付録－6

第3年次調査作業計画（P／O）に関する協議議事録(1993.11.11)

MINUTES OF THE MEETING
ON
THE STUDY ON THE GEODETIC SURVEY
IN
THE PEOPLE'S REPUBLIC OF BANGLADESH
(PHASE III)

On the basis of the "Scope of Work for the Study on the Geodetic Survey in the People's Republic of Bangladesh" agreed between Survey of Bangladesh (SOB), Ministry of Defence and Japan International Cooperation Agency (JICA) on 5th December 1991, JICA Study Team, headed by Dr. Minoru Tajima, have completed Phase I (April-June/92) and Phase II (Sept./92-March/93) Studies.

Following the successful implementation of Phase I and Phase II Studies, JICA despatched a Study Team to Bangladesh to conduct the Phase III field work from October 1993 to February 1994.

In a series of meetings, JICA Study Team explained on the implementation plan based on the "Plan of Operation for the Phase III Study" (P/O) as attached hereto, to the Economic Relations Division (ERD), Ministry of Finance and SOB.

ERD inquired to include financial status onto the P/O, and the Study Team opposed that as the nature of P/O is exclusively technical implementation plan and all financial matters shall be discussed between ERD and JICA Bangladesh Office in later date.

As a result of discussions, those parties confirmed that the Phase III Study shall be carried out according to this Plan of Operation, which has to be in line with the approved planning documents of Bangladesh.

Dhaka, November 11, 1993

Dr. Minoru Tajima
Leader,
Geodetic Survey Team
JICA

Mr. Dewan Zakir Hussain
Deputy Secretary
Economic Relations Division
Ministry of Finance

Witness;

1)
Maj.Kh. Aftab Hossain
Director Defence Survey(C.D.)
Survey of Bangladesh
Ministry of Defence

2)
Mr. Mohammad Nurul Baset
Research Offiser
Ministry of Defence

PLAN OF OPERATION

FOR

THE STUDY ON THE GEODETIC SURVEY

IN

THE PEOPLE'S REPUBLIC OF BANGLADESH

PHASE III

(October 1993 – March 1994)

OCTOBER 1993

JAPAN INTERNATIONAL COOPERATION AGENCY

PLAN OF OPERATION

I. INTRODUCTION

Following the successful implementation of Phase I and Phase II of the Study for " the Study on the Geodetic Survey in the People's Republic of Bangladesh" , the Japan International Cooperation Agency (hereinafter referred to as JICA) despatched a Study Team to Bangladesh to conduct the Phase III field work from October 1993 to February 1994.

This Plan of Operation (hereinafter referred to as P/O) is to describe the implementation plan for the Phase III (3rd Fiscal Year) Study.

The Study shall be carried out according to the P/O.
Survey of Bangladesh (hereinafter referred to as SOB) and JICA Study Team shall consult each other in respect any matter that may arise from or in connection with the Study.

II. IMPLEMENTATION PLAN FOR THE PHASE III STUDY

The following four categories of field work shall be conducted in the Phase III Study;

1. GPS observation for 80 control stations,
2. 1st order levelling for 730 km,
3. Tidal observation and reconstruction of the auxiliary tide gauge station with protection piles and the auxiliary tide pole, and
4. Reconnaissance for local geoidal undulation control points.

The Study Schedule and the Assignment of JICA Study Team are shown in Appendix 1 and 2 respectively.

III. GPS OBSERVATION

In continuation to the Phase II Study, the remaining and final 80 (eighty) control stations in the east and southern part of project area shall be observed by the GPS System. (Figure 1)

12 (twelve) GPS parties, in cooperation with SOB counterpart personnel, shall be deployed in the project area.

More than 2 (two) hours continuous and simultaneous GPS observation shall be conducted for the 1st session, and the 2nd observation session shall be carried out in not less than 5 (five) hours interval after the 1st session.

The quality of each session of GPS observation shall be examined and controlled in Bangladesh.

In parallel with the GPS observation, 28 (twentyeight) GPS stations shall be tied with B.M. by means of direct levelling for obtaining the orthometric height.

IV. FIRST ORDER LEVELLING

1st order levelling of 730 km shall be conducted in the north west part of project area. (Figure 2)

8 (eight) levelling parties, equipped with Wild N3s and NA3000s with Invar staves, shall be deployed to the area.

River crossing levelling in 4 (four) locations shall be conducted by means of either tilting screw method, reciprocal levelling or trigonometric levelling, depending on the length of sight.

The closing error of double run and loop shall be maintained within 4 mm times square root of S ($4mm \cdot \sqrt{S}$). (Note: S means level run in km.)

V. TIDAL OBSERVATION

Auxiliary tide pole and auxiliary tide gauge station in Patenga Beach, which were disturbed in April/93 and August/93, shall be reconstructed with rigid structure, for continuing the tidal observation. (Figure 3)

Tidal observation shall be continued in cooperation with SOB counterpart personnel at the tidal observation station and at the auxiliary tide gauge .

Data collected till February 1994 shall be examined and analysed in Japan to determine the Provisional Mean Sea Level in the Bay of Bengal.

VI. RECONNAISSANCE FOR GEOIDAL UNDULATION CONTROLS

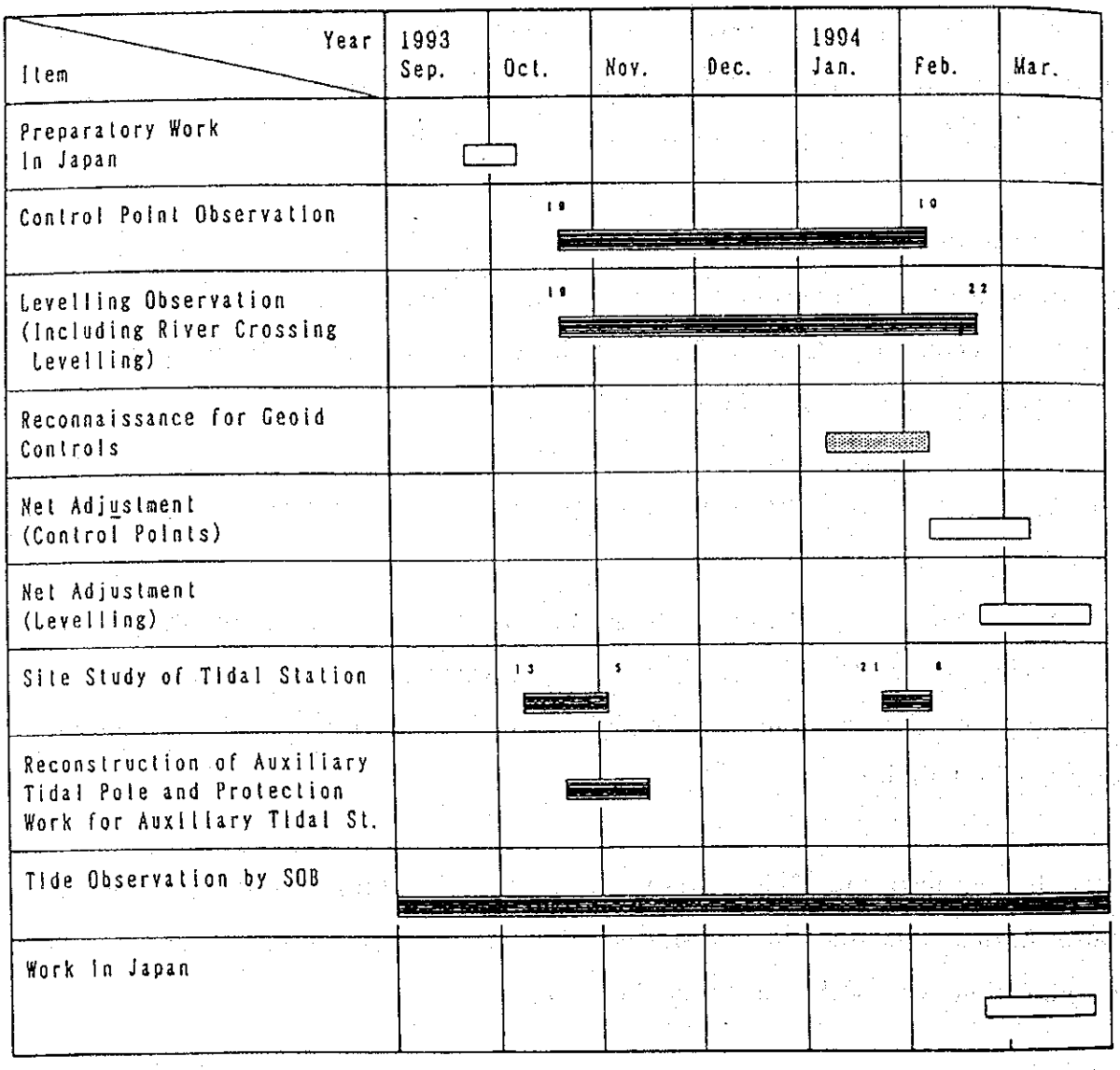
Viewing that a rather steep geoidal undulation is foreseen in the project area (see Figure 4), the preperation of a local geoidal undulation map is necessary to give orthometric height to all GPS Stations, with appropriate degree of reliability.

For this purpose, the JICA Study Team will reconnoitre to select a few GPS stations, those located far outside of the 1st order levelling route, to link the elevation with B.M. in Phase IV Study.

VII. ADJUSTMENTS AND ANALYSIS OF RESULTS

Adjustments and analysis of the results for all the above field work shall be carried out after the JICA Study Team returns to Japan in February/March 1994.

THE STUDY SCHEDULE Phase Ⅲ



THE LIST AND ASSIGNMENT OF TEAM (Phase Ⅲ) Appendix - 2

Organization	Names	Assignment	1993 Sep.	Oct.	Nov.	Dec.	1994 Jan.	Feb.	Mar.
Headquarters	Minoru TAJIMA	Leader							
	Shigehiko SHINO	Deputy Leader							
	Yoshio SASAKI	Planner							
	Hironori KOBAYASHI	Mechanic							
	Noriyuki TOMIZAWA	Coordinator							
Control Point Network	Masaji KOYAMA	Chief Surveyor							
	Takashi ITO	Surveyor							
	Takashi HARADA	Surveyor							
	Mitsuru HAMADA	Surveyor							
	Sachio TAZUKI	Surveyor							
	Isao YAMAMOTO	Surveyor							
	Megumi SHIMIZU	Surveyor							
	Uichi ISHIMURA	Surveyor							
	Shinji YOSHIDA	Surveyor							
	Yuji KIMURA	Surveyor							
	Kousuke INADA	Surveyor							
	Hideo HATTORI	Surveyor							
	Hiroyuki KAWAKAMI	Surveyor							

THE LIST AND ASSIGNMENT OF TEAM (Phase Ⅲ)

Appendix - 2

Organization	Names	Assignment	1993 Sep.	Oct.	Nov.	Dec.	1994 Jan.	Feb.	Mar.
First Order Levelling Network	Masanori TESHIMA	Chief Surveyor		〃	〃	〃	〃	〃	
	Kentarou USUDA	Surveyor		〃	〃	〃	〃	〃	
	Takashi KITANI	Surveyor		〃	〃	〃	〃	〃	
	Yasuyuki NAKAMISE	Surveyor		〃	〃	〃	〃	〃	
	Takeshi TOYOOKA	Surveyor		〃	〃	〃	〃	〃	
	Kazuo KODAMA	Surveyor		〃	〃	〃	〃	〃	
	Manabu TSUTSUI	Surveyor		〃	〃	〃	〃	〃	
	Satoshi OSADA	Surveyor		〃	〃	〃	〃	〃	
	Yoshihiro FURUTA	Surveyor		〃	〃	〃	〃	〃	
Tidal Station	Shigeru MIYAMURA	Coastal Engineer		〃	〃		〃	〃	

