FAP-8B
(Bridging Period)

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

INCEPTION REPORT
DHAKA INTEGRATED FLOOD PROTECTION PROJECT
(BRIDGING PERIOD)
ADB LOAN NO - 1124-BAN (SF)

TECHNOCONSULT INTERNATIONAL LIMITED, BANGLADESH

In association with

ASSOCIATED CONSULTING ENGINEERS LIMITED, BANGLADESH,

DESH UPODESH LIMITED, BANGLADESH,

and

Individual Consultants from LOUIS BERGER INTERNATIONAL INC., USA

February, 1992

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Dhaka Integrated Flood Protection Project
(Bridging Period)

Technoconsult International Ltd.
in Association with
Associated Consulting Engineers Ltd.
Desh Upadesh Limited

DIFP/RT-14/1
February 29, 1992

The **Project Director**
Project Management Office
Dhaka Integrated Flood Protection Project
Bangladesh Water Development Board
Dhaka

Subject : **Dhaka Integrated Flood Protection Project (Bridging Period) - Inception Report.**

Dear Sir,

I have the honour to enclose herewith twenty five copies of the Inception Report for the Dhaka Integrated Flood Protection Project (Bridging Period) for favour of your kind disposal.

The principal object of the report is to present the Work Plan for the activities to be carried out under the project.

Assuring you the best of our cooperation.

Yours faithfully,

(Abdul Barik Bhuiyan)
Team Leader

Enclosure : As stated above.

Sena Kalyan Bhaban 7th Floor 195, Motijheel Commercial Area, G.P.O. Box: 2608 Dhaka-1000, Bangladesh
Phones: 865148, 865149, 862512, 865068, 865069, Telex: 642507 NTI BJ
Cable: NIPTRADE, Dhaka Fax: 880 2 863310, 880 2 863465

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Inception Report

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1. Introduction

The feasibility study on the Dhaka Integrated Flood Protection Project was completed in September 1991. With a view to continuing the project preparation uninterrupted following completion of the project preparatory technical assistance, the GOB decided to engage the ADB TA consultant to continue the services under the loan during the interim period before recruitment of loan consultants. On the basis of the decision taken in the meeting of the National Committee for Flood Control held on January 2, 1992, Technoconsult International Ltd. (Lead firm) in association with Desh Upadesh Ltd. and Associated Consulting Engineers Ltd. with inclusion of key foreign personnel of Louis Berger International Inc., has been selected for the mid-term consultancy services for the period from January 8, 1992 to June 30, 1992. The services to be provided during the bridging period are (i) Project Management advisory services (ii) Detailed Engineering Design and Construction Supervision of work under the work programme for 1991-92 of executing agencies (BWDB, WASA, DCC and RAJUK). This Inception Report is for the services to be rendered under the Dhaka Integrated Flood Protection Project during the bridging period and outlines the programme of activities under the project.

2. Report Objectives

This Inception Report outlines the programme of activities under the project during the bridging period. The activities may be broadly summarized under following items.

(i) Field Survey and Investigation (which include topo-survey, engineering survey, sub-soil boring, field and laboratory tests of soil) for collection of data needed for preparation of design of different physical components under the project.

(ii) Preparation of detailed design, construction drawings, specifications and tender documents for various physical components of work under the project.

(iii) Review of design of drainage improvement works for first year's priority programme of DWASA.

(iv) Assist:

- The PMO in pre-qualifying local/international contractors for different components of work
- The PMO, WASA, DCC and RAJUK in tendering and evaluation of tenders for the first year's work
- The PMO, WASA, DCC and RAJUK in preparation of quality assurance and quality control programme and plan, and in implementation & construction supervision.

3. Project

3.1 General

Dhaka Integrated Flood Protection Project, phase I covers the western part of the Dhaka City and comprises an area of about 137 Km^2 (Fig-1). In 1988 the Dhaka City along with greater part of Bangladesh experienced a catastrophic flood. Following the said flood, the GOB undertook a

crash flood control programme for the Dhaka City which included the following physical components:

(i) Construction of

- flood embankment on western side of the city- 29.2 Km
- RCC flood wall bordering the south-western side of the city- 8.5 Km
- flood embankment around the ZIA International Air port
- new road- 2.0 Km
- 6 drainage sluice on the western flood embankment

(ii) Improvement and raising of road on the eastern side of the Project- 8.5 Km

(iii) Cleaning and repair of drainage khals and sewerage system of the city.

Most of the above components of the flood control programme have nearly been completed.

The project scope covers mainly the completion and augmentation of the flood protection and drainage programme undertaken by the GOB following the 1988 flood. The project consists of four part, viz. Part A: Flood Control, Part B: Drainage, Part C: Environmental Improvement Programme and Part D: Implementation Assistance. As per Feasibility Study Report, the major components of work under the four parts are as follows:

Part A: Flood Protection

- Specialized remedial works and foundation stabilization on 7.8 Km of the existing embankment
- Erosion control and slope protection over 11.5 Km of the existing embankment
- Minor remedial works and slope protection over 24.2 Km of the existing embankment

- Repair and stabilization of parts of 5.3 Km of the existing concrete flood wall
- Construction of 1.6 Km of new flood wall/embankment
- Construction of 5 additional sluices on the existing embankment
- Raising and flood proofing of the Central Spine Road (Tongi Rly Bridge to Friendship Bridge over Buriganal) Burigonga
- Construction of the first stage (capacity 22.5 cms) of the Pump Station No. 3 at Goranchatbari on the western embankment
- Establishment of a maintenance programme and supply of maintenance equipment to safe guard the flood protection investment

Part B: Drainage

- Rehabilitation and upgrading of 21 existing priority khals (including completion of the crash programme initiated by the Government) over a length of 78.6 Km
- Rehabilitation and construction of 50.7 Km of piped drains
- Establishment of a maintenance programme and supply of maintenance equipment to safe guard the drainage investment

Part C: Environmental Improvement Programme

- Slum and squatter area improvement covering about 8725 families
- Solid waste management, including supply of 30 new trucks and complementary waste handling equipment
- Sanitation improvement, including 30 public toilets and 5 mobile toilets, 5500 low-cost sanitary latrines and 2 septic tank dislodging trucks

Part D: Implementation Assistance

A Project Implementation Office headed by BWDB and strengthened by consulting and training services, will be established to provide the following support:

- Planning, detailed design, construction supervision, monitoring and evaluation
- Co-ordination and management of project activities
- Equipment and logistic facilities
- Quality assurance and control, including establishment of materials testing laboratory to complement and work in accordance with the existing laboratories

3.2 Existing Flood Control Structures

The existing flood control structures under the project are

- flood embankment over a length of about 29.3 Km on the western side of the project area
- R.C.C flood wall over a length about 5.3 Km on the southern side of the project area
- 10 sluices on the flood embankment

The above structures were constructed during 1988-89 and 1989-90.

3.3 Existing Drainage System

The existing drainage system of the Dhaka city consists of about 110 Km of piped drains and about 435 Km of khals. Besides, there is a storm water pumping station with a capacity of 9.60 m^3/sec. 21 major open drains totalling about 79 Km in length and 51 Km of piped drains of the drainage system of city are included in the Dhaka Integrated Flood protection project, Phase - I.

4 Problems

ue to exigency of the situation, the works on flood protection of the Dhaka City were taken up y the Government without proper study and site investigation and were executed under extremely ght time constraint and adverse site condition without adequate quality control and coordination f the inter-linking activities. Consequently, there has been serious failures at some points and osion at many sections of the flood embankment and drainage congestion due to blocking of e natural drainage channels. The flood control and the drainage system is neither complete nor lly operative. The flood control measures and the piecemeal efforts made for flood control in e past have generally been ineffective and, in fact, have in some cases, inadvertently mpounded environmental and health hazards in the Dhaka City. Inadequate drainage has sulted in polluted waters remaining stagnant in the low-lying land in density populated slum eas for long periods of time. Uncoordinated collection and disposal of solid waste have ntributed to localized flooding through clogging of drains. Besides, inadequate and ineffective xcreta management has led to high level of exposure to water borne pathogens during floods.

. Performance of the Existing F.C Structures and Drainage System

.1 Embankment

he length of the embankment is 29.3 Km. The embankment provided some level of protection o the western part of the project area against flooding. But the embankment is not in proper hape and condition. The embankment has settled down at several locations and is vulnerable to atastrophic failure. Besides, the R/S slope of the embankment has been eroded over a length bout 8.5 Km in discontinuous stretches, which needs protection with hard materials. The R/S lope of embankment in some other reaches totalling 15.6 Km in length needs patch repair with eo-jute and sod protection. The R/S width of the berm over a length of 2.28 Km is less than the pecified width of 7.6 m. Berm of the specified width is required to be built over the said length f the embankment. The embankment needs rehabilitation.

4.2 Flood Wall

he length of the flood wall is 5.3 Km. The flood wall is not fully operative as there are some ngated openings in it. Besides, the wall is not in proper condition because of apparent design eficiency. It has been damaged at many locations. The wall needs remedial measures to make

it stable and fully operative. The stability of the wall will be assessed and modified design will be prepared, if necessary.

4.3 Sluices

There are 10 sluices on the western flood embankment. Of the 10 sluices, six have been constructed by BWDB (one as deposit work of DCC) and the other four have been constructed by the Bangladesh Army. The sluices constructed by BWDB are found stable and adequate in capacity and are functioning satisfactorily. But the sluices constructed by the Army are of inadequate capacity. Besides, they will not be stable under the extreme condition. One of the said sluices has already collapsed. They will have to be dismantled and removed on construction of the new sluices.

4.4 Drainage System

The existing drainage system is not in proper shape and is not adequate for efficient drainage of the city area covered by the project. The condition of the drainage system has deteriorated over the years. The draining capacity of the system has been greatly reduced because of clogging of khals with debris and blocking of drainage ways by indiscriminate construction of structures on them. The drainage problem of the city has aggravated over the years because of the following reasons.

(i) Indiscrimate filling-up of the low-lying areas of the city without keeping provision for storm water disposal

(ii) Increased run off due to expansion of the city with pucca surface

(iii) Unplanned urbanization

(iv) Increased refused water due to increase in the city population.

5. Work Plan

5.1 Work Plan and Schedule

The work plan and schedule has been prepared keeping in view the work programme of the executing agencies and the extreme tight time constraint. The work plan and schedule is shown in fig 2. It is seen from the work plan that as many as 14 broad tasks will have to be accomplished in a period of little over 5 months. Of the said tasks, preparation of design and drawings of the different physical components is the main and central task. Timely implementation of priority work programmes for 1991-92 of the executing agencies depends upon completion of design and drawings in due time. In view of the priority work programmes, which includes construction of 4 sluices on the western embankment, slope protection, berm building and borrow-pit filling (under BWDB) and construction of covered drains and culverts (under WASA), preparation of design and drawings, and review of the design of the work components proposed for execution during 1991-92, has been accorded top priority in the work plan. Time schedule for top priority design and drawing work has been so prepared that execution of physical works can be taken up as per schedule after completing all procedures and formalities. Timing and period for necessary field survey and investigation for design data collection has been so fixed in the work plan that preparation of design does not suffer for want of field design data. On completion of preparation of design, drawings and estimates of the priority work, efforts will be concentrated on design of 5 sluices on the Central Spine Road (the eastern boundary of the project), flood embankment & flood wall remedial measures, flood embankment/ flood wall, sheet piling and Central Spine Road raising. Flow chart of activities is shown in fig. 3.

Man-power provided and time allowed for the Consultant's tasks in TOR, are too inadequate for their timely completion. It might not be possible to complete all the tasks included in the work plan by June, 1992.

It is evident from the work plan and schedule that work on construction of the proposed sluices on the western flood embankment cannot be taken up before March, 1992. It might not be possible to complete the construction of the sluices by June, 1992 by taking up the work in March, 1992. And if it becomes so, about 6 m high ring bundh will have to be constructed around the structure sites, which will involve huge cost. Moreover, the ring bundh will be vulnerable to breaching and will need protective measure, including raising in the event of abnormally high flood, during flood season. Ring bundh of nominal height (dwarf bundh) will serve the purpose if construction of the sluices is completed in March or early April in one working season. And this is quite possible. Besides, the site condition of the location one of the

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Sec. 5.2 para-last, page-9:

This is with respect to the use of plane-table survey in inaccessible area, being "densely populated area of the city" vis-a-vis the use of aerial photo maps, needed for fixing the alignment of the embankment / flood wall; it is not explained in clear terms as to whether the aerial photo-mosaic will be used or the stereoscopic aerial-photo interpretation will be made on 1:50,000 scale stereo pairs of the latest maps.

It may be recalled that during F.S stage of the study, efforts were made to obtain 30 stereo pairs of such maps in vain, since Phase-1 area covers Cantonment area.

