken into account in designing and constructing bridges, mainly depend on the seismic activity of the region, characteristics of earthquake ground motion and the dynamic characteristics of the structure.

The seismic activity is mainly governed by the geotectonic structure of the region and is estimated from the frequency of earthquake occurrences in the past, magnitudes and the epicentral distances of past earthquakes.

The characteristics of earthquake ground motion are mainly governed by the source mechanism of earthquakes, characteristics of propagation path of seismic waves from the origin to the site under consideration and the site conditions including topographic features and subsoil conditions of the site.

The dynamic characteristics of structures are determined by structures themselves taking into account soil-structure interaction and can be adjusted to the seismic activity and characteristics of earthquake ground motion of the site.

2. Seismic Environment of Bangladesh

Though Bangladesh suffered wide spread damage by the Great Earthquake of 1891 and locally limited damages in the vicinity of epicentres by the Bengal Earthquake of 1885 and Srimangal Earthquake of 1918, there seem to be no seismically activity faults within her territory. However, the causative faults and areas of high seismic activity exist in the north and east of Bangladesh in India and Burma and and earthquakes in these areas affect adjacent regions in Bangladesh.

A comprehensive study was carried out by the Committee of Experts on Earthquake Hazard Minimisation and the Committee published a final report on "Seismic Zoning Map of Bangladesh and Outline of Code for Earthquake Resistant Design of Structures" in November, 1979. By this zoning map, the Meghna and Meghna-Gumti Bridge sites are located in Zone II, where the horizontal seismic coefficient of 0.05 should be considered.

In the appendix II of the report, a catalogue of 215 earthquakes occurred in and arround Bangladesh between August 1833 and July 1971 is listed together with data and origin time, location of epicentre and magnitude of these earthquakes.

The report also shows the seismic zoning map of Bangladesh, which divides the territory of Bangladesh into three zones, that is, Zones I, II and III. Zone I covers north-eastern Bangladesh and is designated as the most active seismic zone. Zone II runs from northwest to southeast covering the central part of Bangladesh. Zone III covers the southwestern Bangladesh and is designated as the least active seismic zone. The seismic zoning map is shown in Ap. Fig. 6–1. The report describes that earthquake shocks of maximum intensity of IV and VIII in Modified Mercalli Scale are possible in Zones I and II, respectively, and the maximum intensity is not likely to exceed VII in Zone III. Thus the report suggests the basic horizontal seismic coefficients of 0.08, 0.05 and 0.04 for Zones I, II and III, respectively. The sites of Meghna and Meghna-Gumti Bridges are located in Zone II.

3. Estimation of Ground Acceleration Caused by Past Earthquakes.

From the earthquake catalogue in the report mentioned above, the Study Team selected earthquakes whose epicentres are located in the area surrounded by latitude N 21° – 26°.6 and longitude E 88° – 92°.6 and plotted their epicenters on a map as shown in Ap. Fig. 6–2.

The date, location of epicentre and magnitude of these selected earthquakes are also shown in Ap. Table 6–2, together with the eqicentre distance from Meghna and Meghna-Gumti bridge sites. The epicentral distances are measured on the amp. In the Table, the Great Earthquake of 1987 is also shown for reference, though the location of epicentre is not shown in the earthquake catalogue.

There are several formulae which estimate the ground acceleration from the magnitude and epicentral distance of an earthquake. Some show good coincidence in cases of selected for estimating ground acceleration caused by past earthquakes as follows:

From Ap. Table 6–2, it can be seen that the epicentral distances exceed 100 km, therefore, a formula which shows good coincidence in case of long epicentral distance is selected for estimating ground acceleration caused by pase earthquakes as follows:

$$A = 40.3 \times 10^{0.2621 M} \times (d + 30)^{-1.208}$$

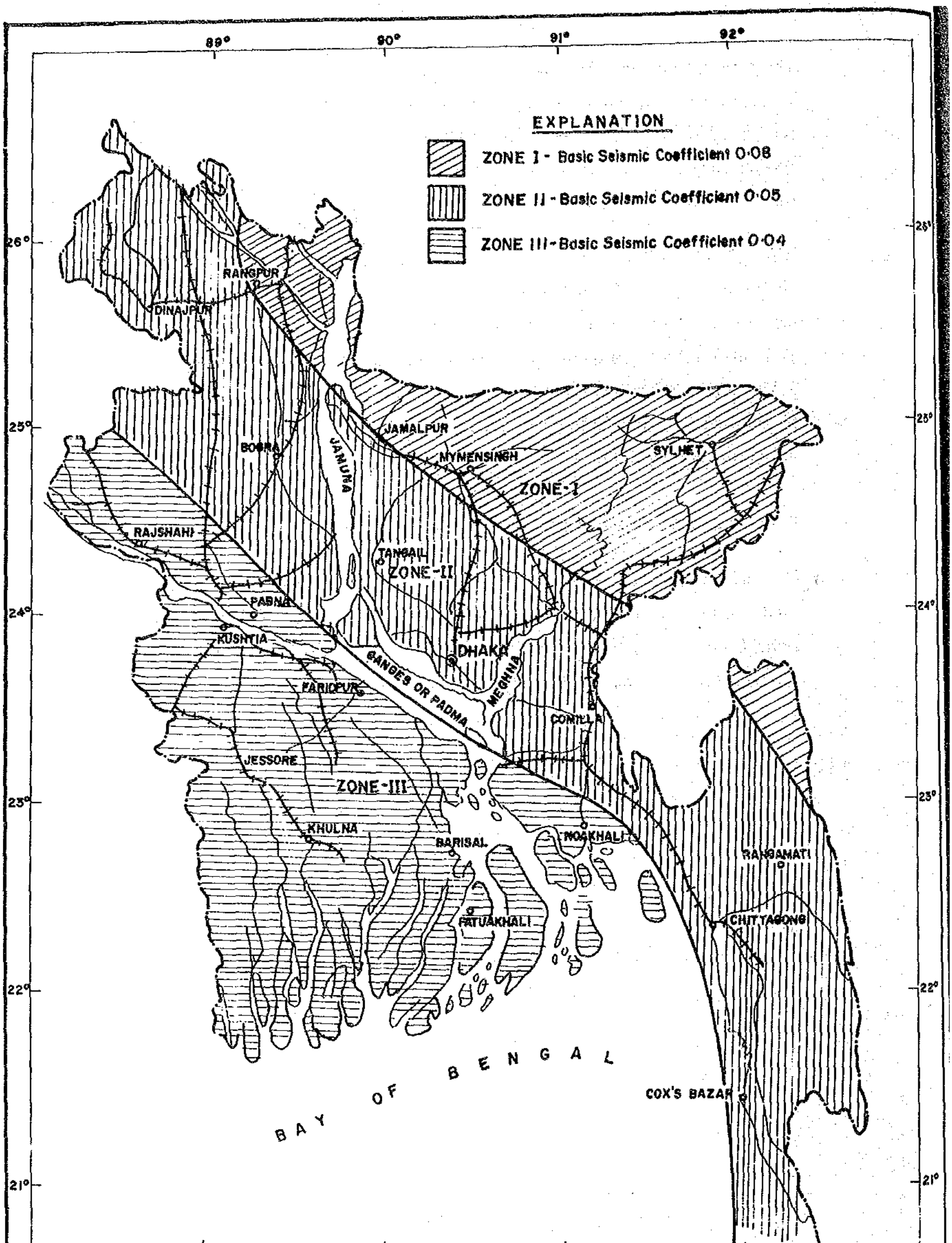
where A = estimated maximum ground acceleration in % of g
M = magnitude of earthquake
d = epicentral distance in km

The estimated ground accelerations are shown in Ap. Table 6–2. As seen from the Table, estimated maximum ground accelerations do not exceed 5% of g except two cases caused by earthquakes of Jan. 10, 1969 and July 8, 1918. Because these two earthquakes took place many years ago, there should be uncertainties on the value of magnitude and location of epicentre.