Figure 1 Distribution Map of Control Station

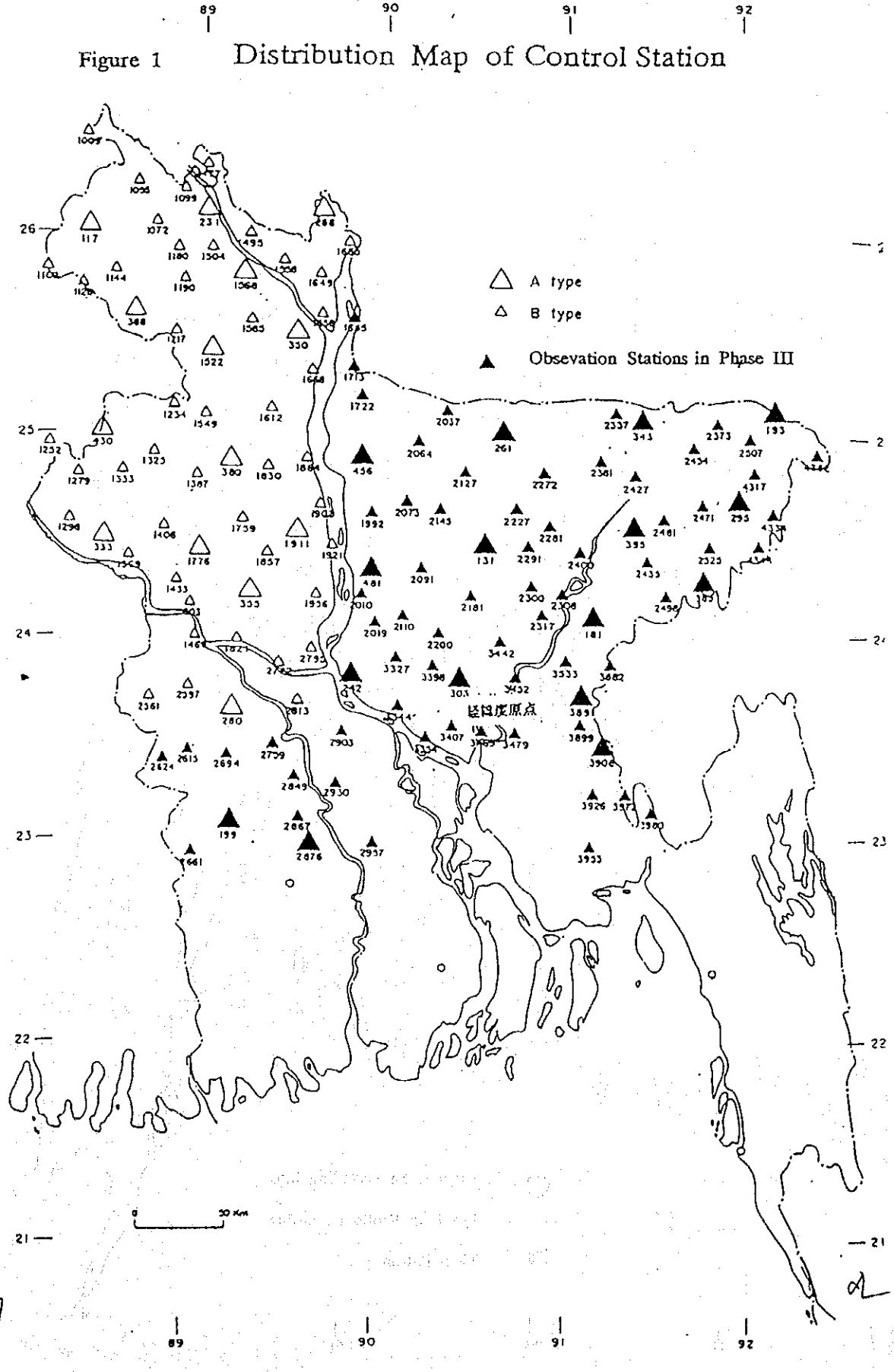


Figure 2 Levelling route

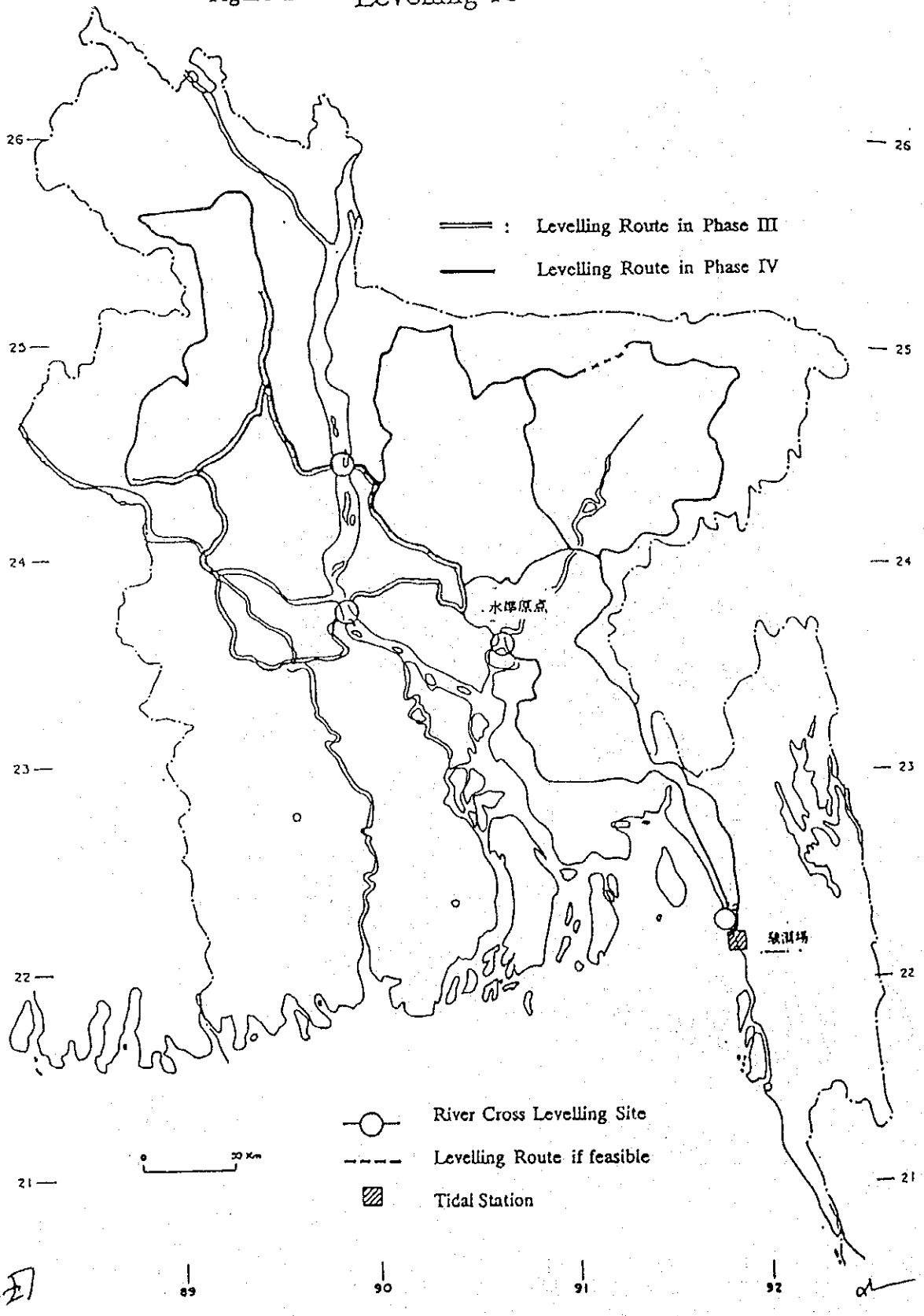


Figure 3

Reconstruction and protection work of the auxiliary tide gauge station

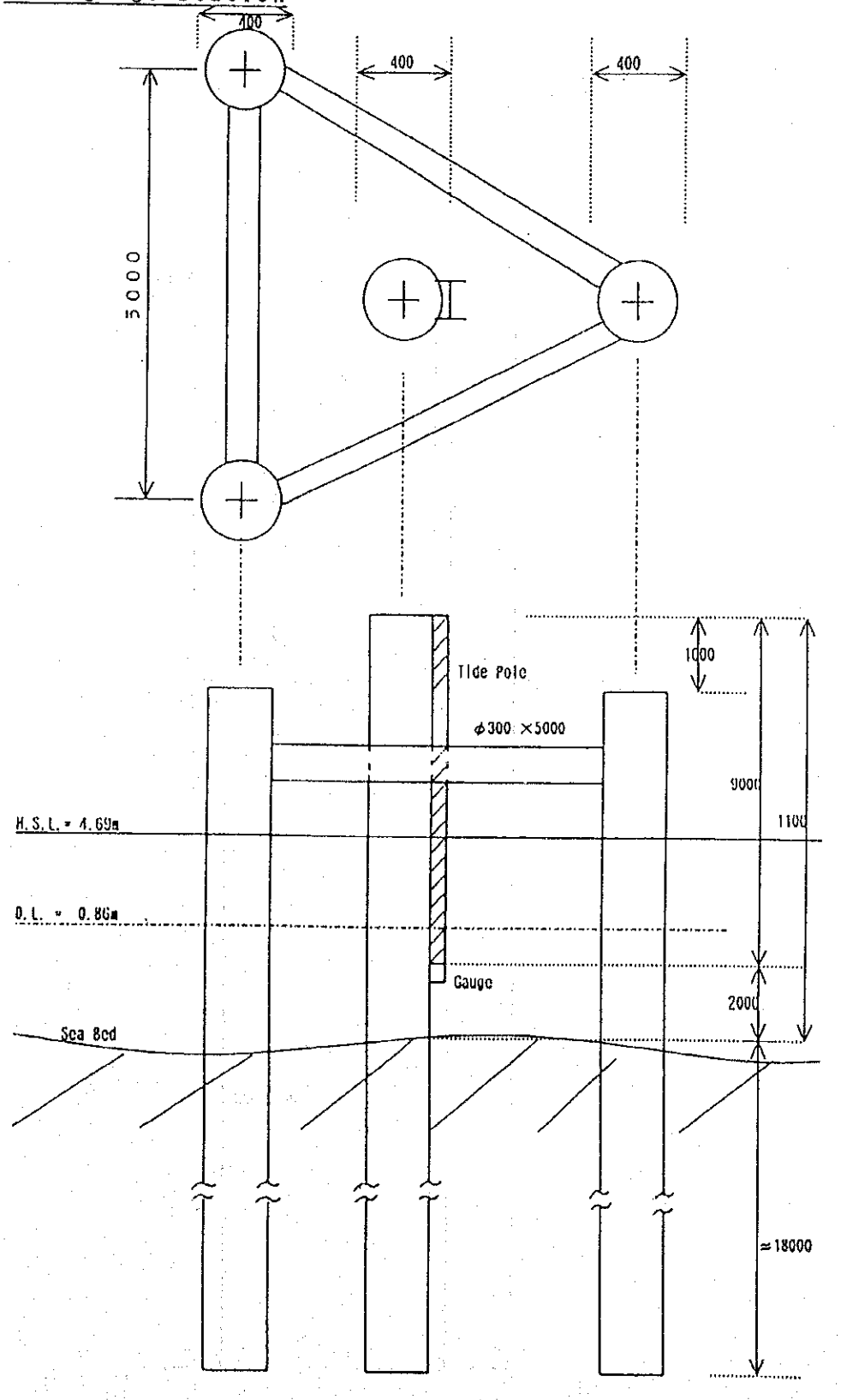


Figure 3'

Reconstruction Work of Tide Pole

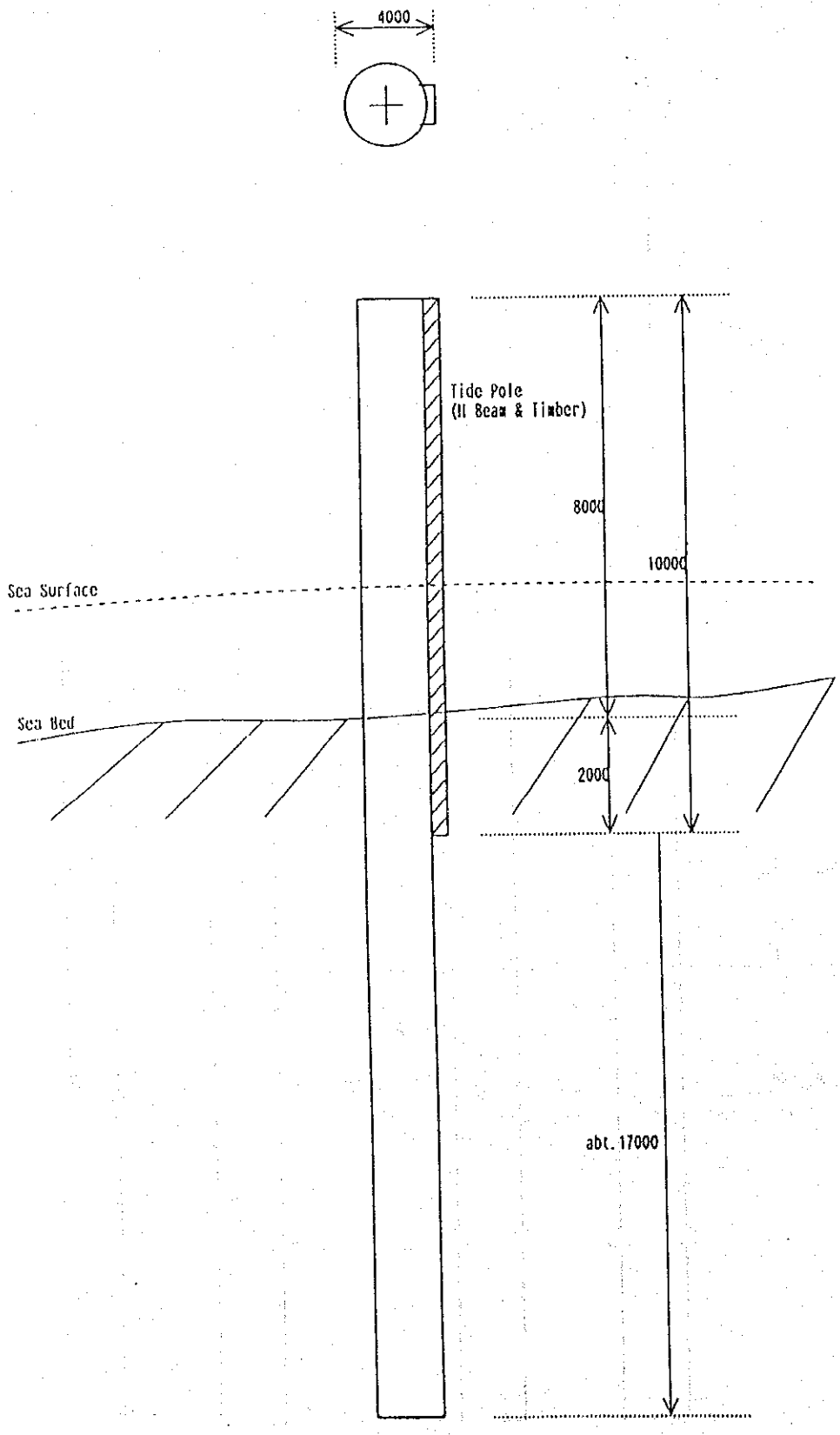
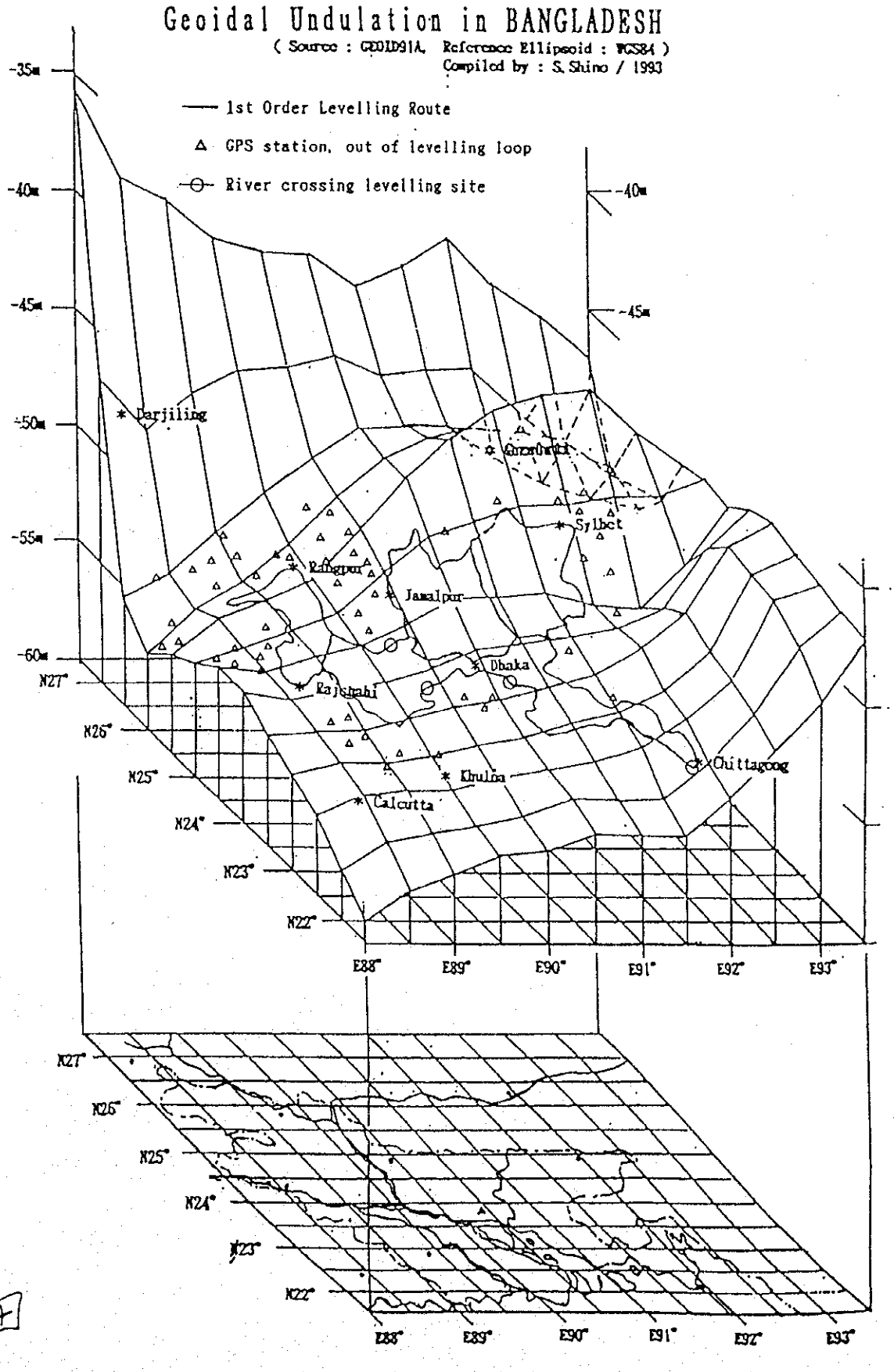


Figure 4


Geoidal Undulation in BANGLADESH
(Source : GEOID91A, Reference Ellipsoid : WGS84)
Compiled by : S. Shino / 1993
1st Order Levelling Route
GPS station, out of levelling loop
River crossing levelling site
-35m
-40m
-45m
-50m
-55m
-60m
Darjiling
Rangpur
Jamalpur
Sylhet
Dhaka
Rajshahi
Khulna
Calcutta
Chittagong
N27°
N26°
N25°
N24°
N23°
N22°
E88°
E89°
E90°
E91°
E92°
E93°

付録－7

第3年次現地作業経過報告(1994. 2.20)

20/02/1994
Dhaka,

To : The Surveyor General of Bangladesh
Survey of Bangladesh

From: The Deputy Team Leader
JICA Study Team (Geodetic Survey)

Subject: The Progress and the Final Report on the field work
Phase III Study to establish Geodetic Control Network
in the People's Republic of Bangladesh

It is my great pleasure to inform you that we have completed all works for the Phase III Study, which was described in the " Plan of Operation" and was recognized by " The Minutes of the Meetings" dated November 11, 1993, with success.

