AN EVALUATION OF OPERATION AND MAINTENACE PRACTICES OF FLOOD EMBANKMENTS

Md. Shahidur Rahman Khan

Department of Water Resources Engineering
Bangladesh University of Engineering and Technology
Dhaka,Bangladesh

April, 1998

AN EVALUATION OF OPERATION AND MAINTENACE PRACTICES OF FLOOD EMBANKMENTS

Submitted by

MD. SHAHIDUR RAHMAN KHAN

In partial fulfilment of the requirement for the degree of
Master of Engineering (Water Resources)

Department of Water Resources Engineering
Bangladesh University of Engineering and Technology

April 20, 1998

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF WATER RESOURCES ENGINEERING

We hereby recommend that the project work prepared by Md. Shahidur Rahman Khan entitled "**AN EVALUATION OF OPERATION AND MAINTENANCE PRACTICES OF FLOOD EMBANKMENTS**" be accepted as fulfilling this part of the requirements for the degree of Master of Engineering (Water Resources).

Chairman of the Committee
(Supervisor)

(Prof. A. Nishat)

Member

(Prof. A. Hannan)

Member

(Prof. M. M. Hossain)

April 20, 1998

CERTIFICATE

This is to certify that this project work has been done by me and neither this project nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

(Prof. Ainun Nishat) 25/4/98
Countersigned by the Supervisor

(Md. Shahidur Rahman Khan)
Signature of the Candidate

ACKNOWLEDGEMENT

Many have contributed to my understanding of water resources engineering during the last few decades. Even if I do not mention their names here, they are, I am sure, aware of my gratitude for the guidance and help, given by them, from time to time.

I must, however, express my sincere indebtedness to my long standing friend and project supervisor Dr. Ainun Nishat. Without adding any adjective, I just want to say, if he had not the Himalayan patience, one more name would have been added to BUET dropout list. His guidance and assistance, which always encouraged independent analytic thinking, without imposing any confinement or boundary condition, is deeply appreciated. His help and encouragement should not go unacknowledged.

I gratefully acknowledge the advises and comments received from Prof. A. Hannan and Prof. M. Monowar Hossain which have undoubtedly improved the quality of my work.

We were proud of BUET as under-graduate students; after 3 decades, the sense of pride is still the same in me now, as post-graduate student. Congratulations to all the dedicated academic and other personnel who did uphold as well as added to the glorious traditions of BUET, among the so many socio-economic and political changes.

The co-operation of the Organisations with whom I worked as a professional engineer, namely BETS of Bangladesh, RRI of Germany and Delft Hydraulics of the Netherlands (specially to Mr. Martin van der Wall) and many others, made it possible for me to pursue the study side by side with professional life. I would like to take this opportunity to express my gratitude to all of them.

Last but not the least, gratitude to my wife and children for the help and co-operation extended by them during the long study period. They magnanimously tolerated the extra stress, occasionally generated on family time and family life.

ABSTRACT

Embankment, one of the earliest civil engineering structures, is still the most favoured option for flood control due to it's simple construction method and use of local labour and material. The recorded history of construction of embankments in Bangladesh dates back to thirteenth century. Effectiveness of the embankment is very important in delivering benefits and for this purpose effective operation and maintenance (O&M) of embankment needs utmost care. Failure of embankment is a common phenomenon in Bangladesh. This study was taken up to evaluate the present day O&M position of flood control embankments.

The main causes of failure of embankments have been identified as: erosion, overtopping, public cut and improper maintenance. Embankments normally do not fail due to design deficiency. Failures due to river erosion, breaches etc., in turn can be linked to poor O&M. Many of the O&M related problems are linked to poor planning and construction. Incomplete evaluation of hydro-morphological impact inside/out side the poldered area often forces people to make public cut to remove drainage congestion.

For evaluation of effectiveness of then maintenance procedure, the performance of the polder and the O&M approach as prevailed in the Meghna-Dhonagoda Irrigation Project (MDIP) was taken up. RRA of the project revealed that either operational requirements and operational problems were not considered during planning/construction stage; or committees proposed for O&M were not functioning & water control structures were under the domination of vested interest groups; or officials were not trained nor did attend to their duties properly. The study found the absence of systematic accounting of O&M expenditure on project basis. The average O&M expenditure has been found to be more than the standard rate; and yet the maintenance were of poor quality. Identification of arrangement for O&M financing was neglected as usual.

The constraints to the achievement of an acceptable level of project operation and maintenance are lack of motivation, organizational & institutional difficulties. O&M resource constraint is part of a more complex problem involving lack of public consultation, construction time and cost over-run, non-availability of proper & suitable O&M manual in the field level; tasks, responsibility & accountability of concerned officials not being defined/poorly defined etc. The major issues with respect to proper operation and maintenance are: non availability of sufficient fund which affects the physical work programme, failure to recover cost, non involvement of beneficiaries, incomprehensive planning, poor construction, compaction not being done upto required degree and overlapping of construction and operation. Deficiencies in BWDB's organizational arrangements, procedures and lack of training of field staff negates O&M activities whatever is possible within the practical circumstances.

Maintenance of embankments is grouped as preventive maintenance, periodic maintenance and emergency maintenance. The O&M stage should directly involve the local population. The routine preventive maintenance has to be done by Embankment Maintenance Groups (EMGS) and periodic maintenance has to be done by Landless Contracting Societies (LCCs). The group formation may be done through Bangladesh Rural Development Board (BRDB) or NGOs. However technical supervision will have to be the responsibility of `Bangladesh Water Development Board (BWDB)' Emergency maintenance has to be got done by engaging contractors.

The study revealed that the difference of flood heights of 25 years and 100 years return periods is less than 1 meter. The embankment with 25 years return period if properly constructed with 1m freeboard should be able to withstand flood of 100 years return period. However in extreme cases, some extra measures like flood wall of gunny bag etc., may be required to prevent overtopping. The study also revealed that there was not much difference in achievement of degree of compaction between the uncompacted and conventionally compacted embankments. The increase in cost of construction, if the conventional 4.2m wide compacted embankment is changed to the 6.5m wide road cum flood control embankment is about 2% more only. Design of embankments with dual purposes of flood control and road communication can partially mitigate the adverse impact on navigation. Construction of embankment-cum-public road; will ensure constant use, more attention of local people and better maintenance of the embankment itself. This type of wide embankment can be used for afforestation without any risk of damage to the hydraulically/structurally minimum required section.

AN EVALUATION OF OPERATION AND MAINTENANCE PRACTICES OF FLOOD EMBANKMENTS

TABLE OF CONTENTS

Page No.

LIST OF TABLES

Page No.

LIST OF FIGURES

ABBREVIATION/GLOSSARY

ABBREVIATION

ADB	-	Asian Development Bank
ADP	-	Annual Development Programme
BADC	-	Bangladesh Agricultural Development Corporation
BCAS	-	Bangladesh Center for Advanced Studies
BETS	-	Bangladesh Engineering & Technology Services
BM	-	Bench Mark
BRDB	-	Bangladesh Rural Development Board
BWDB	-	Bangladesh Water Development Board
CAD	-	Command Area Development
CARE	-	Co-operation for American Relief Everywhere
CEP	-	Coastal Embankment Project
CIDA	-	Canadian International Development Agency
CIP	-	Chandpur Irrigation Project
CKC	-	Chuo Kaihatsu Corporation
CPP	-	Compartmentalization Pilot Project (FAP-20)
DAE	-	Department of Agriculture
DDP	-	Delta Development Project
DoF	-	Department of Fisheries
DLWU	-	Directorate of Land and Water Use (BWDB)
EEC/EC	-	European Economic Community
EIP	-	Early Implementation Project
EMG	-	Embankment Maintenance Group
FAP	-	Flood Action Plan
FCDI	-	Flood Control, Drainage and Irrigation
FFW	-	Food for Work
FPCO	-	Flood Plan Co-ordination Organization
FWUA	-	Federation of Water Users' Association
GoB	-	Government of Bangladesh
IDA	-	International Development Association
IRWP	-	Intensive Rural Works Programme
IO&M	-	Improved Operation & Maintenance
KIP	-	Karnafully Irrigation Project
LCS	-	Landless Contracting Society
LGED	-	Local Government Engineering Department
LPC	-	Local Project Community
LRP	-	Land Reclamation Project
MDIP	-	Meghna - Dhonagoda Irrigation Project
MES	-	Monitoring and Evaluation System
MIP	-	Muhuri Irrigation Project
MPO	-	Master Plan Organization (WARPO)
MOU	-	Memorandum of Understanding
NBB	-	Need Base Budget
NGO	-	Non Government Organization
O&M	-	Operation and Maintenance
PSL	-	Prokaushali Sangsad Ltd.
PWD	-	Public Works Department (Datum)

RMP	-	Rural Maintenance Programme
RRA	-	Rapid Rural Appraisal
R&H	-	Roads & Highways Department
RSA	-	Rapid Social Assessment
SIDA	-	Swedish International Development Agency
SRP	-	SRP Systems Rehabilitation Project
SSFCDI	-	Second Small Scale Flood Control Drainage and Irrigation
TOR	-	Terms of Reference
UNDP	-	United Nations Development Programme
WRS	-	Water Retaining Structure
WUA	-	Water Users Association
WUC	-	Water Users Community
WUG	-	Water Users Group

GLOSSARY

Bazar	-	Country Market
Beel	-	Low Lying Depression
Bundh	-	Earthen Embankment or Dam across an Waterway
Chairman	-	Chief of Union Council
Chiattorer Mannantar	-	Famine of Seventy Six (Bengali Year)
District	-	An Administrative Unit
Fall Board/ Stop log	-	Boards Placed in Slots in a Sluice
Financial Year	-	July 1 to June 30
Flap Gate	-	A Vertical Gate Hung on the Rive Side of a Hydraulic Structure
Flood Plain	-	Area Normally Inundated during the Annual Flood
Freeboard	-	Vertical Distance between the Highest Normal Flood Level and the Top of Embankment
Ghog	-	A Hole across the Embankment Made by Burrowing Animals
Khals	-	A Natural Channel
Mastan	-	Local Muscleman
Samity	-	Society (Generally Co-operative)
Slip	-	Sliding Failure of Embankment Slope
Squatter	-	Landless People Making Residence on Govt. Land/Embankment

CHAPTER I

INTRODUCTION

1.1 Introduction

Embankments are earthen structures, built parallel to the river to protect an area from flooding resulting from overflow of the river. History of construction of flood embankment is as old as history of civilization. The earliest civilization grew along rivers' banks. For protection from seasonal flooding, embankments were built along the Nile, the Tigris, the Euphrates, the Po and the Indus in ancient times. The Nile embankments are four thousand years old (Varma, 1989). The construction of embankment along the Gomti River and in Shanir Haor area of Sunamganj are more than several hundred years old (Siddiqi, 1996). In Bangladesh, the Brahmaputra Right Embankment (244 km), the Ganges Right Embankment (112 km), the Ganges Left Embankment (115 km) and the polders of the Coastal Embankments Project (4800 km) are massive civil engineering endeavors in any standard (MoWR, 1988).