Now that the maps for the area in question, as wanted by the Consultants, does not cover the restricted area of the cantonment, these maps may be easily available from SOB. So, renewed efforts may be made for collection of maps (stereo-pair), covering Phase-1 area, except the portion of the restricted area of Dhaka Cantonment, so that counter-verification of some other areas too, to be done by Plane-tabling is possible. The present position in this regard may please be mentioned in the Report.

sluices (sluice No. S-8 near Nawabgnnj Park) does not permit construction of ring bundh of the required height. There is no other suitable site for the sluice. There is a pipe sluice on the embankment near the site of the proposed sluice. The existing sluice is linked with a sewer line of the city. The inlet and the outlet of the existing sluice will be closed due to construction of ring bundh of the required height. Further, the ring bundh will completely block the channel that flows parallel to the embankment at the sluice site.

In view of above factors, it is advisable to defer construction of the sluices till November, 1992. The BWDB may kindly consider the factors before taking up the work on construction of sluices.

5.2 Field Surveys and Investigations

(a) Field surveys will be made for collection of necessary field design data and information needed in connection with preparation design and estimates of the different structures. The types of survey that will be made are mentioned below:

(i) Cross-section survey of

- the western flood embankment (29.3 Km)
- part (10.4 Km) of the Central Spine Road
- the drainage channels on which sluices will be constructed
- left bank with a part of the bed of Buriganga at the site of proposed sheet piling (0.8 Km)

(ii) Plane-table and levelling survey of the sites of the proposed nine sluices

(iii) Topographic survey of the catchment areas of different drainage khals.

The site of the proposed flood embankment/flood wall is in a densely populated area of the city. Since it is not possible/feasible to make plane-table survey of such area, aerial photo map of the area is needed for fixing the alignment of the embankment/flood wall.

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(b) Field investigation involves sub-soil boring and field testing of soil samples. Sub-soil boring will be done at the following places/points:

- sites of the proposed sluices on the western embankment and the central Spine Road
- different points along the alignment of the existing flood embankment and proposed flood embankment/flood wall
- different points along alignment of drainage channels for a length of about 6.19 Km
- site of the proposed sheet piling.

(c) The field investigation and laboratory testing of soil samples in connection with design of remedial measures for flood embankment will consist of the following :

(i) Sub-soil boring at about 80 locations

(ii) Setting up piezometer and observation well

(iii) Field testing of soil samples (shear vane testing and permeability test)

(iv) Standard laboratory tests

- natural moisture content
- wet unit weight and dry unit weight
- specific gravity
- atterberg Limits
- grain size distribution
- consolidation test

(v) Specialized laboratory tests

- tri-axial (UU)
- tri-axial (CU)

Sec. 5.3.7, para 1, page-11,

As regards preparation of proposed sluices on the N-S Central spine road, it may be mentioned that upper & lower portions of this road for certain length (covering almost 2/3 of the entire length) are formed by the Railway tracks. The Rly. track has culverts at places for drainage. These culverts may be examined for exploring the possibility of renovation for gated structures for operation in the case of need. If possible, this may save both time & money.

- radial permeability

Detailed programme of field investigation, laboratory testing of soil samples and analysis of test results, are furnished in Appendix A.

5.3 Detail Design, Construction Drawings and Specifications

5.3.1 Sluices on the Western Embankment and the Central Spine Road

In the FSR, five sluices have been proposed on the western embankment. It is found on field visit and investigation that one of five sluices is not needed. Construction of the sluices is included in programme of work for 1991-92. As such preparation of design and drawings of four sluices were taken up in the 4th week of January, 1992 on priority basis and completed by the 3rd week of February, 1992. Detailed specifications have also been prepared by the said time. Preparation of design and drawings of the proposed sluices on the Central Spine Road will be taken up by the first week of March, 1992 pending collection of sub-soil data. Sub-soil data will be collected during the 2nd half of March and first half of April, 1992. Specification for construction of the structures will be prepared during preparation of drawing of the sluices.

Design of sluices consists of 4 parts, namely hydrological analysis, hydraulic design, structural design and foundation design. Rainfall pattern/ distribution and run off model followed by JICA in the Study Report on Storm Water Drainage System Improvement of Dhaka City have been taken as the basis of hydrological analysis for the sluices. As recommended in the JICA's report, design discharge is estimated by rational formula. The hydraulic, the structural and the foundation design of the sluices have been prepared as per set design criteria of the BWDB.

Detailed drawings of the structures will be prepared with all necessary details and dimensions. Specifications for the different items of work will be furnished on the drawing sheets in clear terms. In case of inconsistency between the drawings and specifications, the latter shall prevail.

5.3.2 Slope Protection of the Western Flood Embankment

Slope protection work of the embankment is one of priority work of 1991-92. Preparation of design and drawings of the protection work was taken in the last week of January, 1992 on priority basis and completed by first week of February 1992. Preparation of specifications for the

Section 5.3.2. para-3, page-12.

Under the para, on the statement that "Specifications for geotextiles have been fixed....." a question is raised as to whether the action is underway now for making arrangement of procurement of the same.

In this connection, it is to be noted that for these staffs, being not in the list of importable item, CCIE (Chief Controller of Imports & Exports) clearance would be needed and as such, timely action is needed to avoid problems & difficulties likely to arise. If the quantity & the specifications of geotextiles are finalised, the PMO should take up matters with CCIE through the Administrative Ministry for obtaining necessary clearance for importation, well ahead of the time, the contractor is fielded. Else, the Contractor will fall prey to government bauracracy & formalities, with the result of the work remaining incomplete. The Consultant should take a note of it and include in their Work plan as to when the imports of such items are proposed for CCI clearance.

work was also completed by the first week of February 1992.

Toe protection of the embankment for a length of 1.6 Km of the embankment at its extreme downstream is found to be necessary. Design of the toe protection along with the slope protection for the said length of embankment was also prepared by the first week of February, 1992.

The slope protection work has been designed with hard materials and geotextile against flood height of 100 yr. return period. Specifications for geotextile have been fixed with due consideration to grain size and permeability of the embankment soil.

5.3.3 Sheet Piling

Since sheet piling is not included in the work programme of 1991-92, preparation of its design and drawings will be taken up in mid April, 1992 and completed by the 3rd week of May, 1992. The soil properties and site condition will dictate the type of piling to be selected and designed. Specifications for sheet piling will be prepared simultaneously with preparation of drawings.

5.3.4 Flood Embankment/Flood Wall

The embankment construction is not included in the work programme of 1991-92. Design and drawings of embankment will be prepared during the period from mid April, 1992 to 3rd week of May, 1992 on completion of sub-soil investigation by 1st week of May, 1992. The embankment design shall be guided by the limitations imposed by the soil properties and construction practices, vis-a-vis the degree of compaction of embankment soil that can really be achieved. The flood wall (as an alternative of embankment) will be designed keeping in view the deficiencies of the existing flood wall and the limitations imposed by the site condition. Specifications for the structures will be prepared during preparation of their drawings. The site of the proposed structure is in a heavily populated area of the city along the Buriganga river. The site condition will, to some extent, dictates the specifications for construction of the structures.

5.3.5 Flood Embankment Remedial Measures

Since remedy of the structure is not included in the work programme of 1991-92, preparation of their design has been accorded the 2nd priority in the consultant's work plan. Preparation of

their design will be taken up in early April, 1992 and will be completed by end of June, 1992. Their drawings and specification will be prepared during June, 1992. The design of the remedial measures for embankment will be guided by the desired degree and rate of consolidation of embankment sub-soil.

It has been proposed in FSR to adopt a new technology, through use of geotextile, in designing the remedial measures for the flood embankment. The remedial measure will be so designed that the factor of safety of the sub-garde is 1.2 within 5 years. Wick drains, instead of the conventional sand drains have been proposed for consolidation of embankment sub-soil. The relative merits and demerits of sand drains and wick drains will be examined in the context of (i) ease of installation (ii) stability during construction (iii) durability and (iv) cost of installation. The design parameters of the remedial measures will be determined after characterizing the sub-grade soil conditions and evaluation of soil properties through field investigation and laboratory testing of soil samples.

5.3.6 Flood Wall Remedial Measures

Under the "Crash Program" beginning in 1989, the Government, as a priority program of works, constructed 5.3 km of reinforced concrete flood walls along the southern boundary of the project in densely populated area of the Dhaka City. Design top level of R/C wall is 0.80 m above the 100 yr. flood level.

From a recent reconnaissance survey the following existing conditions of the R/C walls have been observed:

(i) Crack due to shrinkage and settlement have developed in the R/C wall at many places. During periods of high water flow, these crack could endanger the stability of the wall.

(ii) At many locations the walls have been breached to facilitate easy pedstrain and vehicular access to the river.

(iii) In some locations spalling out of concrete has occurred.

(iv) Erosion under the R/C wall as observed at one location could lead to failure of the wall during period of high water level. Moreover, the exposure of the wall foundation warrants checking of its stability against lateral pressure during high water level.

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Sec. 5.5, para 1, page-14.

The remedial measure for the wall will be decided on detailed inspection, sub-soil investigation and review of the design of the wall. The design and drawings of the remedial measures will be prepared during the period from the 3rd week of May to 1st week of June, 1992.

5.4 Review of Design of Drainage Improvement Works

DWASA has prepared design, drawings and estimates of drainage improvement works included in priority work programme of 1991-92. The priority programme includes (i) construction of 5 covered drains totalling 6.19 km in length (ii) construction of secondary and tertiary drains for a length 15.11 km and (iii) excavation of open drain for length of 1.56 km. The consultants have, on priority basis, completed review of hydraulic design and checking of estimate of most of the priority work components by the end of February 1992. Design of the different components of work prepared by DWASA is found to be based on inadequate data. The inadequacies found in the design and drawings have been made up as for as possible by the consultants with cooperation of the DWASA official on collection of missing data. DWASA has been advised to maintain acceptable minimum standard in preparation of design and drawings. Review of design and checking of estimate of remaining works under the priority work programme will be completed by the 3rd week of April on completion of Sub-soil boring by 2nd week of April, 1992.

5.5 Study on the Pump Station No.3 at Goranchatbari

A pumping station with one-third of the final design capacity (22.00 cms out of final design capacity of 65.2 cms) is proposed to be constructed. The effect of installing pump of the final design capacity and one-third of the final capacity has been assessed during the feasibility study. The effects as assessed from the study are as follows:

Pump capacity	Return period of storm event	Retarding pond level	Corresponding Flooded area
65.2 cms	5 years	4.0 m	19.9 km^2
22.00 cms	5 years	5.1 m	32 km^2
22.00 cms	2 years	4.25 m	22 km^2
22.00 cm	annual	3.6 m	12 km^2

As opined in the FSR, further studies are needed to determine the best combination of the ultimate pumping capacity and the corresponding flooded area. This study will be made during the bridging period of the project. As shown in the work plan for the bridging period, the study on the pump station will be made during May and June 1992.

5.6 Estimate and Tender Documents

The design and drawings of the various physical components of the project as described above are followed by preparation of estimates. The estimates for the following works under BWDB were prepared and submitted to the Project Director, Project Management Office, BWDB by the end of February, 1992 :

(i) Four sluices on the western embankment.

(ii) Slope protection work with hard materials on the river side of western embankment.

(iii) Slope and toe protection work on the riverside of western embankment.

(iv) Berm building, borrow-pit filling, geo-jute and sod protection work including patch repair work of the western flood embankment.

The cost estimates have been prepared as per the guidelines of BWDB. The estimates of the pipe drainage works included in the programme of 1991-92 under WASA, have been checked.

The executing agencies are following their normal procedures of tendering for works to be done through local competitive bidding. Assistance from consultant for tendering and evaluation tenders will be provided as and when required by the executing agencies. The tender documents for works to be executed through international competitive bidding will be prepared after preparation of the design and drawings of the relevant work.

The detailed schedule for the preparation of estimate and tender documents for the works under first year programme has been shown in fig. 2 (work plan and schedule).

5.7 Quality Assurance and Quality Control Programme and Plans, and Construction Supervision

The quality control is of prime importance in execution of work. For maintaining the desired quality of work, a quality control programme and plan is being formulated with due consideration to the factors that affects the quality of work. A check list of the measures which are required to be adopted in the process of quality control, is being prepared. The detailed procedures of inspection and quality control measures will be established in consultation with the concerned officials of the executing agencies. The consultant's Construction Supervision Engineer will assist the executing agency in ensuring adoption of quality control measures. He will also ensure that the set procedures of quality control measures are understood by the staff of the executing agencies and the contractors. He will maintain necessary records of all matters relating to quality control.

The Construction Supervision Engineer will impart training to the staff of executing agencies and the contractors in the efficient implementation of the quality control measures.

5.8 Project Implementation Monitoring and Evaluation

With the mobilization of project personnel and sequential progress of the work, a process of regular monitoring and evaluation of the on-going, accomplished and future work has been established for the timely execution of the work targetted for the contract period.