The following four categories of the field works had been planned to be conducted in the Phase III Study;

1. GPS Observation for 80 control stations,
2. The 1st order levelling for 730 km,
3. Tidal observation and reconstruction of auxiliary tide pole and auxiliary tide gauge station with protection works, and
4. Reconnaissance for local geoidal undulation control stations.

I. GPS Observation for 80 Control Station

12 (twelve) GPS parties, in cooperation with SOB counterpart personnel, had been deployed in the project area to occupy 80 GPS stations, as shown in Figure 1 blackend triangle symbols.

11 (eleven) GPS observation sessions, namely Session A to Session K, had been carried out.(see Figure 2) In each session, more than 2 hours continious and simultanious GPS obsevation had been conducted in the 1st observation session, and the 2nd observation session had been continued in not less than 5 (five) hours interval after the 1st session.

The quality of GPS observation had been examined by confirming the misclosure of the circumference vectors of one or combined two sessions as shown in Figure 3. Both the misclosure (accuracy) and the reproducibility between two successive observation sessions had been kept within the order of one part per 10 (ten) millions against total travelling distance (Table 1).

27 (twentyseven) GPS Stations were linked in elevation with Bench Marks.

It is worth mentionning that ;

a) The hemisphere metal marker of Tidal Observation Station in Chittagong had been occupied by GPS Antenna in the observation session so that the geographical coordinate of the Station can be determined. In other words, total numbers of GPS observation stations in Phase III could be counted as 81 (eightyone) .
b) On the 2nd, 3rd and 4th of February, 1994, a series of joint GPS observations had been conducted with Geographical Survey Institute (GSI) and JICA Study Team at the Tsukuba GPS Orbits Monitoring Station and the National Geodetic Datum Station (303) to link the GPS Network in this project with the World Geodetic Frame.

II. The 1st Order Levelling for 730 km (Figure 4)

8 (eight) levelling parties equipped with WILD NA3000 Automatic High Precission Levels with Bar–Code Invar Staves, in cooperation with SOB counterpart personnel, had been deployed in the western of the project area to conduct the 1st order levelling for the Phase III Study.

The planned 730 km level run had been completed successfuly, and further , we could succeed to conduct the 1st order levelling in length of 32 km to link and to construct the loop at Sunamganj area, where the JICA Preliminary Study Mission for this project in 1991 had found inaccessible or infeasible to make levelling survey due to the swampy terrestrial condition of the area. Thus, the total levelling run in the Phase III had reached to 762 km .

6 (six) spans of river cross levelling on Megna River at Daudkandi site, Padma River at Aricha site, Karnafuli River Mouth at Chittagong site and Jamuna River at Sirajgandi site (3 spans) had been conducted successfuly by means of Tilting Screw Method.
At each station of opposite river banks, a pair of WILD N–3's mounted on a tripod and a pair of vertically aligned targets had been installed.
4 (four) sessions, each consisting of 20 sets of observation, of continuous and simultaneous observations had been conducted on symmetrical time against noon in 2 consecutive days.

The quality control of levelling had been examined by confirming the descripancies of double run levelling between adjacent B.M. and final misclosure of the loop of 613.28 km was found as 3.4 mm only, which was 1/29th of the tolerance of ± 4 mm$\cdot\sqrt{S}$. (Figure 5)

III. Tidal observation and reconstruction of auxiliary tide pole and auxiliary tide gauge station with protection works

On arrival of the JICA Study Team to Dhaka on 13/10/93, we were informed unexpectedly, that the Auxiliary Tide Gauge Pile at Patenga Beach in Chittagong had been destroyed by a strong force, which might be caused by unknowen floating vessel at night, in the middle of August 1993.
JICA HQ had approved to reconstruct both the auxiliary tide pole and the auxiliary tide gauge station with protection piles. Consequently, reconstruction had commenced on 01/11/93 and completed on 29/11/93 and the tide gauge had been installed to the auxiliary tide gauge station on 18/11/93 to continue the tidal observation.

However the recording of this pressure sensing type tide gauge is somewhat unstable since reinstallment. We could only assumed that this capricious unstability on this precise electronic instrument might be caused by the aftereffect of the strong shock when the previous tide gauge pile had been broken in August 1993.

To continue the tidal observation at this important point, where it is directly located in the Bay of Bengal, the replacement CD ROM, in which operating software is installed, and one back-up tide gauge had been brought by Mr.A.Hanatani, JICA HQ's Officer in Charge, on 02/02/94 and they were installed onto the tide gauge station.

Necessary operating and maintenance instructions had given to the SOB counterpart officials by the Coastal Engineer of the Team for both the Tidal Observation Station and the Auxiliary Tide Gauge Station.

IV. Reconnaissance for Local Geoidal Undulation Control Station

The study, to plan how and which GPS stations shall be linked with the 1st order levelling network in Phase IV Study, had been conducted during this field work.

V. Adjustment and Analysis of the Field Data

Adjustment and analysis for all the above field work will be carried out in Japan in February/March 1994.

VI. Unveiling Ceremony of the National Geodetic Datum Yard

Unveiling Ceremony of the National Geodetic Datum Yard at Gulshan Tank Yard had been held successfuly and prosperously on 05/02/94, under the Chairmanship by Mr. Akhtar Hussain Kahn, Joint Secretary of Defence Ministry.

Surveyor General of Bangladesh, Brig. Md.Mahbubul Karim and the JICA Study Team Leader, Dr. Minoru Tajima had jointly invited as the Chief Guests, His Excellency Ambassador of Japan in Bangladesh and Honourable Secretary of Ministry of Defence, Mr.M. Hasinur Rahman.

Participants of the Ceremony from various organizations and agencies were counted at approximately 170.

VII. The Programme of the Phase IV Study

The JICA Study Team shall commence the Phase IV Study from October 1994, to conduct the last and remainning 1st order levelling survey of approximate 1,550 km in length and levelling survey for the geoidal control.

A Coastal Engineer may be dispatched in June or July 1994 temporarily to conduct tidal observation and instruction.

One day's Seminar may be held in March 1995 on the fundamental geodesy, GPS theory, mapping and on the Study.

****

On concluding this report, on behalf of JICA Study Team, I wish express my sincere thanks to you, your staff and counterpart officials those have assisted the project implementation and I am convinced that with the same cooperation and collaboration from you, that our fourth and final Phase will be a success as this Phase III has been.