Use of embankment for flood protection purpose has its proponents as well as opponents. The proponents put forward the following major advantages:

- simple technology for preventing flooding of a low lying area;
- requirement of low capital investment;
- easy construction procedure which uses local labour and local materials;
- low maintenance cost; and
- scope of implementation in phases.

The critics in opposing construction of embankments cite the following adverse effects:

- increase in flood levels else where;
- fragile nature of the structure;
- failures result in more damages compared to no embankment situation;
- obstruction to flood plain development process and deposition of silt;
- drainage congestion and water logging inside the protected areas;
- obstruction to navigation; and
- obstruction to movement of fishes from and to the flood plains.

Among the various structural options for flood management, embankment is the most preferred one in Bangladesh because of the aforesaid advantages. The adverse impacts can be mitigated if properly planned and managed. 'Inundation' and 'flooding' has separate meaning and acceptability in this region. 'Controlled flooding' could remove many of the adverse impacts (World Bank, 1989). The Flood Policy Study (UNDP 1989) and the eleven guiding principles of the Flood Action Plan (World Bank, 1989) concluded that construction of embankments along major rivers is almost unavoidable.

Conditions of flood embankments are susceptible to rapid deterioration if they are not maintained properly, as they are in most cases simple earthen structures. Failure of an embankment brings more miseries compared to no embankment situation and such occurrences are quite common in Bangladesh. Erosion of river banks by natural river migration process may result in breaches. Breaches due to erosion along with improper construction and weakening due to lack of maintenance are major factors of embankment failure. Local people often cut embankments either to remove drainage congestion or to lower water level elsewhere (Amanullah, 1989).

However, regular monitoring, proper operation and maintenance (O&M) of embankments and their associated appurtenant structures may eliminate most of the causes of the failures (Hunting, 1992b). Increasingly more attention is being paid to O&M aspects of water development projects in which embankments are major component. Manuals for effective O&M have been prepared. Involvement of local communities in embankment is being recommended and attempted on experimental basis in many projects (DDP 1985; Euroconsult, 1994a; Halcrow, 1994a). Still O&M of water development projects remain much below the desired level. This study is thus taken up to understand and evaluate the present day operation and maintenance practices of flood embankments.

1.2 Floods in Bangladesh

The earliest available record of flood of the region has been recorded by Abul Fazal in his book *Ain-e-Akbari* which report the flood of 1584-85 (Rob, 1996). About 200,000 lives were reported to have perished in that flood. The next available record of flooding is the Gomti flood of 1660 in Comilla district. The local King is reported to have constructed embankment along the river bank after that flood. In 1662 another great flood occurred in North Bengal and Assam. The Bengal flood of 1769-70 was one of the reasons of "*Chiattorer Monnantar*" in which one-third of total population of Bengal died. In 1784, the Meghna Basin had to experience another disastrous flood due to excess rainfall in Sylhet and Tripura Hills. Another serious flooding took place 1787 in almost all parts of Eastern and Northern Parts of Bengal. This flood is reported to have changed the course of many rivers of Bengal (Rob, 1996). In recent years the floods of 1954, 1955, 1974, 1987, 1988 and 1995 have been severe. Mahalanabis (1930) studied Rainfall and Flood in North Bengal between 1870-1922 and concluded that moderate floods had occurred in the region once in 2 years on an average while severe floods had a return period of 6/7 years.

Most of Bangladesh is located within the flood plains of the three mighty rivers viz. the Ganges, the Brahmaputra and the Meghna. These rivers drain a total catchment area of about 1.72 million square kilometers located in India, Nepal, China, Bhutan and Bangladesh (World Bank, 1989). These catchments are subjected to heavy rainfall in monsoon months and the resulting flood flows passes to the sea through the lower Meghna River which the common outlet. The mean annual rainfall in the country is 1880 mm with a rainfall of 4000-6000 mm in some locality. Moreover 90% of these downpour occur in the monsoon season of May to September. They bring about 7750 billion cu. meter of run off between June and September (Rob, 1996). The peak flow of the Meghna can be around 1,00,000 cumec of which only 7% is generated within Bangladesh (World Bank, 1989). During monsoon the southwesterly wind causes rainfall as well as rise in the sea level. Concurrently the southwest monsoon wind raises mean sea levels in the Meghna estuary and thus the discharge capacity of the Lower Meghna is reduced as the slope becomes flatter. The elevation of northern most end of Bangladesh is 60 m + PWD while the coastal area elevation is even less than 3 m + PWD. The 65% of land area of the country lies below the 7.5 m + PWD level. *Beels*, *haors* & *baors* spread over an area of 2500 sq.km. Roughly 2.4 billion tons of sediment is carried through the river system of Bangladesh. Deposition of portion of it is a natural phenomenon which raises the river beds. Forests and jungles in the catchment areas delays the peak run off. The denudation process is going on and the run off time is gradually becoming less raising the peak flow. The construction of road, railway & flood control embankments are constricting the free drainage paths and raising water level as well as localized drainage congestion. The construction of coastal embankments has closed many smaller channels and creeks. The marine sediments are being washed ashore and the subsequent sedimentation is also retarding the flood water drainage.

On an average, every year about 26,000 sq.km. of Bangladesh, (about 18% of total area) is inundated by flood water. Over and above the synchronization of flood peaks, whenever takes place, give rise to catastrophic floods. The peak flows of particularly the Ganges and the Brahmaputra when coincides, the result is severe flood as happened in 1988. During a severe flood 52,000 sq.km. (about 36% of the country and nearly 60 % of the net cultivable area) may be affected. **Table 1-1** shows the relationship between Return Period and Affected Area. Properly documented flood reports of the country are available from 1953. **Table 1-2** shows the flood affected areas of the country during the period 1954-1996. Bangladesh Water Development Board (BWDB) considers 82,088 sq.km area of Bangladesh to be flood vulnerable out of total area of 1,42,777 sq.km; which is 58% of the country (BWDB, 1987). The vulnerable area lies mainly in the Ganges-Brahmaputra-Meghna (GBM) region. The north-eastern and south-eastern part of the country is affected by flash flood while the southern Bengal basin is affected by coastal flood. The region-wise distribution of flood-vulnerable areas are given in **Table 1-3**.

Due to variability of rainfall incidence, timing and magnitude of flood peaks of different rivers' the whole flood vulnerable areas are not inundated simultaneously. Moreover same spatial recurrence of flood in all the years are not observed. The changing nature of occurrence of flood gives rise to varied statistics on flood affected areas. The geological location, topography, climatic and hydrologic conditions govern the flooding of a country. Flooding is aggravated by a combination of inter-relative natural and human activities. The factors which individually or in combination causes flood in Bangladesh, may be broadly classified as follows:

- heavy local precipitation and accumulated run-off there from;
- huge cross boundary flow originating from snow melt and/or rain fall in upper catchments;
- rise of sea level due to tide which does not allow quick drainage of river water;
- general flat topography of the country and gradual raising of river bed level due to siltation;
- denudation of forests in the catchment basins causing immediate runoff of the rainfall; increasing the peak flow;
- construction of roads, railways, embankments and other structures which impedes quick drainage; and
- the mass scale siltation of coastal river mouths obstructing free and easy drainage of the upland flow; etc.

In Bangladesh the following types of floods are encountered (Rogers, 1989):

a. Flash floods in the eastern and northern rivers. These are characterized by a sharp rise followed by relative rapid recession a few days later. Water often move at high velocities causing damage to standing crops. Coarse sands are also often deposited in the agricultural land.

b. High intensity rainfall of long duration in monsoon season often generates water in excess of local drainage capacity causing localized flood.

c. During monsoon the rivers fail to drain the upland flow. The major rivers generally rise slowly over a period of 10 to 20 days or more. Water gradually spills over the banks of the rivers and their tributaries. This high level remains for months. Normally the local people are prepared for this prolonged inundation, but when the rise crosses certain level the damage to lives and properties takes place.

d. Floods due to storm surge/tidal wave in the coastal area.

The different kinds of floods of Bangladesh make flood fighting difficult. A well designed policy for fighting a particular type of flood may be useless or even harmful in another flood situation. The usual sequence starts from the month of April and May with flash floods in the northeastern and southeastern regions. The monsoon starts from June. The Meghna and the Brahmaputra reach flood peaks during July and August. The Ganges normally peaks during August and September. The timing and duration of high incoming river levels in relation to regional or local rains decide whether any location in a basin is going to have normal/tolerable inundation or damaging flood. Torrential rainstorm in any part of the lower basin can cause devastating floods almost over night when super imposed on a congested river system: Simultaneous peaking of both Ganges and Brahmaputra makes the congestion problem much more serious.)

1.3 Objective and Scope of the Study

Any embankment is subject to wear and tear due to rain, wind, wave, ruminant activities and human interference. Lack of proper maintenance may weaken the cross-section. This often leads to embankment breach causing immense misery to people as well as damage to crop, agricultural land and infrastructures. The psychological scar of insecurity remains with the people of project areas for years even after repair.

Cost realization is an accepted norm of present day market economy. Operation and Maintenance (O&M) is essential to get optimum benefit out of the embankment vis-à-vis from the project. Failures of many embankments during the floods of 1987 and 1988 have brought the hitherto neglected issue to the forefront (BWDB, 1987; MoWR, 1988). Many studies and evaluations have taken place to improve the O&M situation. Some of the major studies are:

a. BWDB Operations and Maintenance Study (1985), World Bank. Dhaka.
b. O&M Study, FAP-13, (1992), FPCO, Dhaka.
c. FCD/I Agricultural Study, FAP-12 (1992), FPCO, Dhaka.
d. Guidelines for Peoples Participation in Water Development Projects (1993), MoWR, GoB.
e. Operations & Maintenance Plan for BWDB Projects, (1994), SRP, BWDB.
f. Technical Report; Embankment Maintenance Groups (1994), SRP, BWDB.

These studies and reports have tried to identify issues involved and recommend measures for the whole BWDB projects. Embankments as an entity were not given due importance. A study by IFCDR, BUET (RIT, 1992), describes the present situation as follows: *"Inadequate operation and maintenance are amongst the important factors that not only impede the realization at the project objectives but may also contribute to enhancing some negative environmental consequences. Many damages due to inadequate operation and maintenance of the embankments are observed".*

The existing poor conditions of embankments indicate the existence of some major/basic flow in the process. This may be in the presently followed methodology or in the institutional set up or in both. In order to optimize the project benefits and minimize the negative impacts, further improvement of the presently followed O&M is necessary. The objectives of the study are:

- to ascertain the actual O&M practice;
- to find out the factor responsible for the poor O&M; and
- to involve effective non-structural as well as structural measures for sustainable O&M practices for embankments.