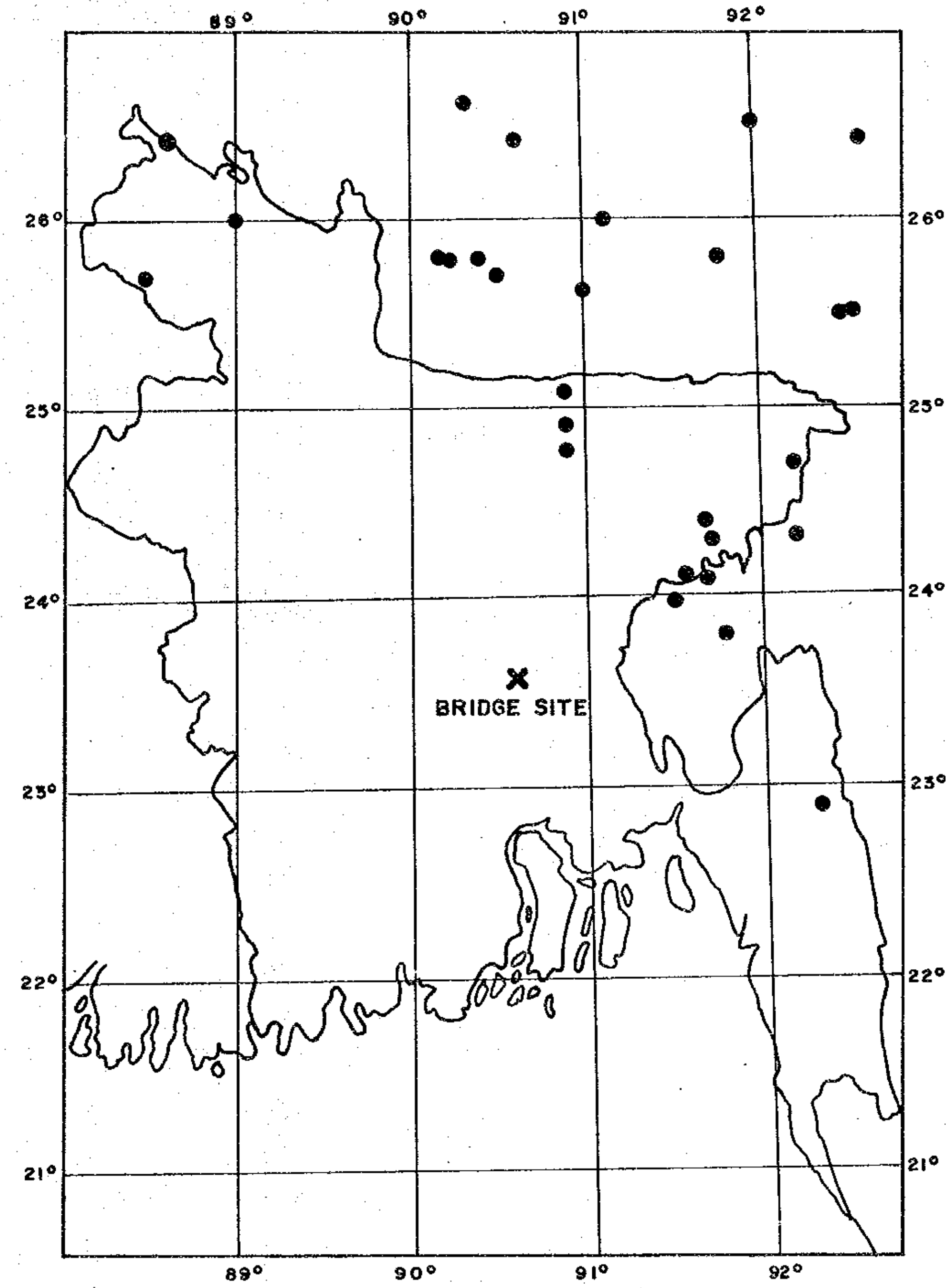
Also, structures need not be designed against maximum ground acceleration. For example, in the case of San Fernando Earthquake of 1971, a strong motion accelerograph installed at Pacoima Dam site recorded about 1.4 g acceleration as a maximum. However, no one will consider that dams located in the region should be designed against 1.4 g horizontal acceleration. By the same reasoning, the Study Team considers that *Meghna and Meghna-Gumti Bridges need not be designed against 0.084 g or 0.059 g* horizontal acceleration.

4. Basic Horizontal Seismic Coefficient at the Bridge Sites

Considering the facts that the estimated ground accelerations caused by past earthquakes shown in Ap. Table 6–2 are relatively low and the bridge sites are located in Zone II, the Study Team adopts the value of 0.05 as the basic horizontal seismic coefficient for designing the Meghna and Meghna-Gumti Bridges.