Shigehiko Shino
Deputy Team Leader
JICA Study Team

Received and acknowledged

20.2-94

Brig.Md. Mahbubul Karim
Surveyor General
Survey of Bangladesh

cc: MoD
ERD
Embassy
JICA

Figure 1

Distribution Map of Control Station

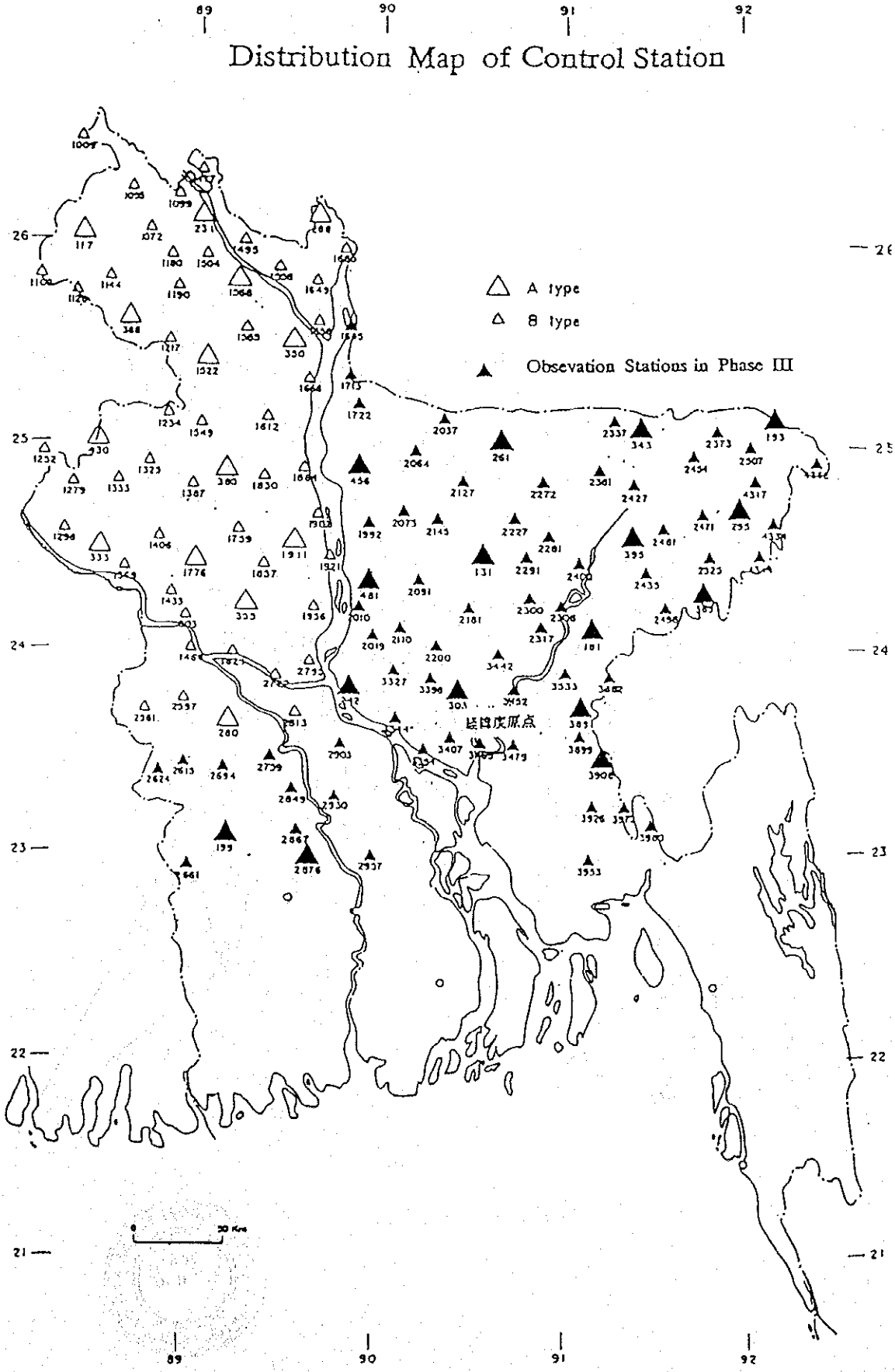


Figure 2

GPS OBSERVATION NETWORK

Session Diagram

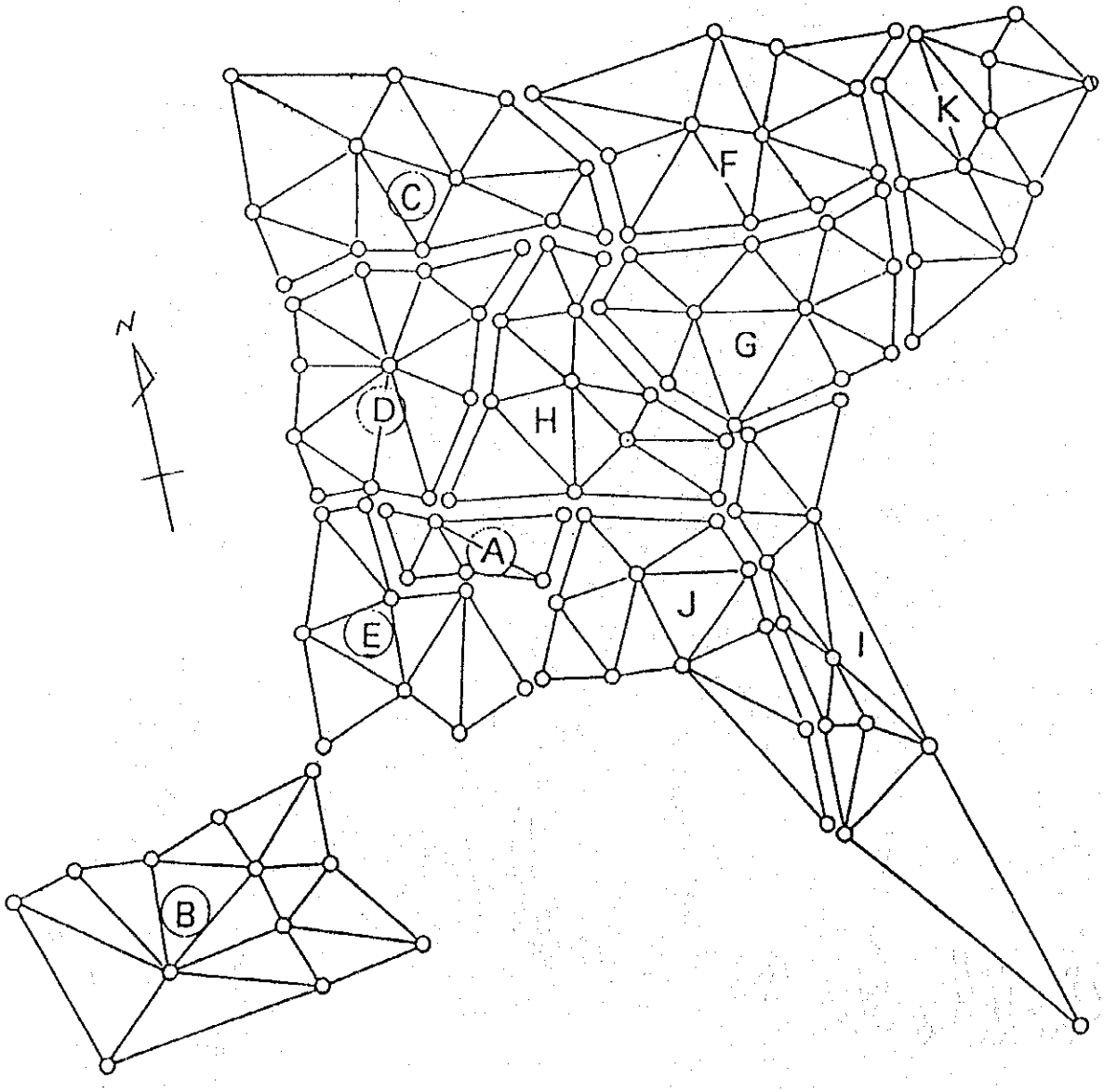


Figure 3

Index Map of GPS Observation

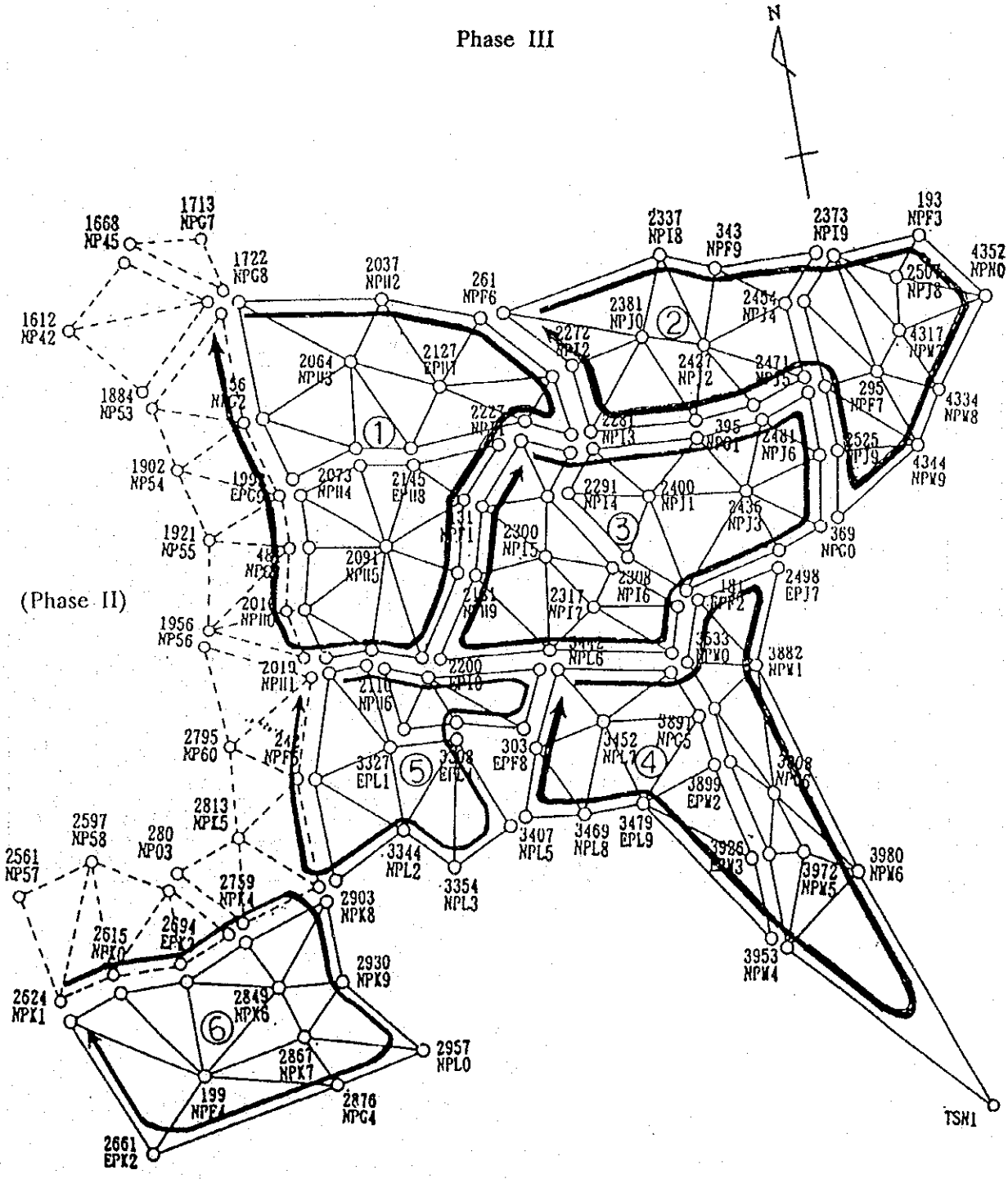


Table 1

Quality Control Sheet

Closure of GPSNET

Section	Day-wise	Latitude difference	Longitude difference	Distance travelled	Height difference	△x	△y	△z	△s	Precision (ppm)
1	1	+0.00383	+0.00652	406437.892 m	-0.107 m	-0.183 m	-0.147 m	+0.061 m	0.243 m	0.60
	2	+0.00251	+0.00403	.904	+0.007	-0.113	-0.026	+0.073	0.137	0.34
difference				-0.012	-0.114					+0.26
2	1	-0.00051	-0.00087	471807.527	+0.029	+0.024	+0.033	-0.002	0.041	0.09
	2	+0.00075	-0.00310	.590	-0.014	+0.087	-0.022	+0.015	0.091	0.19
difference				-0.063	+0.043					-0.10
3	1	-0.00109	-0.00052	395194.597	-0.028	+0.015	-0.011	-0.042	0.046	0.12
	2	+0.00019	-0.00022	.582	-0.066	+0.007	-0.062	-0.022	0.066	0.17
difference				+0.015	+0.038					-0.05
4	1	-0.00064	+0.00295	619776.568	+0.034	-0.084	+0.038	-0.004	0.092	0.15
	2	+0.00001	+0.00203	.559	0.043	0.057	0.040	0.017	0.072	0.12
difference				+0.009	+0.077					+0.03
5	1	+0.00120	0.00014	285860.482	+0.015	+0.004	-0.001	+0.040	0.040	0.14
	2	-0.00008	+0.00266	.449	+0.013	-0.075	+0.013	+0.003	0.076	0.27
difference				+0.033	+0.002					-0.13
6	1	-0.00038	+0.00010	314065.283	-0.224	-0.007	-0.201	-0.100	0.225	0.72
	2	-0.00046	+0.00056	.259	-0.123	-0.018	-0.107	-0.062	0.125	0.40
difference				+0.024	-0.101					+0.32

Figure 4

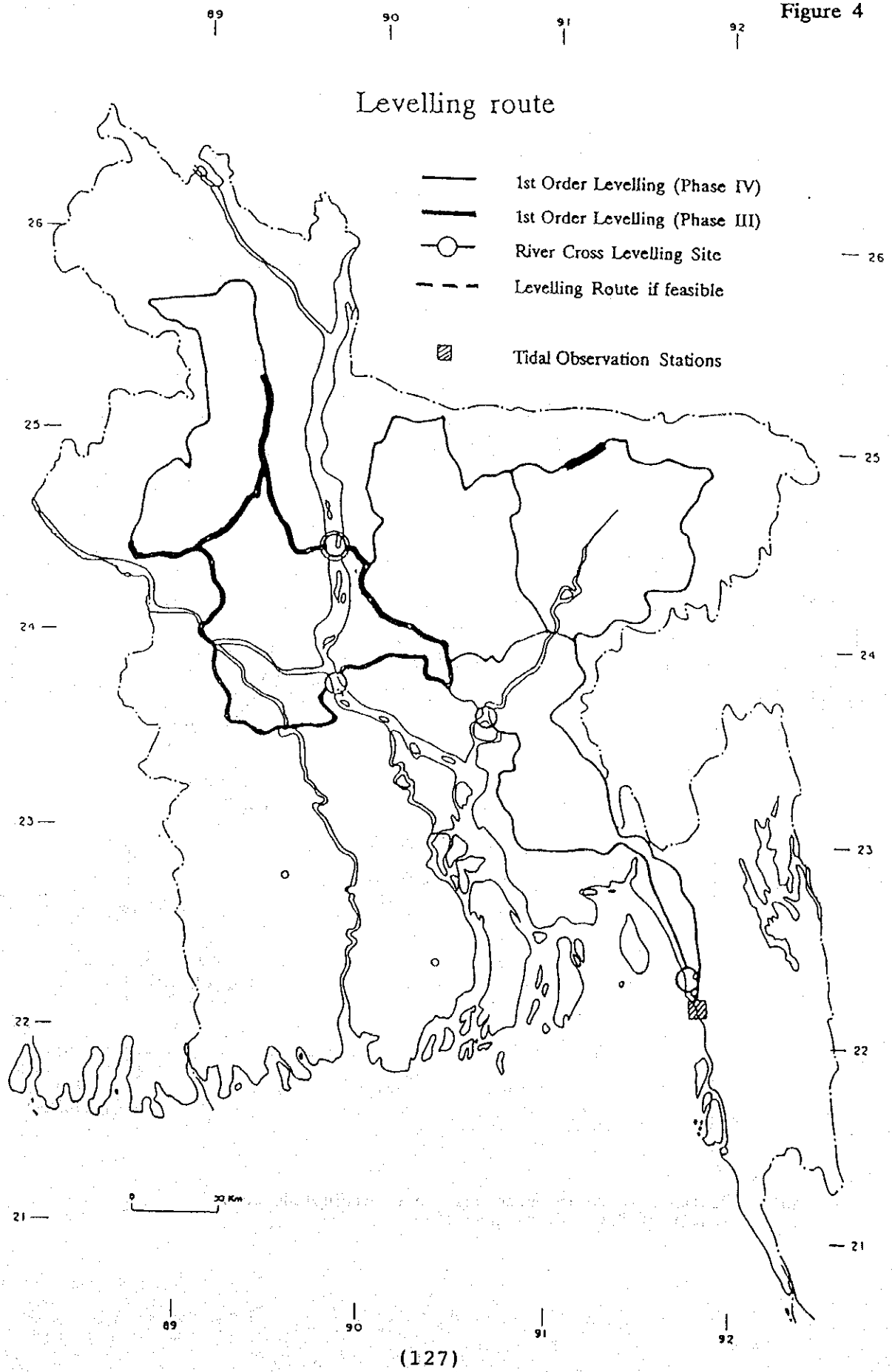
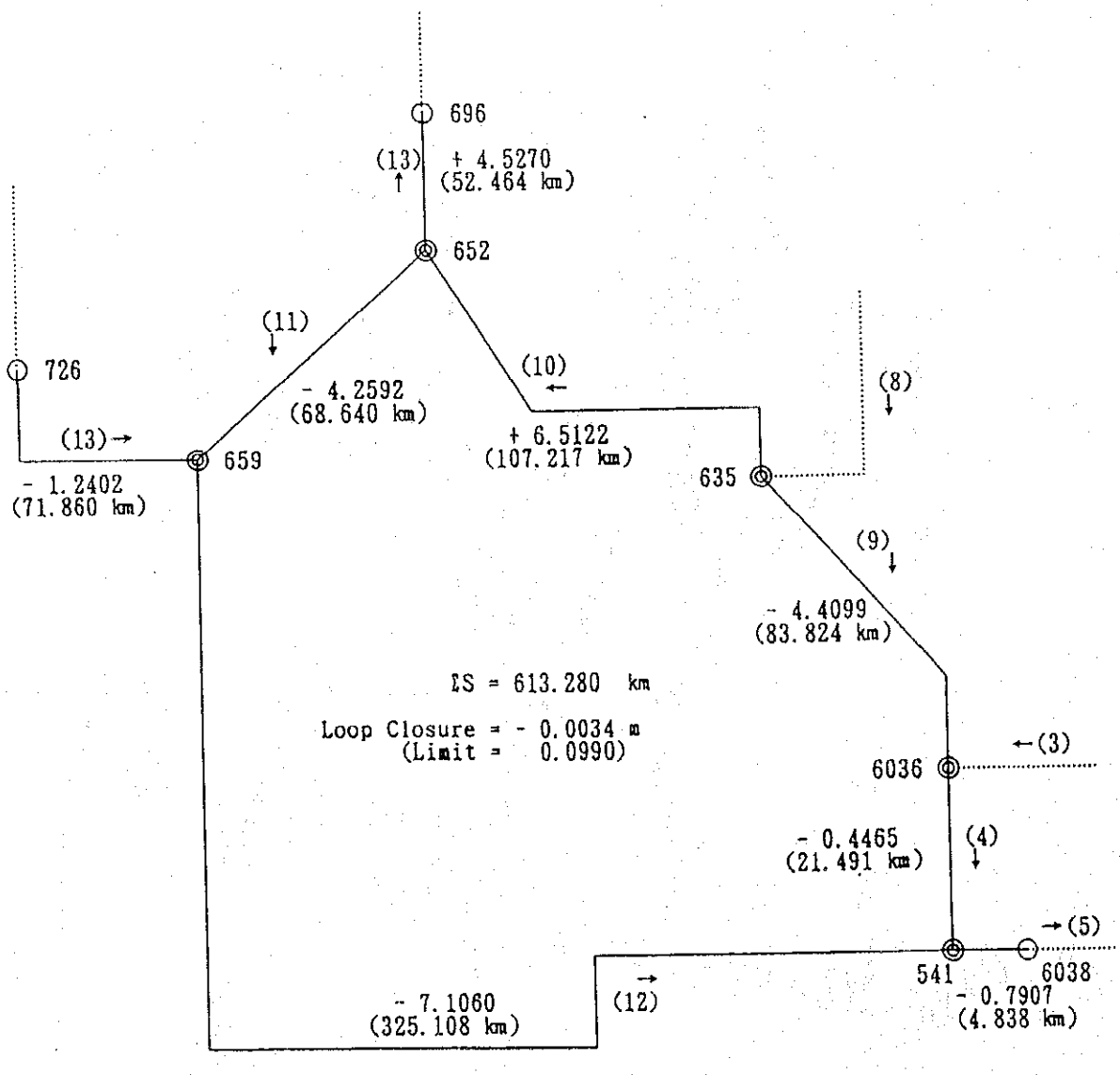

Levelling route
1st Order Levelling (Phase IV)
1st Order Levelling (Phase III)
River Cross Levelling Site
Levelling Route if feasible
Tidal Observation Stations
89
90
91
92
26
25
24
23
22
21
0
30 Km

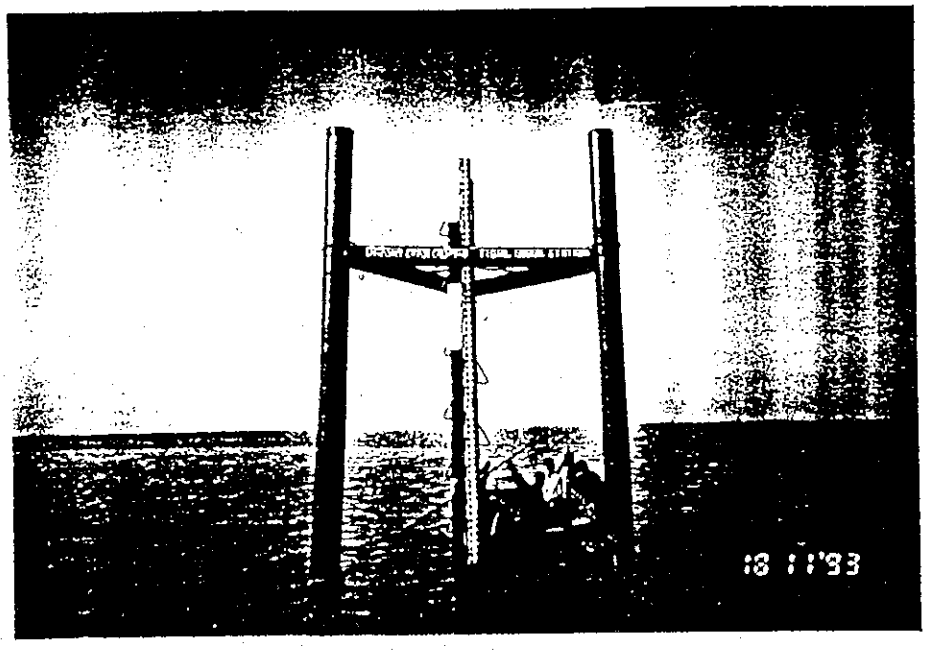
Figure 5

10/2/1994

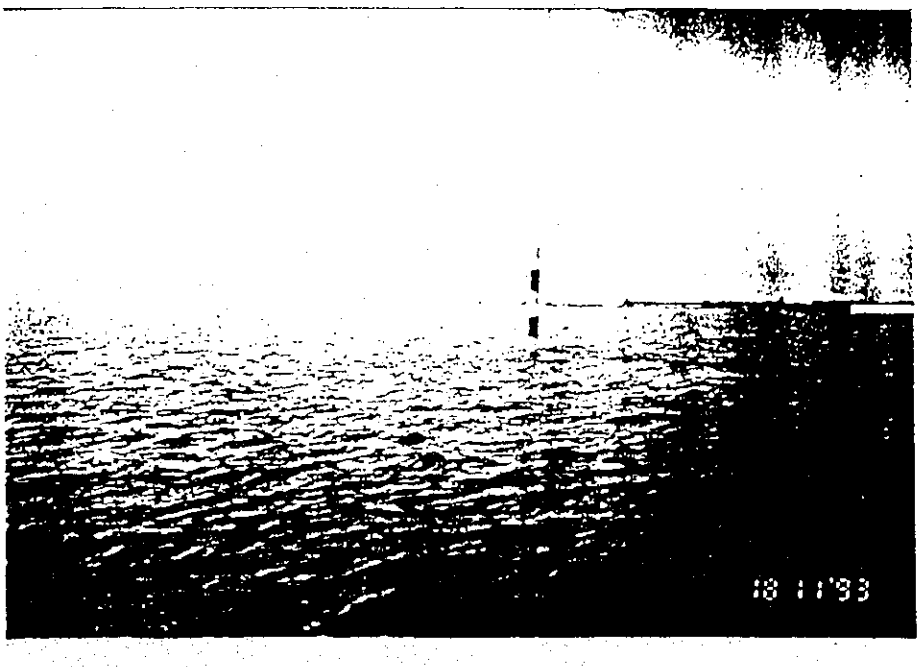
Diaglam of Closure of
1st Order Levelling Loop



Note : Distance shown in parenthesis are not include span length of River Cross Levelling



Reconstructed Auxiliary Tide Gauge Station



Reconstructed Auxiliary Tide Pole

付録－８

第４年次調査作業計画書（Ｐ／Ｏ）提出(1994. 9.28)

28 September, 1994

To : Surveyor General
Survey of Bangladesh

From: Leader
JICA Study Team

Subject : Plan of Operation for the Phase IV Study

Sir,

The JICA Study Team arrived in Dhaka on 7 September, 1994, to undertake the Phase IV field work of "the Study on the Geodetic Survey in the People's Republic of Bangladesh" (the Study) and submitted 5 (five) copies of the Plan of Operation (P/O) for this Phase to the Survey of Bangladesh (SOB).