The present study will try to find the weaknesses in the present O&M of embankments. It will also try to find the extent of involvement of local people in the O&M process. Another important aspect of the study will be the time factor. Timely intervention in a minor scale saves huge amount of money which is required for repair/rehabilitation in later stage. Attempts will be made to find more efficient utilization of embankment and its berm. If embankment or berm could be used for some sort of economic activity, the embankment will be able to generate resources for its own maintenance. At least dependence on others for maintenance expenditure would be reduced. Involvement of local people in those activities will have the secondary benefit of getting their services for guarding the embankment free of cost as well as help in local poverty alleviation.

The aim of the study can be summed up as finding means of economic, self-sustaining effective means of O&M of embankments involving the local people.

CHAPTER II

LITERATURE REVIEW: EMBANKMENT PLANNING, DESIGN AND CONSTRUCTION

2.1 Review of Planning Approach

Social needs are the origin and justification of all engineering activities. Social objectives are translated into engineering objectives and given physical shape by the engineers. Planning is an organized attempt to select the best alternative to achieve this goal. Some of the important implications of planning process are (Nishat, 1987):

- good planning requires the formulation of at least one and perhaps several goals that must be achieved;
- it requires the preparation of alternative plans with the aim of achieving the established goal;
- alternative plans must be multipurpose, because of the competitive nature of the alternative beneficiaries;
- because of probable effect of one project upon the other; the alternative plans better be basin wide. If trans-basin planning is possible, the alternative plans, should consider as may basins as possible;
- because of long useful project life, the planning must extend far into the future;
- in order to select the best alternative plan, an analysis must be made taking into account engineering as well as economic and social considerations.

Embankment is one of the component of the structural flood protection measures to physically prevent flood water entering a designated area. In Bangladesh the primary purpose of embankment is to protect and improve agricultural production while the secondary benefits include protection to life and property. Planning of embankment involves:

- identification of local flood characteristics;
- evaluation of impact of floods locally and needs assessment, and
- identification of technicality including arrangement for financing of construction and O&M.

During the planning process special attention should be given to the disadvantaged groups. People belonging to different social groups should be able to voice their own perception of the existing problems, potential solutions including their ideas about the implication of the technical solutions. Measures should be conceived, designed and implemented on the basis of complementary needs of local people and/or reconciliation of the competing interests of different groups. The planning process should ensure that the proposed solution is:

i. technically sound;
ii. environmentally acceptable to the insider as well as the outsiders; and
iii. capable of being implemented without creating major social disruption or irreparable damage to any social group.

2.2 Review of Design of Embankment

The basic principle of design of any embankment is to produce a satisfactorily functional structure at a minimal cost. The cross-section must be adjusted to fit the site and the available materials. Consideration must be given to O&M requirements, so that economy of initial construction cost does not result in excessive maintenance expenditure. Availability of materials in the vicinity and the foundation condition will determine whether the embankment will be homogeneous type, zoned type or diaphragm type. The essential design criteria are:

- the embankment is safe against overtopping during design flood;
- spillway & outlets are of sufficient capacity to allow passage of the peak flood;
- the embankments have adequate freeboard to be safe against overtopping by wave action;
- the side slopes are stable under all conditions of loading;
- seepage flow through the dam and foundation is controlled within the permissible amount and there is no washing out of fine particles;
- the phreatic line remains within the downstream face, so that no sloughing of the slope takes place; and
- there is no possibility of free flow of water from upstream through either the dam or the foundation.

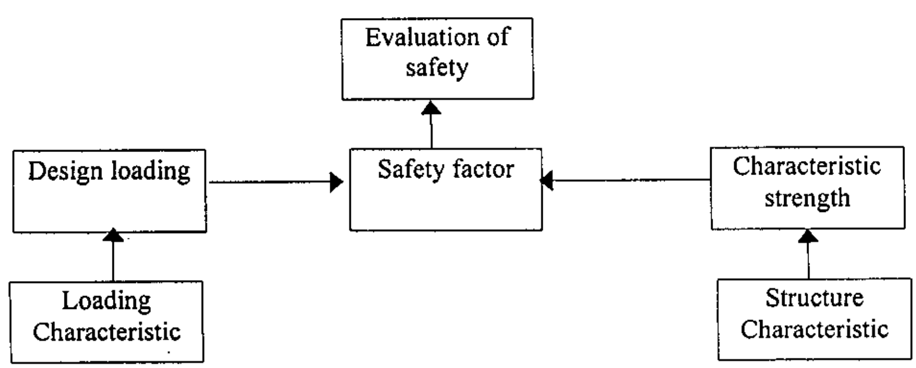
2.2.1 Design Approach

The design approach can be deterministic or probabilistic.

Deterministic approach

The traditional design is based on deterministic approach. In this approach a limit condition is chosen with respect to the accepted loading of the structure corresponding to a certain strength value. The strength value is a function of construction material as well as quality of workmanship. The loading depend on flow, wave, porous flow etc. In the deterministic approach, the safety factor is a fixed pre-selected value; which can be expressed by the following equation :

$S_f = R_d / S_d$, where S_f = Safety factor
R_d = Design strength
S_d = Design load



Example of Deterministic Approach (Source: Hossain, 1993).

The safety factor for embankment in the deterministic design process is taken as 1.5 (Terzaghi, 1967). According to the USBR practice a factor of safety of 1.5 is adopted for all conditions. This is now-a-days considered to be on the higher side. High dams have recently been designed with safety factor even as low as 1.25 (Varshney, 1982). The BWDB recognizes static factor of safety of 1.3 for global stability and bearing capacity as state of practice (GeoSyntech Consultants, 1991).

Probabilistic approach
The presently available probabilistic approach differs with deterministic approach in provision of factor of safety. In this design process the safety factor is solved statistically, implicitly considering the uncertainty of loading and strength variables. This prevents unnecessary conservation in design leading to cost saving. By accepting a certain probability of failure the design adjusts the safety margin in a rational process. It considers the stochastic character of load and strength (CUR, 1991). The application of probabilistic method requires sufficient statistical data at all relevant variables to indicate their distribution. Due to limitations of availability of sufficient data of the relevant variable, deterministic design approach is still being used. Though all categories of events that may cause failure are equally important for overall safety, the engineers responsibility of technical & structural aspects are expressed by designing of:

i. Alignment
ii. Setback distance
iii. Crest level
iv. Crest width
v. Side slopes

2.2.2 Alignment

A sufficient channel must be provided to transmit the design flow with a reasonable freeboard against wave action. The alignment of an embankment is governed mainly by technical, socio-economic and morphological consideration. The best alignment is that which can be built as efficiently and cheaply as possible. An ideal alignment should satisfy the following criteria:

- it should require least land acquisition;
- it should avoid abrupt changes in alignment;
- it should avoid the meandering belt of the flood way as far as possible;
- it should avoid passing over mosque, places of worship, graveyard etc.;
- the alignment should not pass over any subsoil comprised of peat or organic soil;
- the preferable alignment should follow the locations where sub-soil & potential borrow materials contain fair portion of clay; and
- due consideration should be given to avoid existing waterway, road etc., as far as possible.

2.2.3 Setback Distance

Setback distance is the space between actual river bank and riverside toe of the embankment. In no case should the embankment be so close to a bend that bank caving will undermine the embankment. The setback distance is to be based on the following criteria:

i. The area should be sufficient to allow for berm and borrowpits. A shelf of land called "berm" is left between the bottom edge of the embankment and top of the borrowpit. The berm is to be from 3m to 6m depending upon, the depth of the borrowpit.
ii. There should be sufficient space to increase the height of the embankment by putting additional material against outer slope.
iii. There should be adequate floodway for design discharge.
iv. Setback should be fixed by considering scouring of river bank, tendency of the river. In eroding bank there should be an extra margin equivalent to 10 years of present erosion rate (NHCL, 1993).

v. If the above criteria cannot be attained, a minimum setback distance of 6m from the eroded bank may be kept, but bank protection works are to be provided.

2.2.4 Crest Level

The crest level of an embankment is computed from the design flood level with addition of additional height for freeboard and shrinkage & settlement. The design crest level can be obtained from the flowing (Amanullah, 1989)

$$H_{DES} = H_{FL} + H_w + H_Z + l_m$$, where

H_{DES} = design crest level
H_{FL} = design flood level
H_w = wind set-up
H_Z = wave run-up
l_m = safety margin (freeboard)

Design flood level
The design flood level, which the embankment has to retain, is a major criteria for the design of the embankment. The recurrence interval of floods to be selected for the design of a particular embankment depends on the acceptable extent of damage by inundation in the locality. Considering probable agricultural damage, high property values and loss of human lives, the following flood frequencies are adopted (Amanullah, 1989).

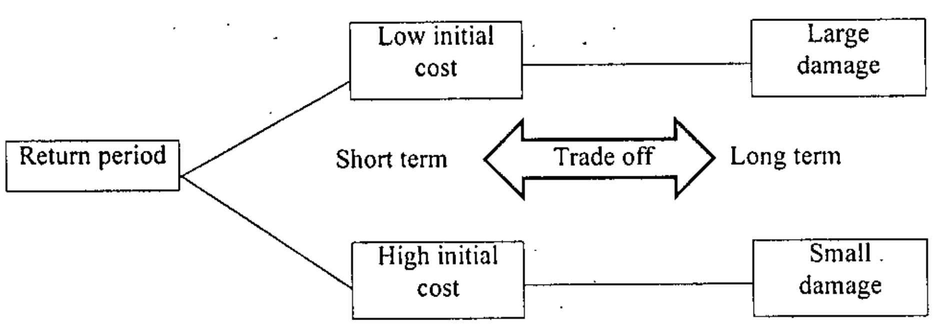
- the 1:20 year flood, where agricultural damage is predominant; and
- the 1:100 years flood, where significant socio-economic development as well as human lives are threatened.

For flood frequency analysis annual maximum values are ascertained and ranked in order of decreasing magnitude. A recurrence of interval (years) is assigned to each annual event according to formula.

$$T = n+1/m$$, where

T = recurrence interval (or return period) in years
n = number of years of flood
m = the rank of the event in order of magnitude (the largest event having m = 1).

Then stage/discharge is plotted against recurrence interval for each event on special plotting paper or probability paper. Commonly used papers are log normal papers, gumbel paper. Plotting on such paper allow linear extrapolation of data. The expected depth of flooding at a particular location is derived from the return period, as it gives the size of adopted flood. The effect of short & long return period is graphically shown below:



Selection of return period (Source: ESCAP,1991)

In Bangladesh considering the agricultural priority the return period is taken as 20 years (World Bank, 1985; 1987b). The Coastal Embankment has a return period of 50 years (ADB, 1986). Having selected the flood frequency the design flood level need to be assessed. The assessment is dependent upon whether embankments are to be provided in one bank or on both banks.