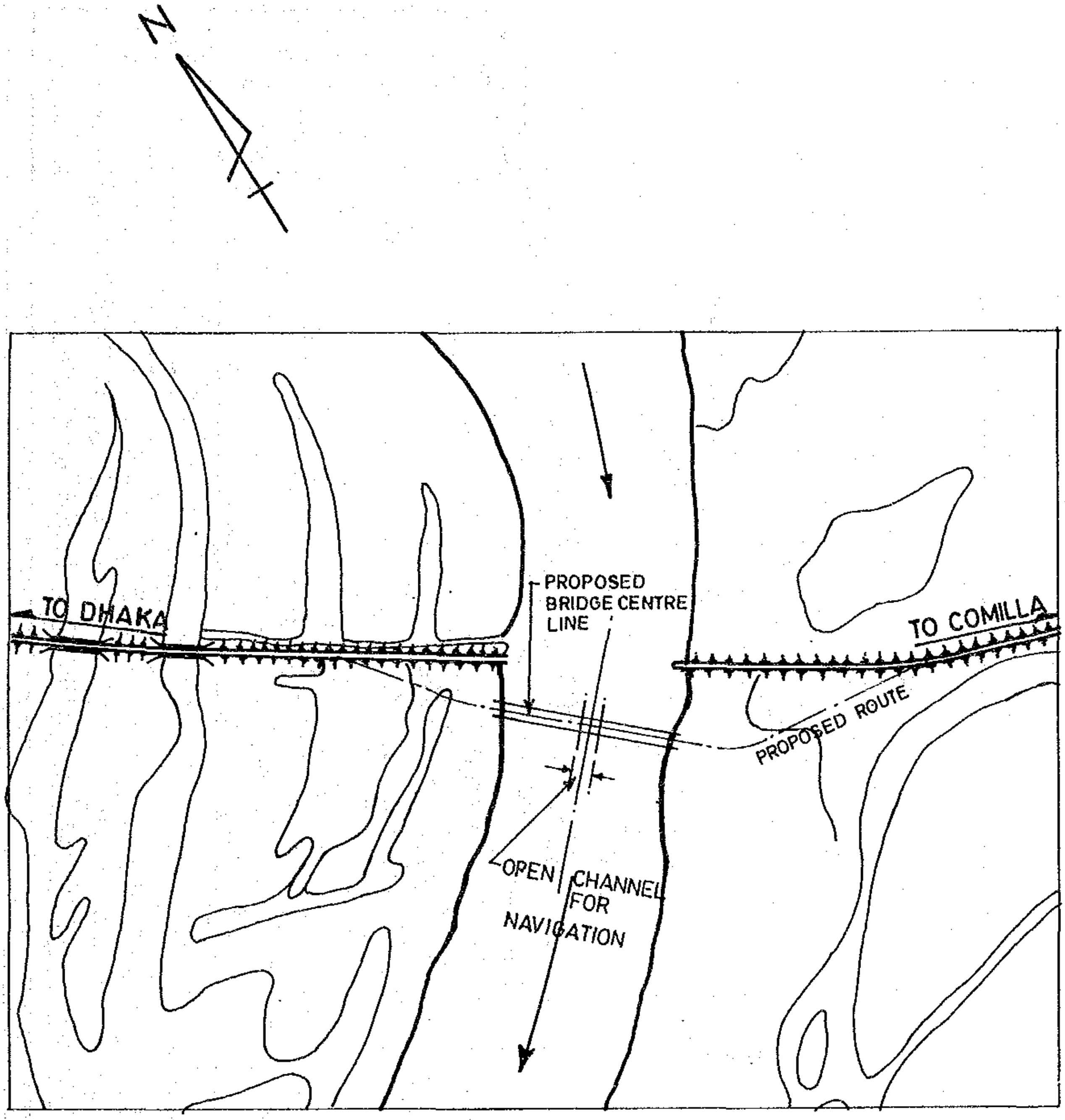
AP.FIG. 6-1 **SEISMIC ZONING MAP OF BANGLADESH**



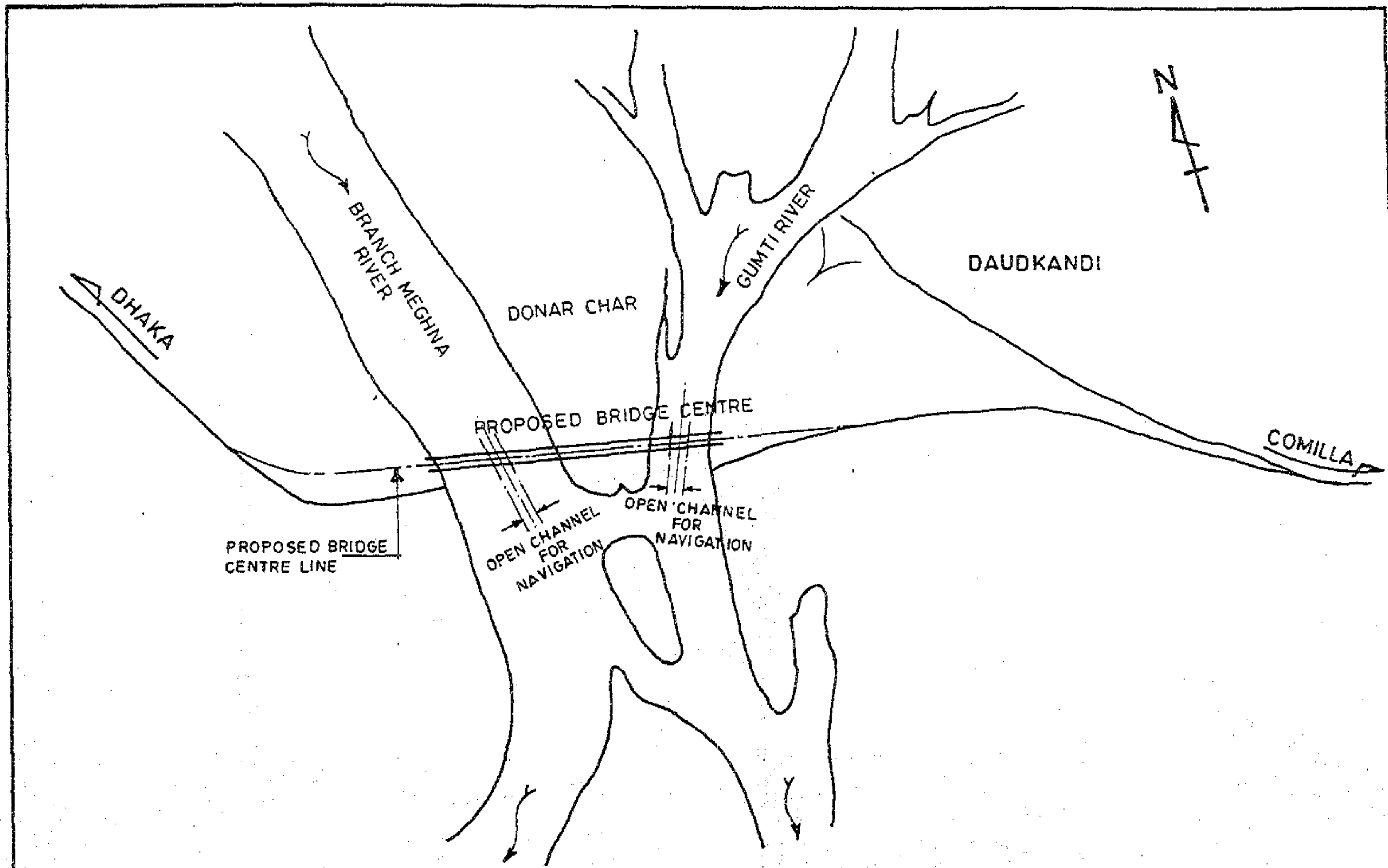
AP.FIG. 6-2 LOCATION OF EPICENTERS IN AND NEAR BANGLADESH (1833-1971)

Ap.Table 6–2 Estimation of Ground Accelerations Caused by Past Earthquakes

No.	Date of Occurrence Year	Month	Day	Epicentre N(o)	E(o)	Magnitude M	Epicentral Distance d (km)	Estimated Accelaration (% g)	Remarks
1	1869	1	10	24.3	92.2	7.5	178	5.9	
2	1897	6	12			8.5	500	3.9	d:Approx. Estimation
3	1918	7	8	24.3	91.7	7.6	134	8.4	
4	1923	9	9	25 ¼	91	7.1	189	4.4	
5	1930	7	2	25.8	90.2	7.1	250	3.2	Six major after shocks of M 5-6 took place
6	1932	3	6	25.5	92.5	5	284	0.8	
7	"	3	24	25.8	90.2	5-6	189	2.2	
8	"	3	27	25.5	92.5	"	284	1.5	
9	"	11	9	26.5	92.0	"	352	1.0	
10	1933	3	6	25.7	90.5	5.8	236	1.6	
11	1936	6	18	26.6	90.3	5.6	336	1.2	
12	1944	12	24	24.7	92.2	6	201	2.1	
13	1945	5	19	25.1	90.9	6	171	2.5	
14	1946	3	16	26.4	92.6	6	368	1.1	
15	1949	12	10	26.0	89.0	6	316	1.3	
16	1950	12	24	24.4	91.7	6.3	142	3.6	
17	1951	4	7	25.8	90.4	6.8	247	2.7	
18	1956	6	12	24.8	90.9	6	139	3.1	
19	1958	2	9	24.9	90.9	5.0	150	1.6	
20	1960	8	21	26.4	88.6		376	0.8	
21	1967	9	6	24.1	91.7	5.0	123	1.9	
22	"	11	14	24.0	91.5	5.1	101	2.4	
23	1968	6	12	26.0	91.1	5.5	273	1.1	
24	"	8	18	26.4	90.6	5.2	312	0.8	
25	"	12	27	24.1	91.6	5.2	114	2.2	
26	1969	1	25	22.9	92.3	5.4	186	1.6	
27	"		1	25.8	91.8	5.0	273	0.8	
28	1970	7	25	25.7	88.5	5.2	321	0.7	
29	1971	2	2	23.8	91.8	4.5	121	1.9	