Following the explanation of the contents of P/O by the JICA Study Team, a series of discussions were held on P/O between SOB and the JICA Study Team.

Please find attached "Plan of Operation" dated 28 September, 1994 for your acceptance.

Sincerely yours,

Minoru Tajima

Minoru Tajima,PhD.
Leader
JICA Study Team

Received and acknowledged
for further study,

28.9.94

Md.Mahbubul Karim,Brig.
Surveyor General
Survey of Bangladesh

Attachment: Plan of Operation for the Phase IV Study

c.c. Secretary, Ministry of Defence, Dhaka

Secretary, Economic Relations Division

Ministry of Finance, Dhaka

Embassy of Japan, Dhaka

JICA Bangladesh Office, Dhaka

PLAN OF OPERATION

FOR

THE STUDY ON THE GEODETIC SURVEY

IN

THE PEOPLE'S REPUBLIC OF BANGLADESH

PHASE IV

(JULY 1994 – MARCH 1995)

28 SEPTEMBER, 1994

JAPAN INTERNATIONAL COOPERATION AGENCY

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PLAN OF OPERATION FOR THE PHASE IV STUDY

I. INTRODUCTION

Following the successful implementation of Phases I, II and III of "The Study on the Geodetic Survey in the People's Republic of Bangladesh" (hereinafter referred to as "the Study"), the Japan International Cooperation Agency (hereinafter referred to as "JICA") will dispatch a Study Team, headed by Dr. Minoru Tajima, to Bangladesh from September 1994 to January 1995 to conduct the fourth and final phase of field work.

This Plan of Operation (hereinafter referred to as P/O) will describe the implementation plan for the Phase IV (the 4th Fiscal Year) Study.

The Study shall be carried out according to this P/O.
Survey of Bangladesh (hereinafter referred to as "SOB") and the JICA Study Team shall cooperate each other in the course of the Study.

II. IMPLEMENTATION PLAN FOR THE PHASE IV STUDY

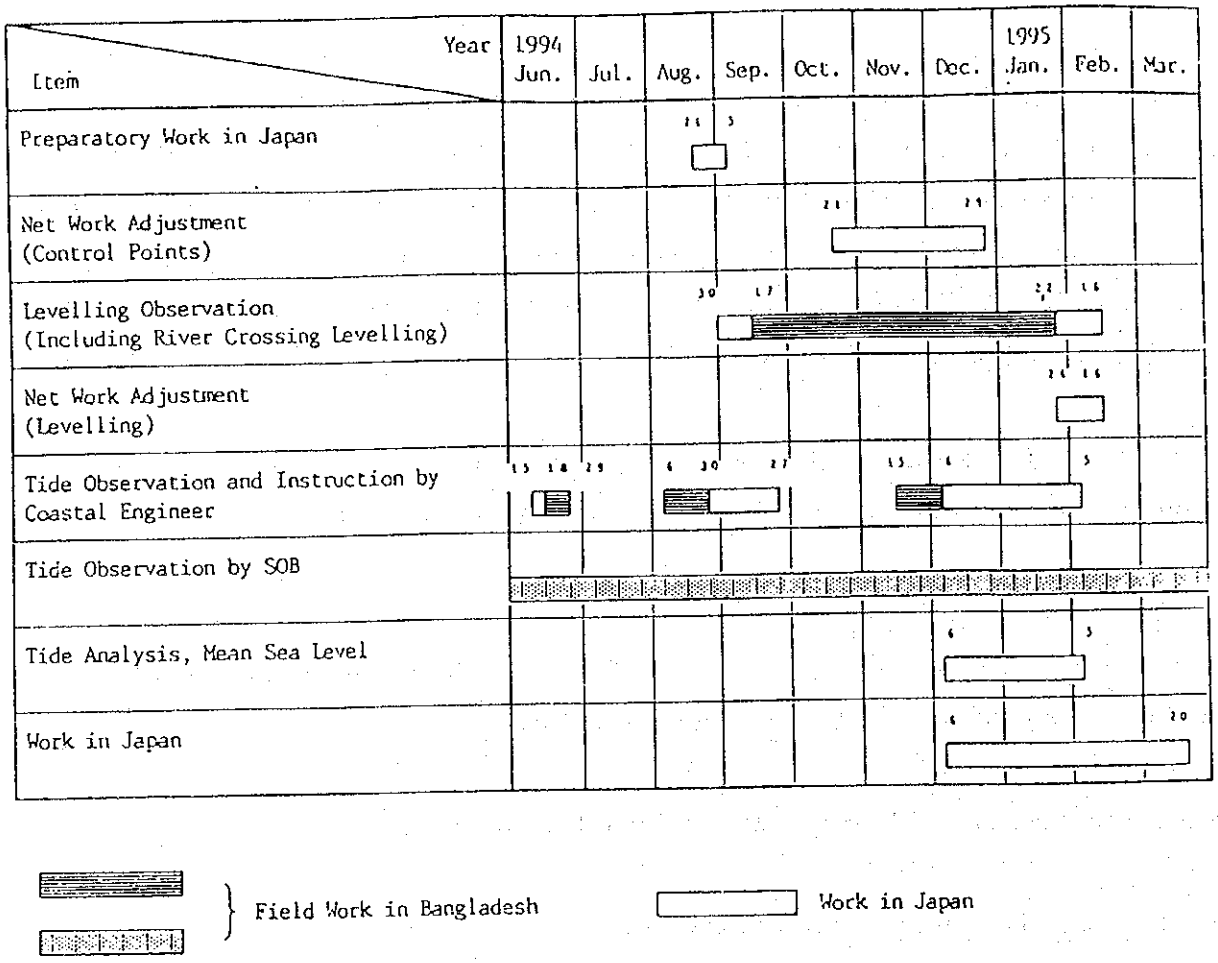
1. The Phase IV Field Work in Bangladesh

The following three categories of field work shall be conducted in this Phase IV Study ;

1) 1st order levelling of 1,550 kilometers linear distance
2) Linking orthometric height of GPS stations with 1st order levelling network to generate local geoid model.
3) Tidal observation at Karnafuli River-mouth Station and Patenga Beach Foreshore Auxiliary Station, and
4) GPS observation on the National Geodetic Datum Station.

The Study Schedule and the Assignment Schedule of the JICA Study Team are shown in page 3 and 4 respectively.

THE STUDY SCHEDULE (Phase IV)



THE LIST AND ASSIGNMENT SCHEDULE OF THE STUDY TEAM (Phase IV)

Names	Assignment	1994 Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	1995 Jan.	Feb.
Headquarters										
Minoru TAJIMA	Leader				24—5				6—13	
Shigehiko SHINO	Deputy Leader				7———	———	———	———	———22	
Yoshio SASAKI	Planner				7———	———	———	———	———22	
Hironori Kobayashi	Mechanic				7———	———	———	———	———22	
Naomi HIRAHARA	Coordinator				7—14				5—22	
1st Order Levelling										
Masanori TESHIMA	Chief Surveyor				17———	———	———	———	———22	
Takashi ITO	Surveyor				20———	———	———	———	———13	
Takashi HARADA	Surveyor				20———	———	———	———	———13	
Yoichi KOJIMA	Surveyor				20———	———	———	———	———13	
Sachio TAZUKI	Surveyor				20———	———	———	———	———13	
Kentaro USUDA	Surveyor				20———	———	———	———	———13	
Takashi KITANI	Surveyor				20———	———	———	———	———13	
Yasuyuki NAKAMISE	Surveyor				20———	———	———	———	———13	
Akio KOSUGI	Surveyor				20———	———	———	———	———13	
Kazuo KODAMA	Surveyor				20———	———	———	———	———13	
Yoshihiro KAMADA	Surveyor				20———	———	———	———	———13	
Masayuki YOKOI	Surveyor				20———	———	———	———	———13	
Kaoru FUJITA	Surveyor				20———	———	———	———	———13	
Satoshi OSADA	Surveyor				20———	———	———	———	———13	
Yoshihiro FURUTA	Surveyor				20———	———	———	———	———13	
Tidal Observation										
Shigeru MIYAMURA	Coastal Engineer	18—29			5——30			13—16		

2. The Phase IV Study in Japan

The field data, collected during Phase II through IV, shall be analyzed, processed, adjusted and examined in Japan by the end of March 1995.

III. DETAILS OF THE PHASE IV FIELD WORK

1. The First Order Levelling

1st order levelling for the remaining 1,550 kilometers linear distance shall be conducted at the north-western end and eastern part of the project area as shown in "Figure 1".

14 (fourteen) levelling parties, equipped with WILD N3s and NA3003s with invar staves, shall be deployed to the area.

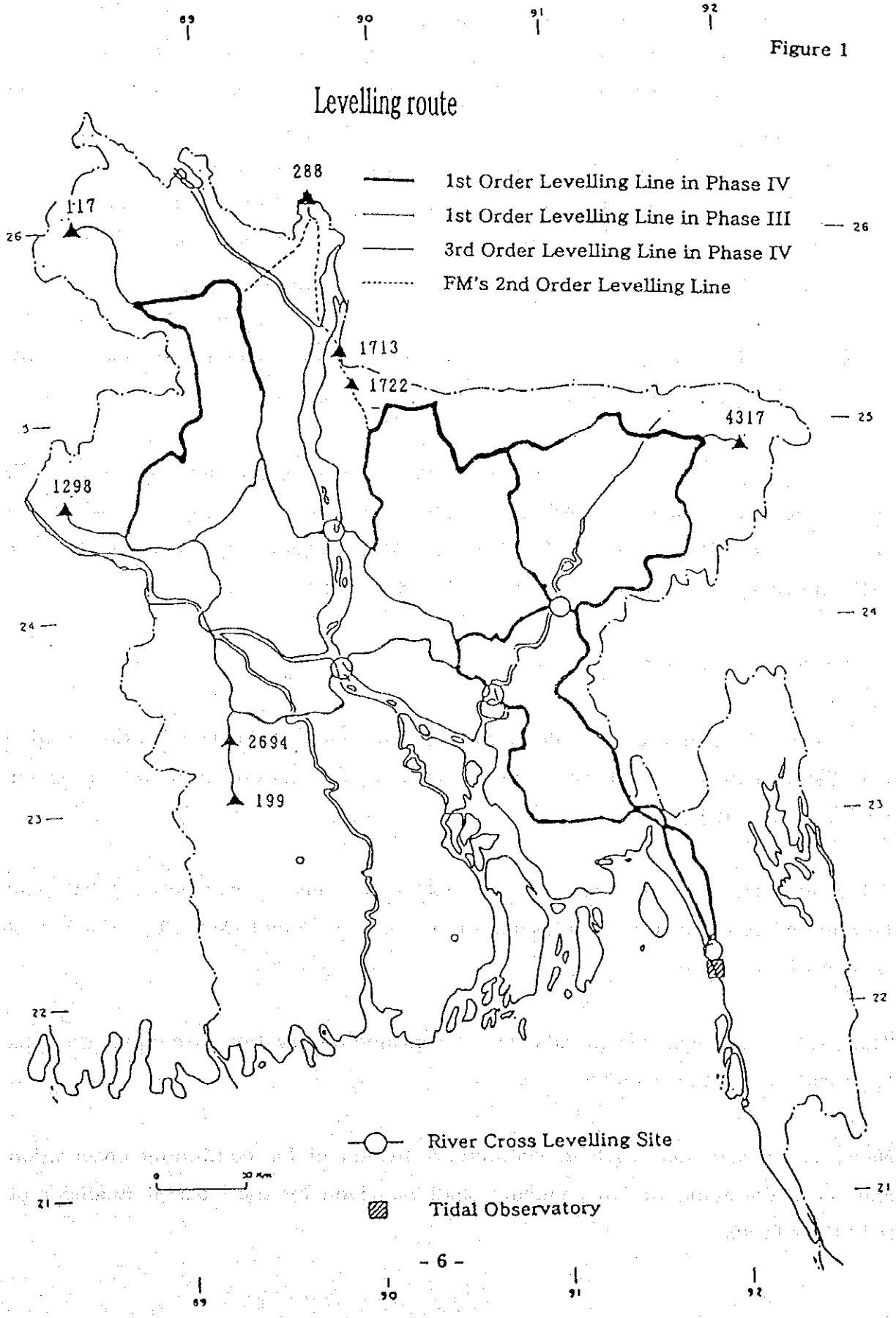
River crossing levelling at the ferry site of Bairab Bazar railway bridge and levelling on the railway bridge near Kaliganj on Lakhya River will be conducted during the first half of this Phase.

The closing error of the double runs and loops shall be maintained within 4 mm times square root of S (4 mm x $\sqrt{S}$). (Note: S means level run in km.)

2. Linking of Orthometric Height of GPS Stations with the 1st Order B.M.s.

To provide orthometric height to all GPS stations with a certain degree of accuracy, 51 (fifty-one) GPS stations among a total of 140 (one hundred forty) GPS stations shall be linked with the 1st order levelling network, either included in the 1st order level line or extended from the B.M.s by means of direct levelling of the 3rd order (closure is 10 mm x $\sqrt{S}$).
These 51 GPS stations as listed below are indicated in "Figure 2" with a blackened triangle symbol.

Figure 1


Levelling route
1st Order Levelling Line in Phase IV
1st Order Levelling Line in Phase III
3rd Order Levelling Line in Phase IV
FM's 2nd Order Levelling Line
River Cross Levelling Site
Tidal Observatory
288
117
1713
1722
4317
1298
2694
199
69
90
91
92
26
25
24
23
22
21

a: GPS stations included in the 1st order level line;

343, 388, 481, 1217, 1549, 1585, 1612, 1759, 1776, 1830, 2037, 2110, 2127, 2200, 2227, 2291, 2300, 2454, 2498, 2759, 2903, 3398, 3891, 3899 and 3972. Sub total: 25 stations.

b: GPS stations extended from B.M. by the 3rd order levelling;

117, 181, 199, 242, 280, 288, 303, 369, 1298, 1369, 1387, 1468, 1568, 1713, 1722, 1911, 1921, 1992, 2317, 2525, 2694, 3327, 3442, 3479, 3908 and 4317. Sub total: 26 stations.

Total: 51 stations.

Note; Underlined stations shall be surveyed in the Phase IV and the rest had been surveyed in the Phase II and III Study.

Using orthometric heights of these 51 stations, which is obtained by direct levelling, and ellipsoidal heights of all 140 stations, which is obtained by GPS solutions, Local Geoid Model shall be generated to give orthometric heights onto the remaining 89 GPS stations.