The M & E procedure will include (i) identification of the tasks to be accomplished within a stipulated period (ii) formulation of work plan and schedule (iii) regular site visits, periodic meeting with the concerned official of the executing agencies, review of progress at each phase of work and preparation of progress report (iv) identification of the constraints and problems, if any, that stand on way to smooth execution of work (v) formulation of measures for removing constraints and solving problem in execution of work.

The above mentioned procedures will be followed in monitoring and evaluation of project implementation.

5.9 Reports

Reporting requirements are specified in the Terms of Reference for the consultancy services under the Dhaka Integrated Flood Protection Project (Bridging period).

The reports specified in the Terms of Reference are :

(i) Monthly progress reports commencing from March, 1992

(ii) Inception Report after 7 weeks from the date of commencement of consultancy services

(iii)Assignment completion report

- draft report will be submitted 10 days before the date of expiry of contract period
- final report will be submitted on 30th June, 1992 period.

The schedule of submission of the above reports are also shown in the work plan and schedule.

6. Implementation and Organisation

6.1 Summary of the Inception Phase Activities

During the Inception Phase, the consultants have maintained close contact with the Project Director, PMO and have met the concerned officials of the executing agencies (BWDB, WASA, DCC and RAJUK) for discussion on the relevant matters.

Submission of this report ends the Inception Phase of the project. As shown in the work plan, quite a number of tasks were completed and some others were in progress during the Inception Phase. The task completed and in progress during the Inception Phase are mentioned below.

Task completed

(i) mobilization

(ii) collection and review of available reports, maps and data

(iii) reconnaissance field visits

(iv) field survey in connection with collection of field design data for the sluices

(v) site selection of 4 sluices on the western embankment

(vi) site selection of sluice on the Central Spine Road

(vii) sub-soil investigation at the four sluice-sites

(viii) cross-section survey of the western flood embankment (about 29.3 m)

(ix) design, drawings and estimate of the slope protection work of the western embankment

(x) design, drawing and estimate of berm building of the western embankment

(xi) design, drawing and estimate of four sluices on the western embankment

(xii) review of hydraulic design of 7.75 km of drainage khals included in the programme of 1991-92 (WASA)

(xiii) review of hydraulic design and checking estimate of 15.11 km of piped drain included in the programme of 1991-92 (WASA)

(xiv) preparation of detailed programme for field investigation of sub-soil and laboratory testing of soil samples of the flood embankment in connection with design of its remedial measures

(xv) preparation of Inception Report, including a detailed work programme

Tasks in Progress

(i) sub-soil boring and field testing of soil samples of the western embankment in connection with design of remedial measures

(ii) estimate of borrow-pit filling of the western embankment

(iii) reconnaissance survey in connection with demarcation of catchment area of one sluice on the Central Spine Road

(iv) sub-soil boring along the alignments of covered drains totalling 6.19 Km in length (WASA)

(v) review of structural design of drainage system improvement works (WASA).

6.2 Project Implementation Summary

Project implementation will be completed through execution of the items of work and activities described in chapter 5 and shown on the work plan and schedule. The schedule of works and activities shown in the work plan conform to those as stipulated in the TOR except the item No. 6 of the work plan. The item of work as mentioned in the TOR under drainage system improvement works is _ _ preparation of detailed engineering design, drawings, specifications and contract documents. But design of the said work has been prepared by DWASA. So the design is to be reviewed and estimates of works are to be checked.

The proposed work plan and schedule will permit execution of the works included in the work programme for 1991-92 of executing agencies, except the flood proofing works (part 1) of the Central Spine Road.

With the existing strength of Design Engineers in project team, it might not be possible to prepare design, drawings and estimates all the physical components as included in the work plan within the contract period.

6.3 Project Organization

The organization chart of the consultant's project team is shown in figure 4. The lines of responsibility within project team are indicated in the chart. Communication and contact with BWDB and other executing agencies will be through the Team Leader. The Project Co-ordinator is responsible for project implementation monitoring and evaluation. He will also coordinate the activities of the expatriate and the domestic consultants as well as administrative and support

service. The Project Implementation Advisor will advise and Assist the Team Leader on technical matters and will coordinate the activities of the expatriate staff of the team.

Mobilization of the staff of the project team started on 8.1.1992. The Team Leader, the Municipal Engineer and two Junior Engineers were mobilized on 8.1.92. The remaining domestic staff of the team were mobilized on the dates as shown in table 2. Mobilization of domestic staff was completed by 5.2.92 and that of expatriate staff is expected to be completed by mid May, 1992. The manning schedule is shown in figure 5.

The matrix of task responsibility of the consultants' staff is shown in figure 6.

7. Comments on Terms of Reference

The Terms of Reference have been reviewed by the consultant. The scope of work in the TOR is tailored to satisfy the objective of formulating work plan for the bridging period under the project. The task involved are, in most cases, well defined. But the tasks and the consultant's responsibility are found overwhelming in relation to the man-power provided and time allowed for them. Preparation of detailed design, construction drawings and estimates of the different components of physical work, are the main tasks of the consultants. Two Design Engineers as provided for the design work are considered inadequate. It might not be possible to prepare detailed design and drawings of all physical components of work by June 30, 1992 with two Design Engineers.

TABLE - 1

Existing and proposed physical components (major) under the DIFP Project, phase-I

Physical Components	Quantity			Remarks
	Total	Existing	Proposed	
Part A : Flood Protection				
1. Western Flood Embankment	29.3 km	29.3 km	Nil	
2. Flood Wall	6.1 km	5.3 km	0.8 km	
3. Sheet piling	0.8 km	Nil	0.8 km	
4. Sluice				
a) on the western embankment	10 Nos.	10 Nos.	4 Nos.	Of the 10 sluices, 4 constructed by Army shall have to be dismantled and removed on completion of construction of four sluices
b) on the central spine road	13 Nos.	Nil	13 Nos.	
5. Pump House	1 No.	Nil	1 No.	
6. Central spine road raising	g 8.0 km	-	8.0 km	
Part B : Drainage				
1. Khals	78.6 k	78.6 km	-	Need rehabilitation and upgrading
2. Piped drains	50.7 k	Nil	50.7 km	
Part C : Environmental Improvement prog.				
1. Slum and squatter area improvement	1 item for 8725 families	-	1 item	
2. Public toilet	35 Nos.	Nil	35 Nos	
3. Low cost Sanitary Latrine	5500 Nos	Nil	5500 Nos	

TABLE - 2

Dates of Mobilization of Project Personnel

Sl. No.	Name	Position	Date of Joining	Expected Date of Joining
A.	DOMESTIC CONSULTANTS			
01.	Mr. Abdul Barik Bhuiyan	Team Leader	08-01-92	
02.	Dr. M. Shadullah	Project Co-ordinator	08-01-92	
03.	Mr. A.K.M. Akhtaruzzaman	Geotechnical Engineer	16-01-92	
04.	Mr. Md. Abdus Sattar	Design Engineer	05-02-92	
05.	Mr. S.M. Muhibbullah	Design Engineer	15-01-92	
06.	Mr. A.Y.M. Imtiazul Hoque	Municipal Engineer	08-01-92	
07.	Mr. Feroze Ahmed	Drainage Engineer	01-02-92	
08.	Mr. Mohiuddin	Construction Supervision Engineer	11-01-92	
09.	Mr. G. Mostafa	Junior Engineer	08-01-92	
10.	Mr. Abu Jalal	Junior Engineer	08-01-92	
11.	Mr. B.A. Hamid	Financial Specialist		07-03-92
12.	Mr. Waliullah	Community Development Specialist		07-03-92
B.	INTERNATIONAL CONSULTANT			
01.	Mr. M. Williams	Project Implementation Advisor		03-03-92
02.	Mr. D. Thirkill	Drainage Engineer		Not yet known
03.	Mr. R. Berlin	Municipal Engineer	15-01-92	
04.	Dr. N. William	Geotechnical Expert		15-05-92
05.	Mr. R. North	Geotechnical Specialist	13-01-92	13-04-92 (Rejoining date)

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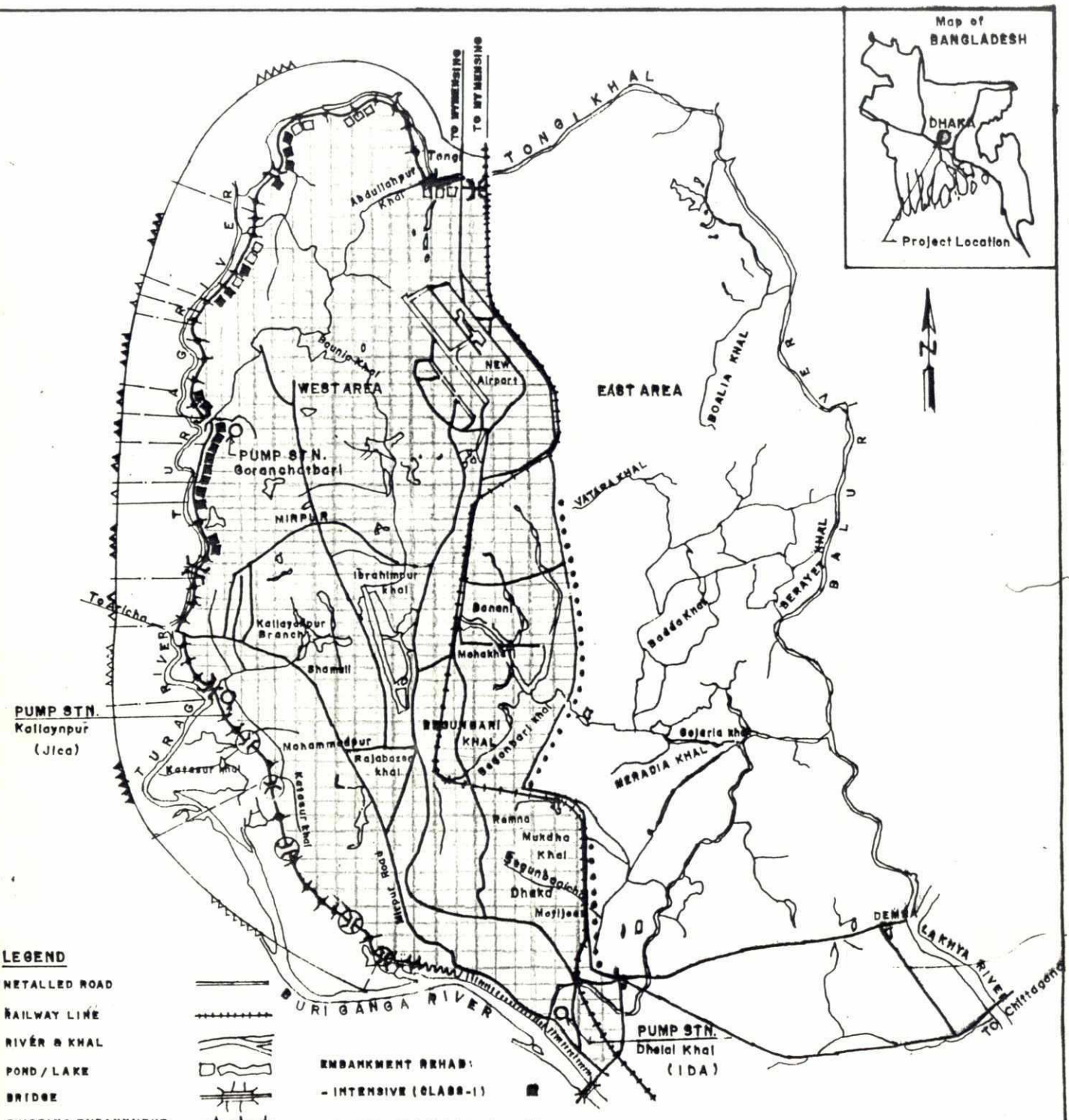
Comments on Fig. 1

Existing sluices are not shown as complete or as ~~and~~ supposed to there. Upto Kallayanpur from Tenji Rly. Bridge There are total 6 (six) nos. of sluices where as only 4 (four) have been shown and 2 (two) more sluices left out.

Further, under the legend, as shown under New works - 13 Nos. proposed sluices have not been shown with tentative locations on the N-S central spine road, forming the Eastern boundary of Phase-1 works.

Furthermore, as regards construction of proposed sluices, as shown under legend, on the western embankment, are 5 (five) in numbers, which is inconsistent with the the statement under Sec. 5.3.1 at page 11 that "It is found on field visit and investigation That one of 5 sluices is not needed."

Therefore, Fig. 1 is subject to necessary corrections, accordingly.