AP. FIG. 6-3 LOCATION OF NAVIGATION (MEGHNA)

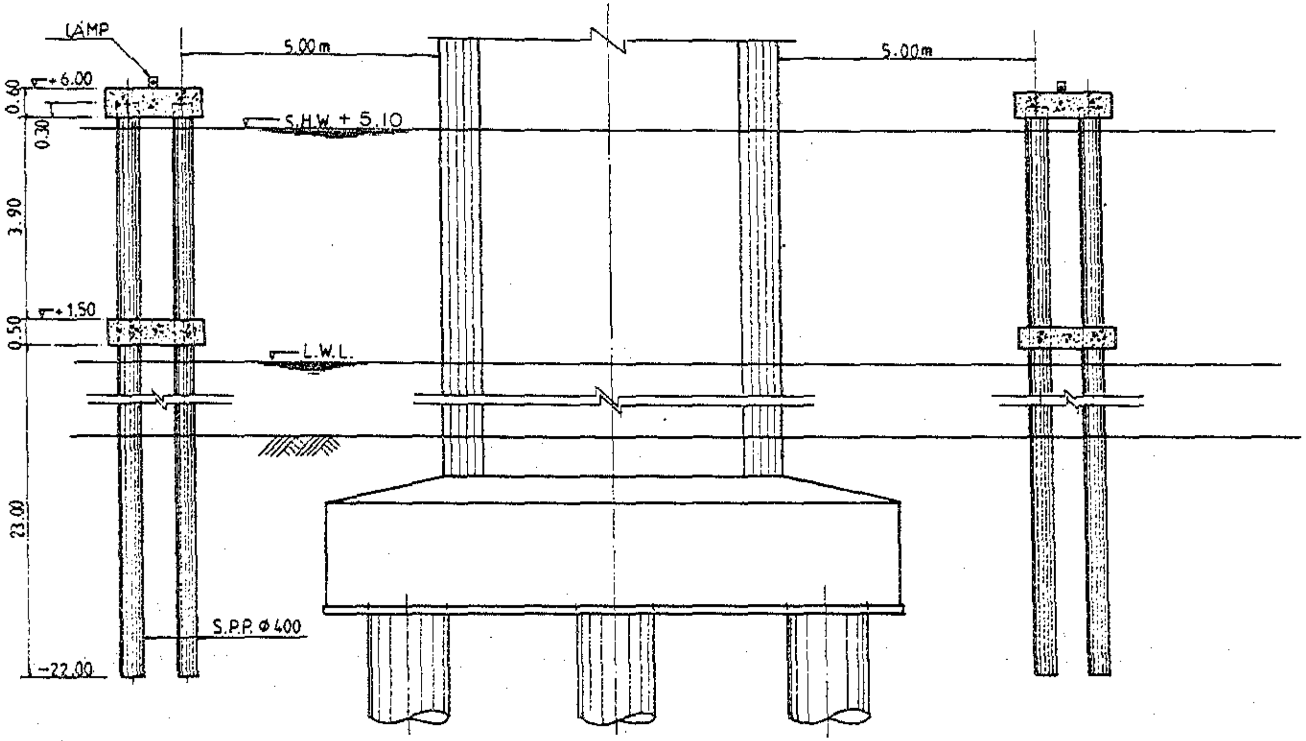


AP. FIG. 6-4 LOCATION OF NAVIGATIONS (MEGHNA-GUMTI)

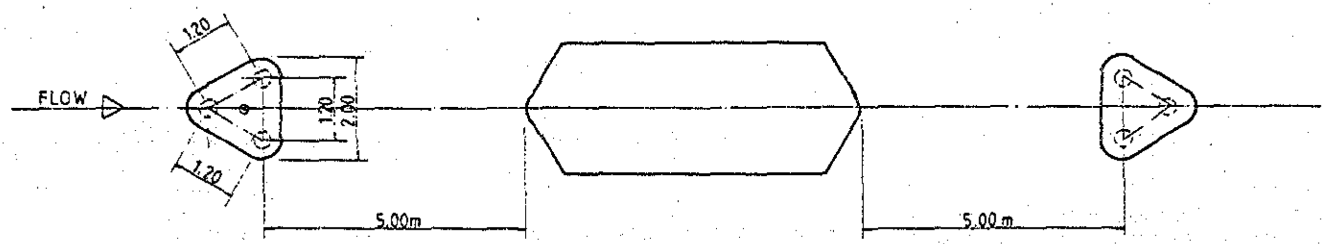
AP. TABLE 7-1 COMPARISON OF ALTERNATIVE ROUTES OF THE MEGHNA BRIDGE

SUBJECTS STUDIED / ALTERNATIVE ROUTES	HORIZONTAL ALIGNMENT OF THE BRIDGES AND APPROACHES	COST OF APPROACH ROAD	LAND REQUIRED FOR THE PROJECT	REPLACEMENT OF EXISTING FERRY	COMPENSATION FOR SHOPS TO BE REPLACED	SCOPE OF COUNTERMEASURE AGAINST LEFT BANK EROSION	INFLUENCE OF UP STREAM SANDBAR IN NEAR FUTURE
X ROUTE A	◎ Straight line	◎ The minimum cost	◎ Required only for temporary use	△ Required	△ Required	X Large scope required	△ Affected
X ROUTE B	△ Large curve in bridge stru-cture	△ Large cost due to a canal bridge required on right approach	○ 33,000 SQ. M. be required	○ Not required	○ Not required	X Large scope required	X Much affected
△ ROUTE C-1	△ Flat curve in bridge stru-cture	○ Not so large	○ 33,000 SQ. M. be required	○ Not required	○ Not required	△ Small scope required	△ Less affected
○ ROUTE C-2	○ Straight line is possible in the bridge	○ Not so large	○ 36,000 SQ.M. be required	○ Not required	○ Not required	△ Required for adjacent eroded bank	◎ Free
○ ROUTE C-3	○ Straight line is possible in the bridge	△ Large cost due to the longest approach	△ The largest; 42,000 SQ. M. be required	○ Not required	○ Not required	○ Not required	◎ Free