3. Tidal Observation

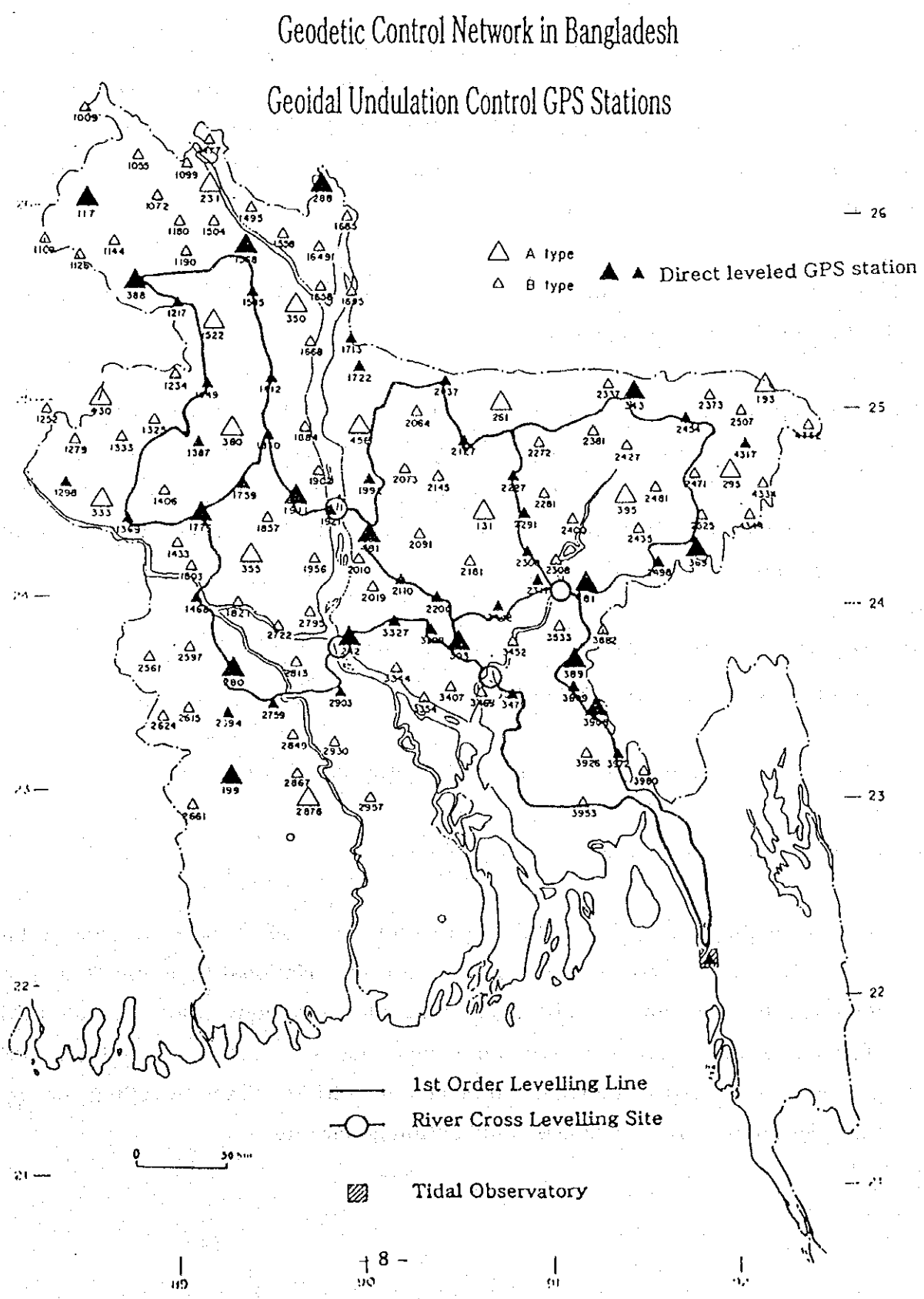
Tidal observation at the Karnafuli Rivermouth Tidal Observation Station and Patenga Beach foreshore Auxiliary Tide Gauge Station, both in Chittagong, shall be continued.

All valid data, collected from January 1993 to the end of November 1994, shall be adopted as the source to determine the Mean Sea Level (M.S.L.) at the Bay of Bengal (Bangladesh).

The JICA Study Team recomends SOB to continue observation to monitor the long term variation of the sea level.

Necessary instructions to SOB counterpart personnel for continuing observation and for maintaining the instruments shall be given by the Coastal Engineer of the Study Team.

Figure 2


Geodetic Control Network in Bangladesh
Geoidal Undulation Control GPS Stations
A type
B type
Direct leveled GPS station
1st Order Levelling Line
River Cross Levelling Site
Tidal Observatory
26
25
24
23
22
21
0
50 km

4. GPS Observation on the National Geodetic Datum Station and TSUKUBA VLBI

To determine accurate absolute geodetic coordinate of National Geodetic Datum in Gulshan, simultaneous GPS observation shall be conducted by the Team at Gulshan Station and at TSUKUBA VLBI (offset GPS station), which is one of the official monitoring station of the International Earth Rotation Service Terrestrial Reference Frame (ITRF).

GPS observation on both stations shall consist of 7 consecutive sessions, each shall continue 24 hours observation.

Note: Similar operations had been conducted on Jan. 1993 and on Feb. 1994, but both observations were 3 sessions with 3 hours continuous observation. Recent scientific experiences and experiments proved that 24 hours continuous observation is a must, for very accurate geodetic coordinate determination.

IV. DETAILS OF THE PHASE IV STUDY IN JAPAN
(Data Processing, Adjustment and Analysis)

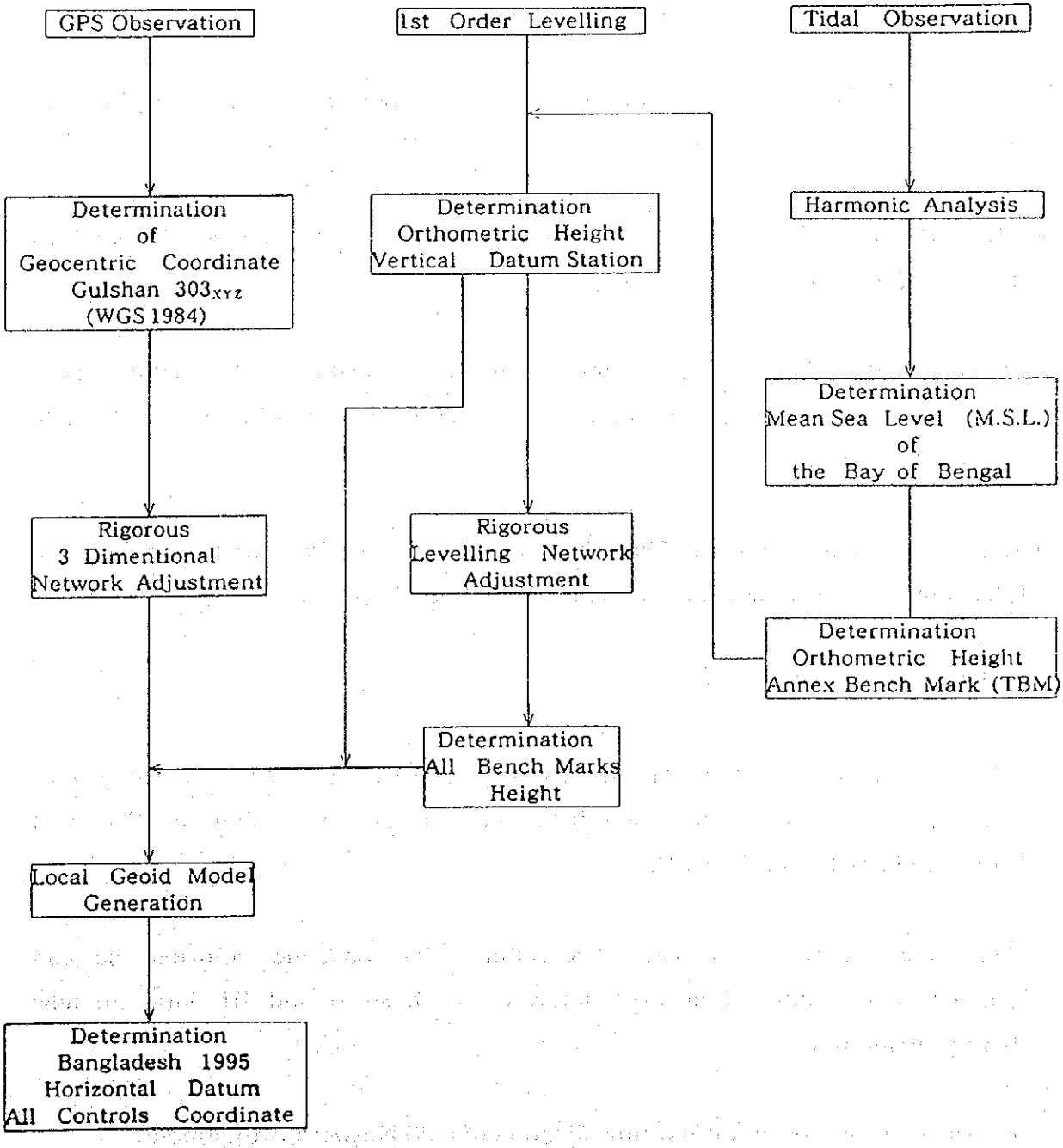
1. General Concept for Establishing the Geodetic Control Network

General concept flow diagram is shown in Figure 3.

All observation data, i.e., GPS observation, 1st order levelling and tidal observation are linked together to determine the National Geodetic Datum of Bangladesh, horizontal coordinates (latitude and longitude) of all GPS stations, orthometric heights of all bench marks in 1st order and all GPS station's orthometric heights, obtained by either direct levelling or by the interpolation from local geoid undulation generation.

Figure 3

Concept Flow Diagram; Geodetic Control Network in Bangladesh



2. Determination of National Geodetic Datum

(a) All published coordinates of existing control stations in the GPS Network shall be analyzed, evaluated and adjusted on the WGS 84 Ellipsoid.
(WGS 84 Ellipsoid ; See Appendix 1, 2 and 3.)

(b) The best fitting transformation from WGS 84 Coordinate System to Everest 1830 Coordinate System shall be solved.

(c) Obtained coordinate at Station No.303 shall be adopted as Bangladesh Horizontal Datum.

(d) Final results of all GPS stations shall be described with Everest 1830 coordinates (Published Coordinates) and WGS 84 coordinates on Control Station Pamphlets.

(e) Datum Shift Parameter and Transformation Parameter from WGS 84 to Everest 1830 shall be determined and supplied in the Final Report.

3. GPS Network Adjustment

The quality of GPS observation has been proved by examining the vector closures of baselines, each sessions and session to session, at the field work in Phase II and Phase III.

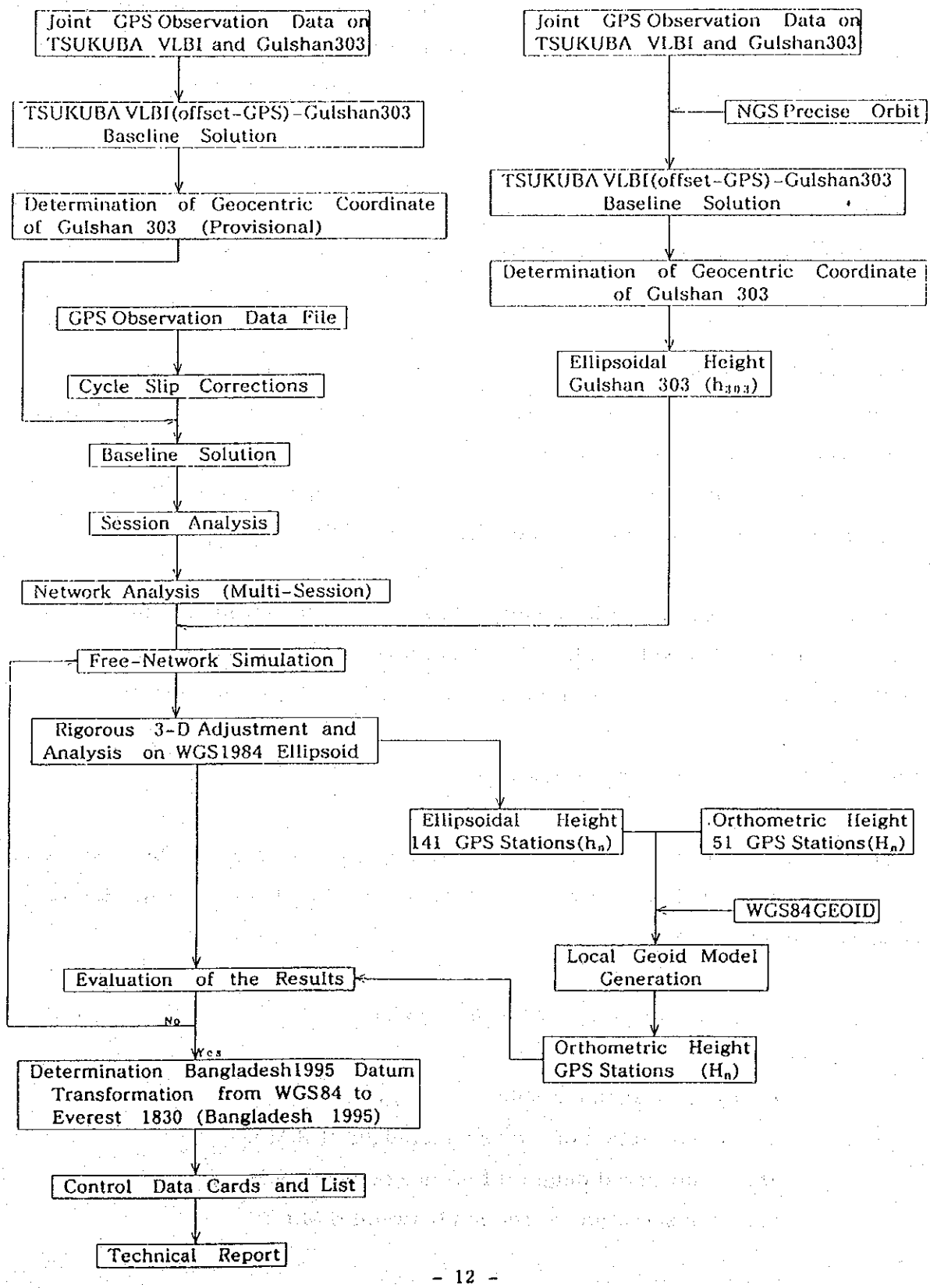
The post processing of the observation data, baseline solution, session analysis and combined network analysis of Phase II and III data are now being carried out.

Figure 4 shows the simplified flow diagram of GPS Network Adjustment.

Geocentric Coordinate of National Geodetic Datum Station (Gulshan 303) shall be determined by means of very long baseline solution between TSUKUBA VLBI (offset GPS) and Gulshan 303.

Figure 4

Flow Diagram: GPS Network Adjustment



7 day continuos GPS observation data shall be adopted for this analysis and absolute coordinate value of Gulshan Datum Station shall be determined in ITRF 92 Reference Ellipsoid, and then transformed to WGS 84 Ellipsoid, in collaboration with Geographical Survey Institute, Tsukuba, Japan, and with the international community of the International Terrestrial Reference System (ITRS).

Rigorous 3 dimensional simultaneous adjustment of the entire network on WGS 84 ellipsoid shall be exercised with different approaches to determihe the best solution.

Viewing the importance of the elevation (orthometric height) for the development and the conservation of the country, JICA Study Team shall give elevation data on all GPS stations.
The decimal unit of the elevation on final records and list shall be classified as follows to represent the degree of reliability.