LEGEND

- METALLED ROAD
- RAILWAY LINE
- RIVER & KHAL
- POND / LAKE
- BRIDGE
- EXISTING EMBANKMENT
- FLOOD PROTECTION WALL (R.C.C.)
- EXISTING SLUICE

NEW WORKS

FLOOD WALL :

- EARTH EMBANKMENT
- SHEET PILE

SLOPE PROT. WORKS :

- MOST VULNERABLE
- VULNERABLE
- MINOR

- PUMP STATION
- PROJECT AREA

EMBANKMENT REHAB:

- INTENSIVE (CLASS-1)
- MODERATE (CLASS-2)

CENTRAL ROAD :

- RAISING/REHAB
- SLUICE
- CONTROL STRUCTURE

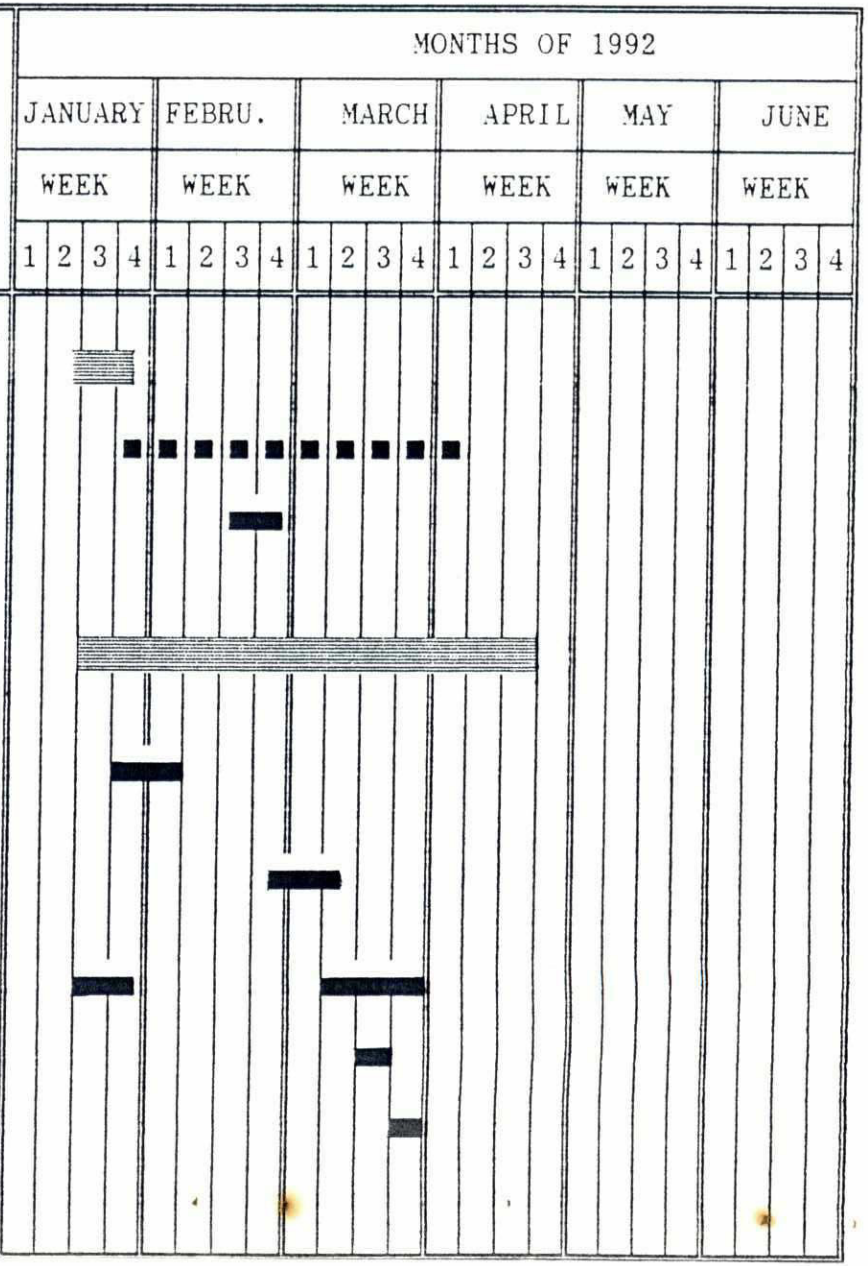
Fig. 1

PROJECT MAP
DHAKA INTEGRATED FLOOD PROTECTION PROJECT
PHASE – I

Fig-2

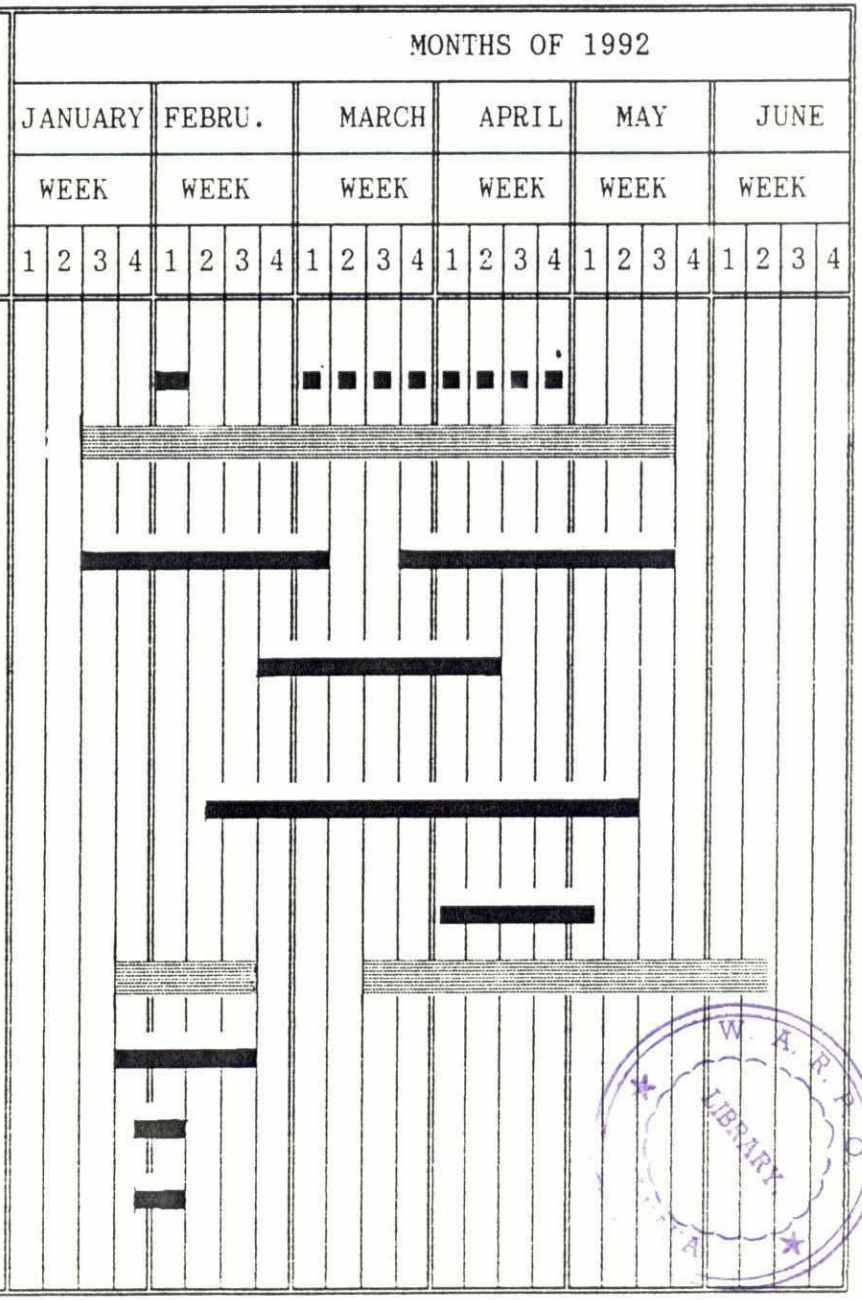
WORK PLAN AND SCHEDULE

Sl. No.	ACTIVITIES
01.	Collection & review of existing report, maps, data, drawings, site visits and assessment of additional data requirement
02.	Collection of additional data
03.	Revised Programme and Inception Report
04.	Survey and investigations
	(a) Field survey :
i.	Condition survey of the existing flood embankment and flood wall (29.3 km)
ii.	Cross-section survey of the existing flood embankment (29.3 km)
iii.	Cross-section and plane table survey in connection with field data collection for sluice design (9 Nos.)
iv.	Cross-section survey of part (10.40 km) of C.S. Road
v.	Cross-section survey of left bank of Buriganga at the proposed site of sheet piling (0.8 km)



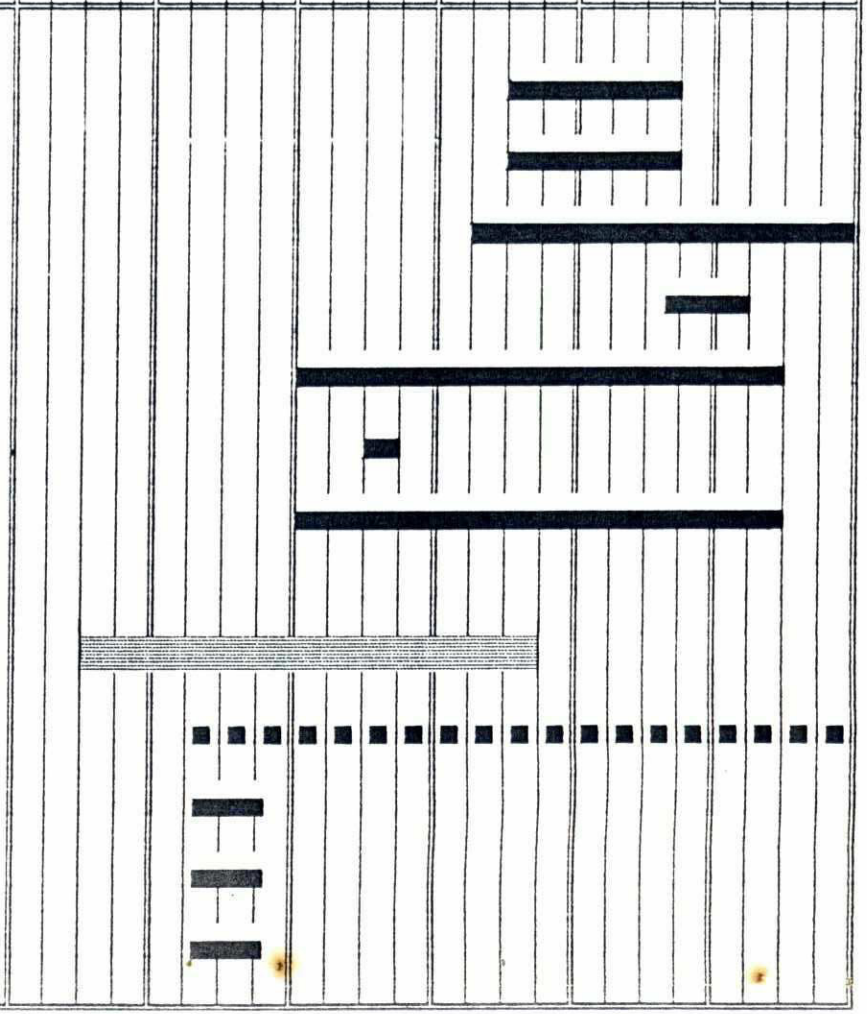
WORK PLAN AND SCHEDULE

Sl. No.	ACTIVITIES
vi.	Topographic survey of the catchment area of drainage channels
(b)	Sub-soil investigation :
i.	Sub-soil boring at proposed sluice sites (9 Nos) and laboratory testing of soil samples
ii.	Sub-soil boring along the alignment of covered drain (6.19 km) and laboratory testing of soil samples
iii.	Sub-soil boring, field testing and laboratory testing of soil samples & analysis of test results in connection with design of embankment remedial measures
iv.	Sub-soil boring at the sites of proposed embankment, sheet piling, flood wall & laboratory testing of soil samples
05.	**Design, drawings and specifications :**
(a)	Sluices on the western embankment (4 Nos)
(b)	Embankment (6.94 km) slope protection with hard materials
(c)	Embankment (1.6 km) slope and toe protection with hard materials