Legend : ◎: Excellent ○: Good △: Poor X: Bad



SIDE ELEVATION
SCALE: 1:100



PLAN
SCALE: 1:100

AP. FIG. 7-1 PIER PROTECTION AGAINST SHIP COLLISION

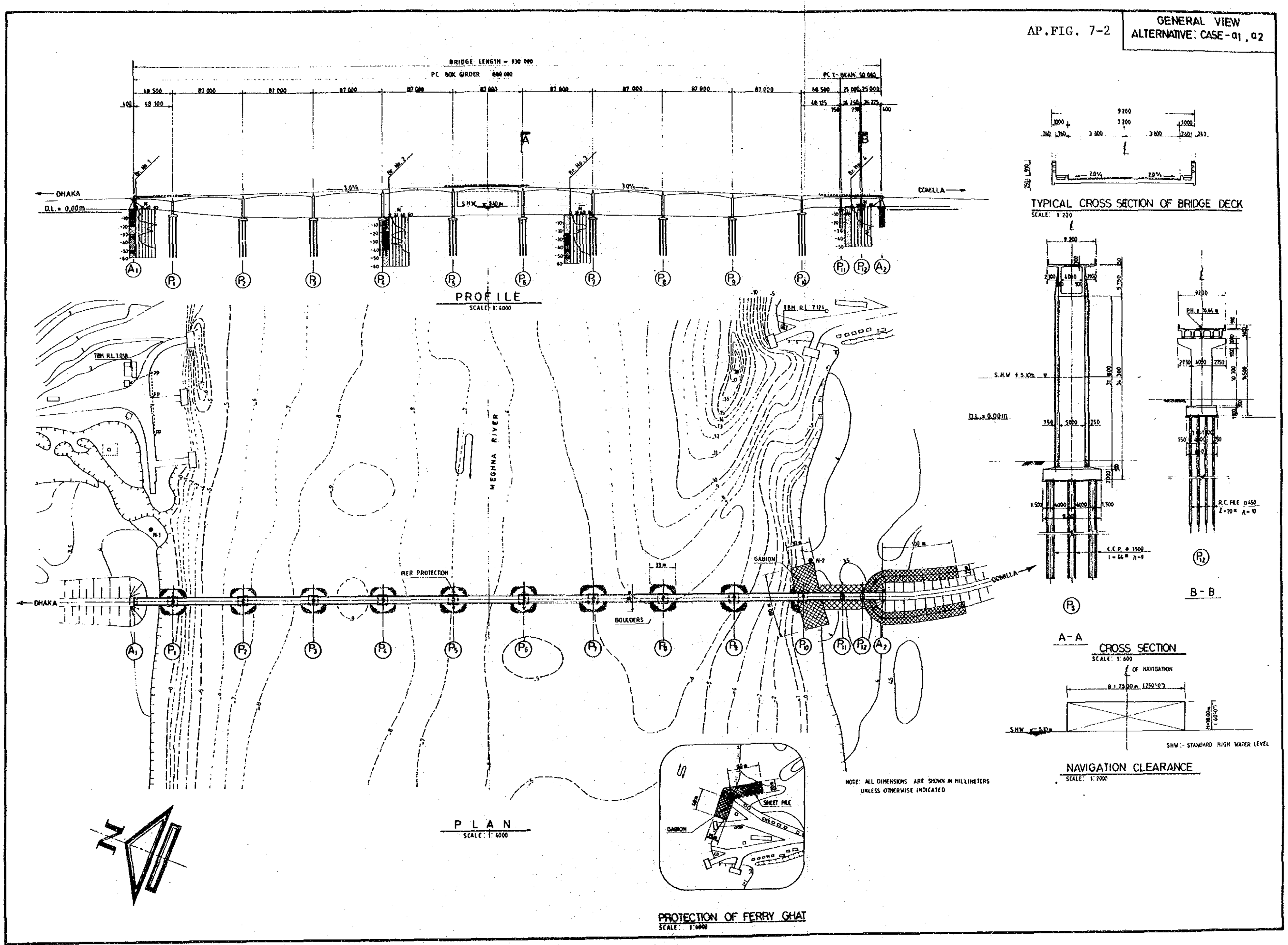
AP. NOTE 7–1 SPAN ARRANGEMENTS SELECTED

Alternatives	Span Arrangement (Towards Dhaka → Towards Comilla)	No. of Piers
A	40m + 55m + 7 @ 90m + 55m + 2 @ 40m	11
B	40m + 2 @ 45m + 55m + 5 @ 90m + 55m + 2 @ 45m + 2 @ 40m	13
C	40m + 4 @ 45m + 55m + 3 @ 90m + 55m + 4 @ 45m + 2 @ 40m	15
D	40m + 6 @ 45m + 55m + 90m + 55m + 6 @ 45m + 2 @ 40m	17
E	30m + 2 @ 40m + 6 @ 120m + 30m	9

Alternative A: Spans in the river have minimum length of 90 m and side spans near the banks have economical lengths.

Alternative B, C, D: To compare the total cost of superstructure and substructure three kinds of side span arrangement which are all modified from Alternative A were selected.

Alternative E: To compare the cost between span lengths of 90 m and 120 m the latter of which is the maximum span length of road bridge in Bangladesh this arrangement was selected.

