社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
SURVEY OF BANGLADESH (SOB)

No. 2

THE STUDY ON THE GEODETIC SURVEY IN THE PEOPLE'S REPUBLIC OF BANGLADESH

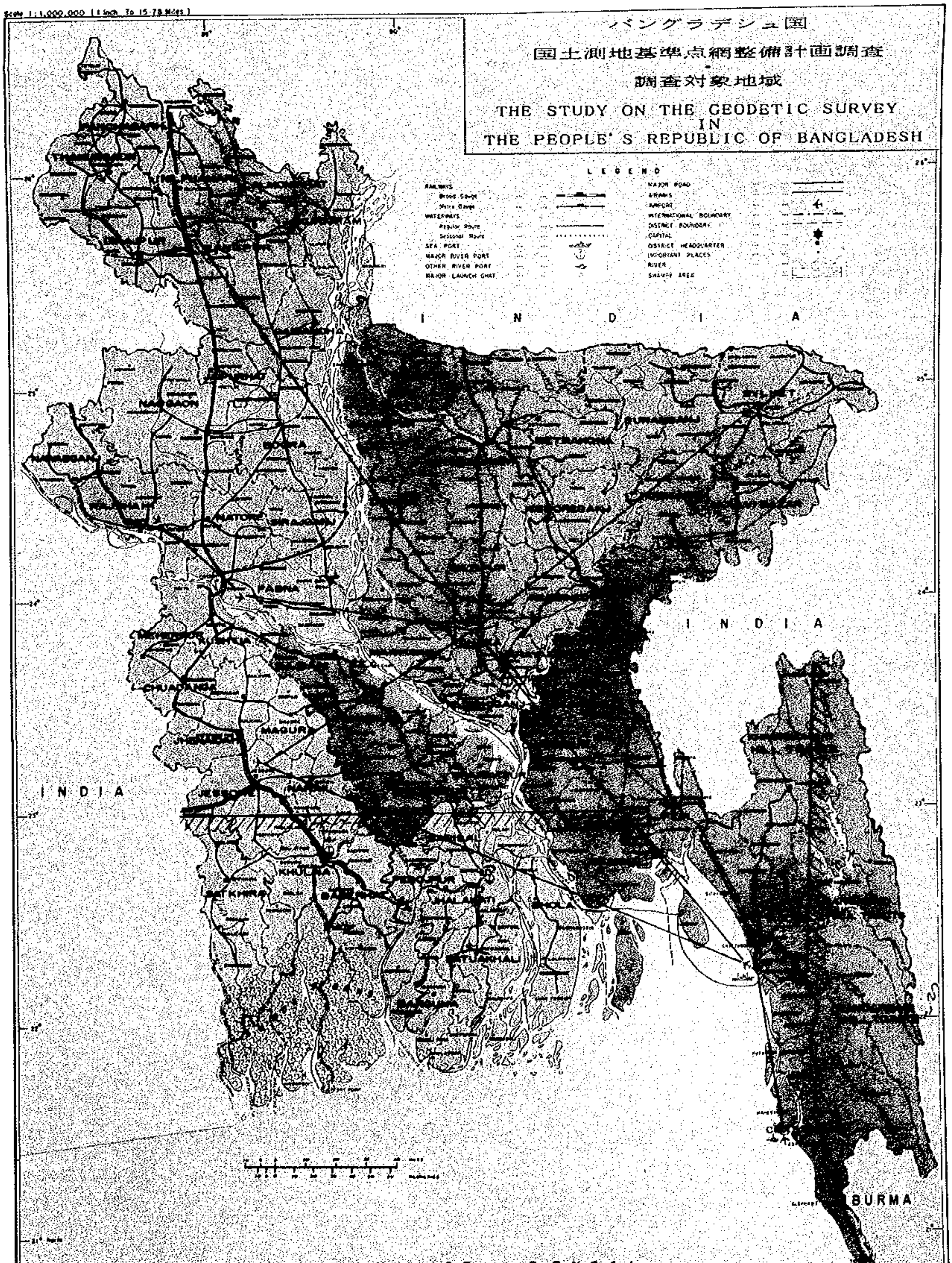
MARCH, 1995

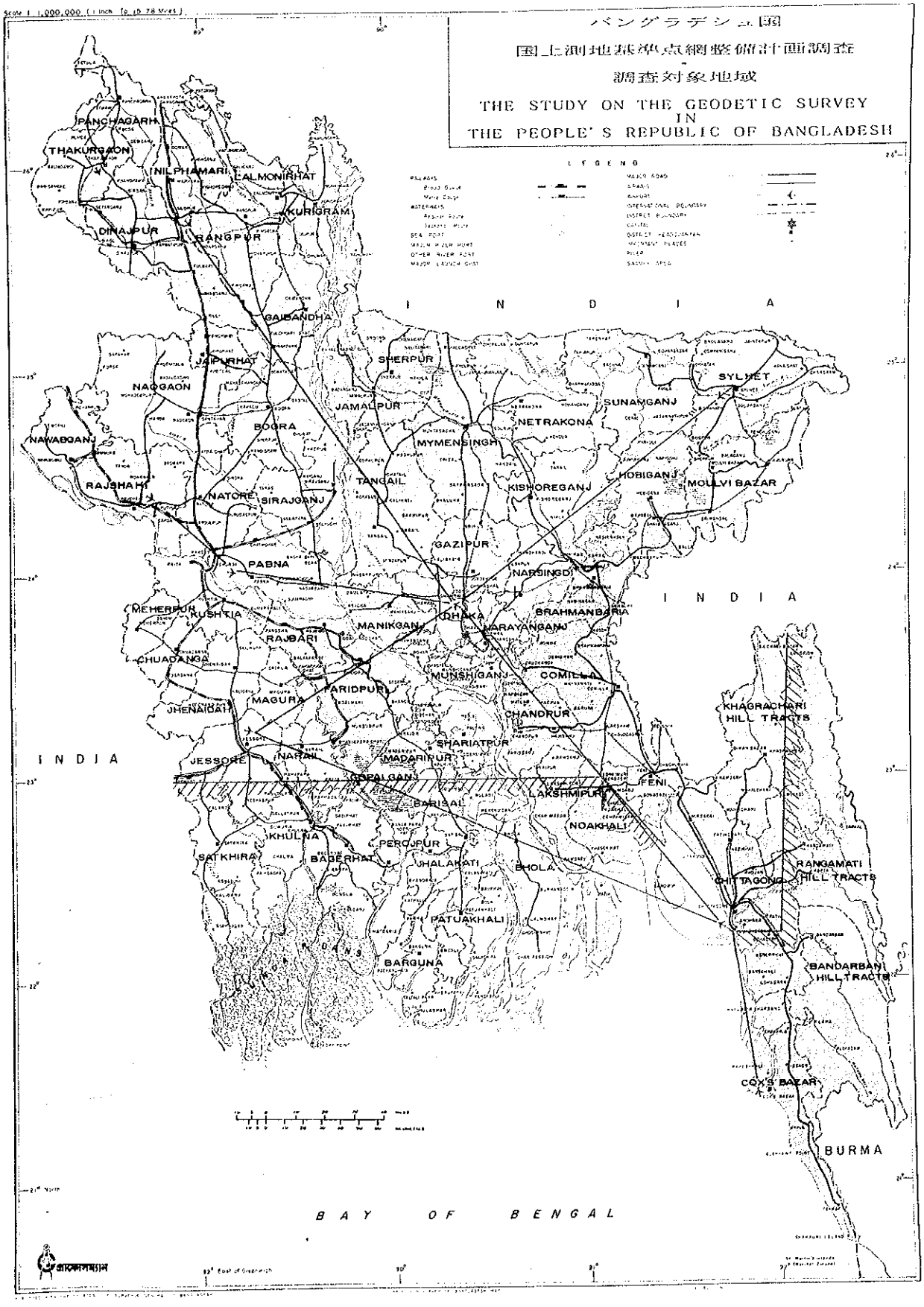
INFRASTRUCTURE DEVELOPMENT INSTITUTE
AERO ASAHI CORPORATION
ASIA AIR SURVEY CO., LTD.

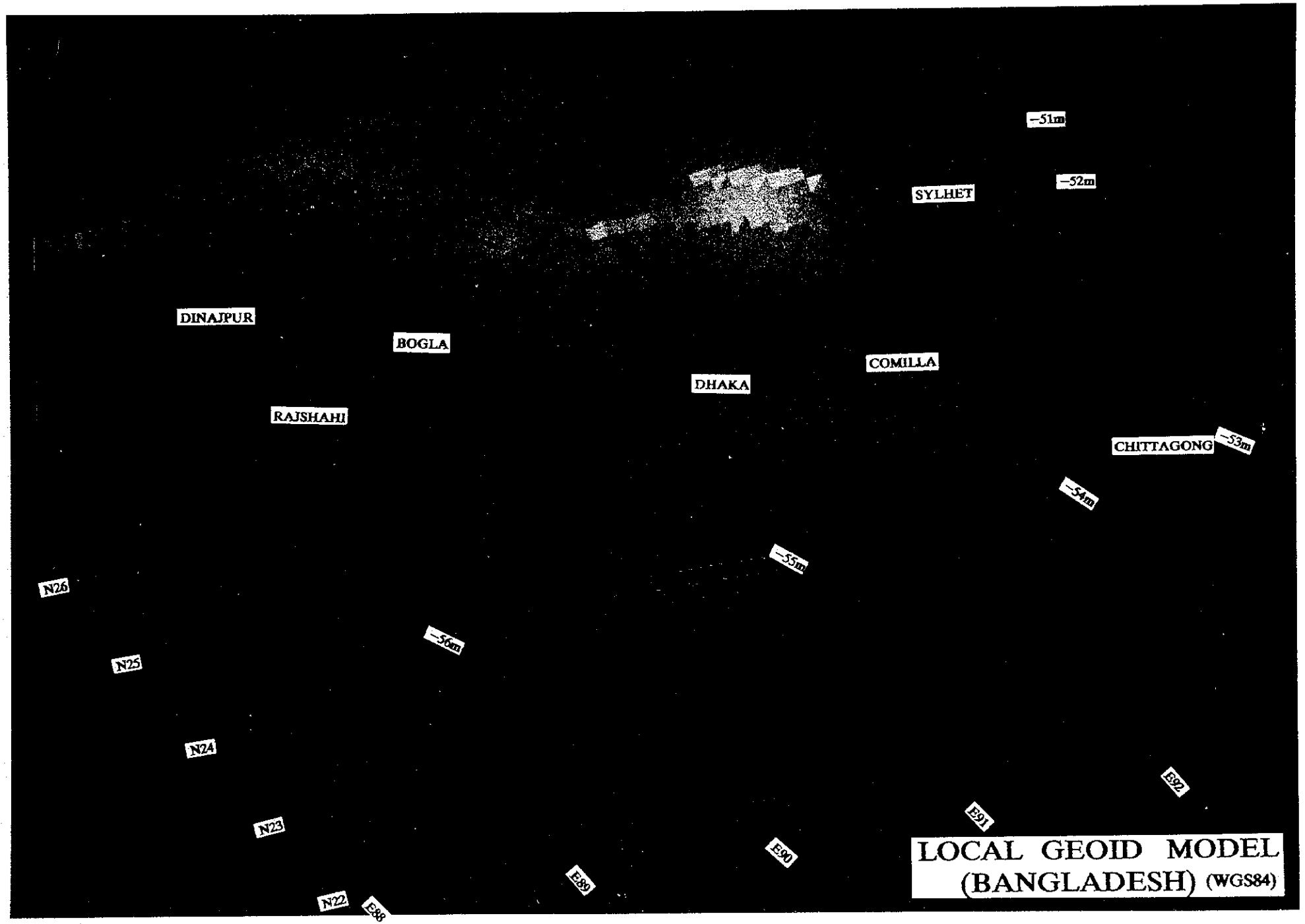
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
SURVEY OF BANGLADESH (SOB)

THE STUDY ON THE GEODETIC SURVEY IN THE PEOPLE'S REPUBLIC OF BANGLADESH

INFRASTRUCTURE DEVELOPMENT INSTITUTE
AERO ASAHI CORPORATION
ASIA AIR SURVEY CO., LTD.