- Where constructed on one bank only, H_{FL} may be computed by frequency analysis of available annual maximum river level data for full flood protection embankments and maximum river level data before some specified time during the year.
- Where constructed on both banks, H_{FL} need to be computed from the design flood discharge under confined conditions.

Wind set-up

According to Amanullah, (1989), wind setup may be estimated from

$$Z_S = (V_w)^2 F/1400d$$, where

Z_S = the rise in feet above still-water level

V_w = the wind speed in mph

F = the fetch or length of water surface in miles, over which the wind blows

d = average depth of the river or beel along the fetch in feet.

If wind is blowing long enough from one direction over a significant water surface, a rise of the water level will result at the down-wind side. The general formula for calculating the wind set-up is given by

$$H_W = (4\times10^{-6}*W^2*l*\cos\phi)/gh$$, in which

Hw = wind set up in meter

W = wind velocity in (m/s) at 6m above water level

l = length of water over which the wind is blowing

g = specific gravity

h = average water depth along stretch

ϕ = angle at which the wind is approaching the coast.

Wind setup develops during wind condition that lasts for at least 24 hours. The effect of wind setup may be included in design calculation in case of water level data from a temporary gauge (or gauge with <10 years record).

Wave run-up

With respect to embankment design, two aspect of waves have to be considered:

- the forces of breaking waves against the slope an embankment causes erosion if no protection is provided.
- the run-up of waves against a slope might cause overtopping of the embankment if the crest level is not high enough.

Waves, generated by wind blowing over water, increases in height, if the fetch increases. A relation between fetch (F), wind velocity (w). Wind duration (t), wave height (H) and wave period (T) is presented by the general expression for the wave run-up as follows :

$$H_Z = 8*f*H*\tan\alpha*\sin\beta(1-B/L)$$, m , in which

f = constant factor

H = wave height (m)

α = slope of embankment

β = direction of increment waves

B = berm width (m)
L = wave length (m)

The factor (1-B/L) may be omitted if no berm is applied. The factor f is dependent on the smoothness of the slope surface (0.75-1.25); 0.75 for very rough rip-rap , 1.25 for very smooth asphalt-concrete slopes, 1.1 for turfed slopes and it should be noted that the formula is only valid for slopes with $1/8 < \tan\alpha < 1/3$.

Freeboard

Freeboard is the vertical distance between the crest of the embankment (without camber) and the maximum water level. It should be provided:

- to prevent over topping of the embankment by wave action which may coincide with the design flood, and
- to ensure a factor of safety against contingencies such as settlement of the embankment more than what was initially estimated, and occurrence of flood greater than the design flood.

A rational determination of freeboard requires a determination of the height and action of waves. The height of waves generated by winds on the surface of a large body of water depends on the wind velocity, the duration of wind, the fetch (the distance over which the wind can act on a body of water, being generally defined as the normal distance from the windward shore to the embankment being designed), depth of water and the width of the water surface. Upon contact with the face of the embankment, the waves move up the inclined plane and expend part of their energy in raising the water level. Sufficient freeboard must be provided so that there is no possibility whatever of the embankment being over-topped. The rational determination of freeboard would require a determination of the height and action of waves, Various empirical formulae depending on wind velocity and fetch have been suggested for computing wave heights. The Molito-Stevenson formulas normally used are

$$h_w = 0.032\,(FV)^{1/2} + 0.763 - 0.271\,F^{1/4}, \text{ where } F>32\text{km}$$

$$h_w = 0.032\,(FV)^{1/2}, \text{ where } F<32\text{km}$$

Where, h_w = wave height in meters measured between through and crest

V = wind velocity in km per hour and

F = fetch in km.

On a sloping surface the wave rides along the slope upto a vertical height of 1.5 times the wave height above the water level (HFL), hence 1.5 h_w is provided as freeboard. Using empirical formulae, USBR recommends freeboards as given in the **Table 2-1**, considering wind speeds of 160 km/hr for the normal case, and upto 80 km/hr for the minimum case. Where data are available, the wind set up and wave run-up may be computed as set out in the preceding sections, and compared with the USBR recommended freeboard. The greater of the two values may be adopted for the embankment design. Where wind and wave data are not available, the USBR recommended freeboard should be taken. Under no circumstances should the freeboard be less than 0.91 m (3 ft) for a full flood protection embankment. Freeboard used by BWDB in design is given in **Table 2-2**.

2.2.5 Crest Width

Design crest width

The crest width of an earthen embankment should be sufficient to keep the phreatic line or upper surface of seepage, within the embankment when the river or beel is full. Crest width should also be sufficient to withstand earthquake shock and wave action. Smaller crest widths will make the embankment more vulnerable in case of overtopping which will cause erosion of inner slope and crest. For the determination of an appropriate minimum crest width of embankments the following empirical rule can be used:

$H <= 2$ m	$B = 2.50$ m	
$H >= 5$ m	$B = 6.00$ m	
$2 < H < 5$ m	B is chosen at a proportionate size in between 2.5 m and 6 m, rounded of to the nearest 0.5 m, in which	
	H =	H_{DES} minus existing ground level; or H_{DES} minus berm level (if available)

U.S. Bureau of Reclamation (USBR, 1974) suggested the formula for the determination of crest width for small earthen embankments:

$W = Z/5 + 10$, where W = width of crest in feet, and
Z = embankment height in ft above the stream bed.

For higher embankments the crest width (B) can be selected as per the following recommendations (Garg, 1989):

$B = 0.55 H^{1/2} + 0.2 H$ for embankment <30 m
$B = 1.65 (H+1.5)^{1/3}$ for embankment >30 m
where H = height of the embankment

According to Varshney, (1982), it can be fixed as

$B = {}^5/_3 * H^{1/2}$, where B = crest width in meters
H = height of the embankment in meters

For most of existing embankments, the width is 8 to 12 m for high embankments and 4 to 7 for low embankments. According to the Design Manual for Polders, Delta Development Project (DDP, 1985) minimum crest width should be 2.5 m. In case inspection of the embankment is to be executed with a vehicle, the minimum crest width should be 4 m. For a road at crest level, a road berm of minimum 1.5 m width has to be provided at both sides of the road. If the embankment is rather high, then it might be more economic to reduce crest width and construct an extra c/s berm at 0.5 m above maximum spring tide level thus reducing earthwork.

2.2.6 Side Slope

The selection of design side slopes shall be based on the following requirements:

- embankment slopes should be stable against adverse seepage flow. As far as possible, the phreatic line should be confined within the downstream face of the embankment;
- the embankment should be stable against wave action and other external forces;
- the embankment should be stable against shear failure through its base.

Generally, side slopes for an embankment are to be fixed at 1V:2H on the country side and 1V:3H on the river side unless stability considerations indicate the requirement of flatter side slopes. Berms may be adopted instead of increasing side slopes if a more economical section results.

Seepage through the embankment

The main purpose of the embankment is to retain water on one side of it. So, it is usual for an embankment to be subjected to differential hydraulic head. Under differential head, there is a tendency of water to seep through the embankment as earthen embankments are never 100% impervious. So there will always be some seepage but the quantity can be significantly reduced by proper selection of materials and construction technique.

The seepage water does not flow throughout the entire cross section. It is usually limited within the phreatic line. The phreatic line means the upper surface of the seepage line i.e. the zero pressure line. Though the capillary fringe above the phreatic line may be saturated due to capillary action, the pressure here is negative. The pressure within the phreatic line is always positive. **Fig. 2-1** and **Fig. 2-2** show the position of phreatic line for a homogeneous section and a zoned section. For the homogeneous section, the phreatic line always cut at the downstream face but the distance of the breakout point from the toe may be reduced by flattening the slope. Soil anisotropy may influence the position of the phreatic line. If soils with different permeability have the same ratio of horizontal to vertical permeability, the phreatic line will eventually reach an identical position. For zoned embankment the phreatic line does not cut the downstream slope. Since the outer zone is much more pervious, the seepage line meets the bottom far inside the outer face. The upstream pervious zone provides stability against rapid draw down and subsequent storage release. The downstream pervious zone provides stability against drainage. The quantity of seepage can be estimated reasonably accurately by flow net method if the top phreatic line is established and other boundary conditions are determined. The phreatic, seepage or saturation line is defined as the line within the embankment section below which there is positive hydrostatic pressure. The hydrostatic pressure on the phreatic line is equal to the atmospheric pressure and hence, equal to zero. Above the phreatic line, there is a zone of capillary saturation called the capillary fringes, in which the hydrostatic pressure is negative. Observations show that the top flow line is close to parabolic in shape for most of its length and deviates from parabola only at the upstream and downstream faces. The appreciable flow through the embankment body, below the phreatic line, reduces the effective weight of this soil and thus reduces the shear strength of the soil due to pore pressures. On the other hand, the insignificant flow through the capillary fringe, leads to greater shear strength, because the capillary tension in water leads to increased inter-granular pressure. As the effects of the capillary fringe are on a slightly safer side, they are neglected. It is, therefore, absolutely essential to determine the position of phreatic line because it:

- gives a divide line between the dry (or moist) and submerged soil. The soil above the phreatic line is taken as dry (or moist) and the soil below the phreatic line taken as submerged for computation of the shear strength of the soil;
- represents the top streamline and so assists in drawing the flow net; and
- helps to ensure that it does not cut the downstream face of the embankment. This is necessary for preventing softening or sloughing of the embankment.

For stability analysis of an embankment, determination of phreatic line, i.e. the seepage gradient, along the embankment cross-section is the prime requirement. The phreatic line is assumed to be a base parabola with its focus at the extreme end of the downstream toe of the embankment.

2.2.7 Uplift and Seepage Quantity

The method involves drawing a flow net for the embankment under the design flood condition and taking values of n_f and n_d, the number of flow channels and number of potential drops respectively, from the flow net.

Uplift

Maximum upward hydraulic gradient $i_{max} = \tan\alpha$
Maximum uplift force $F_u = Y_w \, i_{max} \, v$ (where $v = 1 \, m^3$)
Buoyant weight of soil $\overline{w} = Y_{sat} - Y_w$

$$\text{Factor of safety} = \frac{\overline{W}}{F_u} \not< 1.5$$

Seepage quantity

No. of significant flow channels = n_f
No. of potential drops = n_d

$$\text{Seepage quantity} = q = \overline{K}h\frac{n_f}{n_d}$$

where $\overline{k} = (k_H k_v)^{1/2}$
h = total head loss

A value of $= 5 \times 10^{-3}$ mm/sec may be assumed for preliminary analysis. Where the value of is available from geotechnical investigations, the assumed value should be replaced by the actual one. The limiting value of q should not exceed 1 m^3/day/linear m of embankment. If the limiting value is exceeded in any reach, a filter may be provided to protect the discharge face.

2.2.8 Stability Analysis

The following aspects of the stability of an embankment must be considered:

- stability of the country side slope during steady seepage flow;
- stability of the river side slope during draw down;
- resistance of the foundation to shear failure; and
- stability of the foundation under the weight of the embankment.