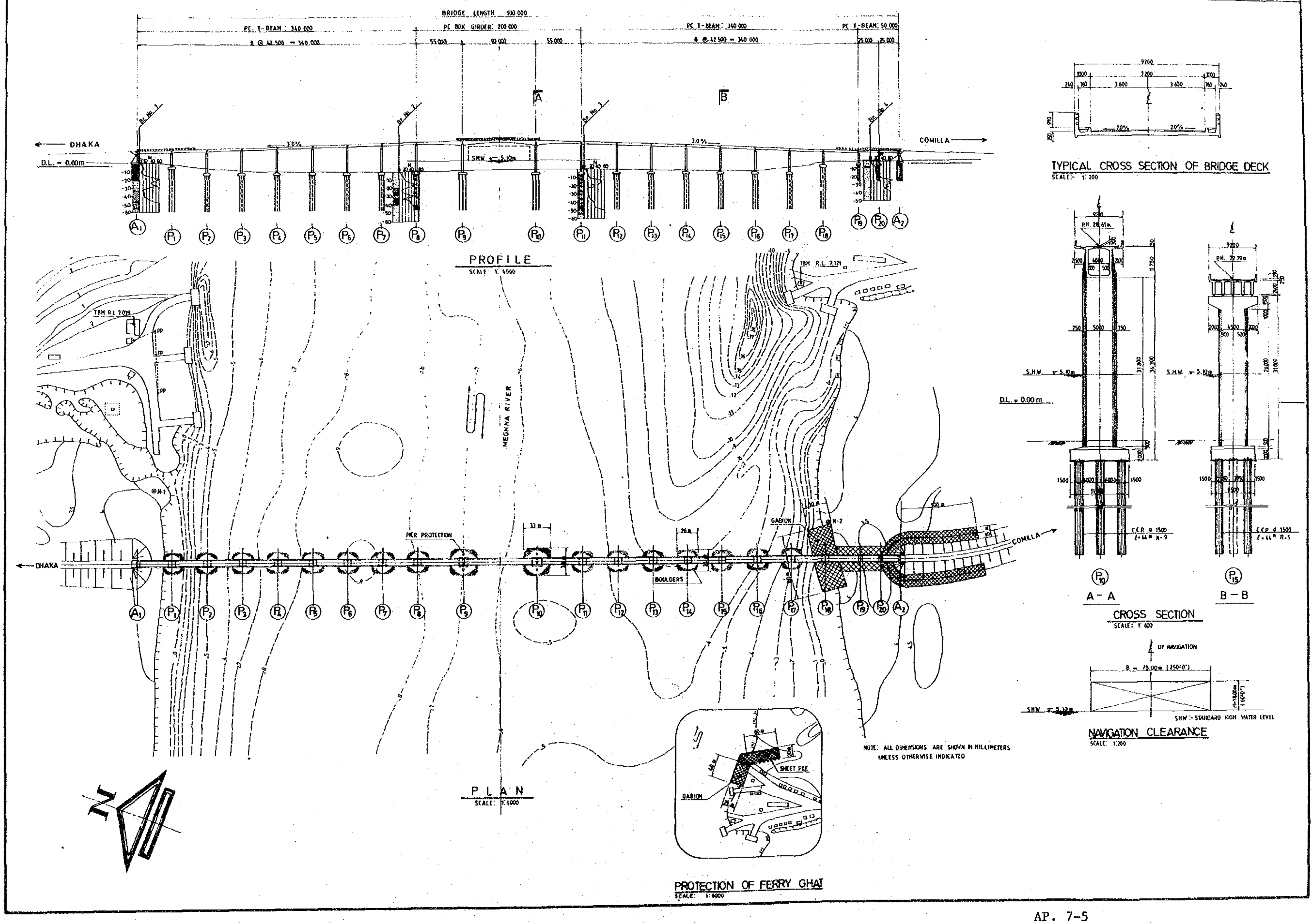


AP.FIG. 7-2

GENERAL VIEW
ALTERNATIVE: CASE-a_1, a_2

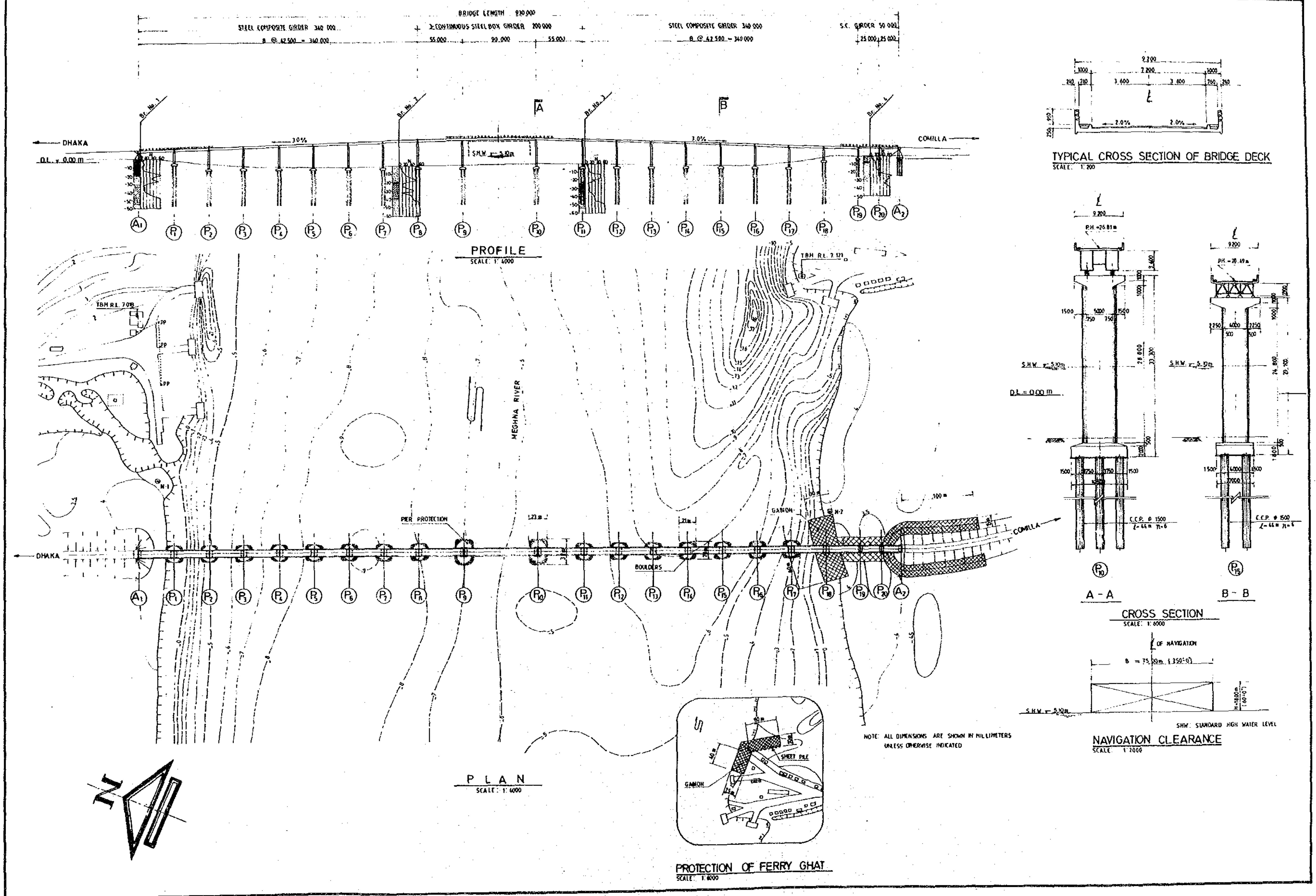
AP.FIG. 7-3

GENERAL VIEW
ALTERNATIVE: CASE-b_1, b_2



AP. FIG. 7-4

GENERAL VIEW
ALTERNATIVE: CASE-b3



AP.TABLE 7-2 COST OF CASE-a1 PC BOX CAST-IN-SITU

(TK)

ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
A. Superstructure				
PC box (C) concrete (P)	CM	7,070	4,860	34,360,200
PC beam concrete (P)	CM	220	7,930	1,744,600
Deformed bar	T	837	21,600	18,079,200
PC cable stressing	T	429	70,440	30,218,760
Railing	LM	1,860	1,290	2,399,400
Footpath & kerb	LM	1,860	850	1,581,000
Expansion joint	EACH	13	110,000	1,430,000
Centre hinge	EACH	18	81,650	1,469,700
Bearing shoe	EACH	24	40,750	978,000
Indirect cost	LS	1		46,130,140
Subtotal				138,391,000
B. Substructure				
RCD pile ø1.5 m	LM	4,070	14,110	57,427,700
Precast concrete pile	LM	2,560	1,980	5,068,800
Excavation in river	CM	10,170	7,100	72,207,000
Seal concrete (X)	CM	1,350	1,810	2,443,500
Footing concrete (A)	CM	3,010	2,330	7,013,300
Pier concrete (A)	CM	4,500	2,890	13,005,000
TORSTEEL bar	T	692	22,190	15,355,480
Indirect cost	LS	1		86,260,220
Subtotal				258,781,000
Total A. + B.				397,172,000

Source: The Study Team

Note
- (C): Cast-in-situ
- (S): Segmental
- (A): Class A concrete for box culvert, footing and piers
- (P): Class P concrete for prestressed T-beam girder and box section bridge
- (X): Class X concrete deposited in water and tremie concrete for cast-in-situ piles