Scale 1:1,000,000 (1 Inch. To 15.78 Miles)
バングラデシュ国
国土測地基準点網整備計画調査
調査対象地域
THE STUDY ON THE GEODETIC SURVEY
IN
THE PEOPLE'S REPUBLIC OF BANGLADESH
LEGEND
RAILWAYS
Broad Gauge
Metre Gauge
WATERWAYS
Regular Route
Seasonal Route
SEA PORT
MAJOR RIVER PORT
OTHER RIVER PORT
MAJOR LAUNCH GHAT
MAJOR ROAD
AIRPORT
INTERNATIONAL BOUNDARY
DISTRICT BOUNDARY
CAPITAL
DISTRICT HEADQUARTER
IMPORTANT PLACES
RIVER
SWAMPY AREA
INDIA
INDIA
INDIA
BURMA
BAY OF BENGAL
NAOGAON
PABNA
NATORE
SIRAJGANJ
KUSHTIA
CHUADANGA
MAGURA
JESSORE
KHULNA
SATKHIRA
PATUAKHALI
BARGUNA


Scale 1 : 1,000,000 (1 inch To 15.78 Miles)
バングラデシュ国
国土測地基準点網整備計画調査
調査対象地域
THE STUDY ON THE GEODETIC SURVEY
IN
THE PEOPLE'S REPUBLIC OF BANGLADESH
LEGEND
INDIA
INDIA
INDIA
BURMA
BAY OF BENGAL
PANCHAGARH
THAKURGAON
NILPHAMARI
LALMONIRHAT
KURIGRAM
DINAJPUR
RANGPUR
GAIBANDHA
JAIPURHAT
SHERPUR
NAOGAON
JAMALPUR
SUNAMGANJ
SYLHET
BOGRA
NETRAKONA
NAWABGANJ
MYMENSINGH
RAJSHAHI
TANGAIL
KISHOREGANJ
HOBIGANJ
MOULVI BAZAR
NATORE
SIRAJGANJ
GAZIPUR
PABNA
NARSINGDI
MEHERPUR
KUSHTIA
DHAKA
BRAHMANBARIA
MANIKGANJ
NARAYANGANJ
RAJBARI
CHUADANGA
MUNSHIGANJ
COMILLA
FARIDPUR
MAGURA
KHAGRACHARI HILL TRACTS
JHENAIDAH
CHANDPUR
SHARIATPUR
JESSORE
NARAIL
MADARIPUR
GOPALGANJ
FENI
LAKSHMIPUR
BARISAL
NOAKHALI
KHULNA
PEROJPUR
SATKHIRA
BAGERHAT
JHALAKATI
BHOLA
RANGAMATI HILL TRACTS
CHITTAGONG
PATUAKHALI
BARGUNA
BANDARBAN HILL TRACTS
COX'S BAZAR


−51m
−52m
SYLHET
DINAJPUR
BOGLA
COMILLA
DHAKA
RAJSHAHI
CHITTAGONG
−53m
−54m
−55m
N26
−56m
N25
N24
N23
N22
E88
E89
E90
E91
E92
LOCAL GEOID MODEL
(BANGLADESH) (WGS84)

PREFACE

In response to a request from the Government of the People's Republic of Bangladesh, the Government of Japan decided to conduct a study on the Geodetic Survey in the People's Republic of Bangladesh and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bangladesh a study team headed by Dr. Minoru TAJIMA, Infrastructure Development Institute (IDI), and composed of members of IDI, Aero Asahi Corporation and Asia Air Survey Co., Ltd., several times between April 1992 and January 1995.

The team held discussions with the officials concerned of the Government of Bangladesh, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that the output of the study will contribute to the social and economic development of Bangladesh, and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the People's Republic of Bangladesh for their close cooperation extended to the team.

March 1995

Kimiro Fujita

President

Japan International Cooperation Agency

LETTER OF TRANSMITTAL

March 1995

Mr. Kimiro Fujita,
President
Japan International Cooperation Agency (JICA)

In response to your request I wish to submit a report on the Study on the Geodetic Survey in The People's Republic of Bangladesh conducted from the 4th Year of Heisei to the 6th Year of Heisei.

The report contains the descriptions of the work operations of the geodetic survey conducted in Bangladesh and the utilization of the survey results. I am convinced that the survey results obtained during the study period will be greatly useful and beneficial to the development programs in Bangladesh and the progress and improvement of scientific studies as well as surveying technology.

I extend my heartiest gratitude to the Surveyor General of the Survey of Bangladesh of the Ministry of Defence, the People's Republic of Bangladesh and his staff, the staff members of Japanese Embassy in Bangladesh and the staff members of Bangladesh Office of Japan International Cooperation Agency who cooperated with us in conducting the survey.

Minoru Tajima, Ph.D.
JICA Study Team Leader,
The Study on the Geodetic Survey
in the People's Republic of Bangladesh

SUMMARY OF THE STUDY

The study on the geodetic survey in the People's Republic of Bangladesh

Study Period: April 1992 - March 1995T
Beneficiary: The Survey of Bangladesh of The Ministry of Defence

1. Background

The control points in Bangladesh were originally established by the Survey of India at the beginning of the nineteenth century. Because of the triangulation chains adopted for the control point surveying, the control points were not evenly distributed throughout the country. Consequently, a large blank area where no control points were installed was found especially in the northeast region and in the northwest region as well and the same blank area was also left in the sourthwest region.

What also should be noted is the fact that because the control points have been poorly and insufficiently maintained since they were installed, they have been left exposed to natural or artificial damages and most of them have now been lost or missing. Even what have surveyed have shown a marked functional deterioration in terms of accuracy. The bench marks were found to have been far more seriously damaged than the control points in terms of accuracy with the passage of time as well as in the number of what have been lost or ruined.

The independence of Bangladesh in 1971 caused the horizontal datum station as well as the vertical datum station to have been left behind in India. For this reason Bangladesh have never had an opportunity of having datum stations of its own since then.

For the above reasons the production of topographical maps and various kinds of civil engineering and construction projects encounter a great deal of difficulties in Bangladesh. Therefore, the Survey of Bangladesh regards the reconstruction of the devastated geodetic system as the greatest and the most urgent issue for Bangladesh.

This study aims to reestablish the geodetic system in Bangladesh on a sound basis, including the determination of a horizontal datum station, a vertical datum station and mean sea level and the installation of control points and bench marks throughout the country and finally the establishment of the network of the geodetic control points.

Also, this study is a significant project in the sense that it not only lays the foundation of various development projects formulated on the basis of the Third National Five-year Plan of Bangladesh (July 1985 to May 1990), but also it responds to especially what are proposed as the necessary step for the urgent reestablishment of the geodetic system pointed out in the reports prepared by the participating countries concerning the Flood Action Plan being carried out by the World Bank and donating countries as well as what are urgently called for in the same tenor in the meetings of donors and experts sponsored by the World Bank.

Recognizing that a study for a national geodetic control network is prerequisite for implementing various national land development and conservation plans as well as projects for improving social infrastructures, the Government of Bangladesh requested Japan for technical cooperation in conducting a study of a national geodetic survey covering approximately the entire nation.

(1) The Survey of Bangladesh in Dhaka was designated as the central survey agency of the national government following the independence of Bangladesh. However, since plans to establish a national geodetic control network, upgrade aerial photography operations and produce a basic national map were greatly delayed, the agency was consequently unable to respond to demands for these services.

(2) Although Bangladesh inherited a national geodetic control network created by the Survey of India in the 1800's, this network lacks a geodetic datum, a vertical datum and tidal stations necessary for determining the national geodetic plane. Currently managed national control points and bench marks do not function as a national control point network in the sense of both density and accuracy. Thus, the nation of Bangladesh urgently requires a modern and own geodetic system.

(3) During the Dhaka Conference of Donor Nations held in January 1990, the World Bank and participating donor nations proposed a Flood Action Plan for Bangladesh. Japan, however, announced that the project at hand would be separated from other action plans and managed bilaterally between Japan and Bangladesh. This decision was subsequently approved by the World Bank, the Government of Bangladesh and participating donor nations.

In response to this request, the Japanese Government dispatched a study team to Bangladesh from late July to mid August in 1990 and from late November to mid December in 1991. After negotiations with the Survey of Bangladesh (the counterpart agency of the study team hereafter referred to as SOB), a (S/W) for this study was sanctioned between the two sides on December 5, 1992.

According to this (S/W), it was decided to carry out a study for a national geodetic control network in April of 1992.

2. Objectives

(1) Reconstruction and reestablishment of the network of geodetic control points

1) Mounmentation and observation (141 points)
   * Reconnaissance, point locationing and mounmentation
   * Control point surveying by GPS (Global Positioning System)
   * Adjustment and computation of the network of control points

2) Restoration of standard datum of geographical coordinates (1 unit)
   * Repair and restoration of the old, temporal standard datum of geographical coordinates.
   * Determination of the standard datum of geographical coordinates values by GPS

3) Monumentation and observation (465 points, 2,386 km)
   * Reconnaissance, point locationing and monumentation for bench marks
   * Levelling at bench marks (river crossing level included)
   * Adjustment and computation of the network of bench marks

4) Construction of the vertical datum station and a housing facility
   * Designing and point selection and construction of the datum station of levelling
   * Construction of the facility that protects the datum station (horizontal and vertical)

5) Construction of a tidal observations station (one standard station and one auxiliary)
   * Designing, point selection and construction of the tide observation stations
   * Installation and operation of tide gauges

6) Observation of tides
   * Analysis of tide levels (determination of mean sea level)

(2) Technology Transfer

The technologies related to the survey of datum points and bench marks, tidal level observatioin and determination of average sea surface level will be transfered to the benefitiary through this research.

3. Project Area to be Covered by the Study

The project area to be covered by the study is located within the range of approximately 95,000 km2 (an approximately 70% of the total area of Bangladesh) that extends between 22°13' to 26°38'N and between 88°01' to 92°41' E as shown in the map that appears at the beginning of this report under the title of "The Study on the Geodetic Survey in the People's Republic of Bangladesh."

4. Frame of the study

(1) Yearly Plans of the Study

Year	Operation	Workload	Remarks
Phase I (1991 F/Y)	Preparations (Japan)	Plan & preparations, P/O drafting	
	Control point surveying	Reconnaissance- Area: 95,000km^2, Selected points: 140 nos.	Existing points: 24 nos.
	Levelling	Reconnaissance: 2,280 linear km, Selected points: 465 nos.	Existing points: 2, including vertical datum, river cross points, annex points
	Tidal observation	Reconnaissance: 1 location (tidal station location)	Including topographic, geological studies
	Report; Preparations (Japan)	Work report: 2 copies (in Japanese) Plan & preparations, P/O drafting, facility design	
Phase II (1992 F/Y)	Control point surveying	Monumentation: 115 points Geodetic datum renovation: 1 Control point surveying: 60 stations Calculation: 60 nos.	A-type 26 nos., B-type 89 nos. points Linking orthometric height (4 points: 3rd order, 23 km)
	Levelling	Monumentation: 461 points Vertial datum construction: 1	standard type 228 nos., small type 233 nos. including housing facility construction
	Tidal observation	Construction of the tidal observation station and auxiliary tidal station Tidal observation / data analysis: 1 set	including annex bench mark for tidal station including tidal gauge installation
	Report	Work report (in Japanese)	
Phase III (1993 F/Y)	Preparations (Japan)	P/O drafting	
	Control point surveying	Control point surveying: 81 station Computation: 81 points	Linking arthometric height (23 points: 3rd order, 59km) 1 additional observation for observation (tidal station)
	Levelling	Levelling: 762km Calculation: 762km	River analysis leveling (6 sites) Including additional observation for 32km of unsurveyed routes
	Tidal observation	Tidal observation / data analysis: 1 set	
	Report	Work report: 2 copies (in Japanese)	
Phase IV (1994 F/Y)	Preparations (Japan)	Plan & preparation, P/O drafting	
	Control point surveying	Network adjustment computation: 141 nos.	
	Levelling	Levelling (including river cross levelling): 1,550 km Computation: 1,550 km Network adjustment computation: 2,312 km	Linking orthometric height (24 points: 3rd order, 213 km) River cross surveys
	Tidal analysis	Tidal observation / data analysis: 1 set	
	Report	Completion report: 3 copies General report (Japanese): 10 copies General report (English): 100 copies	

(2) Elevation of the Bench Mark Annexed to the Standard Tide Observation Station (Analytical Data of Tide Levels)

Name of Location	Attitude difference	Elevation	Remarks
Observation datum level	m -3.4860	-3.4860	(Elevation difference)
MSL (mean sea level)		m 0.0000	Tide level analysis
Tide pole (10m pole)	+6.3005	6.3005	Computation
SM (standard mark)	+0.3148	6.6153	Direct levelling
BP (base point)	+1.3957	8.0110	Direct levelling
SM (standard mark)		6.6153	
TBM (tidal station bench mark)	+0.9613	7.5766	Direct levelling