Various methods have been proposed for computing embankment stability. In general, these methods are based upon the shear strength of the soil and certain assumptions with respect to the character of an embankment failure. The Swedish Slip Circle Method, which supposes the surface of rupture to be a cylindrical one, is a comparatively simple method of analyzing embankment stability. In this method, the factor of safety against sliding is the ratio of the average shear strength to the average shear stress determined by static on a potential sliding surface. The factor of safety should be not less than 1.5. The factor of safety against shear failure along the arc of a circle determined by the slip circle method is as follows:

$$F.S. = \frac{cL + \tan\phi(N_s - U_s)}{T_s}$$

where F.S. = factor of safety
T_s = sum of tangential forces tending to produce movement of the soil along the circumference
N_s = sum of normal forces for all the slices
U_s = sum of uplift pressures
ϕ = angle of internal friction of the soil used for embankment fill
L = length of arc intersecting the embankment
c = cohesion of the soil used for embankment fill

2.2.9 Shrinkage and Settlement

A settlement of an impervious zone varies according to factors such as type of materials, degree of compaction & water control, and a settlement of a pervious zone varies according to factors such as the type, gradation and grain shape of materials, compaction method, thickness of layers of dumping height and whether or not water jetting is employed.

Settlement

Stability of the foundation is checked by using Terzghi's standard settlement equation:

$$S = \frac{C_c H}{1+e_0} \log \frac{P_0 + \Delta P}{P_0}$$

C_c and e_0 values are obtained from the soil test reports. P_0 is computed at the mid point of the maximum depth upto which significant consolidation is expected to take place, i.e. $P_0 = Z\gamma_b$ and ΔP may be calculated using the method given by Punmia (Punmia, 1982).

It is to be estimated how much the design crest level should be raised to allow for shrinkage and settlements. From experience, it is observed that shrinkage of a fresh embankment averages 10% of the maximum fill height. In case of organic subsoil layers, a shrinkage allowance of 50% has to be considered and should be added to the 10% allowance for fill-shrinkage. According to Varshney (1982) the settlement allowance of 2% can be adequately taken both for the foundation and the embankment and for embankment more than 30 m in height, an extra 1% allowance is provided to account for the settlement due to earthquake. There exist some empirical formulas for predicting the settlement of the embankment. The formula is, however, not often used.

2.2.10 Slope Protection

The evaluation of slope stability is complicated due to the fact that embankment contain heterogeneous soil due to non-uniform compaction and non-uniformity in borrow material. The slopes of the embankments vary widely depending on the character of the materials available, foundation conditions and the height of the structure. The slope also depend upon the type of embankments (i.e. homogeneous, zoned embankment type etc.) and on the nature of construction materials and other geotechnical characteristics. In many situations the variables that affect the shear strength in the field are only approximately known. Hence, for small projects and for embankments of low height, it may be adequate to rely for slope selection on the available experience for a zone. **Table 2-3** and **Table 2-4** give the side slopes for preliminary design of embankments according to Terzaghi and BWDB's recommended side slopes for flood embankments.

Master Plan Organization (MPO) noted that the conventional practice of BWDB the country side slope of 1:2 and the river side slope of 1:3 provide sufficient safety against slope in stability. Riverside slope may vary from 1:2 to as flat as 1:4 for stability because of the relatively poor construction materials. Taking into account the geotechnical conditions of Bangladesh, a realistic design should take a value of 1:2 for the countryside and 1:3 for the riverside. To protect the side slopes against erosion by rainfall and waves, turfing of the side-slopes and the berms with different grass species may be undertaken. Turfed surfaces will also increase the stability of the side-slopes. Where severe wave action or erosion due to currents is anticipated, revetments may be provided to protect the side-slopes. Surface protection of river side (R/S) slope is meant to prevent the destructive wave action. Usual type of surface protection for the R/S slope is stone rip-rap either dry dumped or hand placed. When a thin layer is used, hand placed rip-rap may be more economical than dumped rip-rap.

Size and gradation of rock and thickness of riprap layer:
The minimum suitable size and gradation of rock thickness of riprap layer depend on the intensity of the wave action expected and on the steepness of the embankment slope on which the riprap rests. The riprap sizes given in **Tables 2-5, 2-6 and 2-7** are reasonable and conservative for earthen embankments with ordinary slopes. Horizontal or inclined drainage blankets are sometimes used to facilitate easy and safe drainage of seepage water, otherwise, might cause erosion and subsequent failure of the embankment. The drainage blankets should be properly laid and compacted. Filter materials should be properly selected so that finer embankment materials are not washed away. Sometimes toe drains are provided to collect and discharge the seepage water.

2.3 Review of Construction Technique

2.3.1 Types of Embankments

Embankments may be classified according to their method of construction: compacted, semi-compacted, and un-compacted fill. The entire embankment cross section is not necessarily constructed by one method; the central core may be compacted or semi-compacted with berms semi-compacted or un-compacted. However in our country the embankments (earthen) are of homogeneous type and are constructed as un-compacted. The various construction methods as described by the U.S. Army Corps of Engineers are listed in **Table 2-8.**

2.3.2 Methods of Construction

There are mainly two methods of earth embankments construction followed in most countries:

i) Rolled fill method and
ii) Hydraulic fill method

In rolled fill method the embankment is constructed in successive mechanically compacted layers. The material from borrowpits and that suitable from required excavations is delivered to the embankment site. It is then spread by bulldozers after moisture adjustment, if necessary, to layers of limited thickness. Rolled fill construction accounts for practically all dams constructed in recent years.

In hydraulic fill method, construction materials are excavated, transported and placed by hydraulic methods. The materials is washed or pumped from the borrowpits into flumes or sluices extending along the outer edges of the embankment; provided with outlets at intervals along their length. Discharge form these outlets flows inward to a central pool. The coarse material is automatically deposited on the outer edges of the embankment, the fines moves towards the center, and the finest and most impervious is deposited in the pool to form the central or impervious central core; supported by relatively pervious & more stable outer zones - grading in particle size from the fine to coarse towards the outer slopes.

In Bangladesh, the embankments are constructed by head basket method. In this method construction materials are excavated from borrowpits parallel to the embankment and are carried in a bamboo made basket on head by unskilled labourers to the site of construction. The labourers dump the earth and buildup the embankment.

2.3.3 Construction Phase

The acquired land is demarcated and permanent pillars are placed. In the preparatory stage some temporary B.Ms are established along the proposed alignment. The centerline of the proposed embankment is pegged at every chain with curves being properly set. The base of the embankment is cleared of all tree roots, shrubs, etc. All loose and soft soil is removed for a depth of about 15 cm and the surface is ploughed rough. Dug bailing is done to demarcate the toe lines, berm and the borrowpits. Bamboo & rope profiles of the finished embankment is then set up at regular intervals of about 150 m.

Earth excavated from borrowpit should be placed first at the country side toe of the embankment. From there placing should proceed towards river side toe. Baskets of earth are to be thrown close against each other, working systematically across the section and so forming a layer of about 22.5 cm (9") thickness. On completion of the first layer, the second layer shall begin on the country side toe and finished at the riverside toe as before, and this is repeated until the top of the embankment is reached. This procedure involves the labourers walking over every basket of earth which helps to achieve compaction. Some extra labourers need be engaged for clod breaking and hand tamping.

It is a normal practice to specify a somewhat higher working crest level (higher than 10% - 20% the designed crest level) to allow for subsequent settlement. The adequacy of extra provision is dependent on the type of soil, moisture content and the adopted compaction method. With completion of the embankment in a section the country side and riverside slopes are graded to the designed profile and the crest is provided with about 1 in 20 camber. After some stabilization the top and sides of embankment are to be properly dressed. Side slopes and about 60 cm of crest are then turfed preferably with "*Durba*" grass sods. This should be done just at the commencement of the monsoon rain so that natural watering is ensured for the growth of the turf. Where the fill material is not of appropriate quality, it is preferable to have a 15 cm layer of top soil at the slopes for sustaining a healthy growth of the turf. Sod level of the crest should be flushed with embankment crest, so that no accumulation of rainwater is allowed. The sods of approximate size 15 cmx15cm should be closely packed to avoid rain cuts.

2.3.4 Borrowpits

To make least use of the valuable land and to encourage siltation, the borrowpits are made at the river side. These may be located in such a way that a berm of approximately 6-10 m width is left between the toe of the embankment and the edge of the borrowpit. To prevent the development of flow concentration during high river stages cross berms perpendicular to the embankment should be left in the borrowpits every 30 m measured along the embankment. The borrowpits may be rectangular and the depth of cutting should not exceed 1-2 m on the river side and 0.5-1 m on the country side. In most areas, soils at more than these depth below ground level are more moist than required for proper compaction. Besides, deeper borrowpits increases the cost of excavation. Shallow borrowpits (approximately 0.6 m) can be used for cultivation.

2.3.5 Soil Selection

Suitable soils, according to Indian standard 8826-1978, for construction of earthen embankments are shown in **Table 2-9** (Islam, 1991). But as earthen embankments require very large quantities of materials, it is necessary to utilize whatever is available near the site. In general an embankment can be designed to fulfill its functions satisfactorily with any type of material available. Thus a homogeneous embankment section can be designed entirely of highly pervious non-cohesive material like sand and gravel or entirely of impervious cohesive material like silts and clays. It is much more desirable to have at least two types of materials available, one sandy to provide stability and good drainage and the other clayey to cut off seepage. Sections designed with materials of two or more types in the different zones of the embankment are called non-homogeneous sections.

While earthen embankments can be designed with any type of material as stated above, more economical designs will be possible at locations where the materials posses desirable properties. For the sandy material, desirable properties are good grading, high compacted density, high angle of internal friction and quick drainage. For the clayey materials, the requirements are moderate plasticity index, high shear strength, high compacted density and low permeability. The last criteria would be available in all clayey soils and it is necessary to look for the others so far as possible. Sand alone should not be used because of high permeability. Similarly clay swells when wet and cracks when dry. A soil containing 60:25:15 proportion by weight of sand, silt and clay is most suitable as fill material of flood protection embankment.

2.3.6 Compaction

Compaction increases soil strength, prevents erosion & cracking. It makes the activities of ruminants difficult. In order to get the designed standard seepage control and stability features as well as proper bonding between successive layers, the soil with proper moisture content has to be compacted to the requisite level. For optimum mechanical compaction the thickness of layer should be between 0.2 to 0.3 m. These layers should be individually compacted by 8 to 12 passes of tamping rollers under proper moisture control. Cohesionless materials are best compacted by vibrating rollers. The embankment samples should be routinely tested for quality control. Field density tests are necessary for compaction control. It is unlikely that implementation of mechanical compaction is going to be possible in all flood control embankment project of Bangladesh. However 70%-80% compaction can be attained with:

- right type of soil;
- optimum moisture content;
- placement of earth in 15-20 cm layers;
- clod breaking; and
- hand tamping.