GPS Stations, on the 1st order levelling line: 0.0001 m (10^{-4}m)
GPS Stations, linked with B.M. by 3rd order levelling: 0.001 m (10^{-3}m)
GPS Stations, interpolated from Local Geoid Model: 0.1 m (10^{-1}m)

3. 1st Order Levelling Network Adjustment

The entire levelling network shall be adjusted rigorously by the least square method, weighted by the reciprocal of the distance, with following observation equation:

$$v_{ij} = -x_i + x_j - (h_i - h_j + \Delta h_{ij})$$

where

h_i, h_j : provisional height of B.M.*i*, *j*
x_i, x_j : correction of provisional height of B.M.*i*, *j*
Δh_{ij} : observed height difference between B.M.*i*, *j*
v_{ij} : observation correction between B.M.*i*, *j*

The given point, for the simultaneous network adjustment, is Annexed Bench Mark (TBM) at the Chittagong Tidal Observatory.
Orthometric height of TBM shall be determined from the Mean Sea Level (MSL) of the Bay of Bengal (in the territorial water of Bangladesh), by the Harmonic Analysis adopting all valid tide observation data collected from January 1993 to the end of November 1994.

Ellipsoidal correction, in respect of latitude, shall be applied simultaneously.

4. Tide Analysis

The Harmonic Tidal Analysis shall be executed based on all the valid tide observation data collected by Fuess Type Tide Gauge of the Tidal Observation Station at Karnafli River mouth, to determine the Mean Sea Level (MSL) of the Bay of Bengal.

Although some vacancy of the data exist, tide observation data, collected by the pressure sensing tide gauge of the Auxiliary Tide Gauge Station at the foreshore of Patenga Beach, Chittagong, shall be analyzed to study the correlation between both sets of data.

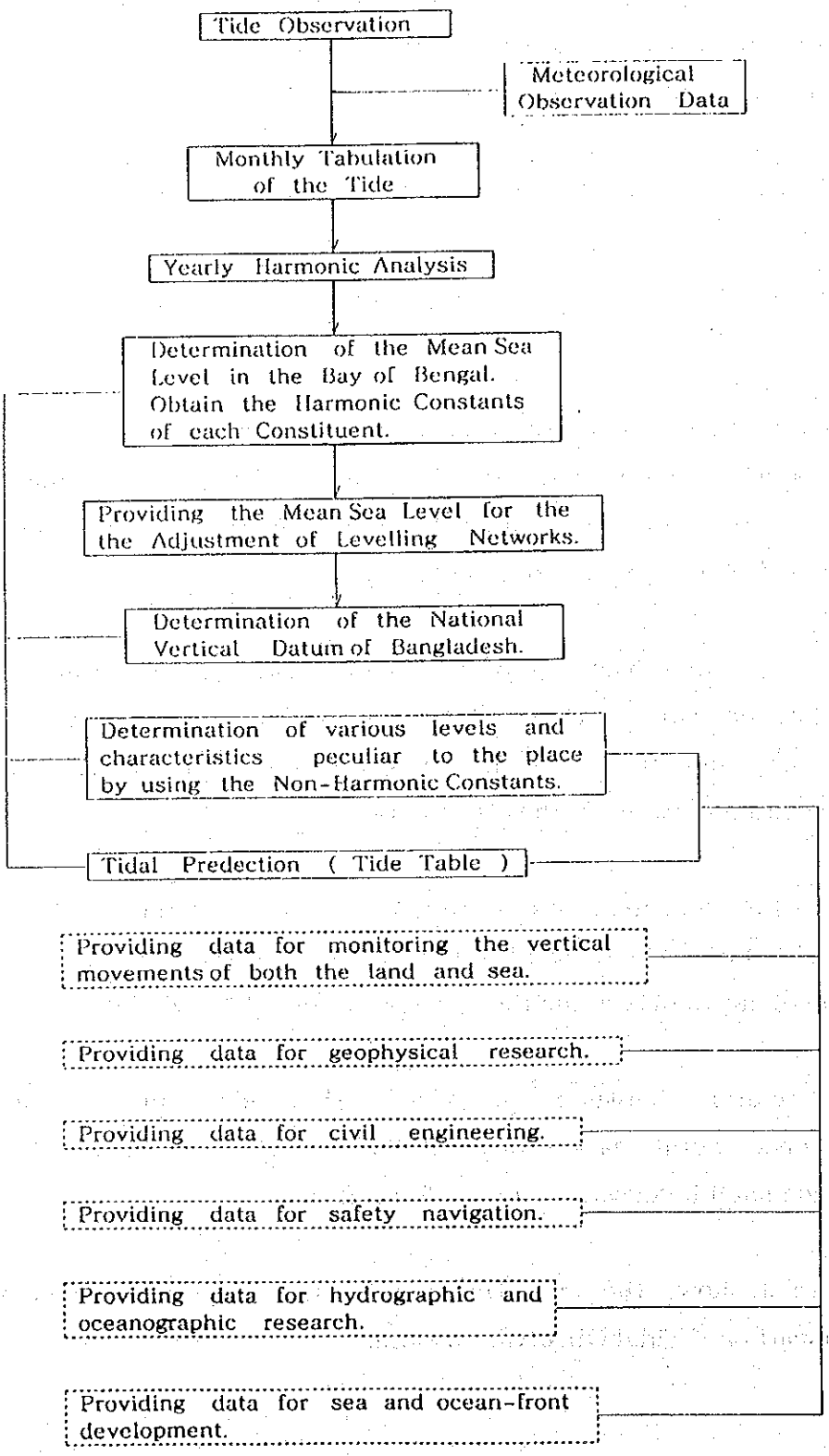
After the determination of the M.S.L., the orthometric height of Annexed Bench Mark (TBM) shall be decided for the 1st order levelling network adjustment to determine the Vertical Datum of Bangladesh.

The relation between the M.S.L., the index line of Tide Gauge, the reference metal marker of tidal Station, TBM and Gulshan Vertical Datum Station shall be described in the Final Report.

Figure 5 shows the Flow Diagram for the Determination of M.S.L. and the Application of Tidal Observation Data.

Figure 5.

Flow Diagram for the Determination of M.S.L. and the application of Tidal Observation Data



V. REPORT AND FINAL RESULTS

1. The Monthly Progress Report on the field study in Bangladesh shall be submitted by the Team Leader (Deputy) to the Surveyor General.

2. The final output of the Study is as follows:

(1) Geodetic Control Survey

1) Tables of control points, 3 sets
2) Descriptions of control points, 3 sets
3) Index map of control points, 3 sheets
4) Monuments of control points
5) Ornament of horizontal datum station

(2) Levelling

1) Tables of 1st order levelling bench marks, 3 sets
2) Descriptions of bench marks, 3 sets
3) Route map of levelling, 3 sets
4) Network map of levelling, 3 sheets
5) Monuments of 1st order levelling

(3) Determination of Mean Sea Level

1) Documents on determination of mean sea level, 3sets
2) Monument of Vertical Datum at Dhaka
3) Annex Bench Mark close to tidal observation station at Chittagong
4) Tidal Observation Station

(4) Final Report, 80 sets

WGS84 Ellipsoid
- Four Definitive Parameters -

Parameters	Notation	Magnitude	Accuracy (1σ)
Semimajor Axis	a	6378137 m	±2 m
Normalized Second Degree Zonal Harmonic Coefficient of the Gravitational Potential	$\bar{C}_{20}$	$-484.16685 \times 10^{-6}$	$+1.30 \times 10^{-9}$
Angular Velocity of the Earth	ω	7292115×10^{-11} rad s^{-1}	$\pm 0.1500 \times 10^{-11}$ rad s^{-1}
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Included)	GM	3986005×10^{8} $m^3 s^{-2}$	$\pm 0.6 \times 10^{8}$ $m^3 s^{-2}$
Parameter Values for Special Applications			
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Not Included)	GM	3986001.5×10^{8} $m^3 s^{-2}$	$\pm 0.6 \times 10^{8}$ $m^3 s^{-2}$
Angular Velocity of the Earth (In a Precessing Reference Frame)	ω'	$(7292115.8533 \times 10^{-11} + 4.3 \times 10^{-15} T_0)$ rad s^{-1}	$\pm 0.1500 \times 10^{-11}$ rad s^{-1}

T_0 = Julian Centuries From Epoch J2000.0

WGS84 Ellipsoid
- Derived Geometric Constants -

Constants	Notations	Value
Flattening (Ellipcity)	f	1/298.257223563 (0.00335281066474)
Semiminor Axis	b	6356752.3142 m
First Eccentricity	e	0.0818191908426
First Eccentricity Squared	e^2	0.00669437999013
Second Eccentricity	e'	0.0820944379496
Second Eccentricity Squared	e'^2	0.00673949674227
Linnear Eccentricity	E	521854.0084 m
Polar Radius of Curvature	c	6399593.6258 m
Axis Ratio	b/a	0.996647189335
Mean Radius of Semiaxis	R_1	6371008.7714 m
Radius of Sphere With Equal Area	R_2	6371007.1809 m
Radius of Sphere With Equal Volume	R_3	6371000.7900 m

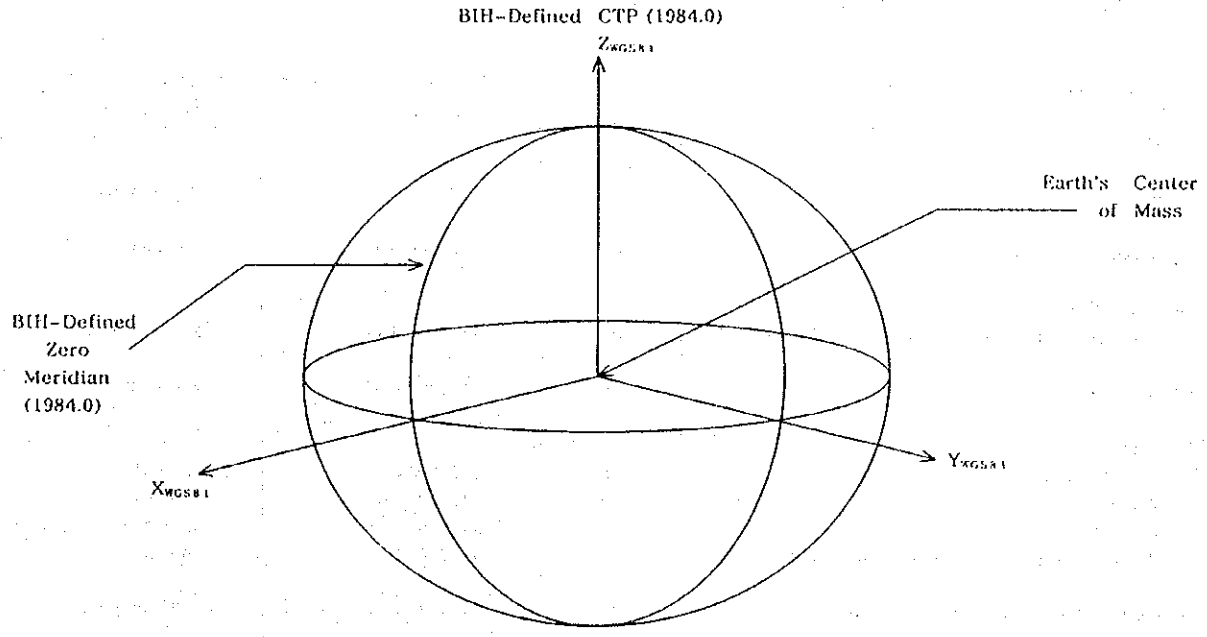
The WGS84 Coordinate System* Definition

Origin = Earth's center of mass.

Z-Axis = The direction of the Conventional Terrestrial Pole (CTP) for polar motion, as defined by the Bureau International de l'Heure (BIH) on the basis of the coordinates adopted for BIH stations.

X-Axis = Intersection of the WGS84 Reference Meridian Plane and the plane of the CTP's Equator, the Reference Meridian being the Zero Meridian defined by the BIH on the basis of the Coordinates adopted for the BIH stations.

Y-Axis = Completes a right-handed, Earth Centered, Earth Fixed (ECEF) orthogonal coordinate system, measured in the plane of the CTP Equator, 90° East of the X-Axis.



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* Analogous to the BIH Defined Conventional Terrestrial System (CTS), or BTS, 1984.0.

Table 1

ELLIPSOID CONSTANTS World Geodetic System WGS1984 and Everest 1830

Reference Ellipsoids	Semi-Major Axis (a)	Flattening Reciprocal (f) (Ellipcity)	Semi-Minor Axis (b)
WGS1984	6378137.000 m	f = 298.257223563 (1/f = 0.00335281066474)	6356752.314 m
Everest 1830 (Indian Bangladesh)	6377276.345 m	f = 300.801700000 (1/f = 0.00332444929666)	6356075.413 m
Difference (WGS84 - Everest1830)	Δa = 860.655 m	Δf = -1.544476437 (Δ^1/f x 10^4 = -0.28361368)	Δb = 677.901 m

Table 2

Various Reference Ellipsoid Names and Constants

Reference Ellipsoid Name	ID Code	Semi-Major Axis (a) (in Meters)	Flattening (f^{-1}) (Ellipcity)
Airy 1830	AA	6377563.396	299.3249646
Australian National	AN	6378160.000	298.000
Bessel 1841			
Ethiopia, Indonesia, Japan and Korea	BR	6377397.155	299.1528128
Clarke 1880	CC	6378206.400	294.9786982
Everest			
Brunei and East Malaysia	EB	6377298.556	300.8017
India 1830	EA	6377276.345	300.8017
Pakistan	EF	6377309.613	300.8017
West Malaysia and Singapore 1948	EE	6377304.063	300.8017
Geodetic Reference System 1980	RF	6378137.000	298.257222101
Helmert 1906	HE	6378200.000	298.300
Indonesian 1974	ID	6378160.000	298.247
International 1924	IN	6378388.000	297.000
Krassovsky 1940	KA	6378245.000	298.300
Modified Fischer 1960 (Singapore)	FA	6378155.000	298.300
South American 1969	SA	6378160.000	298.250
WGS1972	WD	6378135.000	298.260
WGS1984	WE	6378137.000	298.257223563

Source: DMA Technical Report DEPARTMENT OF DEFENSE
WORLD GEODETIC SYSTEM 1984
Second Edition, 1 September 1991

付録－9

第4年次現地作業経過報告(1995. 1.11)

11/01/1995
Dhaka

From : The Team Leader
JICA Study Team of Geodetic Survey

To : The Surveyor General
Survey of Bangladesh

Subject : The Completion Report on the Field Work of Phase IV Study
(final phase of the Study) of "the Study on the Geodetic Survey in the People's Republic of Bangladesh"

It is my pleasure to inform you that we have completed with great success all field work in Bangladesh for the Phase IV Study, as per the "Plan of Operation" dated 28 September 1994.

The following four categories of field work were planned and executed as scheduled, with extensive collaboration of SOB counterpart personnel.

1) 1st Order Levelling of 1,550 kilometer linear distance

2) Linking Height onto 51 GPS Stations from 1st Order Levelling Network

3) Continuation of Tidal Observation in Chittagong

4) Fixation of the National Geodeic Datum onto the Global System

The outline of the field work and some preliminary evaluations are described as follows.

I. 1st Order Levelling

1. In continuation of the Phase III Study, remaining 1,550 km of 1st order levelling had been planned and were executed. The actual distance of level run resulted to be 1,626 km.

Thus, the total length of level run executed in Phase III and Phase IV turned out to be 2,388 km in distance, including river cross levelling.

Preliminary examination of misclosure is shown in Figure 1, and it proves that the result obtained rests well within the specified tolerance of;

$$\pm 4.0 \text{ mm} \times \sqrt{S}$$

2. River cross levelling by Tilting Screw Method with 4 sets of WILD N3 and a pair of target were conducted for the medium range of distance (0.5 km ~ 5 km) at the following 7 sites :

Chittagong (0.9km, 20 sets), Daudkandi (1.2km, 30 sets), Aricha (3.1km, 100 sets), Tangail (0.5km, 20 sets), Sirajganj (1.7km, 40 sets), Sirajganj (1.8km, 40 sets) and Bhairab (0.8km, 40 sets).