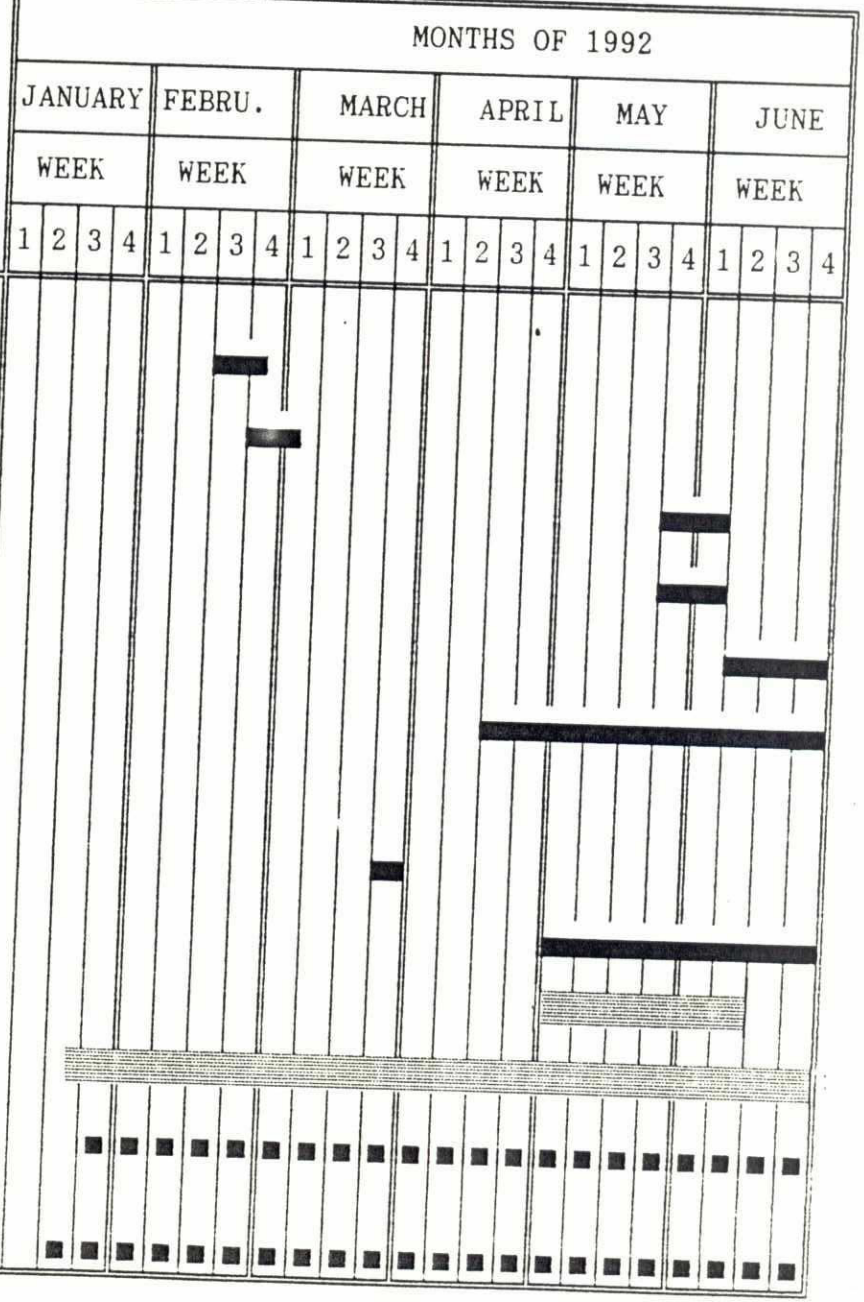
WORK PLAN AND SCHEDULE

Sl. No.	ACTIVITIES	MONTHS OF 1992
		JANUARY | FEBRU. | MARCH | APRIL | MAY | JUNE
		WEEK 1 2 3 4 | WEEK 1 2 3 4 | WEEK 1 2 3 4 | WEEK 1 2 3 4 | WEEK 1 2 3 4 | WEEK 1 2 3 4
(d)	Sheet Piling (0.8 km)	
(e)	Embankment/flood wall (0.8 km)	
(f)	Embankment (2.5 km) remedial measures	
(g)	Flood wall (5.3 km) remedial measures	
(h)	Central spine road raising and flood proofing works	
i.	Road raising (10.40 km)	
ii.	Flood proofing (5 sluices)	
06.	**Review of design and checking estimates of drainage improvement works (for the first year priority works) under DWASA**	
07.	**Preparation of estimate and contract documents :**	
(a)	4 sluices on the western embankment	
(b)	Slope protection of embankment by hard materials	
(c)	Slope and toe protection with hard materials	



WORK PLAN AND SCHEDULE

Sl. No.	ACTIVITIES
(d)	Slope protection of embankment by geo-jute and sods and berm building
(e)	Borrow pit filling
(f)	Sheet piling
(g)	Flood embankment
(h)	Flood wall remedial measures
(i)	Embankment remedial measures
(j)	Central spine road raising and flood proofing work :
i.	Road raising
ii.	Flood proofing
08.	Study on the pump station No. 3 at Goran Chatbari
09.	Construction supervision
10.	Project implementation monitoring and evaluation
11.	Assist PMO in preparation of quality assurance and quality control programme



WORK PLAN AND SCHEDULE

Sl. No.	ACTIVITIES
12.	Finalize construction schedule for remedial measure on the westerly embankment
13.	Assist the PMO in prequalifying local/international contractors for different components of work
14.	Assist the PMO, WASA, DCC and RAJUK in tendering and evaluation of tenders for the first year's work
15.	Reporting :
(a)	Inception report
(b)	Monthly activity report
(c)	Assignment completion report
i.	Draft
ii.	Final

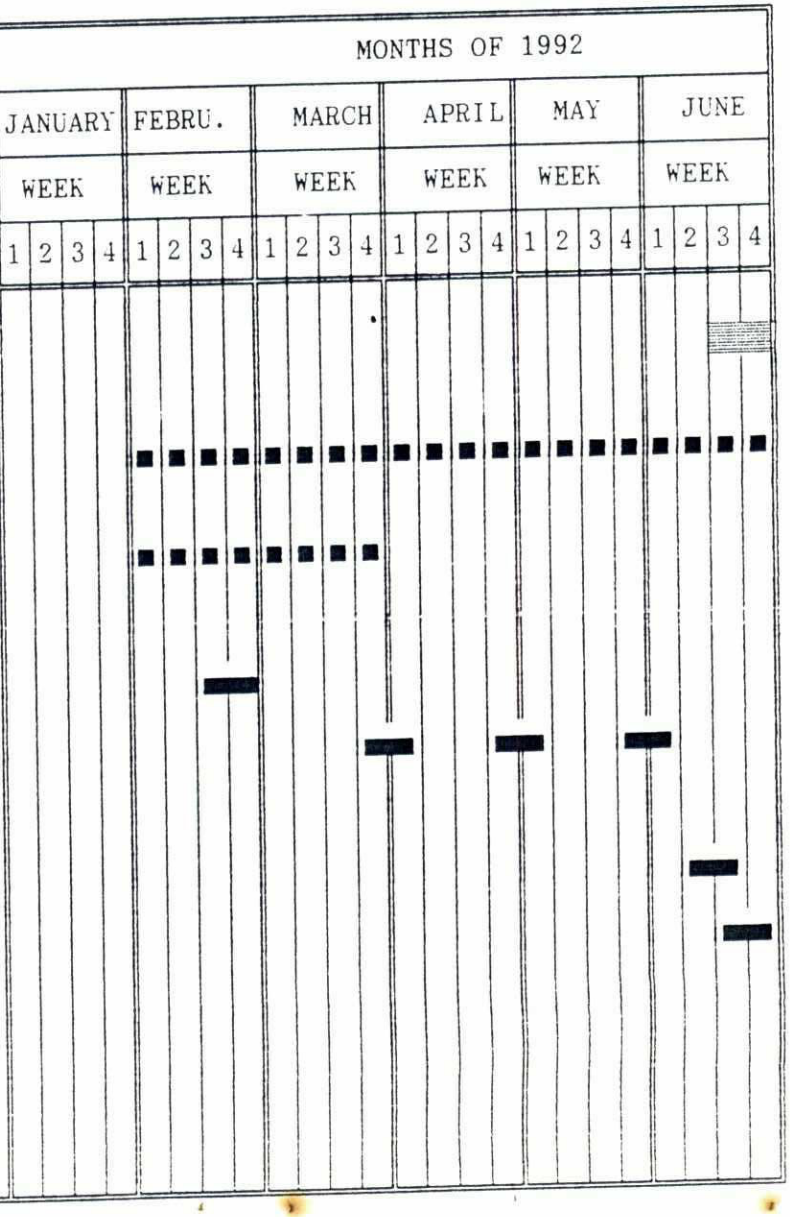
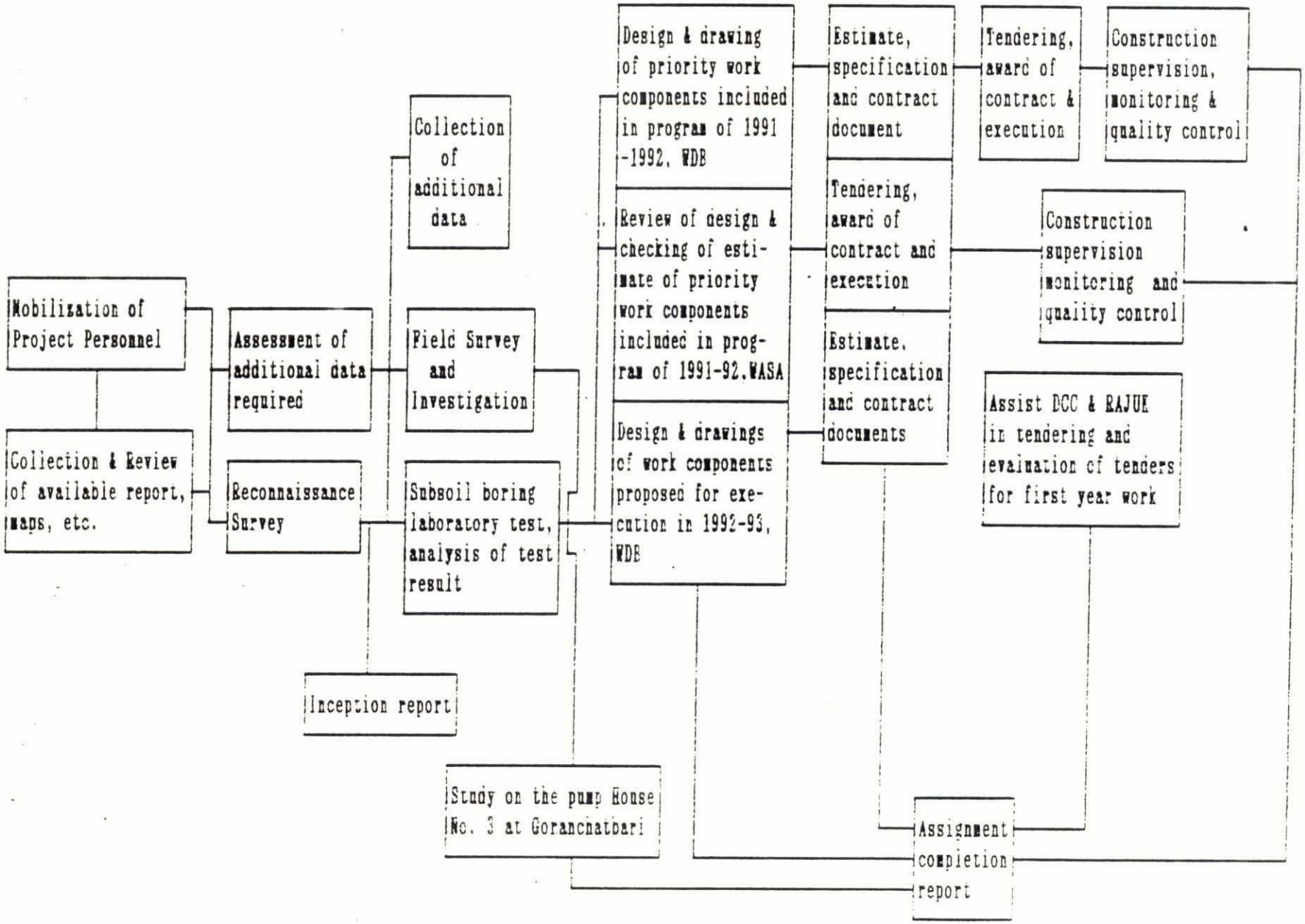


Fig-3

FLOW CHART OF ACTIVITIES
DIFP PROJECT (BRIDGING PERIOD)