Placing of earth in 15-20 cm, baskets of earth thrown one against the other, construction of embankment in successive layers, clod breaking and hand tamping ensures good degree of manual compaction due to repeated treading over the entire area by the labours. For any particular method of compaction the density which can be achieved is dependent on the moisture content of the soil. **Figure 2-2** shows the relation between dry density and moisture content. The position and shape of the curve vary according to the material and method of compaction. The most common test is "Proctor Test" and it is possible to specify the density required as a percentage (say 90%) of the maximum achieved in the Proctor Test. For the proctor test a standard method of compaction is used and the resulting curve is known as the proctor curve. It can be seen that both maximum dry density and optimum moisture content vary with the method of compaction. For any particular soil, the relationship is defined by laboratory testing. Moisture content tests may be carried out in a simple site laboratory. In the absence of proper test, an approximate field indication can be obtained by squeezing a handful of soil. If the moisture content is much above the optimum, than the soil will stick to the hand; if it is much below the optimum, than it will not squeeze into a contact lump.

There is the danger of excessive pore pressure being induced in the underlying ground or embankment it self, with high embankment where the moisture content of soil is also high. If the soil moisture controlling is not possible, than the embankment should be built in 2 stages. In the first season a portion say up to 2/3rd height is to be built and the rest in next season. The World Bank is constantly-reminding BWDB to adequately compact the embankment to secure them from subsidence of crest due to shrinkage of embankment and subsoil settlement as well as erosion due to animal activities or human use. They have suggested to split the single item of earthwork of "Schedule of Work" into 2 items. One of these shall be placement of earth in layers of 15 cm and the other for necessary clod breaking and proper compaction by labour intensive methods (World Bank; 1985, 1987a, 1987b).

2.3.7 Supervision

The necessity for quality control in construction of embankments has been recognized for many years. In 1932, Justin wrote (after Amanullah, 1989): *"An entirely safe and substantial design may be entirely ruined by careless and shoddy execution, and the failure of the structure, may very possibly be the result. Careful attention to the details of construction is, therefore, fully as important as the preliminary investigation and design".*

The consequences of ignoring control are exemplified by the failure of large number of earthen embankments. Records show that most of these embankments were constructed without moistening the soil and without applying proper compactive effort. Areas to be excavated are selected, depths of cut are determined, and the zone of the embankment in which a particular material should be placed is predetermined. The amount of water to be added to the borrowpit or to be removed to attain proper water content of the materials prior to placing should be determined.

The most important variables affecting construction of earthen embankments are distribution of soils, placement, water content and its uniformity throughout the spread material, water content of the borrow material, methods for correcting borrow material water content if to wet or too dry, roller characteristic, number of roller passes, thickness of layers, maximum size and quantity of gravel sizes in the material, condition of the surface of layers after rolling, and effectiveness of power tamping in places inaccessible or undesirable for roller operation. Adequate inspection and laboratory testing are essential to maintain the control of earthfill. There is no satisfactory substitute for control testing to determine the degree of compactness for cohesive soils. The testing must include all critical areas where seepage or loss of strength may induce failure.

Either the rapid method of compaction control or the proctor needle value can be used to determine the status of natural moisture conditions in the borrowpit with respect to the optimum water content. Every effort should be made to have the excavated material as close as possible to the optimum water content prior to delivery on the embankment. After the materials are placed in the proper location the embankment inspector determines whether they contain the proper amount of moisture prior to compaction. This is of utmost importance. The rapid compaction control method or the proctor needle value should be used for this determination. Should the materials arrive on the embankment too dry, it will be necessary to condition them by sprinkling prior to, during, or after spreading.

Another important inspection task is the determination of the thickness of the compacted layer, a layer that is spread too thick will not give the desired density for given compaction conditions. Initial placing operations will determine the proper spread thickness of a layer that will compact to the specified thickness. This is usually 8 to 9 inches for a 6 inch compacted lift of earthfill. A method of determining average thickness of placed layers is to measure & plot daily a cross section of the fill at a reference station. The final check on the degree of compaction attained is done by the rapid method of compaction control. If the field dry density of the material passing the No. 4 screen is above the minimum allowable density and if the water content is within the allowable limits, the embankment will be ready for the next layer after such scarifying and moistening as may be necessary to secure a good bond between the layers. Mechanical tamping, when used around structures, along abutments and in areas inaccessible to the rolling equipment, should be carefully watched and checked by frequent density tests. The procedure to be followed for mechanical tamping will depend greatly on the type of tamper used. When embankment operations are concentrated in a small area (i.e. if many layers is material are being placed one over the other in a single day), tests should be made in this area in every third or fourth layer to assure that the desired density is being attained. If areas of doubtful compaction do not exist and no tests are required because of concentrated areas, at least one field density test should be made for each 2000 cubic yards of compacted embankment and it should be representative of the degree of compaction being obtained.

The poor quality of construction of BWDB embankments has been criticized by World Bank (World Bank, 1987b). World Bank required proper construction certificate from BWDB (World Bank; 1985, 1987a, 1987b). The requirement has been expressed as:

> *"BWDB would be required to certify that compaction was properly done".*

2.4 Review of O&M Requirements

Embankments are earthen structures extending over hundreds of kilometers across different soil zones. The safety and stability of embankment depends on, among others:

- the physical and mechanical properties of materials used;
- hydro-geological condition of the subsoil;
- physical and mechanical properties of subsoil;
- control of seepage etc.

Soil is a natural material which is not homogenous. Enforcement of technical specification is not always possible for practical limitations. Poorly compacted embankment deteriorates rapidly, seepage and ruminants activities become easy. Even properly constructed embankments need maintenance. The construction related O&M requirements are:

a) keeping the embankment to design height,
b) protection of crest and side slopes against depressions and gully formation,
c) protection of embankment against sliding,
d) protection of embankment from erosion,
e) protection of embankment against seepage & piping,
f) protection of embankment against uplift and pore pressure.

Keeping the embankment to design height
Embankments settlement is the combined effect of shrinkage (i.e. natural compaction) of embankment body and subsidence of underground layers due to the extra load of the new embankment. The embankment has to be brought to designed level by periodic earthwork.

Protection of crest and side slopes against depressions and gully formation

Protection of crest and side slopes against depressions and gully formation
Concentrated rain flow creates depression & gully. If left unattended these gradually widen endangering the embankment itself. Maintenance after each monsoon season is necessary to preserve the integrity of the embankment.

Protection of embankment against sliding
A high void ratio combined with saturation of the earth filled with water may cause a shear slide. The situation becomes critical when the embankment is built of pre-dominantly sandy material. In such case bamboo mat supported by bamboo pin can be a immediate protection measure. As a long term measure clay blanketing can be resorted to; to reduce the soil saturation. Embankments if built with peat or such organic soil will swell and slide when moist. Organic soils are non cohesive and does not take any load. In such case replacement of the organic soils is the only solution.

Protection of embankment from erosion
If the embankment slope erosion takes place due to current or wave action of rivers/sea, than resistance against erosion has to be increased by turfing, lining revetment etc., depending degree of erodibilty. If the river erosion tends to attack the toe of embankment, than construction of x-bar, groynes etc., may be necessary to deflect the current. Parallel current through borrowpits may develop which is likely to endanger the embankment. Construction of cross-bar is necessary in such case to break the flow.

Protection of embankment against seepage & piping
Embankments are constructed to withstand prolonged submersion of riverside and countryside under different water levels. Care has to be taken so that, the differential head difference between the two sides does not give rise to damaging seepage or percolation. The hydraulic gradient of the saturation level in an embankment holding water against one face is greatly influenced by the porosity of the soil. When the hydraulic gradient exits the embankment slope at the country side, danger of failure is imminent. Soil will be washed out from the country side toe resulting in failure of the embankment. Piping flow gradually widen the flow channel by removing soil. Depending on the amount of materials removed the embankment may settle unevenly, crack or even fail by overtopping. To remedy this the seepage path has to be lengthened. Impervious clay blanket or asphalt layer in front of embankment can be utilized for the purpose.

Protection of embankment against uplift and pore pressure.
Installation of relief wells, ditches and inverted filter toes on the country side of embankment reduces uplift and pore pressure. The stability of embankment can thus be increased.

2.5 Afforestation

Afforestation of embankments cannot be encouraged for technical and legal reasons. The East Bengal Embankment and Drainage Act, 1952 (modified by EP Ordinance XXVIII of 1960, EP Ordinance VII of 1962 and EP Ordinance XIII of 1966) defines activities damaging to the embankment as punishable offense. The Acquisition and Requisition of Immovable Property Ordinance, 1982 stipulates that otherwise use of acquired land needs prior permission of Government. Some of the technical reasons, which do not justify afforestation, can be summarized as ;

- trees with root system, if uprooted by storm, may create holes. This becomes weak spot in the embankment;
- roots may dislodge soil, which if washed by rain water, will reduce the effective embankment section;

- rain water and tidal water may form holes surrounding the tree trunk. The water accumulating in the hole may subsequently seep through the embankment body and damage it;
- turf dies/ does not grow under some species of trees. Lack of grass cover accelerates land erosion;
- fruit bearing trees invite rats and other burrowing animals, which make ghogs resulting in damage to embankments;
- rotten roots of dead trees create holes. Passage of water through these holes may damage the embankment;
- micro-tunnels are developed around the roots of wind swept trees. Passage of water through these micro-tunnels may damage the embankment;
- evapo-transpiration from the embankment body during summer may cause uneven settlement of the embankment top; and
- trees dry up the soil in summer and reduce the volume of subgrade which may be upto 6 percent and thus drop the surface and crack it (Khanna, 1979).

Traditionally BWDB favoured growth of turf on the embankment slope and discouraged plantation of trees (BWDB 1963, Euroconsult 1994a). BWDB circular No. 325-WDB/Sectt./Imp-1/Misc-13/91 dt. 15.8.92 categorically directed to plant only grass and shrub on the slopes of the embankments. But trees are being planted on BWDB's coastal embankments and other embankments since long. No breach due to trees has been reported till now. This gave rise to a conflict between technical logic and physical observations. The above mentioned circular was withdrawn subsequently vide BWDB circular no. 349-WDB/Sectt./Imp-1/Misc-13/91 dt. 11.8.94 permitting Forest Department to take necessary action for plantation in consultation with BWDB officials. The reason or justification of withdrawal was not mentioned in the order.

The reasons for apparent contradictions may be due to the limitations in the range of observations. The observations cover mainly the coastal embankments, which has different design criteria and is meant for different purpose. The coastal embankments are designed to withstand onslaught of tide and tidal surges. The tide and tidal surge, though come with great force, do not last for long period. The coastal embankments have slopes 1:7 and 1:3 on the sea side and country side respectively. The section is much bigger than the optimal section required for seepage/percolation consideration. There is allowance for tree root zones beyond the minimum required section. The trees planted on the sea side slope rather help the embankment stability by reducing the erosive force of tidal surge. The interior embankments, on the other hand, are designed with the economical section of 1:3 slope on the river side and 1:2 slope on the country side. They have to withstand prolonged submersion under differential water level on two sides. Embankment breaches in Bangladesh mainly occurs due to seepage or percolation and subsequent washout of soils.