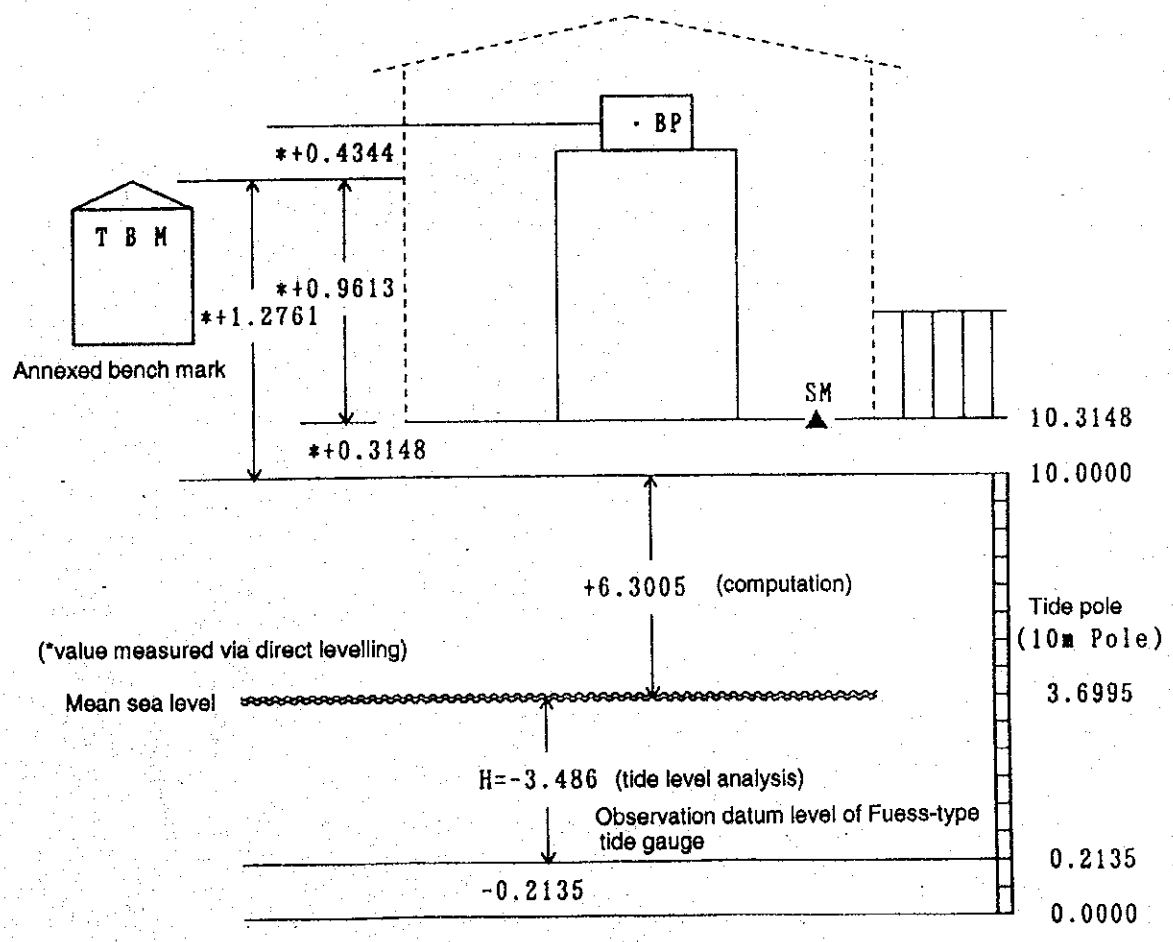


Figure 1 Elevation Chart for Standard Tidal observation Station

(3) Control point surveying Observation Route

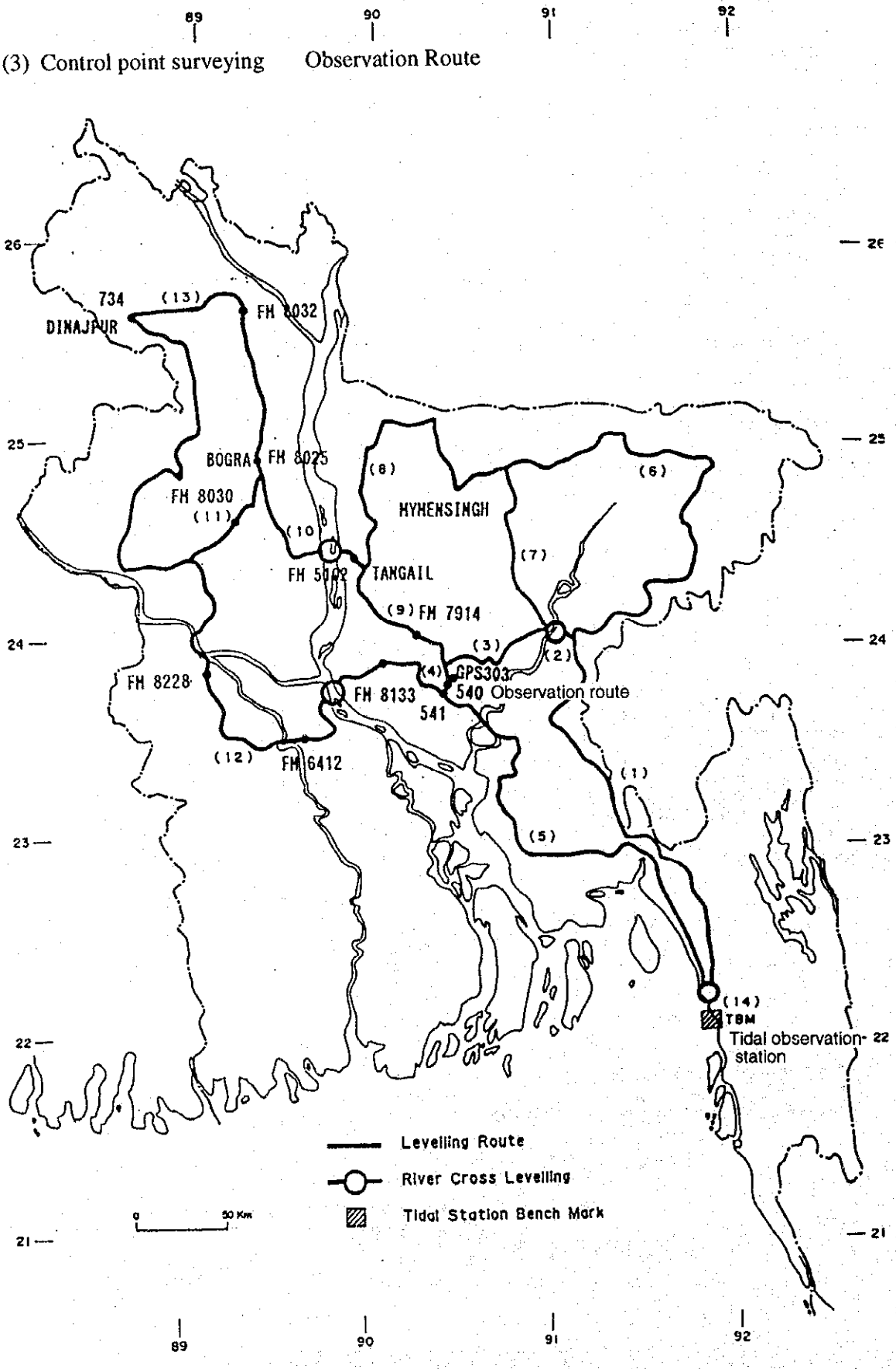


Figure 2 1st Order Levelling Observation Route

(4) Control point surveying Distribution of Points

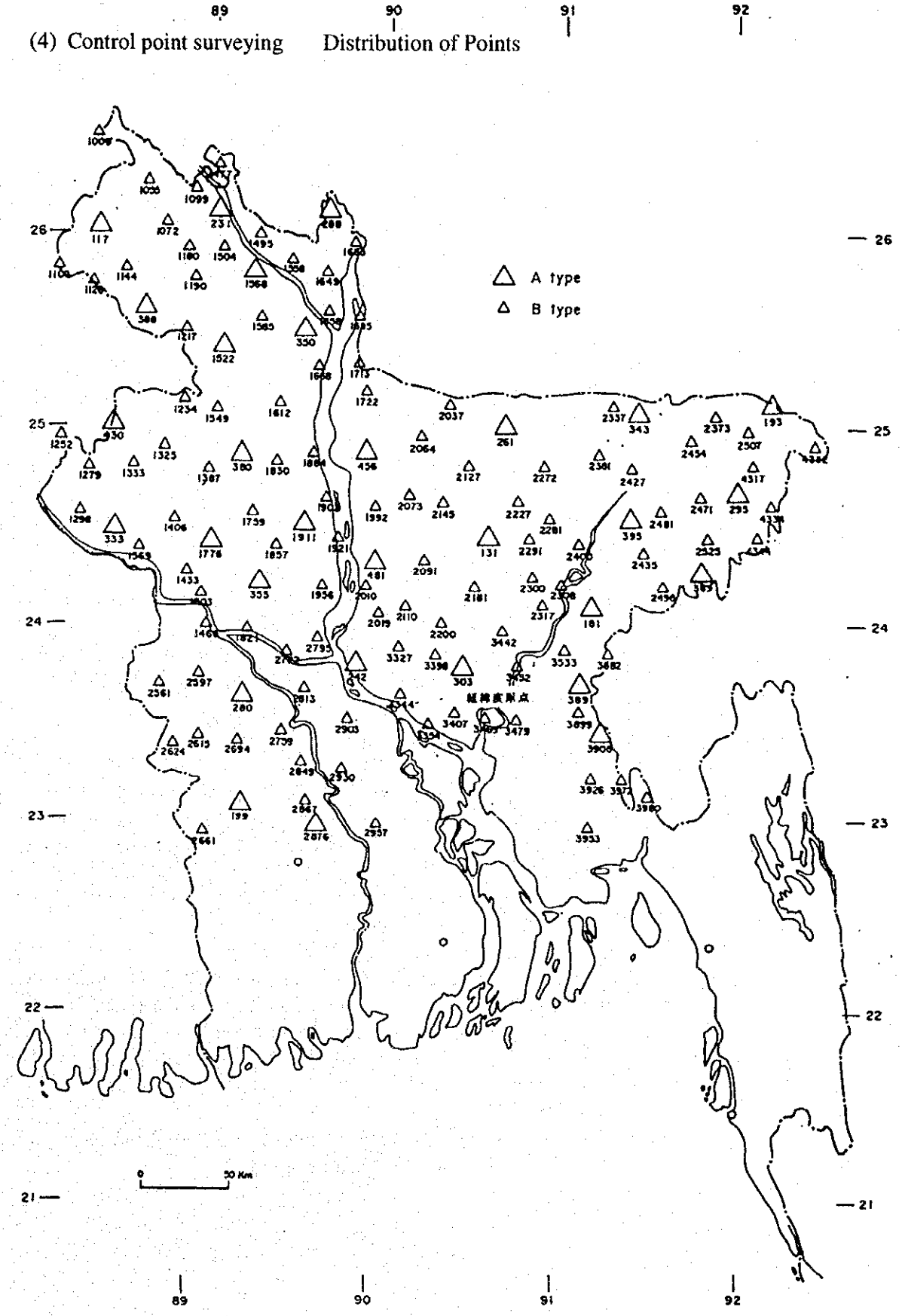


Figure 3 Control point surveying Distribution of Points

5. Result of the Study

1) Determination of above-sea levels

An analysis of the tide levels obtained through the tide observation for about two years determined the mean sea level of the Bay of Bengal that determined the elevation of the annexed bench mark at the tide observation station and then the orthometric height of the vertical datum station as well as the corresponding heights of the bench marks established and distributed nationwide were determined by the network adjustment of the bench marks obtained through the levelling, including the river-cross levelling. (See Figure 1 and 2)

A) The Elevation of the Annexed Bench Mark (TBM):
H1 = 7.5766 m (Analysis of tide levels through observation for 22 months)

B) The Orthometric Height of theVertical Datum Station:
H2 = 6.4292 m (Standard deviation = ±0.9mm: The result of network adjustment)

The orthometric heights of the 461 bench marks installed nationwide were complied into a "Result of 1st Order Levelling", which is given in the latter part of this report. To give rothometric heights onto all GPS points, 51GPS points among total 140 GPS points have been linked in elevationwise with newly established 1st order B.M.S. by either included in 1st order levelling line or extendes from B.M.S. by direct 3rd order levelling for generating local geoidal undulation map of the project area, and then orthometric heights of remaining 89 GPS points had been given by interpolating from the local geoid model.

2) Determination of Coordinates of Horizontal Datum

Viewing the fact that the published coordinates of existing triangulation points as well as the existing topographic maps are still in use basing on the old datums, values of existing coordinates were verified by the three-dimentional free network adjustment and new values of existing triangulation points, refered to Everest 1830 Ellipsoid, have been given with slight correction to an extent that they might not hamper the cartographic represantation of map and cause difficultes in proctical uses due to the correction.

Using these two kinds of data, one refered to WGS-84 as other refered to Everest-1830, obtained form the newly-installed datum station and the old one as the prerequisites, the locations of the 141 control points installed nation wide were computed to determine the locations on the earth by the GPS observation data after the network adjustment of the control points were figured out.

The locations of the nationally-installed 141 control point were compiled into a control points data list, which is given in the latter part of this report.