ORGANIZATION CHART

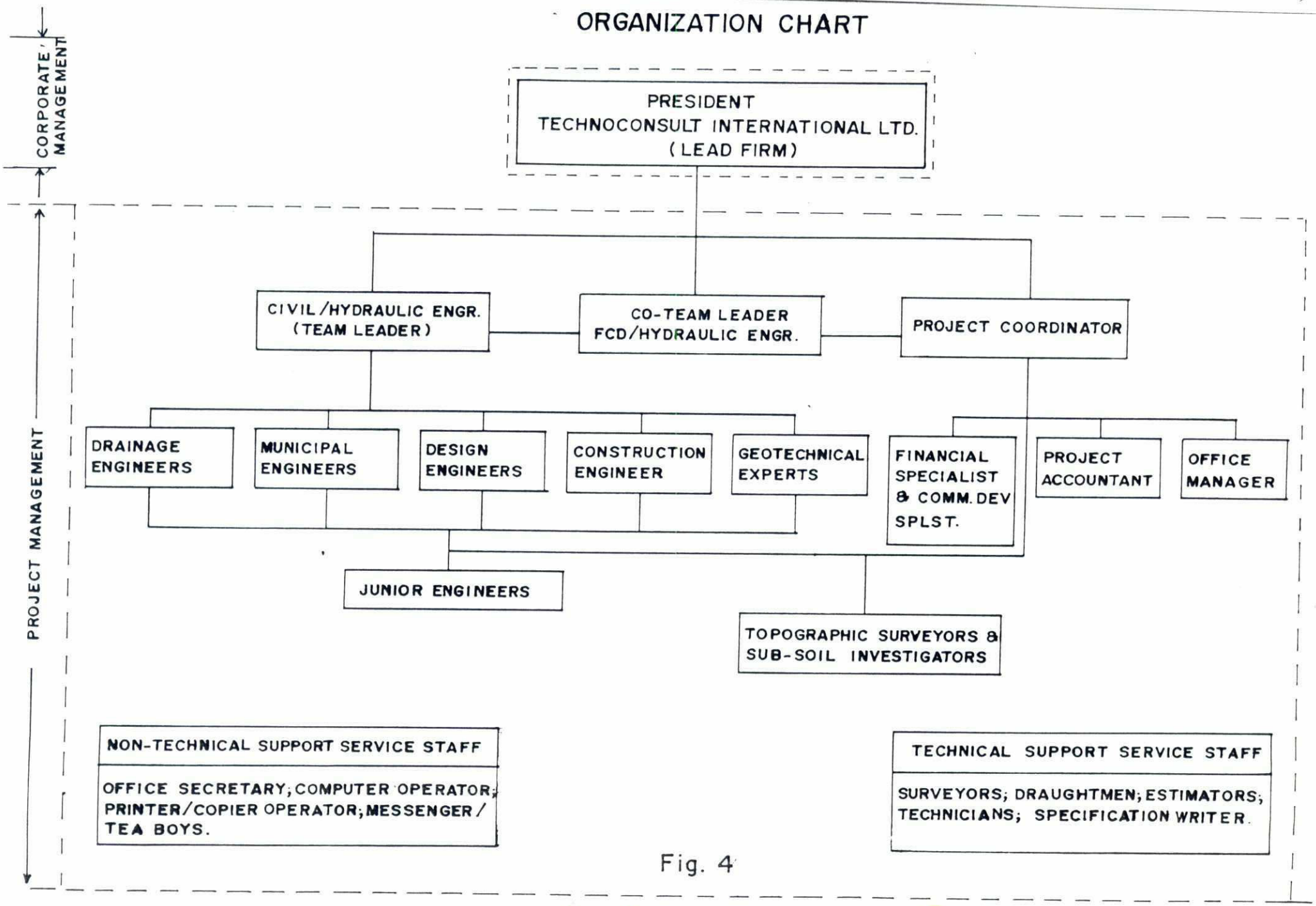


Fig. 4

MANNING SCHEDULE

Fig-5

POSITION	NAME	TIME IN MONTHS 1991 J	A	S	O	N	D	1992 J	F	M	A	M	J	J	A	S	O	N	D	MAN-MONTHS EXPAT.	LOCAL	TOTAL
A) DOMESTIC CONSULTANTS																						
01. Civil/Hydraulic Engineer(Team Leader)	A.B.Bhuiyan							▬	▬	▬	▬	▬	▬								5.80	5.80
02. Project Co-ordinator	Shadullah							▬	▬	▬	▬	▬	▬								5.80	5.80
03. Geotechnical Specialist	A. Zaman								▬	▬	▬	▬	▬								5.00	5.00
04. Design Engineer	Muhibbullah								▬	▬	▬	▬	▬								5.40	5.40
05. Design Engineer	M.A.Sattar								▬	▬	▬	▬	▬								5.00	5.00
06. Drainage Engineer	F. Ahmed								■	■	■	■	■								1.50	1.50
07. Municipal Engineer	I. Haque							▬	▬	▬	▬	▬									5.00	5.00
08. Construction Supervision Engineer	Mohiuddin							▬	▬	▬	▬	▬									5.00	5.00
09. Junior Engineer	G. Mostafa							▬	▬	▬	▬	▬									5.00	5.00
10. Junior Engineer	Abu Jalal							▬	▬	▬	▬	▬									5.00	5.00
11. Financial Specialist	B.A. Hamid									■	■	■									1.00	1.00
12. Community Dev. Specialist	Waliullah									■	■	■									0.50	0.50
B) INTERNATIONAL CONSULTANTS																						
1. Project Implementation Advisor/ (FC&D/Hydraulic Engr.)	M. Williams									▬	▬	▬	▬							4.00		4.00
2. Drainage Engineer	D. Thirkill									▬	▬	▬	▬							3.50		3.50
3. Municipal Engineer	R. Berlin							■	■	■	■	■								0.50		0.50
4. Geotechnical Expert	N. Williams											▬	▬							1.00		1.00
5. Geotechnical Specialist:	R. North							▬	▬	▬		▬	▬							4.00		4.00
TOTAL																				13.00	50.00	63.00

Legend: Time in field : ▬ Continuous Service ■ ■ ■ Intermittent Service

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FIG. 6

MATRIX OF TASK RESPONSIBILITY

	TASK / POSITION	01 Collection & review of existing reports, maps data, drawing, site visits & assessment of available data	02 Collection of additional data	03 Revised program and inception report	04 Field survey: 1 Condition survey of existing flood embankment & flood wall	04: 2 X-Section survey of the existing flood embankment, C.S. road, sheet piling site	04: 3 Plane table & x-section survey for sluice design	04: 4 Topographic survey of the catchment area drainage channels	05 Sub Soil investigation: 1 At proposed sluice locations (9 number)	05: 2 At proposed embankment, sheet piling & flood wall sites	05: 3 Along the alignment of covered drains (6.2 km.)	05: 4 For design of embankment remedial measures	06 Design, Drawing & Specification: 1 Sluices on western embankment (4 number)	06: 2 Embankment slope protection with hard materials	06: 3 Embankment slope & toe protection with hard materials	06: 4 Sheet piling	06: 5 New embankment	06: 6 Embankment remedial measures	06: 7 Flood wall remedial measures	06: 8 Central spine road raising (8 km.)	06: 9 Flood proofing (5 sluices)	07 Review of design & checking & estimate of drainage improvement works under WASA	08 Estimate & Tender Documents: 1 Sluices on western embkt. slope & toe protection work, geojute & sod protection, berm build up & borrow pit filling	08: 2 Sheet piling, flood embkt. flood wall remedial measures, c/s road raising & flood proofing	08: 3 Embankment remedial measures	09 Study on pump station at Goranchatbari	10 Assist PMO in prepn. of quality assurance and quality control programe	11 Final construction schedule of remedial measures of embankment	12 Assist PMO, WASA, RAJUK in tendering & evaluation	13 Construction supervision	14 Project implementation monitoring and evaluation	15 Community Development activites including establishing procedre for dissemination of project publicity	16 Strengthening of financial accounting procedure, budgetory controls & reporting system	17 Reporting
(A)	DOMESTIC CONSULTANTS :																																
1.	TEAM LEADER	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	○	●	○	○	○	●
2.	PROJECT CO-ORDINATOR	○	○	○		○	○	○	○	○	○	○															○				●	○	○
3.	GEOTECHNICAL ENGINEER	○	○	○	○				○	○	○	●				○	○	○							○			○				○	○
4.	DESIGN ENGINEER - 1	○	○	○	○	○	○		○				●			○	○			●	●		○	○		○					○	○
5.	DESIGN ENGINEER - 2	○	○	○	●	○	○			○	○			●	●	●	●		●	○	○	●	○	○		○					○	○
6.	MUNICIPAL ENGINEER	○	○	○				●			●											●									○	○
7.	DRAINAGE ENGINEER	○	○	○				●														●										○	
8.	CONSTRN. SUPERVISION ENGR.			○									○	○	○	○	○			○	○	○	○	●	●	●		○	○	○	●	○		○
9.	JUNIOR ENGINEER - 1				○	○	●		○	○											○			●	●	○							
10.	JUNIOR ENGINEER - 2				○	●	●		●	●		○												●	●	○							
11.	FINANCIAL SPECIALIST																															●	
12.	COMMUNITY DEV. SPECIALIST																																
(B)	INTERNATIONAL CONSULTANTS:																																
1.	PROJECT IMPLEMENTATION ADVISOR			Advise the Team Leader & Co-ordination of Activites of Expatriate Staff																			●				●	○			●	○	○
2.	DRAINAGE ENGINEER							○															○					○					
3.	MUNICIPAL ENGINEER							○																		○		○	○		●		○	○
4.	GEOTECHNICAL EXPERT	○	○	○	●					●		●				○	○	○								○		○				○	○
5.	GEOTECHNICAL SPECIALIST											●						●								○		○		●		○	

LEGEND: ● Direct Responsibility
○ Assistance

APPENDIX A

DETAILED PROGRAMME OF FIELD INVESTIGATION

AND

LABORATORY TESTING OF SOIL SAMPLES

FOR

EMBANKMENT REMEDIAL MEASURES

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Scope

Field investigations will be located along and across the alignment of the existing western embankment starting at Tongi Bridge and proceeding in a westerly and southerly direction.

1.2 Intent

Several contractors will be simultaneously involved in undertaking the field and laboratory testing works described herein. It is therefore essential that minimum and uniform quality standards, methods and report documents are used by all contractors. Sophisticated testing and analyses will be performed as part of this project and it is of critical importance to obtain high quality samples from the field program, and high quality results from the laboratory testing.

It is the intent of this document to provide a framework for the work to be completed in a consistent manner. The Contractor should understand and be aware of the contents of this document and should ensure that involved personnel implement appropriate sections. All work will conform to the standards of the American Society for Testing and Materials (ASTM) except as described differently herein or as amended by the Consultant.

1.3 Objectives

Soft soils are present along the embankment alignment, and catastrophic failure of the embankment has occurred in several locations due to the inability of the underlying soils to support the embankment. The embankment has also sustained considerable damage due to erosion, vectors, poor construction, and poor construction quality control and quality assurance. Sections of the embankment have been repaired. However, some repaired sections have failed after being repaired and other sections of the embankment are considered to be at risk of further catastrophic failure.

Louis Berger International, Inc. and their associates performed an investigation in February 1990 to determine the causes of failure and to develop remediation options. The findings of this investigation were presented in "Interim Report No. 1, Dhaka Integrated Flood Protection, FAP-88", dated May 1991.

The report characterizes the damaged sections into three Classes: I, II, and III, as those requiring immediate (I), short-term (S), and medium- to long-term (M) remedial actions, respectively. The lengths of embankment in the different classes were as follows:

Class	Action Level	Embankment Length (m)	Embankment Length (%)
I	I	4,700	16.1
II	S	3,050	10.4
III	M	3,150	10.8
		10,900	37.3

The objectives of the present field and laboratory testing program and subsequent analyses will be to:

- better characterize the extent of the problems;
- refine the estimates of the limits of the Class I, II and III areas;
- determine the interface between the embankment fill soils and the original soils;
- characterize the stratigraphy along the embankment alignment;
- perform in situ tests to obtain quantitative soil parameters;
- obtain disturbed and undisturbed soil samples for identification and laboratory testing;
- perform laboratory tests to obtain quantitative soil parameters; and
- use the data collected to perform remedial designs.

1.4 Field and Laboratory Testing Program Organization

The Consultant recognizes that the proposed field and laboratory testing program comprises a quantity of work which is beyond the capacity of a single contractor. The Consultant anticipates that at least two contractors will be engaged to perform the field program. The Consultant also anticipates that these contractors will also be capable of performing most of the routine laboratory tests. However, the Consultant appreciates that additional laboratory tests (namely: consolidation, unconsolidated undrained triaxial (UU), consolidated undrained triaxial with pore pressure measurement (CU), and triaxial permeability) will require the services of contractors other than the field program contractors. The Consultant will stipulate which other contractor(s) will perform these additional tests and the Contractor entering into this agreement will be responsible for transporting and delivering the soil samples to the laboratory testing contractor(s) in a timely manner.

1.5 Document Organization

The remainder of this document is organized as follows:

- Section 2 details the soil borings that will be drilled and the procedures that will adopted to drill the borings.

- Section 3 describes the field sampling procedures that will be followed to obtain disturbed and undisturbed samples.
- Section 4 describes the in situ field tests that will be performed and the procedures that will be followed.
- Section 5 describes the laboratory testing that will be performed and the procedures to be followed.
- Section 6 describes the periodic and final reports which are to be submitted.
- Section 7 contains a list of references.