To remove the contradiction and to formulate a policy for plantation of embankments the Government of Bangladesh formed an Expert Committee. An inter-ministerial meeting reviewed the recommendation of the Expert Committee recommendations (Nishat,1998) and formulated the following basic principles :

- close afforestation of borrowpit, berm and areas in front of embankment is good for its stability. So these areas should be closely planted to build a dense tree barrier;
- no tree should be planted on the embankment's top surface;

- there should be turf all over the embankment. This will help stoppage of land erosion;
- easily uprootable types or trees which are not friendly to turf growth should not be planted;
- areas around the tree trunks should be covered with raised earth to control formation of holes;
- regular pruning should be done, so that no massive canopies are developed. There should be regular cleaning of fallen dry leaves;
- there should be fixed rotation and trees should be harvested in time;
- plantation of fruit bearing trees should be avoided in general. If planted, fruits should be harvested regularly so that embankment is not damaged by rats;
- local people should be incorporated to the plantation activities on profit sharing basis;
- the embankment slopes have to be divided into different zones for plantation purpose depending on their steepness.

The side slopes, their corresponding zones and suggested plant species for the zones are given below,

Side slope	Zone	Recommend species
1:3 or more	Lower 1/3rd	Coconut, Palmyra palm, Date palm, Betelnut, Tamarind, *Koroi*, Lemon, Cotton, *Kodom*, *Sharifa*
	Middle 1/3rd	Lemon, *Sharifa*, Shrub & Grass
	Upper 1/3rd	Grass, Indigo, *Dhaincha, Arahor*
Less than 1:3	Lower 1/3rd	Coconut, Palmyra palm, Betelnut, Date palm, Tamarind, *Sisoo*
	Upper 2/3rd	Grass, Indigo, *Dhaincha*, *Arahor*, Shrub

It was decided on principle that the Forest Department will be responsible for afforestation while BWDB will be responsible for stability of the embankments. The Ministry of Water Resources has been given the responsibility of preparing a detailed guideline for afforestation of BWDB embankment slopes on the basis of principles mentioned above.

2.6 Summary

Many of the O&M related problems are linked to poor planning and construction. Incomplete evaluation of socio-economic or hydro-morphological impact inside/out side the poldered area often forces people to make wilful damages like public cut. Identification of arrangement for O&M financing has often been neglected in the past, which is necessitating costly rehabilitation.

In the early ages embankment were constructed by workers following the past construction practice. Subsequently design criteria have been developed to give perfection to the construction practice and to economise it. Due to this reason embankment has seldom failed due to design. However importance of proper alignment and necessity of requisite setback distance is yet to get due recognition. In this country major O&M expenditure of embankments involve protection against river erosion and slope protection. Judicious fixation of alignments with provision of requisite setback can save many subsequent problems. Return period for design flood level is fixed on the basis of conventional damage criteria. There are other more preferable consideration because of flat terrain of Bangladesh plain.

Proper compaction during construction can save many subsequent O&M requirements. Defects arising due to poor compaction are often difficult to repair other than costly resectioning or rehabilitation. Construction related O&M requirements are keeping the embankment to design height as well as protection of the embankment against sliding, ghogs, depression, erosion, seepage, piping etc.

Experience of coastal afforestation is being replicated in the interior embankments. The two types of embankments due to their fundamental difference require different plantation pattern. An inter-ministerial meeting has formulated the basic principles for plantation of the interior embankment slopes, on the basis of Expert Committee recommendations. MoWR is preparing a guide line for interior embankment slope plantation in accordance with the inter-ministerial meeting's decision.

CHAPTER III

LITERATURE REVIEW: EMBANKMENT FAILURE

3.1 Introduction

A structure fails if it can no longer perform any one of its main functions. In case of flood control embankment the main function is to protect an area from the onslaught of inundation. Failure may or may not be the result of collapse of the structure or its component. Collapse may be defined as the deformation to such a magnitude that original geometry and integrity are lost. It is however conceivable that a collapse may occur without failure e.g. slip circle affecting a dike during a long period of low water level. The opposite may occur in the event of overtopping. The dike may fail without collapse (RPT, 1989). Embankment may fail due to improper design, faulty construction or lack of maintenance. Garg (1989) has grouped the embankment failures in 3 broad groups as follows:

(i) Hydraulic failures
(ii) Seepage failures
(iii) Structural failures

Hydraulic failures

Hydraulic failures of embankments occur due to overtopping, erosion of upstream face, cracking of surface, erosion of downstream face by gully formation, and erosion of downstream toe.

Seepage failures

Limited seepage is inevitable in any earthen embankment and ordinarily it does not produce any harm. However uncontrolled or concentrated seepage may lead to piping or sloughing and subsequent failure of the embankment. Seepage failures may occur due to piping through foundations, piping through embankment body, and sloughing of downstream toe.

Structural failures

Structural failures are generally caused by shear failures causing foundation slides and/or slide in embankment.

3.2 Review of Studies of Amanullah

Amanullah (1989) studied the failure of flood control embankments in Bangladesh randomly selecting 8 FCD/I projects scattered over the country which suffered from colossal damage of embankments. His findings into failures of embankments were divided into 4 general groups, namely:

(i) causes of failures of embankment prior to 1987;
(ii) causes of failures of embankment during the flood of 1987;
(iii) causes of failures of embankment during the flood of 1988; and
(iv) general observations.

Causes of failures of embankment prior to 1987

The causes of failures of embankment prior to 1987 flood was attributed to erosion and breach.

Causes of failures of embankment during the flood of 1987

The percentage wise causes of failures were as follows;

- overtopping 45%
- erosion 27%
- public cut 18%
- breach 10%

100%

Causes of failures of embankment during the flood of 1988

The percentage wise causes of failure were as follows;

- breach 60%
- erosion 24%
- overtopping 9%
- public cut 7%

100%

General observation

The general observations were as follows:

- design criteria and construction standards were not uniform even in neighboring projects;
- embankment designed with return period of 100 years and a free board of 1.50m were not overtopped in case of big river even during the 1988 flood;
- the failures of embankments were aggravated as groynes, retirement works, breach closures etc. were only partially completed; and
- maintenance of embankment got less priority.

He proposed the flood embankments to be used as roads as in that case the maintenance was likely to be better. He also proposed a study related to the involvement of beneficiaries in the O&M of embankments.

3.3 Review of IFCDR Case Studies

Institute of Flood Control and Drainage Research (IFCDR) of BUET took up a research project to determine the main causes of failure (or poor performance) and to suggest remedial measures to minimize the embankment failures in the country (Islam, 1991). The study quoted statistics on failure from Trans. ASCE Centennial Volume(1953) as follows:

- overtopping - 30%
- seepage - 25%
- sliding - 15%
- conduit leakage - 13%
- misc. - 7%
- unknown - 5%

The study also quoted the following as main causes of embankment failures in Bangladesh from a BWDB study (1987):

i. exceedence of hydraulic design parameters;
ii. erosion of embankment due to wave action and current;
iii. inadequate section of embankment and construction below specification;
iv. lack of compaction during construction;
v. lack of maintenance; and
vi. inadequate assessment of effects of other neighboring projects.

The investigators visited 14 failure locations of 10 embankments in the country. From these they selected 10 failure locations of 8 embankments. They collected detailed information, analyzed soil samples. The studied failures locations and rivers were as follows:

Sl. No.	Failure Location	Project
1	Sataishkandi	Tayebpur-Kashimpur FC Embankment
2	Iarpur	Tayebpur-Kashimpur FC Embankment
3	Malipukur	Chalanbeel FC Embankment
4	Dangapara	Chalanbeel FC Embankment
5	Nandibari	Noagaon-Atrai FC Embankment
6	Akcha	Bakorsharhat – Akhainager
7	Arazi salapak	Teesta Left Embankment
8	Palashbari	Dharala Right Embankment
9	Sirajganj	Brahmaputra Right Embankment
10	Shingimari	Teesta Right Embankment
11	Gazaria	Brahmaputra Right Embankment
12	Gobargaon	Jamuna left Embankment
13	Kushaichar	Padma Left Embankment
14	Baoitara	Brahmaputra Right Embankment

They soil samples of following 10 failure locations were analyzed:

Sl. No.	Failure Location	Project
1.	Sataishkandi	Tyebpur-Kashimpur FC Embankment
2.	Iarpur	Tyebpur-Kashimpur FC Embankment
3.	Malipukur	Chalanbeel FC Embankment
4.	Dangapara	Chalanbeel FC Embankment
5.	Nandibari	Naogaon-Atrai FC Embankment
6.	Akcha	Bakorsharhat – Akhainagar FC Embankment
7.	Baoitara	Brahmaputra Right Embankment
8.	Palashbari	Dharala Right Embankment
9.	Arazisalapak	Teesta Left Embankment
10.	Shingimari	Teesta right embankment

Summary of findings (Islam, 1991)

Sl	Name of Embkt.	Observation
1	Tayebpur-Kashimpur FC Embankment	Soil was suitable for embankment. The embankment was structurally inadequate according to BWDB standard, signifying poor construction and/or poor maintenance. Failed due to overtopping signifying design factor.
2	Chalan Beel FC Embankment	Soil was suitable for embankment. The embankment was structurally inadequate according to BWDB standard, signifying poor construction and/or poor maintenance. Failure may be due to piping through ruminant holes.
3	Noagaon-Atrai FC Embankment	Soil was suitable for embankment. The embankment was structurally inadequate according to BWDB standard, signifying poor construction and/or maintenance. Failure may be due to sliding of embankment slope.
4	Bakorsharhat-Akhainagar FC Embankment	Soil was suitable for embankment. The embankment was structurally inadequate according to BWDB standard, signifying poor construction and/or maintenance. Failure was attributed to poor construction (lack of compaction).
5	Teesta Left Bank Embankment	Soil was suitable for embankment. The embankment was structurally inadequate even according to BWDB standard, signifying poor construction and/or maintenance. Failure was attributed to overtopping signifying design failure.
6	Dharala Right Embankment	Soil was suitable for embankment. Big discrepancy between design section and actual field section was observed. Tender documents showed 80.90 m^3/m earthwork while actual field measurement showed 56.34 m^3/m earth. Poor construction. Failure was attributed to sliding of slope.
7	Brahmaputra Right Embankment	Soil was suitable for embankment. There was big difference in tendered and actually executed earthwork. Designed earthwork was 59.50 m^3/s while in field actually 35.63 m^3/m were found. Failure was observed due to piping through burrowing animal holes.
8	Teesta Right Embankment	Soil was suitable for embankment. There was big difference in tendered and actually executed earthwork. The design showed 108.70 m^3/m earthwork while in actual field it was found to the 45.20 m^3/m. Failure may be due to instability of the side slope.