AP.TABLE 7-3 COST OF CASE-a2 PC BOX SEGMENTAL

(TK)

ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
A. Superstructure				
PC box (S) concrete (P)	CM	7,070	10,630	75,154,100
PC beam concrete (P)	CM	220	7,930	1,744,600
Deformed bar	T	837	15,550	13,015,350
PC cable stressing	T	429	70,420	30,210,180
Railing	LM	1,860	1,290	2,399,400
Footpath & kerb	LM	1,860	850	1,581,000
Expansion joint	EACH	13	110,000	1,430,000
Centre hinge	EACH	18	81,650	1,469,700
Bearing shoe	EACH	24	40,750	978,000
Indirect cost	LS	1		63,991,670
Subtotal				191,974,000
B. Substructure				
RCD pile ø1.5 m	LM	4,070	14,110	57,427,700
Precast concrete pile	LM	2,560	1,980	5,068,800
Excavation in river	CM	10,170	7,100	72,207,000
Seal concrete (X)	CM	1,350	1,810	2,443,500
Footing concrete (A)	CM	3,010	2,330	7,013,300
Pier concrete (A)	CM	4,500	2,890	13,005,000
TORSTEEL bar	T	692	22,190	15,355,480
Indirect cost	LS	1		86,260,220
Subtotal				258,781,000
Total A. + B.				450,755,000

Source: The Study Team

AP.TABLE 7-4 COST OF CASE-b1 PC BOX (C) AND T-BEAM

(TK)

ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
A. Superstructure				
PC box (C) concrete (P)	CM	1,600	6,050	9,680,000
PC beam concrete (P)	CM	4,180	7,930	33,147,400
Deforced bar (Box)	T	185	21,600	3,996,000
Deformed bar (Beam)	T	497	15,550	7,728,350
PC cable stressing (Box)	T	98	70,440	6,903,120
PC cable stressing (Beam)	T	139	56,100	7,797,900
Railing	LM	1,860	1,290	2,399,400
Footpath & kerb	LM	1,860	850	1,581,000
Expansion joint	EACH	21	110,000	2,310,000
Centre hinge	EACH	2	81,650	163,300
Bearing shoe (Box)	EACH	4	40,750	163,000
Bearing shoe (Beam)	EACH	180	30,300	5,454,000
Indirect cost	LS	1		40,661,530
Subtotal				121,985,000
B. Substructure				
RCD pile ø1.5 m	LM	4,400	14,830	65,252,000
Precast concrete pile	LM	2,610	1,980	5,167,800
Excavation in river	CM	12,590	7,100	89,389,000
Seal concrete (X)	CM	1,680	1,810	3,040,800
Footing concrete (A)	CM	3,470	2,330	8,085,100
Pier concrete (A)	CM	6,020	2,890	17,397,800
TORSTEEL bar	T	940	22,190	20,858,600
Indirect cost	LS	1		104,595,900
Subtotal				313,787,000
Total A. + B.				434,772,000

Source: The Study Team

AP.TABLE 7-5 COST OF CASE-b2 PC BOX (S) AND T-BEAM

(TK)

ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
A. Superstructure				
PC box (S) concrete (P)	CM	1,600	10,630	17,008,000
PC beam concrete (P)	CM	4,180	7,930	33,147,400
Deformed bar (Box)	T	185	15,550	2,876,750
Deformed bar (Beam)	T	497	15,550	7,728,350
PC cable stressing (Box)	T	98	70,420	6,901,160
PC cable stressing (Beam)	T	139	56,100	7,797,900
Railing	LM	1,860	1,290	2,399,400
Footpath & kerb	LM	1,860	850	1,581,000
Expansion joint	EACH	21	110,000	2,310,000
Centre hinge	EACH	2	81,650	163,300
Bearing shoe (Box)	EACH	4	40,750	163,000
Bearing shoe (Beam)	EACH	180	30,300	5,454,000
Indirect cost	LS	1		43,765,740
Subtotal				131,296,000
B. Substructure				
RCD pile ⌀1.5 m	LM	4,400	14,830	65,252,000
Precast concrete pile	LM	2,610	1,980	5,167,800
Excavation in river	CM	12,590	7,100	89,389,000
Seal concrete (X)	CM	1,680	1,810	3,040,800
Footing concrete (A)	CM	3,470	2,330	8,085,100
Pier concrete (A)	CM	6,020	2,890	17,397,800
TORSTEEL bar	T	940	22,190	20,858,600
Indirect cost	LS	1		104,595,900
Subtotal				313,787,000
Total A. + B.				445,083,000

Source: The Study Team

AP.TABLE 7-6 COST OF CASE-b3 STEEL BOX AND GIRDER

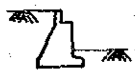
(TK)

ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
A. Superstructure				
Steel box fabrication	T	780	34,680	27,050,400
Steel box transport	T	780	8,290	6,466,200
Steel box erection	T	780	11,480	8,954,400
Steel girder fabrication	T	1,445	28,260	40,835,700
Steel girder transport	T	1,445	7,680	11,097,600
Steel girder erection	T	1,445	5,040	7,282,800
Slab concrete (B)	CM	2,180	3,070	6,692,600
Deformed bar	T	485	27,980	13,570,300
Railing	LM	1,860	1,290	2,399,400
Footpath & kerb	LM	1,860	850	1,581,000
Expansion joint	EACH	20	110,000	2,200,000
Bearing shoe	EACH	146	40,750	5,949,500
Indirect cost	LS	1		60,335,100
Subtotal				194,415,000
B. Substructure				
RCD pile ø1.5 m	LM	3,560	14,830	52,794,800
Precast concrete pile	LM	2,240	1,980	4,435,200
Excavation in river	CM	9,170	7,100	65,107,000
Seal concrete (X)	CM	1,230	1,810	2,226,300
Footing concrete (A)	CM	2,270	2,330	5,289,100
Pier concrete (A)	CM	5,150	2,890	14,883,500
TORSTEEL bar	T	745	22,190	16,531,550
Indirect cost	LS	1		80,633,550
Subtotal				241,901,000
Total A. + B.				436,316,000

Source: The Study Team

Note (B): Class B concrete for slab of steel bridges of alternative plans

AP. TABLE 7-7 GUIDE TO THE SELECTION OF ABUTMENT TYPE

Type	Height (m) 10 20	Remarks
Gravity	4	
Semi-Gravity	6	
Invert-T	6 12	
Buttress		
Rigid Frame	15	
Box	12	

AP. NOTE 7–2 PAVEMENT DESIGN

1. Traffic Survey and Prediction

The traffic pedicted by the Study Team was used in the calculation. Average annual daily heavy vehicle traffic volumes in the design years 1990, 2000, 2010 and 2020 are as follows:

Year	1990	2000	2010	2020
Truck	1,410	2,360	3,470	5,150
Bus	780	1,180	1,700	2,390

The above volumes are for two lanes and half of the traffic is assumed to use either of the two.