2. SOIL BORINGS

It is proposed to drill eighty-two borings (minimum 120-mm (5-in.) nominal diameter) along the embankment alignment. The borings will be drilled from the top of the embankment and on the side slopes of the embankment. Many of the borings will be drilled in areas where embankment failures have occurred.

The borings will be located by the Consultant. The Consultant will also establish the ground surface elevation and/or the elevation of a reference marker at each boring position. The Contractor will use the reference elevations in performing and reporting field activities. The Contractor will drill the boring within 0.5 m (1.5 ft) of the marked position; greater deviations will require the approval of the Consultant. Companion in situ shear vane testing will be performed within 0.5 m (1.5 ft) of a boring after the boring is completed.

The intent is to drill each boring through the silt and clay stratum, which is thought to underlie the embankment alignment, and a minimum of 3 m (10 ft) into a continuous sand stratum. This depth may be increased if conditions at a particular location are thought to consist of alternating clay and sand strata having thicknesses greater than 3 m (10 ft). It is anticipated that boring depths will not exceed 35 meters (120 ft). The actual depths will be dependent on the field conditions.

2.1 Boring Method

The borings will be drilled vertically using a wash boring technique and rotary equipment capable of pushing undisturbed sample shelby tubes by hydraulic pressure. Casing will be installed in each boring as it is advanced to stabilize the upper part of the boring and to provide a drilling fluid return conduit. Water will be used as the drilling fluid; however, if the sides of the boring are unstable bentonite shall be mixed with the drilling fluid to increase its density, and/or the casing will be advanced to a greater depth.

If the casing is driven by a free falling hammer the number of blows of the hammer and the drop height of the hammer will be recorded for each 0.3 m (1 ft) of casing length. This resistance to penetration information may be helpful as an additional guide to determining the subsurface stratigraphy.

In situ tests will be performed in the borings and both disturbed and undisturbed soil samples will be obtained from the borings.

Ground-water levels should be obtained in each boring as it is being advanced, as a minimum when ground water is initially encountered and subsequently at the commencement and end of each day's drilling. In addition, ground-water levels should be checked after breaks (eg. equipment failure, delays, and meal times) and as casing is installed to different depths.

Upon completion, each boring will be left open sufficiently long to obtain stabilized ground-water levels, no less than 24 hours, prior to backfilling. At the end of each days drilling and during the time that a boring is left open upon completion the boring shall be provided with a temporary protective cover.

As a minimum the following information should be recorded for each ground-water level recording:

- the elevation of the ground surface (or other reference position);
- the height of the top of the casing above the ground surface; and
- the distance from the top of the casing to the water in the boring. This should be recorded with a weighted tape or other device approved by the Consultant. The measurement will be made twice to ensure reliability. The measurements should agree to within 6 mm (0.25 in.).

Piezometers or wells will be installed in some borings to record piezometric and ground-water level variations with time. ASTM D 4570 shall be followed when measuring water level readings in boreholes or monitoring wells. Decisions will be made at the time of drilling whether to install a ground-water monitoring device and the type of device to install.

In order to obtain the detailed information that is being sought by this field investigation it is imperative that the top elevation and depths of the borings, samples, casing, etc., be known at all times. Therefore the lengths of all drilling equipment must be accurately known and recorded. Drilling rods and casing should all be of standard lengths. 'Odd' length equipment should neither be brought to the site nor used. The Consultant may require that any such equipment be removed from the site.

All equipment must be maintained in good and proper working condition. The Consultant may direct that inadequately maintained or calibrated equipment not be used.

2.2 Sampling and Testing Intervals

Different sampling and in situ testing intervals and sequences will be used in depending on the subsurface materials and circumstances. Four different conditions have been identified for which different sequences are proposed, as follows, and as detailed in Table 2.1.

Sequence 1. Embankment fill soils will be sampled and tested continuously in all borings using a combination of SPT's and undisturbed samples.

Sequence 2. The silt/clay stratum will be sampled and tested continuously in areas where deep seated failures have occurred until the failure surface has been reached. SPT's and undisturbed samples will be taken.

Sequence 3. The silt/clay stratum will be sampled and tested at intervals in areas where deep seated failures have not occurred and below the failure surface in areas where they have occurred. SPT's and undisturbed samples will be taken.

Sequence 4. The underlying sand stratum will be sampled and tested at intervals using SPT's.

The sequences, test orders, and intervals described above and shown in Table 2.1 should not be construed as fixed; they may be changed as the field program progresses to reflect experience gained and may be changed in individual borings in response to individual conditions. In developing Table 2.1 it has been assumed that both SPT's and undisturbed samples will have a length of approximately 0.45 m (1.5 ft).

TABLE 2.1
IN SITU SAMPLING AND TESTING

SAMPLE AND IN SITU TEST ORDER (5)	CONTINUOUS SAMPLING		INTERVAL SAMPLING	
	SEQUENCE 1	SEQUENCE 2	SEQUENCE 3	SEQUENCE 4
	Embankment soils (1)	Silt/clay stratum above failure surface (2)	Silt/clay stratum below failure surface and in non-failure areas (3)	Sand (4)
1	SPT	SPT	SPT	SPT
2	Undisturbed	Undisturbed	Undisturbed	Gap
3	SPT	Undisturbed	Undisturbed	SPT
4	SPT	SPT	SPT	Gap
5	Undisturbed	Undisturbed	Gap	SPT
6	SPT	Undisturbed	SPT	Gap
7	SPT	SPT	Undisturbed	SPT
8	Undisturbed	Undisturbed	Undisturbed	Gap

Notes:
1. Sequence 1, approximate undisturbed sample interval 1.5 m (5 ft).
2. Sequence 2, approximate SPT interval 1.5 m (5 ft).
3. Sequence 3, approximate SPT interval 1.5 m (5 ft) and approximate interval between pairs of undisturbed samples 3.0 m (10 ft).
4. Sequence 4, approximate SPT interval 1.5 m (5 ft).
5. Assumed SPT sample length approximately 0.45 m (1.5 ft) and undisturbed sample length approximately 0.45 m (1.5 ft).

2.3 Sample Descriptions

In order to achieve consistency between different parties it is essential that a consistent system of soil description be adopted. A description must be provided for every sample obtained. Sample descriptions should follow ASTM D 2488. The following descriptors may be used to indicate material composition of secondary constituents:

- trace < 10%,
- little 10 - 20%,
- some 20 - 35%, and
- and 35 - 50%.

Specimens must be classified using the following material limits:

- clay < 0.002 mm,
- silt 0.075 - 0.002 mm, <#200 sieve,
- fine sand 0.425 - 0.075 mm, #40 - #200 sieve,
- medium sand 2.0 - 0.425 mm, #10 - #40 sieve,
- coarse sand 4.75 - 2.00 mm, #4 - #10 sieve,
- fine gravel 19.0 - 4.75 mm, 0.75 in. - #4 sieve, and
- coarse gravel 75 - 19 mm, 3 in. - 0.75 in. sieve.

In addition the following descriptors should be used when appropriate (abbreviated explanations/examples are provided, see ASTM D 2488 for complete explanations) and those underlined should always be given:

- group name (e.g. Fill, Alluvium, Residuum),
- color,
- consistency (very soft, soft, firm, hard, very hard),
- moisture condition (dry, moist, wet),
- dilatancy (none, slow, rapid),
- structure (stratified (>6 mm layers), laminated (<6 mm layers), fissured, slickensided (polished failure planes), blocky, lensed (note thickness of lenses), homogeneous),
- dry strength (none, low, medium, high, very high),
- cementation (weak, moderate, strong),
- angularity of coarse-grained material (angular, subangular, subrounded, rounded),
- particle shape (flat, elongated, flat and elongated),
- organic material, clay, silt, or peat,
- odor (particularly for organic deposits),
- toughness (low, medium, high), and
- additional data (roots, holes, mica, etc).

In the description the group name (if given) and the primary component should be capitalised. The first letter of secondary components should be capitalised. Descriptors should be separated by commas. For example:

FILL. Light brown, red and grey, fine to medium SAND, little Gravel, some Silt

and Clay, moist, roots of diameter less than 6 mm. Fines have moderate plasticity.

2.4 Records

The driller, or person responsible for each boring, shall maintain for each boring, at the time of drilling, as a minimum the following details:

- the project name and location;
- the boring reference and location;
- the date and time of drilling;
- personnel information, as a minimum the name of the driller and any supervisory staff;
- the make and type of drilling equipment used;
- a sketch of the boring location including its position relative to site features;
- soil descriptions of samples recovered;
- sample records as described in Section 3;
- details of casing installation;
- details of ground-water readings;
- details of piezometer or observation well installation;
- details of other subsurface and drilling information, such as presence of hard or soft layers, change of materials, change in return water color;
- details of equipment breakdown, and intervals between continuous drilling (e.g. meal breaks, shift changes and normal end of day and start of day breaks); and
- other such information as may assist in interpreting the subsurface conditions.

To assist in the correlation and interpretation of the data the Consultant has prepared a standard Field Boring Log to be used to record the boring information. A copy of this log must be given to the Consultant at the completion of each boring. The Contractor may also use its own field record in addition to the above log. The Consultant may also, at his discretion, develop additional standard forms during the field program, that the Contractor will be required to complete, to assist in record keeping.

3. SAMPLING

Field sampling will be undertaken, at the intervals described in Section 2.2 above, to obtain representative samples of the different subsurface materials encountered. Both disturbed and undisturbed samples will be obtained. Each sample, whether disturbed or undisturbed, will be identified as described in ASTM D 420 showing, as a minimum, the following information:

- the project name and location;
- the boring reference;
- the date;
- the sample reference; and
- the depth and interval below ground level of the sample;

Samples shall be transported to the laboratory, at least on a daily basis, for storage and testing, in accordance with ASTM D 4220. In particular, undisturbed samples will be classified as Group D (samples that are highly sensitive and which will be subjected to, inter alia, consolidation, permeability and stress-strain tests) and shall be transported and stored in cushioned purpose made containers which will permit the samples to remain in a vertical position.

3.1 Disturbed Samples

Disturbed soil samples will either be obtained by hand sampling from cuttings or from the split-barrel sampler used to perform standard penetration tests. Hand samples will be collected at the Consultant's or driller's discretion for visual identification and possibly classification type laboratory tests.

Standard penetration testing and split-barrel sampling (SPT) will be performed in accordance with ASTM D 1586. A split-barrel sampler, 1.38-in. (34.9-mm) internal diameter and 2.0-in. (50.8-mm) external diameter, is driven into the soil using a hammer weighing 140 lb (63.5 kg) and falling freely from a height of 30 in. (0.76 m). The number of blows of the hammer required to advance the split-barrel each of three consecutive 6-in. (150-mm) increments is recorded unless one of the following has occurred:

- a total of 50 blows is applied in any one of the three 150-mm (6-in.) increments;
- a total of 100 blows have been applied; or
- there is no observable advance of the sampler during the application of 10 successive hammer blows.

The standard penetration resistance is recorded as the sum of the blows required to drive the split-barrel sampler the final 300 mm (12 in.).

Essential procedures in performing this test are:

- clean the boring to the sampling elevation;
- maintain the liquid level in the boring above the piezometric ground-water level;
- lower the sampler to the bottom of the boring; and
- perform the test using a trip-hammer without interruption.

After removing the sampler from the boring it will be opened and the following performed:

- the soil recovery will be measured, discounting any cuttings, and recorded;
- the soil will be described by the driller on a field log; and
- a sample of the soil will be preserved for laboratory testing.

3.2 Undisturbed Samples

Undisturbed samples will be taken to obtain samples suitable for laboratory consolidation, permeability and triaxial stress-strain tests. Undisturbed samples will be obtained in clay and silt deposits using thin-wall (shelby) tube and piston sampling techniques. The aim of this type of sampling is to obtain soil samples of the highest quality that have been subjected to a minimum degree of sample disturbance.

The tubes will be circular in cross section and must be free of rust and dirt. The tubes shall have a minimum diameter of 70 mm (3 in.) and a retrieved sample length of at least 0.45 m (1.5 ft). The drilling equipment must be capable of both pushing the tubes into the soil and extracting

the tubes from the soil at a steady rate. Tubes should not be "hammered" into or out-of the soil.

The sampling procedures are described in ASTM D 1587. Essential sampling procedures are:

- clean the borehole to the sampling elevation;
- maintain the liquid level in the boring at or above the piezometric ground-water level during sampling;
- lower the thin-wall sampler (or piston sampler) to the bottom of the hole;
- push the sampler into the soil using a continuous motion at a rate of approximately 75 to 150 mm/sec (3 to 6 in./sec);
- withdraw the sampler from the soil carefully to minimize sample disturbance; and
- remove disturbed cuttings from the upper end of the tube and measure the length of sample;
- determine the shear strength of the sample using a hand operated miniature vane, in accordance with ASTM D 4648 on the soil in the bottom of the tube;
- remove approximately 1 in. (25 mm) of soil from each end of the tube for identification purposes and preserve separately; and
- seal both ends of the sample with wax and attach a protective cap to both ends of the tube.