River cross levelling by Reciprocal Method with 1 set of WILD N3 and Invar Staves were conducted for the short range of distance (less than 500 m) at the following 7 sites :

Mohnganj (101m, 4 sets), Jamalpur (260m, 4 sets), Sunamganj (330m, 4 sets), Sylhet (107m, 4 sets), Saidpur (148m, 4 sets), Chandpur (146m, 4 sets) and Netrakona (115m, 4 sets).

The accuracy of the river cross levelling was confirmed by the direct levelling after the construction of "Meghna-Gumti Japan-Bangladsh Friendship Bridge No.2" and the reconstruction of Karnafuli Bridge at Daudkandi and Chittagong sites.

Discrepancy between both methods are within the torelance and it was decided to adopt the value obtained by river cross levelling method.

3. Due to heavy traffic, levelling on some bridges were forced to be conducted midnight, by obtaining assistance of police in traffic control.

4. Following 2 Bench Marks among 461 Bench Marks were founded as missing ;

BM 6144 : by Jamuna River erosion in 1993.
BM 6203 : by road widening project on Rangpur area in 1994.

II. Linking orthometric height of GPS stations with 1st order levelling network to generate local geoid model.

To give orthometric height to all GPS stations, 51 GPS stations were linked to the 1st order levelling network by direct levelling, in order to generate Local Geoid Map in Bangladesh.

Blackened triangle symbols in Figure 2 represent directly levelled GPS stations.

III. Determination of Mean Sea Level (M.S.L.) in the Bay of Bengal

Continous tidal observations at Karnafuli River mouth by a Fuess Type tide gauge and at foreshore of Patenga Beach by Pressure Sensing Type tide gauge, both in Chittagong, were conducted, which originally started at 16:00 hrs. 28/01/1993 and 12:00 hrs. 28/05/1993 resp..

All observation data obtained upto 23:00 hrs. 30/11/1994 at both observatories were adopted, excluding some vacancies of data caused by mechanical and accidental failures, to determine Mean Sea Level (M.S.L.) in the Bay of Bengal.

Preliminery examinations of the tidal observation is shown in the Interim Report attached as "Appendix 1".

However, as the period of tidal observation conducted in this Study is short in scientific view point to analyse the long term oceanographic phenomena, it is expected that both Survey of Bangladesh (SOB) and Chittagong Port Authority (CPA) shall continue observation at both stations.

IV. Fixation of the National Geodeic Datum onto the Global System

7 day continous GPS observation was executed from 17/ 9/94 to 23/ 9/94 in corabollation with Geographical Survey Institute (GSI), Japan and the International Earth Rotation Service, to determine the exact geocentric coordinate of Gulshan 303 Station, the National Geodetic Datum of Bangladesh.

Solution of results by GSI with reference to WGS 84 Ellipsoid is as shown in the attached Table.

Both parties agreed to adopt abovementioned value in WGS 84 and to transform to Everest 1830 by free network adjustment by using 19 existing station values.

V. Data Processing, Data Analysis and the Final Report

All obtained data of GPS observation, tidal observation and 1st order levelling shall be analyzed in Japan according to the procedure shown in the Flow Diagram (Figure 3).

Results of preliminery examination of coordinates of all GPS stations with reference to WGS 84 Ellipsoid are shown in Appendix 2.

The Final Report and all other outputs of the Study as prescribed in the Scope of Work of the Study will be prepared by the Study Team by March 1995, and delivered to SOB from JICA through its representative office in Bangladesh.

Submitted by:

Dr.Minoru Tajima
The Team Leader
JICA Study Team

Acknowledged by:

11.1.95

Col.Shahedul Islam Mondal
Surveyor General
Survey of Bangladesh

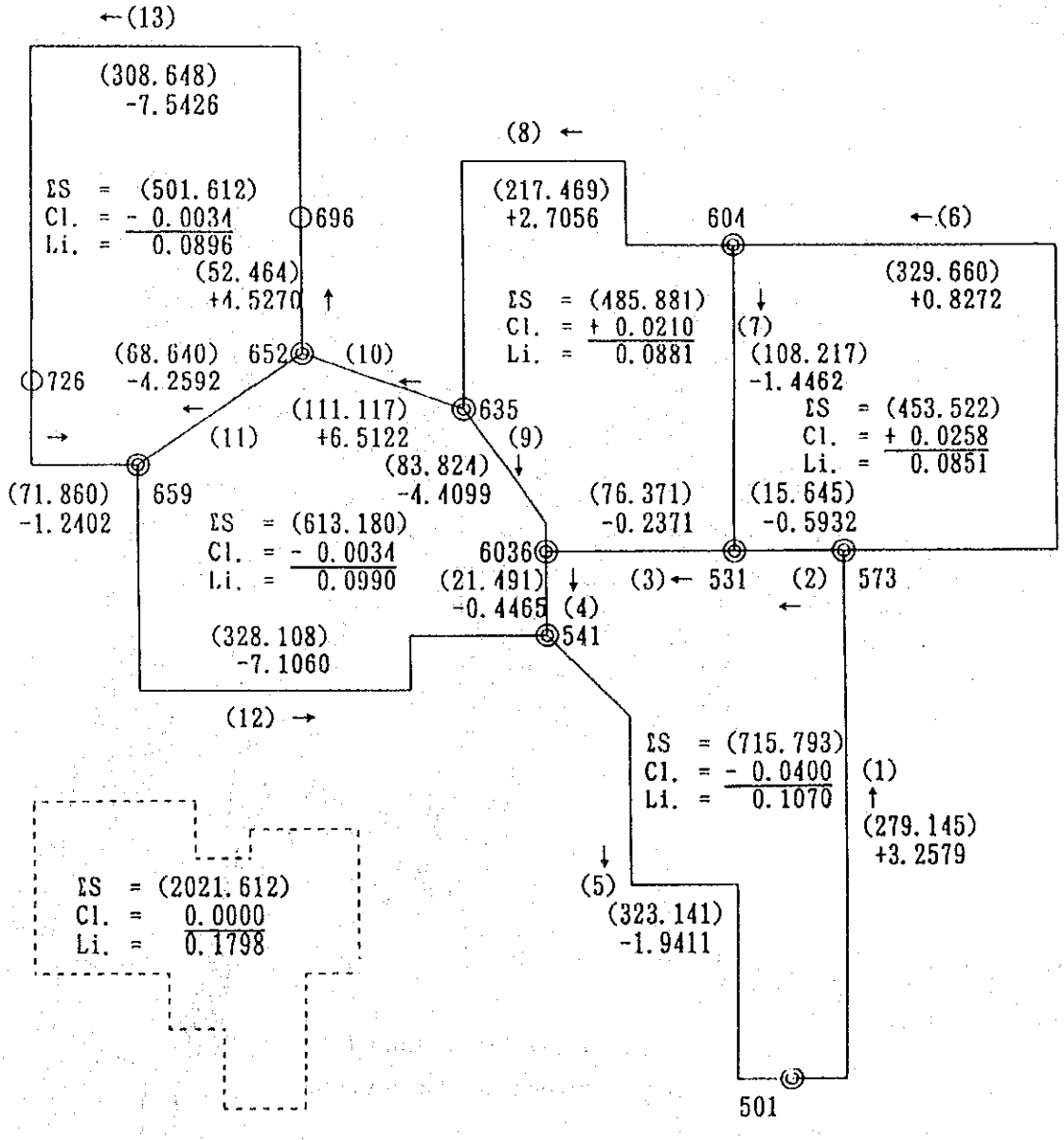
c.c.:

External Relations Division, MOF
Secretary,MOD
Embassy of Japan
JICA Bangladesh Office
JICA HQs

Fig. 1

10/01/1995

Diaglam of Closure of 1st Order Levelling Loop

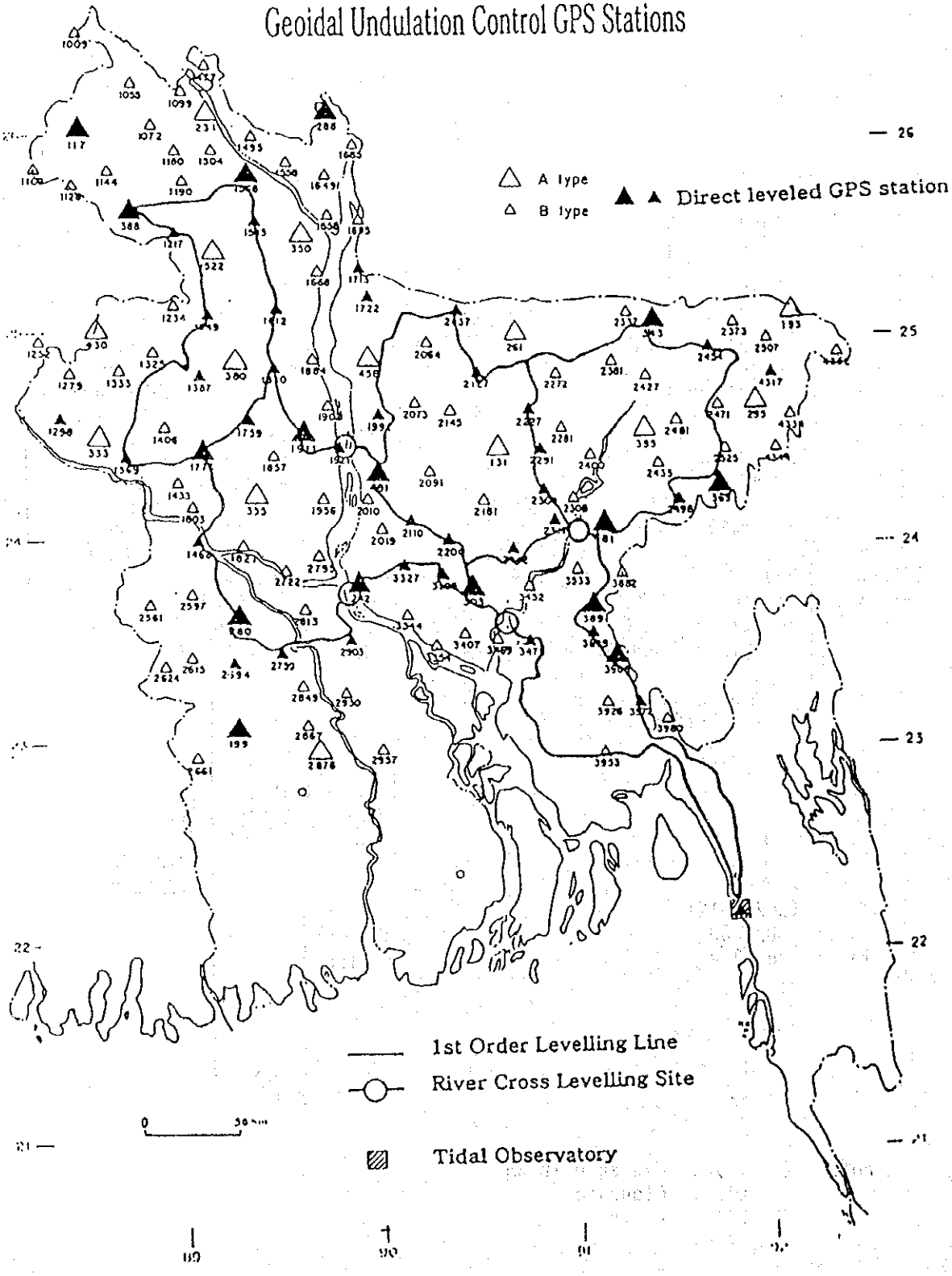


Note ( ) : distance in km
Cl. : Clousure
Li. : Limit

Figure 2

Geodetic Control Network in Bangladesh

Geoidal Undulation Control GPS Stations



DETERMINATION OF ABSOLUTE POSITION OF DHAKA303 STATION ON WGS-84 ELLIPSOID

In GPS Tracking Network of the International GPS Service for Geodynamics

GLOBK Ver 3.1. Global Solution

Solution commenced with	:	1994/ 9/17	15:19	(1994. 7109)
Solution ended with	:	1994/ 9/23	16:19	(1994. 7274)
Solution refers to	:	1994/ 9/23	16:19	(1994. 7274)
Satellite IC epoch	:	1994/ 9/23	11:59	50.00
Run time	:	1994/12/15	16:08	42.00

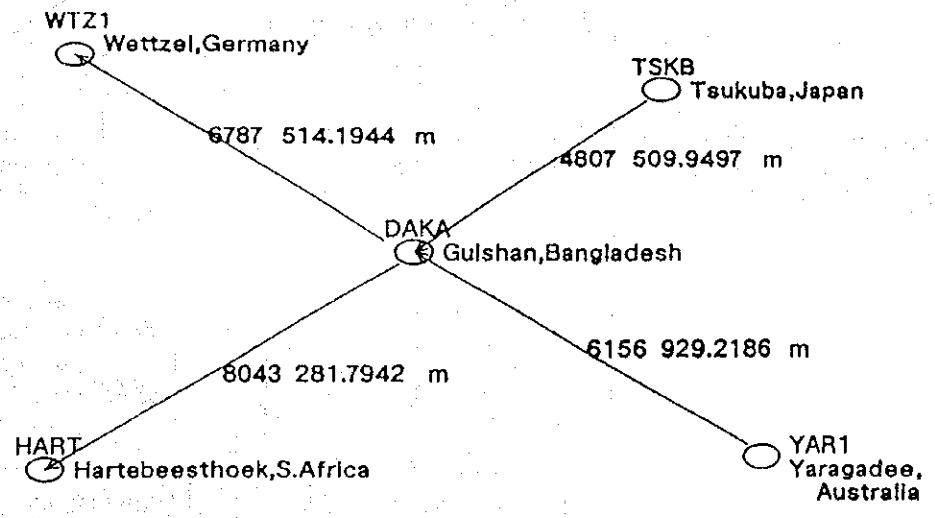
There were 7 exps from 7 global files in the solution
There were 91679 data used. 0 data not used and 91679 data total.
There were 15 global parameters estimated
There were 5 stations. 0 radio sources. and 25 satellites

Parameter Estimates From GLOBK Vers 3.1

	Estimate	Adjustment	Sigma
DAKA GPS X coordinate (m)	-42358.1522	0.0389	0.0022
DAKA GPS Y coordinate (m)	5838826.2338	0.0171	0.0035
DAKA GPS Z coordinate (m)	2557788.4491	-0.2349	0.00194
DAKA GPS N coordinate (m)	2649156.7947	-0.2219	0.00094
DAKA GPS E coordinate (m)	9209261.7213	-0.0390	0.0022
DAKA GPS U coordinate (m)	-44.8288	-0.0794	0.00397
NE NU EU position correlations	0.5440	0.1028	0.02031

GLOBK: BASELINE LENGTH

Base Line	Length (m)	Adjust (m)	Sigma (m)
TSKB GPS to DAKA GPS	4807509.9497	0.0983	0.0025
YARI GPS to DAKA GPS	6156929.2186	-0.1980	0.0021
DAKA GPS to HART GPS	8043281.7942	-0.1736	0.0030
DAKA GPS to WTZ1 GPS	6787514.1944	0.0664	0.0023



GPS Universal Computation Program (Without Geoid Model)
VER.J1.0 1994-12-7

Dhaka,Gulshan 303		ITRS92	WGS84
Latitude	B =		23° 47' 52.02714"
Longitude	L =		90° 24' 56.34024"
Ellipsoid Height	H(m) =		-45.4494
3D Coordinate	X(m) =	-42358.1522	-42358.2817
3D Coordinate	Y(m) =	5838826.2338	5838825.4441
3D Coordinate	Z(m) =	2557788.4491	2557788.6983

Everest 1830 (Kalianpur Datum)			- WGS84
Latitude	B =	23° 47' 49.547"	- 02.480"
Longitude	L =	90° 25' 06.742"	10.402"

FLOW DIAGRAM OF GEODETIC CONTROL NETWORK IN BANGLADESH