Ellipsoid Parameters and Coordinates of Horizontal Datum

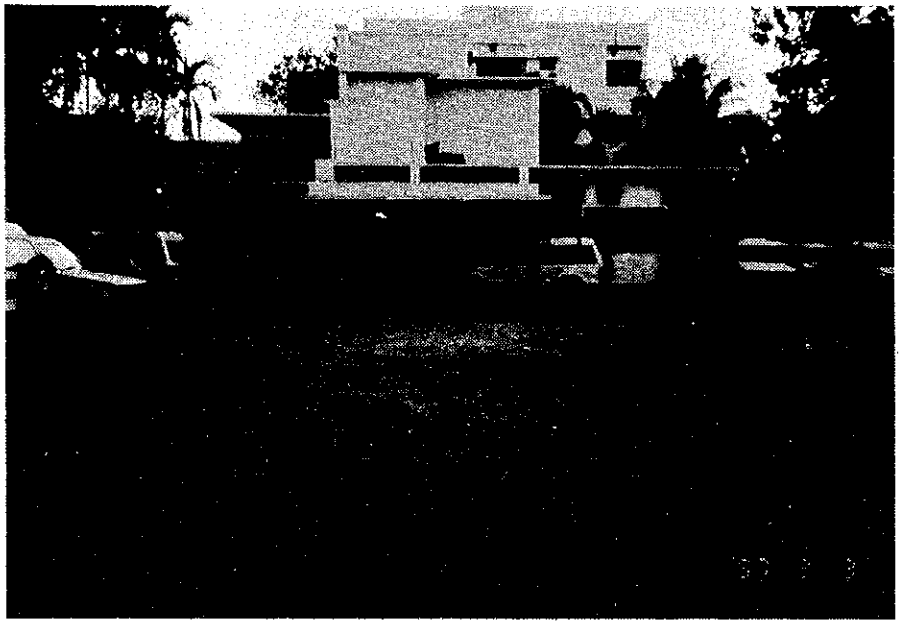
	WGS-84	EVEREST-1830
Semi-major axis	6378137.000m	6377276.345m
Semi-minar axis	6356752.314m	6356075.413m
Flattening (inverse)	298.257223563	300.801700000
Latitude	23 47 52.02714	23 47 49.4850
Longitude	90 24 56.34042	90 24 06.5527

The relative position of the tide observation station, the networks of bench marks and control points are as shown Fig. 1,2 and 3, respectively. The detailed layouts of the individual control points and bench marks, the survey results and the materials of analytical and computation data will be separately given and reported.

All our efforts and activities poured into the construction and completion of the key facilities indispensable for the network of the control points for the national geodetic system in Bangladesh such as the tide observation station, the control points and the bench marks installed throughout the land of Bangladesh and the relevant operational and surveying activities conducted at these facilities were compiled into this comprehensive report.

We expect that the report and the completed network of the control points for the national geodetic system will greatly contribute to the land development and the development of flood preventive measures in Bangladesh, including the preparation of maps, and the results obtained from the surveying activities will be widely used and applied in scientific researches and studies in Bangladesh.

Photo 1 Project Office of the JICA Study Team

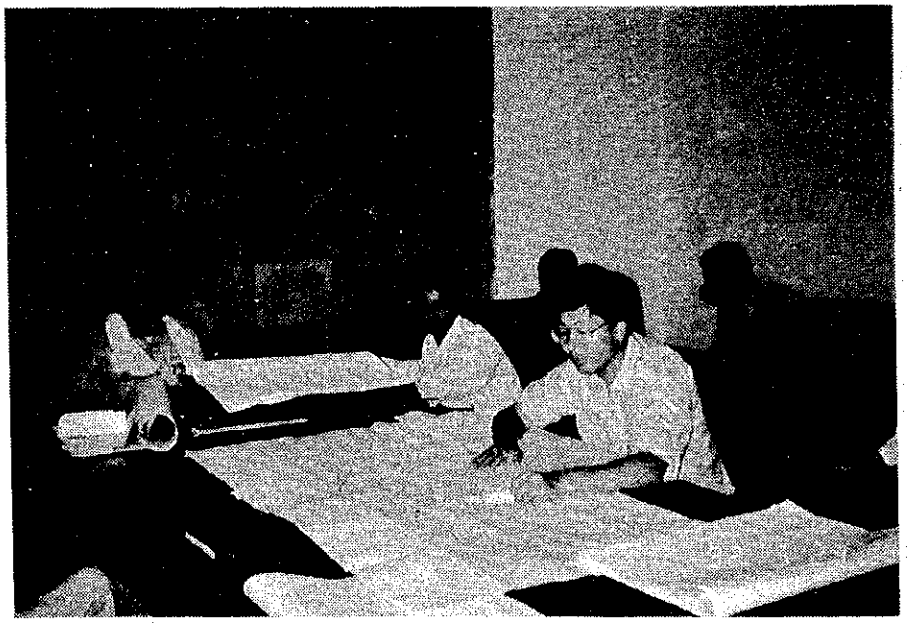


JICA Study Team Office

Prior to departure for field work (car park)

Photo 2 Work preparations under way

JICA Study Team Office
(Meeting Room)



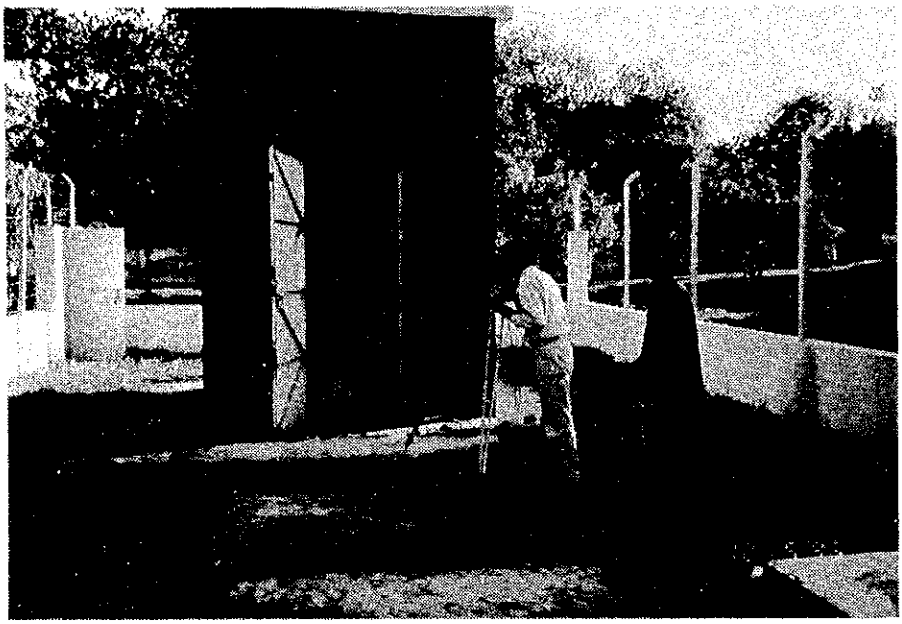
Survey of Bangladesh
(Meeting Room)

Photo 3 Meetings with SOB etc.

Minutes being signed (P/O)

Courtesy call and discussion with Defence Secretary

Photo 4 National geodetic datum

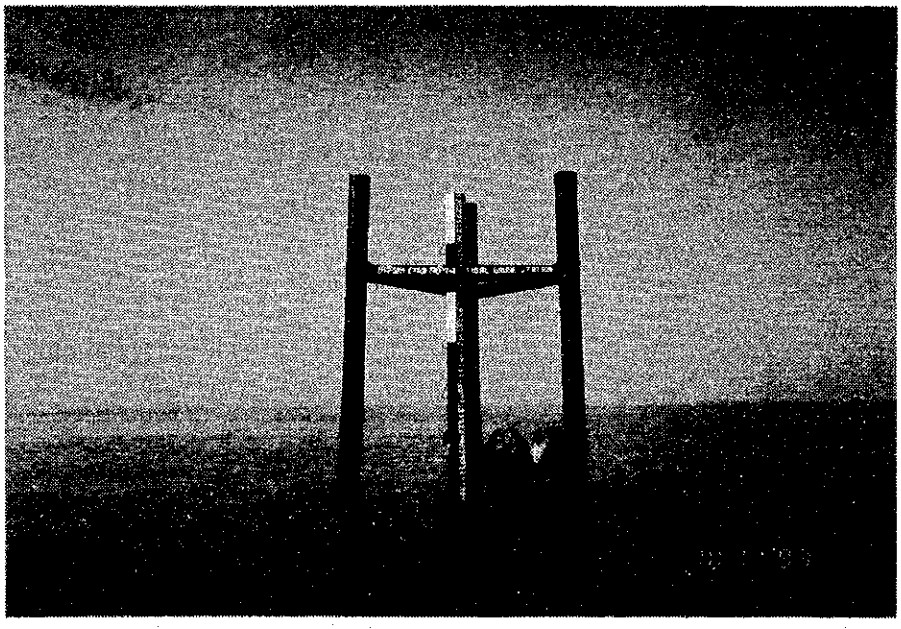


Vertical datum

Horizontal datum

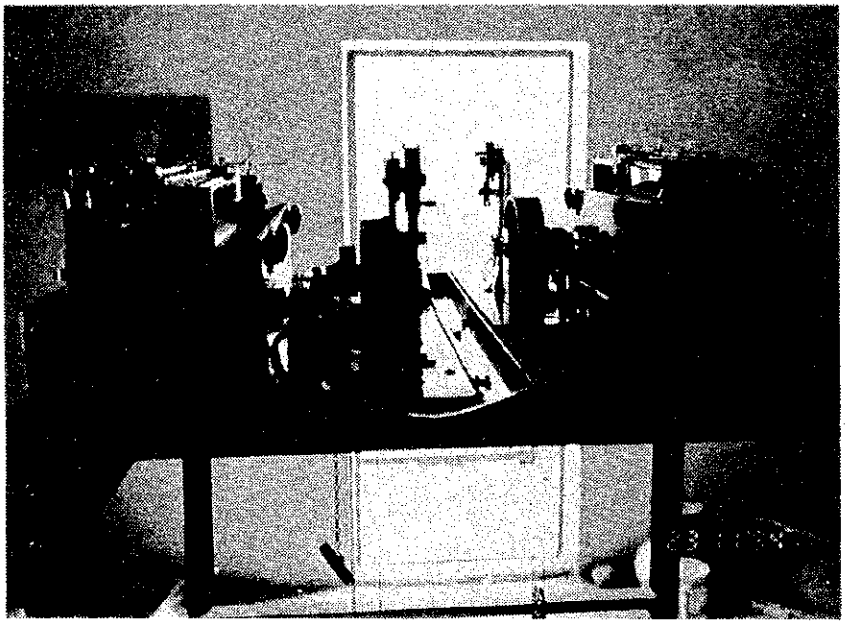
Photo 5 Tidal observation station

Standard tidal observation station

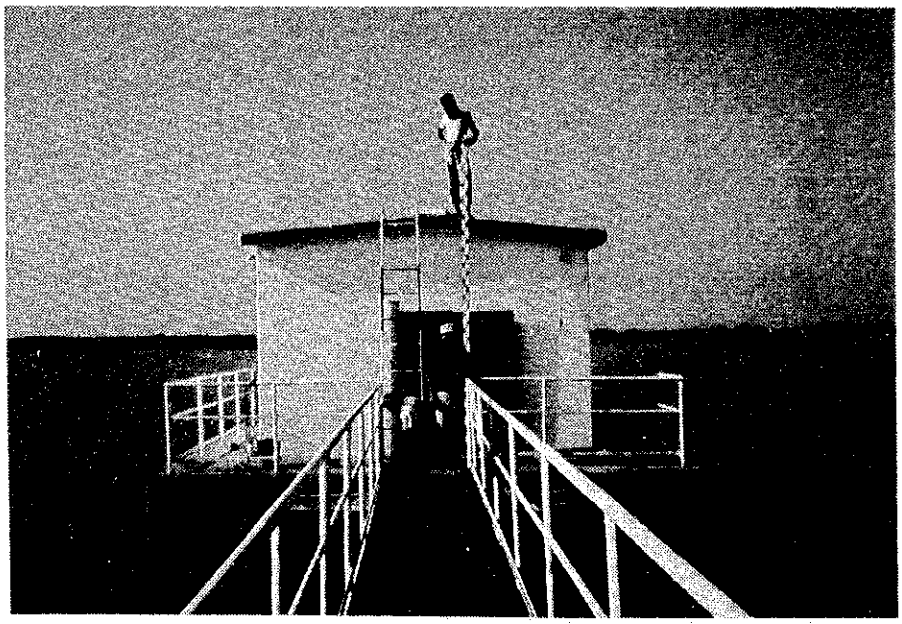


Auxiliary tide gauge station

Photo 6 Tidal observation

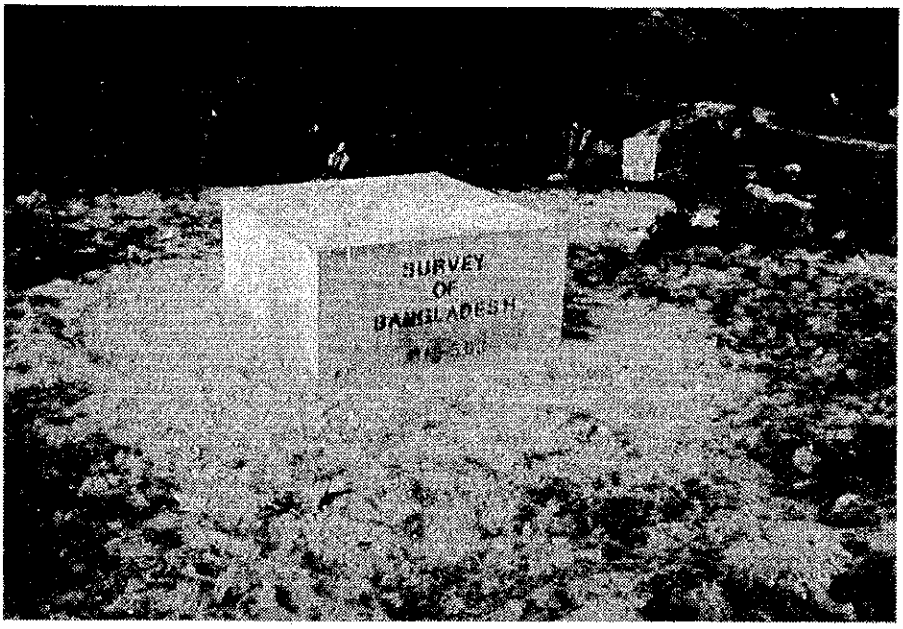


Tide gauge (Fuess type)