2. Axle Load Equivalent and Yearly Equivalent Standard Axles

The axle load equivalents were surveyed in 1979 and 1981 as reported in the design report of Comilla and Chandina Bypasses (by Vallentine, Laurie and Davies). They are as follows:

Type of Heavy Vehicles	Monsoon Section	Dry Season
Truck	0.62	2.2
Bus	0.28	0.52

The estimated yearly equivalent standard axles (E.S.A.) is calculated as follows:

E.S.A at 1990

Truck : $150 \times 705 \times 2.2 + 215 \times 705 \times 0.62 = 327 \times 10^3$

Bus : $150 \times 390 \times 0.52 + 215 \times 390 \times 0.28 = 54 \times 10^3$

Subtotal : 381×10^3

E.S.A at 2000

Truck : 150 x 1,180 x 2.2 + 215 x 1,180 x 0.62 = 547 x 10^3

Bus : 150 x 590 x 0.52 + 215 x 590 x 0.28 = 82 x 10^3

Subtotal : 625 x 10^3

E.S.A at 2010

Truck : 150 x 1,735 x 2.2 + 215 x 1,735 x 0.62 = 804 x 10^3

Bus : 150 x 850 x 0.52 + 215 x 850 x 0.28 = 117 x 10^3

Subtotal : 921 x 10^3

E.S.A at 2020

Truck : 150 x 2,575 x 2.2 + 215 x 2,575 x 0.62 = 1,193 x 10^3

Bus : 150 x 1,195 x0.52 + 215 x 1,195 x 0.28 = 165 x 10^3

Subtotal : 1,358 x 10^3

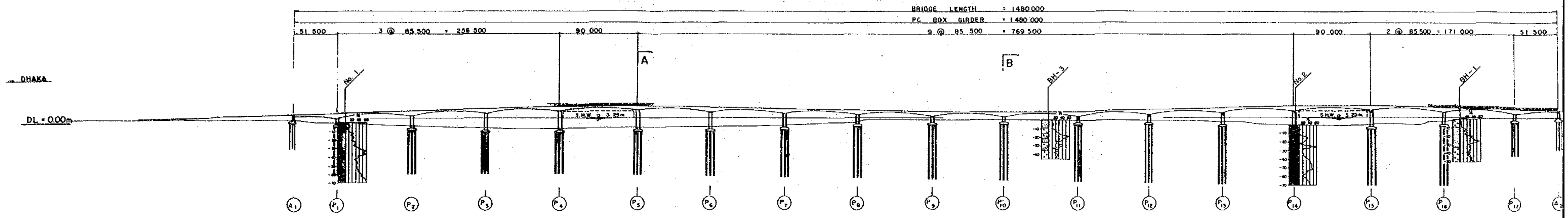
Comulative Equivalent Standard Axles

Year		E.S.A.
1990 – 2000	(381 + 629)/2 x10^3 x 10 =	5,050 x 10^3 = 5.0 x 10^6
2000 – 2010	(629 + 921)/2 x 10^3 x 10 =	7,750 x 10^3 = 7.8 x 10^6
2010 – 2020	(921 + 1,358)/2 x 10^3 x 10 =	11,395 x 10^3 = 11.4 x 10^6

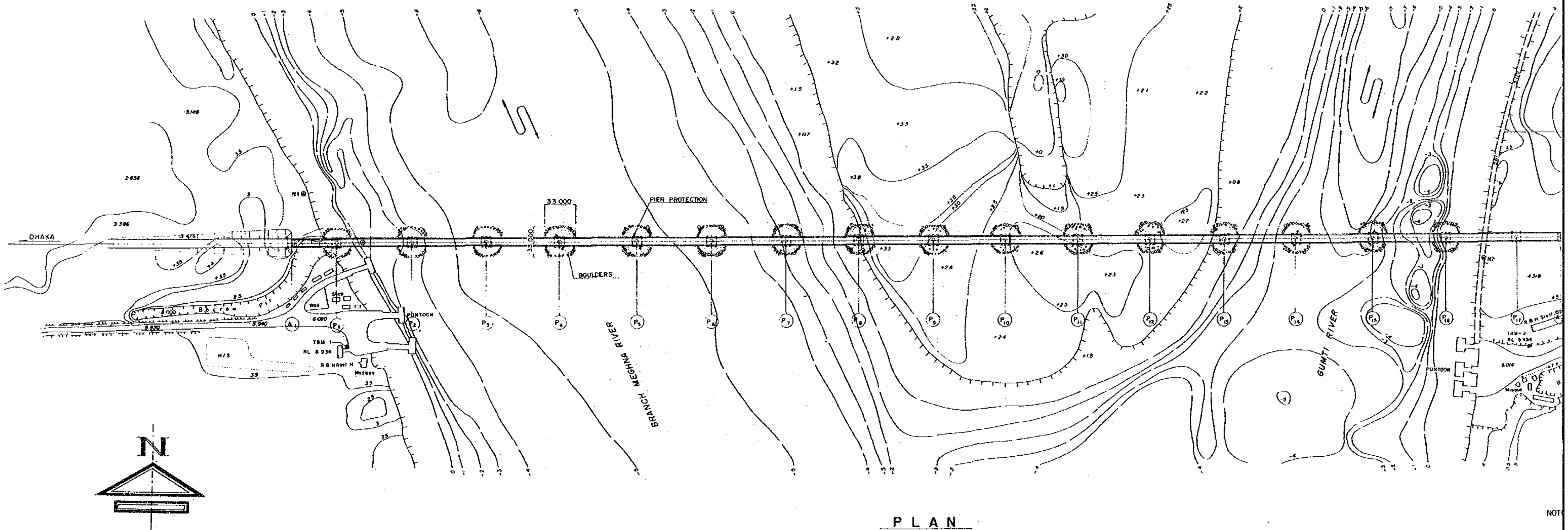
AP. TABLE. 7-8 ROUTE COMPARISON OF MEGHNA GUMTI BRIDGE

ROUTE	ROUTE ALIGNMENT	CROSSING ANGLE WITH RIVERS FLOW	WIDTH OF RIVERS UNDER BRIDGE (meters)	LENGTH OF NEW APPROACH ROADS (meters)	LAND ACQUISITION (sq.meters)	BRIDGE UNDER CONSTRUCTION: CROSSING WITH FERRY LINE	BRIDGE UNDER CONSTRUCTION: SHIFT OF ROADS, FERRY GHATS & SHOPS
△ A	◎ Bridge in a Straight line	△ 80°	△ 1320	X 1100	X 33,000	◎ Not Cross	◎ Not required
○ B	◎ Bridge in a Straight line	○ 83°	△ 1290	○ 750	◎ 12,000	△ Cross	△ Required only for a jetty in Dhaka side
△ C	△ Approach on Daudkandi Side in a curved line	△ 78°	○ 1280	○ 750 Profile of existing roads be changed to connect bridge profile	◎ 10,000	X Cross	X Required for Roads & Ferry Jetties: 2 for Dhaka & 2 for Comilla
X D	○ Approach on both sides in a curved line	◎ 90°	◎ 1230	○ 750	X 23,000	X Cross	X Required for Roads & Ferry Jetties: 3 for Dhaka & 2 for Comilla
X E	X Bridge in a large curved line	○ (85° on Shortest tangent line)	○ 1270	X 1050	X 32,000	◎ Not Cross	◎ Not required

LEGEND:
◎ Excellent ○ Good △ Poor X Bad



PROFILE
SCALE 1:4,000



PLAN
SCALE 1:4,000

AP.FIG. 7-5

GENERAL VIEW
ALTERNATIVE : CASE - A