4. FIELD TESTING

In addition to the SPT tests, described in Section 3.1, and hand operated miniature shear vane tests mentioned in Section 3.2, in situ permeability tests and shear vane tests shall be performed. The actual test schedule will be determined at the time of drilling to reflect the actual field conditions encountered and the test equipment available.

4.1 Permeability Tests

In situ permeability tests will be performed using either open hole rising or falling head tests or double packer tests. Borings in which permeability tests are performed must be drilled with clear water to reduce the possibility of forming a smeared zone along the walls of the boring. When the boring has reached the desired depth the boring is thoroughly cleaned by washing with clear water until a clean surface of undisturbed material is present along the sides and at the bottom of the boring.

In open hole tests, rising head tests will be preferred to falling head tests since with falling head tests there is a possibility of clogging the soil pores with sediment from the water in the boring. However, falling head tests will have to be performed if there is a risk that the soil at the bottom of the hole will become quick due to the hydrostatic pressure gradient. The bottom of the boring must be sounded after each rising head test to determine if the bottom of the hole has heaved. The tests will be performed twice at each depth to ensure a consistent result.

Rising head tests will be performed by bailing water from the boring and recording the rate of rise of water in the boring at intervals until the rate of level change becomes small. Falling head tests are performed by filling the casing with water and recording the rate of fall of the water level as the water seeps into the soil.

The appropriate reading intervals will depend on the permeability of the soils but frequent enough to establish an equalization diagram. The test time should be greater than 5 minutes. Water level readings are usually taken 1, 2, and 5 minutes after the start of the test and at 5 minute intervals thereafter until the rate of change has become negligible.

Appropriate procedures for packer tests will be determined based on the equipment which may be available.

For either test the following minimum information must also be recorded:

- the depth from the ground surface to the ground-water (piezometric) level before and after the test;
- the inside diameter of the casing;
- the height of the casing above the ground surface;
- the installed length of casing;
- the diameter of the boring below the casing;
- the depth to the bottom of the boring below the top of the casing;
- the zone being tested;
- the depth to the standing water level from the top of the casing; and
- a description of the material being tested.

4.2 Vane Shear Tests

In situ vane shear tests will be performed in cohesive soils to obtain shear strength information. Vane shear tests will be performed in accordance with ASTM D 2573. It is the intent that vane shear be performed in borings advanced adjacent to the borings used to collect samples. However, at the Consultant's discretion, tests may be performed in the same boring used to collect samples.

The Consultant recognizes that different types of vane shear equipment are available in Dhaka and the Contractor's equipment may not comply with the requirements of ASTM D 2573. Approval of such equipment will be at the Consultant's discretion and appropriate test methods will be agreed. The following notes apply to the desired method of testing using equipment with a drive gear mechanism.

The vane shear test should be performed in such a way that friction between the soil and rods and within the gear housing is determined. The recorded vane shear strength will be adjusted to compensate for friction. The vane shear test will be conducted at a rate of angular

rotation of less than 0.1 degree/sec (6 degree/min). It should be anticipated that time to failure will be on the order of 5 to 10 minutes. If rapid failures occur the angular rotation rate will be reduced. After the maximum torque has been determined the vane will be rotated rapidly through at least 10 complete revolutions to remould the soil and the remoulded resistance determined immediately using the same procedure as initially. The vane shear tests will generally be conducted at an interval of 1 m (3.3 ft) in companion borings.

The following minimum information must be reported for each test:

- boring number;
- date and time of test;
- name of person performing test;
- size and shape of vane;
- depth of vane tip;
- torque readings at 1 degree intervals during undisturbed test and 2 degree intervals during remoulded test and maximum torque readings;
- time to failure;
- rate of rotation; and
- notes on deviation from standard practice.

Prior to performing any tests on the project the equipment must be calibrated and friction components determined. The friction components must be rechecked at regular intervals during the project. The appropriate interval will be determined by the Consultant depending on the type of equipment, its performance and treatment in the field.

5. LABORATORY TESTING

Laboratory tests will be performed to evaluate the properties of embankment and subgrade soils. The laboratory program is designed to obtain parameters to analyze the stability of the existing embankments and to design appropriate remedial measures.

The tests detailed in Table 1.1 and described in the subsections below are planned. References of the ASTM designations given in the text are presented in Section 6. Other tests or variations of the proposed tests may be deemed necessary during execution of the Field Investigation Plan depending on the soils encountered and the results obtained. The actual laboratory test schedule will be determined by the Consultant as the field work is performed.

All equipment used, including gauges, balances, load cells, etc. must be calibrated and the documentation made available for inspection.

In order to assist in the compilation and analysis of the laboratory data the Consultant will prepare forms for all or some of the tests and the Contractor will be required to submit the data to the Consultant upon the completion of each test.

5.1 Moisture Content

Moisture content determinations will be routinely performed on all samples. The tests will be performed in accordance with ASTM D 2216.

5.2 Wet and Dry Unit Weights

Wet and dry unit weights will be routinely determined on all undisturbed samples.

5.3 Atterberg Limits Tests

Atterberg Limits tests will be routinely performed on all plastic inorganic and organic

samples. The tests will be conducted in accordance with ASTM D 4318.

5.4 Particle Size Analysis

Particle size determinations will be routinely made on cohesive and cohesionless samples. The tests will be conducted in accordance with ASTM D 422. Sieve analyses will be performed on all samples and hydrometer analyses on samples passing the No. 10 (2.00-mm) sieve.

Sieve tests will be performed using, as a minimum, the following sieve sizes: 3/4 in. (19 mm), 1/2 in. (12 mm), 3/8 in. (9.5 mm), No. 4 (4.75 mm), No. 10 (2.00 mm), No. 20 (0.85 mm), No. 40 (0.425 mm), No. 60 (0.250 mm), No. 100 (0.150 mm), and No. 200 (0.075 mm).

Hydrometer tests will be performed using a hydrometer of type 151H or 152H for which a composite correction graph has been determined. The composite correction graph, showing the date of calibration, should be submitted to the Consultant for approval prior to performing any hydrometer tests.

5.5 One-Dimensional Consolidation Test

One-dimensional consolidation tests will be performed on cohesive soil samples. The tests will be performed in accordance with ASTM D 2435. Precautions must be taken to minimize disturbance to the soil samples during preparation of the samples. Specific gravity determinations will be made in accordance with ASTM D 854 on samples adjacent to the test specimen. The following procedures will be used for the consolidation test:

- the specimen will be subjected to a load increment ratio (LIR) of one to produce a doubling of pressure on the soil. Values of 12, 25, 50, 100, 200, 400, 800 and 1,600 kN/sq. m (0.12, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0 and 16.0 tons/sq. ft), or a similar sequence will be used. Smaller increments may be used at low pressures in the region of the preconsolidation pressure if poorly defined curves are consistently produced;
- the loading will be continued to a pressure of at least four times the preconsolidation pressure;

- an unload-reload cycle will be performed at a pressure approximately 1.5 to 2 times greater than the preconsolidation pressure. A load increment (decrement) ratio of two will be used during unload-reload cycles and unloading will span two pressure decrements;
- an unloading schedule will be performed after application of the maximum load using an LIR of two.
- the change in height of the sample will be read for each load application, as a minimum, at times of 0.1, 0.25, 0.5, 1, 2, 4, 8, 15 and 30 minutes and, as necessary, at 1, 2, 4, 8, and 24 hours. Each load will be left in place until at least two cycles of secondary compression have occurred; however, load increments may be applied at 24 hour intervals if primary consolidation has completed;
- time-deformation curves will be produced for each load increment using both the log of time method and the square root of time method. The coefficient of consolidation and the time for primary consolidation will be computed from the average of the log of time and the square root of time methods and secondary compression coefficients will be determined from the log of time curves;
- the consolidation readings will be adjusted to determine the deformations at the end of primary consolidation for each load;
- a curve of cumulative work done at the end of primary consolidation (vertical effective stress * cumulative strain) (y-algebraic scale) versus vertical effective (x-algebraic scale) will be prepared (Becker, 1987);
- a curve of strain at the end of primary consolidation versus log of pressure will be prepared;
- the recompression ratio (RR), virgin compression ratio (CR), and preconsolidation pressure (P_c) will be determined, using the methods of Casagrande, Schmertmann (1955) and Becker (1987); and
- a graph of coefficient of consolidation versus log of pressure will be prepared.

5.6 Unconsolidated, Undrained Triaxial Compression (UU) Test

UU tests will be performed on cohesive samples in accordance with ASTM D 2850. Three specimens will be tested from each specimen at different confining pressures. The pressures will be approximately 0.5, 1, and 2 times the in situ vertical total stress.

5.7 Consolidated, Undrained Triaxial Compression (CU) Test

Neither in situ vane shear tests nor laboratory UU tests can relate changes in strength to increases in consolidation in a rational manner. In addition, both shear vane and UU tests may give unreliable estimates of shear strength due to sample disturbance and the applied shear system. CU type testing will be performed to overcome these deficiencies. These tests will be performed generally in accordance with ASTM D 4767. However, to obtain data that can be used and interpreted rationally, the tests will be run to obtain normalized soil parameters using the SHANSEP method developed by Ladd and Foott (1974).

The following general procedures will be used. However, the Consultant will develop specific procedures in consultation with the contractor(s) who will perform these tests:

- test specimens will be consolidated anisotropically under a K_o stress system based on the stress history data gathered from consolidation tests;
- some specimens will be consolidated to different pressures above the preconsolidation pressure and then sheared (i.e. at an overconsolidation ratio (OCR) of 1). Other specimens will be consolidated to pressures above the preconsolidation pressure and then unloaded to different stress levels, to simulate overconsolidation (i.e. to produce specimens with OCR's >1), and then sheared;
- all specimens will be sheared in compression (unless the capability exists to perform extension tests) with pore pressure measurements; and
- shear strength data will be presented in terms of p, q stress path plots; and
- in addition, at least the following plots will be required for each test:
  - $(p_1 - p_3)$ versus axial strain;
  - (p_1'/p_3') versus axial strain;
  - change in pore pressure versus axial strain; and
  - pore pressure parameter "A" versus axial strain.

5.8 Triaxial Permeability Test

Triaxial permeability tests will be performed on cohesive soil samples. The tests will be

conducted generally in accordance with ASTM D 5084. Two test methods may be used. One method follows ASTM D 5084 and permits only vertical drainage to obtain the vertical permeability. The other method developed by GeoSyntec Consultants only permits radial drainage and prevents vertical drainage. The Consultant will develop specific procedures in consultation with the contractor(s) who will perform these tests.

6. REPORTING

The Contractor will be required to prepare a final report which, as a minimum, contains the following:

- details of the field and laboratory work performed;
- details and descriptions of the methods employed;
- data from the work performed;
- test results;
- analysis of test results where appropriate;
- conclusions and recommendations.

The report format shall contain a mixture of text, tables, graphs and location plans.

In addition, the Contractor will be required to submit such reports and documents necessary to enable the Consultant to remain current with the testing program and to verify the Contractor's monthly invoices.

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7. REFERENCES

ASTM D 420 Standard Guide for Investigating and Sampling Soil and Rock.

ASTM D 422 Standard Test Method for Particle-Size Analysis of Soils.

ASTM D 854 Standard Test Method for Specific Gravity of Soils.

ASTM D 1586 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D 1587 Standard Practice for Thin-Walled Tube Sampling of Soils.

ASTM D 2216 Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

ASTM D 2435 Standard Test Method for One-Dimensional Consolidation Properties of Soils.

ASTM D 2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM D 2573 Standard Test Method for Field Vane Shear Test in Cohesive Soil.

ASTM D 2850 Standard Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression.

ASTM D 4220 Standard Practices for Preserving and Transporting Soil Samples.

ASTM D 4318 Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

ASTM D 4648 Standard Test Method for Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil.

ASTM D 4750 Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well.

ASTM D 4767 Standard Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils.

ASTM D 5084 Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.

Becker, D.E., Crooks, J.H.A., Been, K., and Jeffries, M.G. (1987). "Work as a Criterion for Determining In Situ and Yield Stresses in Clays." Journal of Canadian Geotechnical Journal, Volume 24, pp 549-564.

Ladd, C.C., and Foott, R. (1974). "New design procedure for stability of soft clays." Journal of Geotechnical Engineering Division, ASCE, 100(7), pp 763-786.

Schmertmann, J.H. (1955). "The undisturbed consolidation of clay." Transaction ASCE, 120, pp 1201 to 1233.