Tide gauge (levelling observation)

Photo 7 Levelling

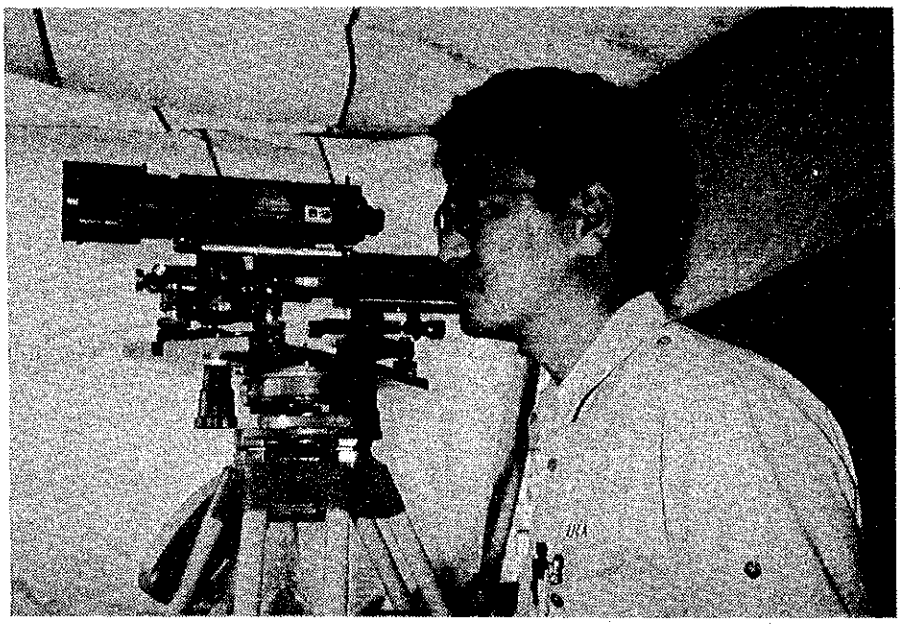


Bench mark (standard type)

Levelling (observation)

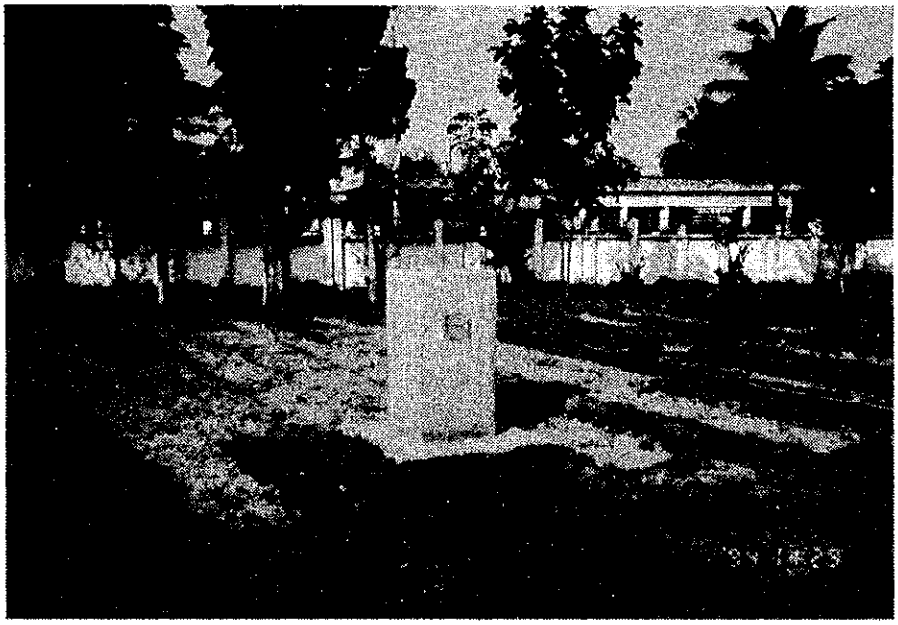
Photo 8 Levelling

River cross levelling (platform)



River cross levelling (observation)

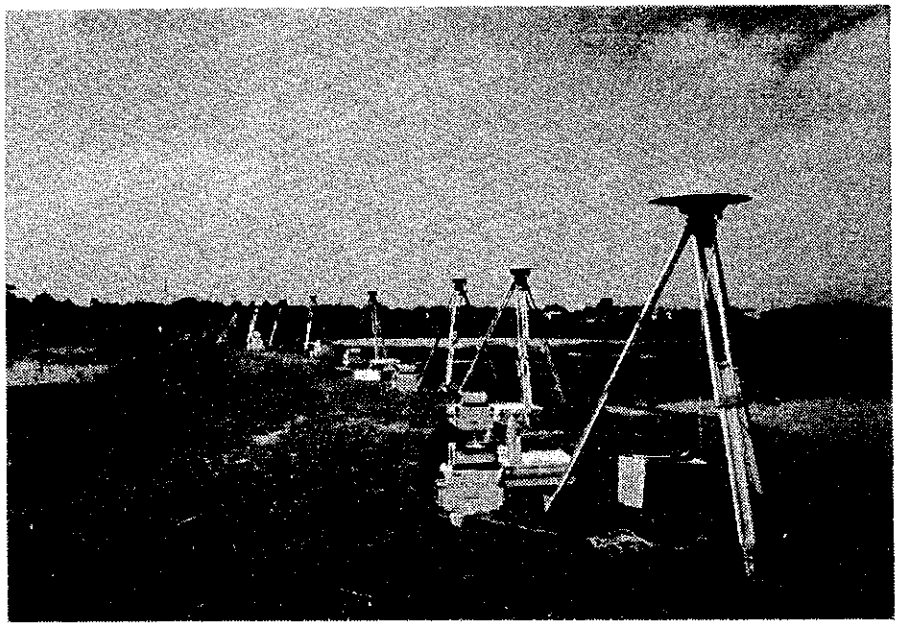
Photo 9 Control point surveying



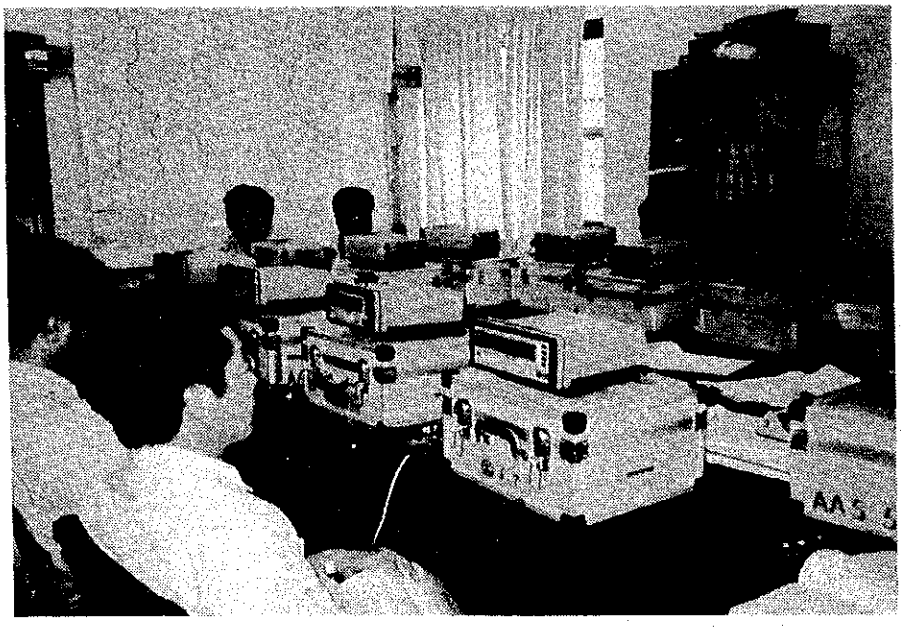
Control point (type A)

Control point surveying (observation)

Photo 10 Control point surveying

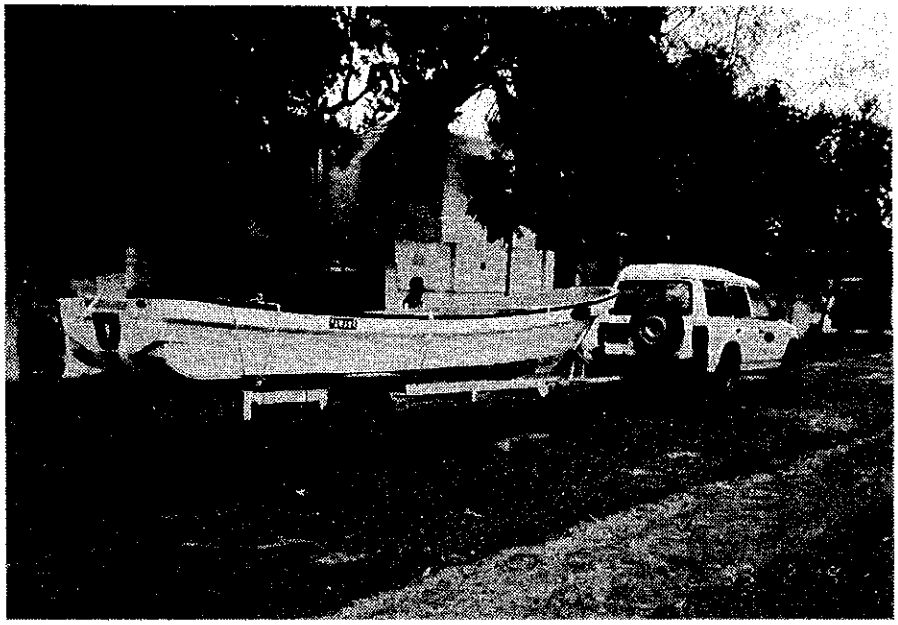


Control point surveying
(calibration of GPS)

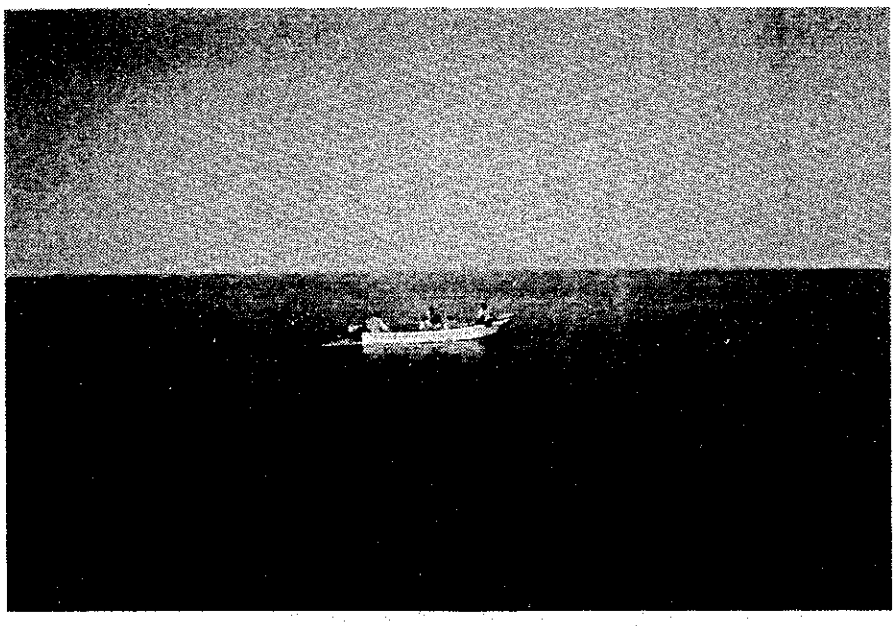


Control point surveying
(function test of GPS)

Photo 11 Control point surveying



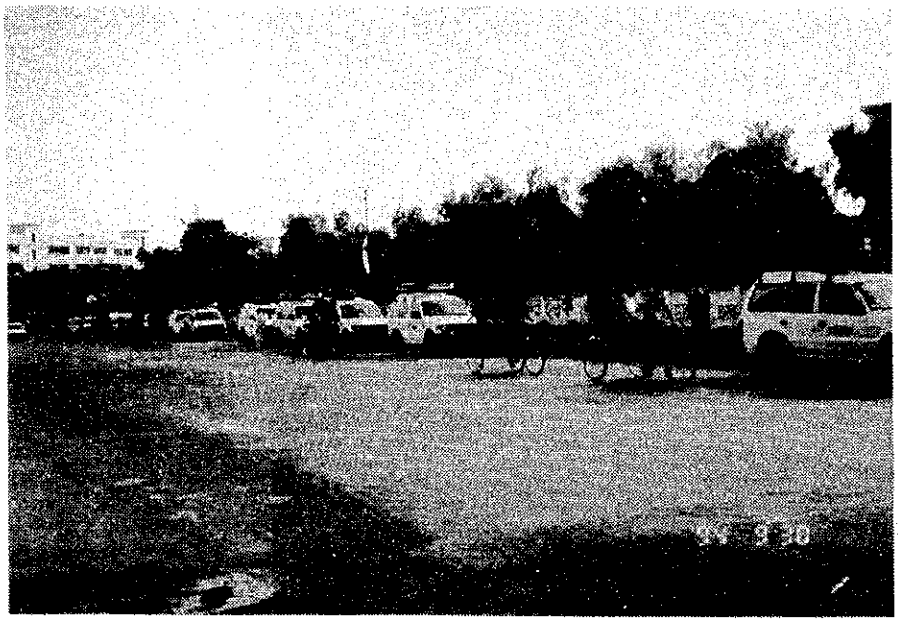
Speed beat
(land transport)



Speed boat
(river cross surveying)

Photo 12 Control point surveying

4WD vehicle
(levelling team)



On the way to the work site
(control point team)

STUDY ON THE GEODETIC SURVEY OF BANGLADESH
GENERAL REPORT
INDEX

APPENDICES

MINUTES OF MEETINGS AND REPORTS

A LIST OF DESCRIPTIONS OF ABBREVIATIOINS

SOB	:	Survey of Bangladesh
GPS	:	Global positioning System
TBM	:	Annexed Bench Mark of Tidal Observation Station
FM	:	FINN MAP, Finnish survey firm participating FAP
WGS-84	:	World Geodetic System (1984)
EVEREST (1830)	:	Reference Ellipsoid after Sir Geoge Everest
SESSION	:	The specific time period chosen for an GPS observation
GEOID	:	Equipotential surface of the Earth's gravity field
IGS	:	International GPS Service for Geodynamics
Kalianpur	:	Place name in India, Indian geodetic datum
$\sqrt{Q}$	:	The value indicating geometrical strength of triangular net
B.M.	:	Bench Mark
CUFL	:	Chittagong Urea Fertilizer LTD.
RMS	:	Standard deviation (Root Mean Squre Error)
M.S.L.	:	Mean Sea Level
BIWTA	:	Bangladesh Inland Water Transport Authority
CPA	:	Chittagong Port Autority
NNSS	:	Navy Navigation Satellite System
UTC	:	Coordinated Universal Time
IERS	:	International Earth Rotation Service
IAG	:	International Association of Geodesy
ITRF(92)	:	IERS Terrestrial Reference Frame 1992

A LIST OF TABLES AND CHARTS

1. OUTLINE OF THE STUDY

1-1 Background

The control points in Bangladesh were originally established by the Survey of India at the beginning of the nineteenth century. Because of the triangulation chains adopted for the control point surveying, the control points were not evenly distributed throughout the country. Consequently, a large blank area where no control points were installed was found especially in the Northeast Region and in the Northwest Region as well and the same blank area was also left in the Sourthwest Region.

What also should be noted is the fact that because the control points still in existence have been poorly and insufficiently maintained since they were installed, they have been left exposed to natural or artificial damages and most of them have now been lost or missing. Even what have surveyed have shown a marked functional deterioration in terms of accuracy. The bench marks were found to have been far more seriously damaged than the control points in terms of accuracy with the passage of time as well as in the number of what have been lost or ruined.

The independence of Bangladesh in 1971 caused the datum station of triangulation as well as the datum station of levelling to have been left behind in India. For this reason Bangladesh have never had an opportunity of having datum stations of its own since then.

For the above reasons the production of topographical maps or charts and various kinds of civil engineering and construction projects encounter a great deal of difficulties in Bangladesh. Therefore, the Survey of Bangladesh regards the reconstruction of the devastated geodetic system as the greatest and the most urgent issue for Bangladesh.

This study aims to reestablish the geodetic system in Bangladesh on a sound basis, including the determination of a datum station of triangulation, a datum station of levelling and mean sea surface level and the installation of control points and bench marks throughout the country and finally the establishment of the network of the geodetic control points.

Also, this study is a significant project in the sense that it not only lays the foundation of various development projects formulated on the basis of the Third National Five-year Plan of Bangladesh (July 1985 to May 1990), but also it responds to especially what are proposed as the necessary step for the urgent reestablishment of the geodetic system pointed out in the reports prepared by the participating countries concerning the Flood Action Plan being carried out by the World Bank and donating countries as well as what are urgently called for in the same tenor in the meetings of donors and experts sponsored by the World Bank.

Recognizing that a study for a national geodetic control network is prerequisite for implementing various national land development and conservation plans as well as projects for improving social infrastructures, the Government of Bangladesh requested Japan for technical cooperation in conducting a study of a national geodetic survey covering approximately the entire nation.

(1) The Survey of Bangladesh in Dhaka was designated as the central survey agency of the national government following the independence of Bangladesh. However, since plans to establish a national control point network, upgrade aerial photography operations and produce a basic national map were greatly delayed, the agency was consequently unable to respond to demands for these services.

(2) Although Bangladesh inherited a national control point network created by the Survey of India in the 1800's, this network lacks a geodetic datum, a vertical datum and tidal stations necessary for determining the national geodetic plane. Currently managed national control points and bench marks do not function as a national control point network in the sense of both density and precision. Thus, the nation of Bangladesh urgently requires a modern and own geodetic system.

(3) During the Dhaka Conference of Donor Nations held in January 1990, the World Bank and participating donor nations proposed a Flood Action Plan for Bangladesh. Japan, however, announced that the project at hand would be separated from other action plans and managed bilaterally between Japan and Bangladesh. This decision was subsequently approved by the World Bank, the Government of Bangladesh and participating donor nations.

In response to this request, the Japanese Government dispatched a study team to Bangladesh from late July to mid August in 1990 and from late November to mid December in 1991. After negotiations with the Survey of Bangladesh (the counterpart agency of the study team hereafter referred to as SOB), a (S/W) for this study was sanctioned between the two sides on December 5, 1992.

According to this (S/W), it was decided to carry out a study for a national geodetic control network in April of 1992.

1-2 Objectives

What were presented by the SOB as the objectives of this study were as follows:

1) To extend the national geodetic control point network
2) To monument permanent geodetic control stations
3) To produce topographical maps necessary for working out various development programs
4) To upgrade the deteriorated technology of SOB

Based on the preliminary study results and the consulations with the SOB, all the objecties presented above were reexamined and modified to make them feasible and what were considered to be irrelevant to the basic study objectives were deleted. Consequently, the objectives of this study were defined more explicitely and clearly as follows:

1) To establish the first order control point network
2) To establish the first order bench mark network
3) To determine the mean sea level
4) To transfer the state-of-the-art geodetic technology

To achieve the above objectives the scope of the study was defined as follows:

(1) Reconstruction and reestablishment of the network of geodetic control points

1) Mounmentation and observation (141 points)
   * Reconnaissance, point locationing and monumentation
   * Control point surveying by GPS (Global Positioning System)
   * Adjustment and computation of the network of control points

2) Restoration of standard datum of geographical coordinates (1 unit)
   * Repair and renovation of the old, temporal standard datum of geographical coordinates.
   * Determination of the standard datum of geographical coordinates values by GPS

3) Monumentation and observation (465 points, 2,386 km)
   * Reconnaissance, point locationing and monumentation for bench marks
   * Surveying at bench marks (over-river survey included)
   * Adjustment and calculation of the network of bench marks

4) Construction of the datum station of levelling and a housing facility
   * Designing and point selection and construction of the datum station of levelling
   * Construction of the facility that protects the datum station (levelling, longitude and latitude)

5) Construction of a tide observations station (one standard station and one auxiliary)
   * Designing, point selection and construction of the tide observation stations
   * Installation and operation of tide gauges

6) Observation of tides
   * Analysis of tide levels (determination of mean sea surface level)

(2) Technology Transfer

The technologies related to the survey of datum points and bench marks, tidal level observatioin and determination of average sea surface level will be transfered to the benefitiary through this research.

1-3 Study Area

(1) Topography

Bangladesh covers a total area of 144,000Km^2 located between 20°34' to 26°38' latitude and between 88°01' to 92°41 east longitude. The country borders with the Bay of Bengal in the south, and is almost completely surrounded by India with the exception of part of the Southeast Region which borders with Myanmar.

In regards to topography, the entire national land is part of the Bengal Delta, and the river basin was formed from soil desposited by large rivers such as the Padma (Ganga), Jamuna (Brahmaputra) and Meghna. A basically low and flat country, the maximum elevation of the valley region, mostly below 8m, is only about 90m. Diluvial plateaus with elevations between 10m to 17m cover the area surrounding the Chittagong hills and low grounds between the Ganges, Brahmaputra and Meghna rivers in the northeastern part of the valley region.

(2) Social and economic characteristics

The population of Bangladesh was recorded as approximately 141 million in 1987, meaning that population density has risen to 720 people per km^2. Demographic distribution in urban and farming areas is 84.8% and 15.2% respectively, showing that a large proportion of the population is concentrated in cities. Although 86.6% of the population is Muslim, there are

also small representations of Hindus (12.2%), Buddhists (0.6%) and Christians (0.3%). The economy relies heavily on agriculture, with 85% of the population, or 61.3% of the work force, participating in this sector. Textile production, primarily of jute, is the largest manufacturing industry accounting for 9.0% of the work force and 47.4% of all factory output, followed by tobacco (13.7% of factory output), basic metals (12.1%) and chemicals (10.5%).

The national government administers five "Divisions" in Dhaka, Chittagong, Khulna, Rajshahi and Barisal. Each of these divisions are comprised of, "Districts" (or "Zilas"), "Municipalities", "Thanas", "Unions" and "Mouzas".

(3) Climate

Bangladesh belongs to the subtropical monsoon zone and has three basic seasons. The monsoon season from May to October is characterized by hot and humid weather during which 90% of annual precipitation falls. The dry season from November to February is a dry and relatively comfortable period. The pre-monsoon season from March to April is subject to heavy rains and is the hottest period of the year. The country occasionaly experiences cyclons during May and October, the months before and after the monsoon season.
The nationwide average rate of precipitation per year is about 2,320mm. However, precipitation figures vary greatly according to region, ranging from 1,250mm in the south to 5,750mm in the northeast. The highest and lowest temperatures recorded were 43°C and 3°C respectively.

Meteorological Data, Dhaka (capital)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Maximum temperature (°C)	26.7	30.4	33.1	33.8	34.9	33.7	31.4	31.9	32.2	32.4	30.2	27.4
Minimum temperature (°C)	12.8	16.1	20.0	23.5	24.8	22.2	26.4	26.4	26.5	24.3	20.1	15.2
Precipitation (mm)	3	0	33	230	109	316	526	462	363	104	7	33

Meteorological Data, Chittagong (Southeast Region)

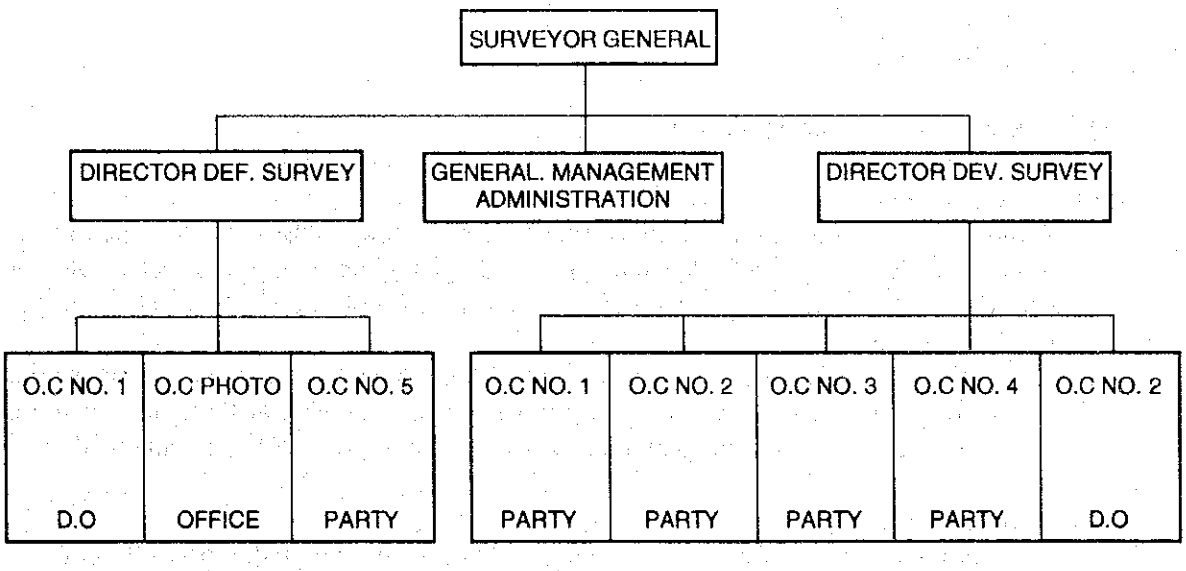
Month	1	2	3	4	5	6	7	8	9	10	11	12
Maximum temperature (°C)	26.5	28.5	31.1	31.4	33.8	31.7	30.3	30.3	29.9	32.3	30.4	27.8
Minimum temperature (°C)	14.6	16.6	19.5	22.0	25.5	25.6	24.6	25.3	24.2	24.0	20.6	16.2
Precipitation (mm)	3	20	80	297	63	394	1267	673	411	36	49	17

(4) SOB organization, survey achievements and facilities

1) Organization and functions

The Survey of Bangladesh (SOB) of the Ministry of Defence is the national agency solely in charge of basic survey operations, basic map production and survey administration. The SOB has a staff of approximately 800 which is headed by the Surveyor General and is divided into administration, planning and management staffs. In addition, the SOB also manages two departments called Director Defence Survey and the Director Development Survey. The Director Defence Survey is primarily in charge of medium- to small-scale maps and consists of the O.C. No. 1 for Drafting, the O.C. Photogrammetry Office, the O.C. No. 5 of Field Party, as well as education and management sections. The Director Development Survey supervises production of large-scale maps and consists of O.C. No. 1 to 4 of Field Parties, the O.C. No. 2 for Drafting as well as education and management sections. The planning and management staffs oversee data collection and map reproduction.

Organization of the SOB



2) Facilities and available equipment

Enough equipment has been prepared for total survey and map production spanning from control point surveying, aerial photogrammetry, plotting / compilation, drafting to printing.

a) Primary equipment

(a) Theodolites	Wild T3	2
	1' direct-reading	5
(b) Telrometer	CA-1000	1 set
(c) Levels	Wild N-3	4
	Kern	2
	others	10
(d) Plotting instruments	Wild A7	1
	Wild A8	1
	Wild B8	4
(e) Rectifier	SEG-V	1
(f) Pantograph		1
(g) Contact printer		1
(h) Process camera		1
(i) Offset printer		4

3) Present status of control points and maps

a) Control stations

Although the triangulation station was inherited from the days of British rule in the 1880's, monuments have been badly maintained and a large number have either been stolen or destroyed. Therefore, only thirty or so remain intact, not enough to create a proper geodetic network.

Level routes were also installed fairly uniformly throughout the nation during British rule. These routes, however, have been only partially maintained. Furthermore, elevation datum were adopted from India and many datum planes have yet to be confirmed.

b) Aerial photography

Although scale courses for aerial photography have not been united, most of the country was photographed from the air by 1952. In addition, aid provided by Canada from 1974 and 1975 enabled aerial photographs at a scale of 1/30,000.

c) Maps

- 1/50,000 scale topographic map: A 1/63,360 (1 inch to 1 mile) scale map produced in 1900 and revised between 1905 to 1958, was re-edited as a 1/50,000 scale map (422 map sheets).
- 1/31,680 (2 inch to 1 mile) scale topographic map: Covers part of the country.
- 1/25,000 scale topographic map: Covers part of the country.
- 1/250,000 scale regional map: Covers the entire country.
- 1/20,000 scale city maps: Covers Dhaka, Chittagong, Rajshahi (1st editions produced in 1970)
- 1/15,000 scale guide maps: Covers Comilla, Sylhet, Mymensingh, Bogra (1st editions produced in 1970)

1-4 Specific Points Noted as Important in Conducting The Study

Judging from the target area to be researched in the study project and the study requirements, what were taken into consideration as specific factors in formulating and carrying out the necessary plans for the surveying and fieldwork activities can be summarized as follows:

1) The project area to be surveyed in the project extends widely, encompassing an approximately 70% of the total land area of Bangladesh.
2) The project area is subject to natural disasters and frequently hit by floods and cyclone.
3) The project area is behind in infrastructure.
4) The project includes construction works.
5) The project uses up-to-date technologies, instruments and equipment.
6) The project calls for the establishment of an independent national geodetic system.

To make the study work proceed smoothly and uninterruptedly, what were specifically taken into consideration in carrying out the assignment were as follws:

(1) Fieldwork

1) In view of the bad road conditions, four-wheel drive (4WD) vehicles and vehicles with roof carriers necessary for the transportation of the instruments, materials and tools were used.

2) Speed boats were used in areas inaccessible by vehicles as well as for river crossing surveying.

3) Wireless radio stations or transceivers that can communicate between each vehicle and the Headquarters were used for the dual purposes of facilitating the fieldwork efficiently and for emergency communication.

(2) Construction Work

1) It was thought necessary to install the control points or the bench marks on the ground that has no risk of overflow in the rainy season and is geologically secure and stable.

2) The necessity of selecting contractors who are capable of procuring construction materials and machinery and have experiences of similar constuction work was pointed out.

3) It was thought necessary to conduct a boring study prior to the construction of a tide observation station and to layout and structural design after the boring study.

(3) Control Point Surey

1) The location where a control point is installed often coincides with the environment that has the risk of disturbing GPS observation because of the village houses and plants that grow in the vicinity. To avoid the risk, the erection of a simple telescopic mast that can keep holding a GPS receiver's antenna high was proposed as a solution.

2) The determination of a horizontal coodinate on the control point was decided to be refered to Everest (1830) Ellipsoid and the possibility of adopting its substitute was also

examined. It was decided to obtain analytical data by the simultaneous GPS observation both in Japan and in Bangladesh based on the numeric values of the world geodetic coordinates system.

3) In determining elevation computation should be made by taking into account geoid.

(4) Levelling

1) Introduction of digital bar code levels for ensuring the efficiency and the accuracy of the fieldwork

2) Efforts to link the unconnected ring of the levelling route in the northeast region into the network that enables the ring to close will be made as much as feasible.

3) To ensure the safety of fieldworkers, safety working clothes will be used for the levelling work and life jackets for the river-cross levelling.

(5) Tide Observation

1) An auxiliary tide station will be installed off the Patenga Beach to assist the standard tide station installed at the mouth of Karnafuli River for the verification of the mean sea level.

2) In view of the observation data gathered during the slightly short period of two years, the data will also be obtained from BIWTA and CPA for reference.

1-5 Specifications

(1) Specifications of the study

The study was executed according to the S/W, Minutes of the S/W, Instruction Manual for Operations and the JICA Specification for Overseas Surveys. Tab.-1 shows the basic specifications based on these standards.

Tab.-1: Basic Specifications of the Study

Item	Details	Application
Survey Results	Control point survey result Levelling Results Tidal observation Results	S/W, Instruction Manual for Operations S/W, Instruction Manual for Operations S/W, Instruction Manual for Operations
Specification	JICA Specification of Surveying for Overseas	Instruction Manual for Operations
Survey standards	Geodetic coordinate system: Everest (1830) (reference ellipsoid) Vertical datum: Mean Sea Level of the Bay of Bengal	JICA Working Regulations S/W
Accuracy	Control point surveying: $\pm 10^{-5}$ Leveling: $\pm 4\ mm\sqrt{S}$ diference of double running, $\pm 4\ mm\sqrt{S}$ closure of loop (S: Km)	 S/W, attached M/M S/W, attached M/M S/W, attached M/M
Inspection of the result	A certificate from the Japan Surveyor's Association shall be issued	Instruction Manual for Operations

(2) Study contents

The workload of the main study is as follows.

1) Control point surveying

a) Reconnaisance and monumentation
After surveying the approximately 95,000km^2 study area, 140 points in the area for control point surveying were investigated and115 selected control points (26 A-type and 89 B-type points) were installed.

b) Renovation of the geodetic datum
One geodetic datum in Dhaka was renovated.

c) Control point surveying
141 control points were observed, and 51 of these points were linked to BMs for geoidal undulation generation.

d) Computation and network adjustment
Network adjustment computation were applied to observed control points.

2) 1st Order Levelling

a) Reconnaissance and monumentation
After investigating the 2,280km leveling route, points for bench mark monumentation were selected and 228 standard bench marks were insatlled at approximately 10km intervals.
Furthermore, 233 small type bench marks were installed at 10 km intervals between the standard bench marks.

b) Construction of the vertical datum
One vertical datum, along with a housing facility was constructed in Dhaka.

c) Levelling
1st Order Levelling (including river cross levelling) was conductes to the approximately 2,386 linear km.

d) Computations and network adjustment
Network adjustment computation were applied to the observed bench marks.

3) Tidal Observation

a) Construction of tidal station
A tidal station was constructed in Chittagong, and auxiliary tidal stations were built in nearby areas.

b) Tidal observation
Tidal observations were continued after construction of the standard tidal observation station, and auxiliary tidal observations were conducted for about 22 months and 15 months respectively.

c) Determination of the mean sea level
The mean sea level was calculated after analyzing tide level observation records.

Works for each year of this four year study which began in 1991 F/Y are as follows.

Phase I (1991 F/Y)
Work in Japan: Preparations, P/O drafting, report organization
Work in Bangladesh: Control point reconnaissance/ selection, bench mark reconnaissance/ selection, tidal station location

Phase II (1992 F/Y)
Work in Japan: Preparations (including facility design and order preparations), P/O drafting, report organization
Work in Bangladesh: Renovation of the geodetic datum, control point monumentation, control point surveying (including elevation linking surveys), vertical datum construction, bench mark monumentation, tidal station construction (including tide gauge installation surveys), auxiliary tidal station construction, tide level observation

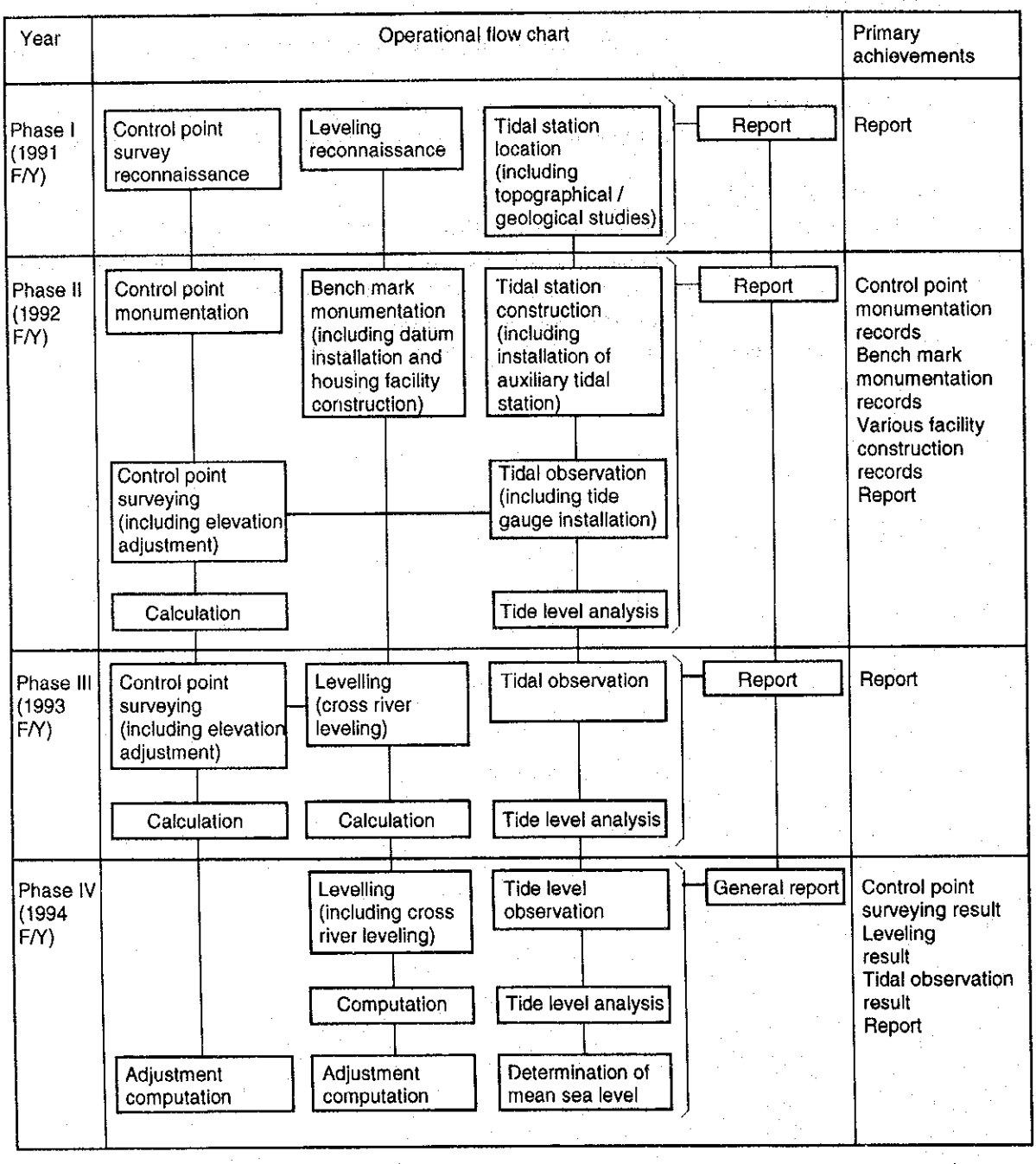
Phase III (1993 F/Y)

Work in Japan:	Preparatory operations, P/O drafting, calculations for control point surveying, calculations for leveling, tide level analysis, report organization
Work in Bangladesh:	Control point surveying (including elevation adjustment surveys), levelling (including cross river levelling), tide level observation

Phase IV (1994 F/Y)

Work in Japan:	Preparations, P/O drafting, calculations for control point network adjustment, calculations for leveling, calculations for bench mark network adjustment, tide level analysis (determination of the mean sea level), report organization
Work in Bangladesh:	Levelling (including river cross levelling), tidal observation

1-6 Flow Chart of Yearly Operations



1-7 Yearly Plans of the Study

Year	Operation	Workload	Remarks
Phase I (1991 F/Y)	Preparations (Japan)	Plan & preparations, P/O drafting	
	Control point surveying	Reconnaissance- Area: 95,000km^2, Selected points: 140 nos.	Existing points: 24 nos.
	Levelling	Reconnaissance: 2,280 linear km, Selected points: 465 nos.	Existing points: 2, including vertical datum, river cross points, annex points
	Tidal observation	Reconnaissance: 1 location (tidal station location)	Including topographic, geographic studies
	Report; Preparations (Japan)	Work report: 2 copies; Plan & preparations, P/O drafting, facility design	
Phase II (1992 F/Y)	Control point surveying	Monumentation: 115 points Geodetic datum renovation: 1 Control point surveying: 60 stations Calculation: 60 nos.	A-type 26 nos., B-type 89 nos. points Linking orthometric height (4 points: 3rd order, 23 km)
	Levelling	Monumentation: 461 points Bench mark construction: 1	standard type 228 nos., small type 233 nos. including housing facility construction
	Tidal observation	Construction of the tidal observation station and auxiliary tidal station Tidal observation / data analysis: 1 set	including annex bench mark for tidal station including tidal gauge installation
	Report	Work report	
Phase III (1993 F/Y)	Preparations (Japan)	P/O drafting	
	Control point surveying	Control point surveying: 81 station Computation: 81 points	Linking arthometric height (23 points: 3rd order, 59km) 1 additional observation for observation (tidal station)
	Levelling	Levelling: 762km Calculation: 762km	River analysis leveling (6 sites) Including additional observation for 32km of unsurveyed routes
	Tidal observation	Tidal observation / data analysis: 1 set	
	Report	Work report: 2 copies	
Phase IV (1994 F/Y)	Preparations (Japan)	Plan & preparation, P/O drafting	
	Control point surveying	Network adjustment computation: 141 nos.	
	Levelling	Leveling (including river cross levelling): 1,550 km Computation: 1,550 km Network adjustment computation: 2,312 km	Linking orthometric height (24 points: 3rd order, 213 km) River cross surveys
	Tidal analysis	Tidal observation / data analysis: 1 set	
	Report	Completion report: 3 copies General report (Japanese): 10 copies General report (English): 100 copies	

1-8 Plan and Execution

1-8-1 Outline of Study Plan and Execution

Kind of Work	Planned	Executed	Remarks
Survey at control points (Reconnaissance and point selection)	140	141	Includes standard datum of geographical coordinates, existing control points
Survey at bench marks 2,280 km (Reconnaissance and point selection)	2,280 km	465	Includes datum station of levelling, annexed bench mark, over-river points, existing points
Tide observation station (Examination and selection)	1	1	Chitt. Karnafuli River mouth (Includes an auxiliary station)
Control points survey (Mounmentation)	115	115	A type: 26 B type: 89
1st order levelling (Monumentation)	461	461	Standard type: 228 Small type: 233
Repair and decoration of horizontal datum station	1	1	Dhaka Gulshan - 2 Tank Park
Construction of vertical datum station	1	1	Dhaka Gulshan - 2 Tank Park
Construction of a tide observation station (includes an auxiliary one)	1	1	Chitt. Karnafuli River mouth
Reinforcement and repair work of an auxiliary tide station	—	1	Chitt. Potenga Besch
Tide level observation at the standard tide station	About 2 years	22 months	Jan. '93 - Nov. '94
Tide level observation at the auxiliary station	About 1 year	15 months	May. '93 - Nov. '94
1st order levelling (Observation)	2,280 Km	2,386 Km	levelling observation (includes over-river bench marks: 7)
Control points survey (Observation)	140	141	GPS observation
Elevation linking survey (Observation)	295 km	296 km	51 GPS points Third order levelling
Tide observation (Analytical calculation)	1	1	Calculation of mean sea level
1st Order Levelling (Network adjustment)	2,312 km	2,386 km	First order levelling
Control points survey (Network adjustment)	140	141	All GPS observation

(1) Differences Between Planning and Execution

1) Number of control points
Since analysis of tidal levels requires the exact location of the tidal observation station, a metal mark was erected in the corner of the station, which enabled to figure out the geodetic position by GPS observation. For this purpose a control point was added.

2) Reinforcement and repair of an auxiliary tidal observation station
The auxiliary tidal observation station constructed in the second year of the study required a repair work because it was broken by the strong wind or supposedly by the contact of a vessel in August of 1993.

3) Tide level observation
It was originally planned to determine mean sea level by the tide level observation at the standard tide observation station (about two years) and the auxiliary tide observation station (about one year).

Although the delay in the construction work for the standard tide station and the malfunctioning of the tide gauges caused to have yielded data slightly less than what was originally planned, the data obtained were found to be good enough for tide level analysis and satisfactory results were finally obtained for analytical purposes.

4) Levelling (Observation)
The observation distance for levelling at S/W was first figured out on the map to be about 2,200 km, which was, however, corrected to about 2,280 km by the actual route surveying conducted in the first year of the study.

The observation of bench marks was conducted in the third and fourth year of the study after having waited for the newly monumented bench marks to become secure after natural subsidence for a period of one year. In the third year the fine weather contributed to the extension of the observation distance as far as the swamp area in the northeast region (an unexplored route of 32 km), which served to extend the observation distance slightly, leading to the finally explored distance of 2,386 km.

5) Elevation linking survey an GPS stations
In an initial plan after the determination of elevation by the direct levelling method about 40 PGS station were to be linked with B.M., which were intended to be used for computing orthometric height at all GPS points. Aiming to enhance the accuracy of orthometric height, GPS stations were additionally given to the eleven control points located at the periphery of the geodetic network by specifically taking into consideration significant geoid undulation in the country.

1-8-2 Period of Study

1) Changes in day-to-day schedules

The delay in the construction work of the tide observation station in the second year study attributable to the difficulties of hammering the piles and drilling an observation well and as a result the schedules of deputy team leader were inevitably altered and finally adjusted so as to meet the final completion day of the construction work. The inspection and approval of the construction work were conducted in line with the work altered completion day.

In the third year study the delay in the reconstruction work of the auxiliary tide observation station due to the bad weather caused the stay of the dispatched coastal engineer to extend and he was obliged to stay longer for seven days. (See Fig. 4: Work Process Chart)

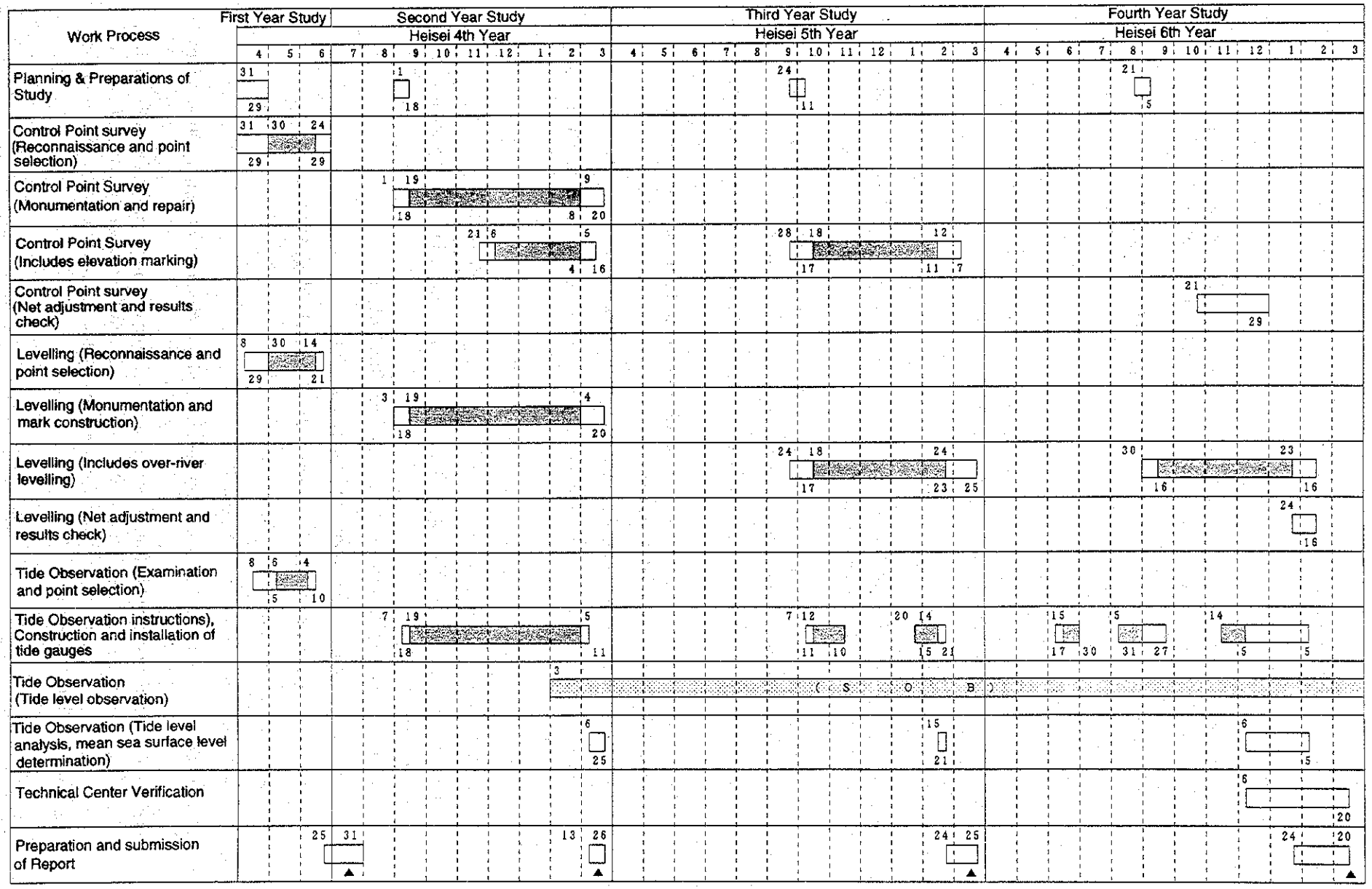


Figure 4 Work process timetable

1-8-3 Technical Consultations

(1) Outline of study plan

This study was intended to establish the national geodetic control network in an area that covers about 70% of the total land area of The People's Republic of Bangladesh. The explanation of the detail of the study was given to the Survey of Bangladesh (SOB) based on the Plan of Operation that compiled the contents of the work plan formulated for each year. (See Appendix: 2-9, Plan of Operation for each year (P.O) and Minutes of Consulations)

(2) Consultations on plan of operation

Consultations were made on the yearly work load, work order, work period, work formation and the services and facilities provided by Bangladesh.

(3) Presentation of Plan of Operation (P/O)

After the presentation of the Plan of Operation (P/O) to the Surveyor General of the SOB what were mainly discussed were as follows:

* Reconnaissance and locationing of control points and bench marks and the specifications of the monumentation work for the control points and bench marks
* Reconnaissance and site selection of the tidal station location and construction of the station
* Specification of a repair and decoration of horizontal datum station construction of vertical datum and the related facility
* Monumentation work of control points and bench marks
* Repair and decoration of horizontal datum, construction of vertical datum and related facility
* Observation of the control points network by GPS
* Construction work for the standard tidal station and the auxiliary station
* Observation schedule for control points and 1st order levelling and the arrangement of the counterpart staffs
* Reinforcement and repair work for the auxiliary tidal station
* Opening ceremony of National Geodetic Datum Yard
* Tidal observation work (tidal level observation and technology transfer)
* Observation for 1st order levelling survey
* Elevation linking survey (GPS points)
* Geodetic network adjustment and computation and determination of datum station values

The above-mentioned consultations were carried out in the meeting room of the SOB and in the office room of the Surveyor General. What were agreed upon between the two parties were properly processed through the direct instructions by the Surveyor General given to the subordinate divisions of the SOB.