The conclusions were:

1. The reasons of failures were classified into 3 broad categories.
   a. failure due to improper construction, 50% failures could be attributed to improper construction. It was observed considerable difference between the designed section and actual field sections;

b. failure due to improper maintenance. 30% failures could be attributed to improper maintenance;

c. failure due to river migration. 20% failures could be attributed to river erosion.

2. Most of the embankment country side slope were unstable due to seepage.

3. Embankments were not generally compacted properly. FFW embankments were not properly designed.

4. Maintenance of embankments were generally inadequate.

It was recommended that:

1. Embankments should be properly designed and constructed.
2. Seepage control should be there.
3. Borrow pits should preferably be located on the river side with cross bar and should not be too deep.
4. Embankments should be properly compacted during construction, and
5. Maintenance should be done properly.

Safiullah (1977) found the slope of DND Embankment as 1:1.15, 1:1.25, 1:1.38, and 1:1.15. All these were below the BWDB's own standard. Islam (1994) clearly and categorically stated: *"Inadequate embankment section construction below specification and poor maintenance of the embankment have been an usual matter in Bangladesh"*

Islam (1994) presented his findings as :

Sl	Embankment	Failure location	Soil type	R/s Slope	C/s Slope
1	Tayebpur-Kashimpur FC Embankment	Jarpur	CL	1:1	1:1.1
2	Tayebpur-Kashimpur FC Embankment	Sataishkandi	ML	1:1.2	1:1.2
3	Chalan Beel FC Embankment	Malipukur	ML	1:1.4	1:1.4
4	Chalan Beel FC Embankment	Dangapara	CL	1:1.3	1:1.2
5	Noagaon-Atrai FC Embankment	Nandibari	ML	1:1.2	1:1.2
6	Bakorsharhat-Akhainagar FC Embankment	Akcha	SC	1:1.7	1:1.6
7	Teesta Left Bank FC Embankment	A.Salapak	SC	1:1.3	1:1.2
8	Dharala Right Bank FC Embankment	Palashbari	SC	1:1.3	1:1.2
9	Brahmaputra Right Bank Embankment	Baoitara	CL	1:1.7	1:1.7
10	Teesta Right Bank Embankment	Shingimari	ML	1:2	1:1.9

He also quoted that the conventional slopes according to BWDB (1984) & LGED (1983) as follows:

BWDB:	1:2 for country side (c/s) slope and 1:3 for river side (r/s) slope.
LGED:	1:2 to 1:3 for normal soils (silt and silty clay) and 1:3 to 1:5 for other soils, both r/s & c/s slopes.

He also showed a comparative position of designed and actually executed earth work.

Name of Project	Designed quantity	Executed quantity	Difference
Brahmaputra RB Embankment	5950 m^3/100m	3563 m^3/100 m	(-) 2387 m^3/100 m
Dharla RB Embankment	8090 m^3/100 m	2456 m^3/100 m	(-) 5634 m^3/100 m

3.4 Review of Studies in Failures of Brahmaputra Right Flood Embankment

The Brahmaputra Right Flood Embankment Project (BRE) consists of 220 km of flood embankment from Kaunia in the Rangpur district to Bera in the Pabna district. The first 36 km is for protection from inundation of Teesta overflow and the remaining 184 km is for protection from the Brahmaputra inundation. The fixation of crest level was based on 1 in 100 years flood with 0.9m free board along the Teesta bank and 1.5m free board along the Brahmaputra bank. The riverside and country side slopes were 1:3. The 84km embankment from upstream end had top width 4.27m while the top width of the rest portion was 7.32m. The Teesta bank set back was kept 0.4 km to 0.8 km while in case of Brahmaputra the set back distance was kept 0.8km to 1.6km.

The feasibility Study for the project prepared in 1962, was an engineering study for improvement of agricultural production only. The feasibility study did not consider environments, O&M or beneficiary participation in the project. The design criteria were as follows:

Proposed length of embankment	-	About 217 km (135 miles)
Flood frequency	-	1 in 100 years
Side slope	-	1:3 on both side
Type of construction	-	mechanically compacted
Top width	-	24 feet / 14 feet
Free board	-	5 feet
Repair & maintenance cost	-	2% of construction cost
Set back distance	-	(1/2 to 1 mile) & (1/4 to 1/2 mile)

The embankment failed to deliver the desired results as it failed at various locations at different times. There has been several studies on it's performances. Some of these are BWDB (1977), Rahman (1984), Parvez (1987) and Halcrow (1994b).

BWDB (1977) studied the failure pattern of the BRE. To reduce erosion of embankment by borrow pit canal the study recommended construction of cross-dams in canal. Among the total 160 miles length of the embankment, it was found that resectioning was required for (106.3 miles) and retirement was required for (30 miles). The study reported the problems as:

(i) Drainage congestion,
(ii) Inadequate O&M,
(iii) Lack of irrigation water,

(iv) Navigation problems for want of locks, and
(v) Adverse impact on fisheries.

The study paid attention to re-alignment of embankment section for protection from river erosion, problem of borrow pit canal eroding the embankment, rehabilitation of embankment, providing irrigation to the area, and removal of drainage congestion. The informations of bank movement during 1830-1963 (IECO, 1962) is given in **Table 3-1**. According to Project Completion Report the embankment has been completed as per design. But the 1977 survey found the crest level lowering of even 3 feet at places. It did not find top width or side slope to be as per design. They found side slope steeper than even 1:2 in few places. The study reported that till 1977, out of total 135 miles, 24 miles of embankment was retired and 30 miles was under threat. But that was not unexpected as during construction it was assumed that 30 miles of embankment would have to the retired during first 3 years with 5 miles of retirement in each subsequent years. But in reality no programmed retirement i.e. maintenance was done. The report further stated that out of 166.7 miles of total borrowpits, 81 miles about 50% turned into dangerously eroding flood channel. It suggested construction of numbers of permanent cross bars to convert the flood channel into number of ponds.

According to Rahman (1984) the embankment had to be retired again and again due to river erosion. He suggested river bank stabilization as main O&M of embankment. According to him 6723 families were residing on the embankment as on May 1982. These unauthorized occupants built their houses by cutting the embankment slope. This made the embankment structurally unsafe which was one of the main reason of breaches of the embankment. He suggested inclusion of retirement of embankment in the operation and maintenance itinerary. Parvez (1987) was also of the same opinion as Rahman (1984) regarding the failure of the embankment due to river erosion. He mentioned that the 274 km stretch of Brahmaputra river shifted at 86 point during the period 1830 to 1963. The shift was 1.3 km to 12.8 km. Due to this huge shifting of river even multiple retirement of embankment was necessary at some places. He was also of opinion of embankment breach due to damage of embankment sections by unauthorized settlers. **Table 3-2** shows the bank movement of the Brahmaputra river during the period 1965-66 to 1983-84.

Halcrow et al. (1994b) in their report has stated 140 km of retired embankment has been constructed over the past 20 years due to river erosion. They have quantified the average rate of bank movement for the period from 1953 to 1992. **Table 3-3** shows the quantified rate. The assessment of BRE by Halcrow can be summarized as: *The construction of BRE between Belka (on the Teesta) and Fulchari was started in 1957. The remainder from Kaunia to Belka and Fulchari to Bera was constructed between 1963 and 1968. The original set back distance of about 1.5 km was taken giving a nominal life of 25-30 years to the embankment. From the late 1970s the embankment started to come under isolated attack due to bank erosion. There ware no substantiated reports of other forms of failure (e.g. overtopping, piping, slumping etc.) During the mid 1980s the frequency at which the BRE came under attack from the river increased rapidly. During 1988 flood the embankment breached in 3 known locations, all apparently attributable to river bank erosion. In 1991 only 70 km of the original embankment survived in reaches where erosion has been relatively minor"*

According to Halcrow, in case of BRE failures, the principal failure mechanism is undermining as a result of river bank erosion. Overtopping, slope failure, wave action piping such other failure mechanisms had minor roles. Few cases of wave action or localized slumping were observed in cases of retired embankment. Inference made by them was poor consolidation and/or over steep side slope, of retired sections. Stability checking found no sign of instability.

3.5 Summary

Failure to perform any of the main functions of any of the structures' component is considered as failure of the project; which may or may not be associated with the collapse of the structure or it's components. Structure failures are grouped into hydraulic failures, seepage failures or structural failures.

In Bangladesh embankment failures prior to 1987 was caused mainly due to erosion and breaches. Whereas during 1987 and 1988 floods the major failures occurred due to overtopping and breaches. Erosion and public cuts were the next causes of embankment failures during the above mentioned floods. In one of the studies, it was observed that embankment with return period of 100 years withstood the severe floods mentioned before. Less priority of embankment maintenance was focused in the same study.

Another study attributed 50% failures to improper construction. The study observed considerable discrepancy between the designed section and actually constructed one. 30% failures were attributed to improper maintenance and 20% failures to river erosion. The conclusions were drawn after studying the failure locations of 8 different embankments spread over different regions of Bangladesh. The study recommended proper design construction and maintenance of embankment to get the full benefit.

BWDB study reported the problems associated with Brahmaputra Right Embankment as drainage congestion, inadequate O&M, lack of irrigation facilities and adverse impacts on navigation and fisheries. Another study reported undermining as a result of river5 bank erosion to be the principal failure mechanism for BRE, while overtopping, slope failure, wave action or piping to have minor roles.

CHAPTER IV

LITERATURE REVIEW : O&M MANUALS

4.1 General

O&M Manuals are basically reference books for the beneficiaries, operators & the managers for effective operation and maintenance of any project. It provides direction for maximizing the benefit out of the project. They provide guidance and training, until the necessary skill and experience is gained. The success of operation and maintenance ultimately depends on the training, experience, common sense, enthusiasm and initiative of those who are involved with it. Dedication to duty, sense of vocation, patience, tact and an active interest is important for O&M personnel as professional and technical qualification, discipline and active co-operation of the beneficiaries is also important for smooth running of O&M activities. The O&M Manuals that are currently available are usually for the guidance of the operating engineers and technician. Their aim should be to reach the beneficiaries as well as the operators.

Maintenance is the activity of preservation of the facilities from deterioration while they are being used or in operation. The aim of maintenance is the preservation of project features from deterioration in an economic manner concurrent to their being used for the desired purpose. The objectives of maintenance are:

- to keep the system in top operating condition; and
- to obtain greatest use and longest life at most economic cost.

Maintenance may be classified as follows (Harza 1982, Euroconsult, 1994a);

(i) Preventive Maintenance
(ii) Periodic Maintenance
(iii) Rehabilitation
(iv) Emergency Maintenance

Preventive maintenance
Preventive maintenance is the routine daily continuous process of inspection to discover deterioration or weakness in facilities and taking necessary action to rectify the weakness deterioration. In this type of maintenance, while operating, no damage is allowed. Basic concept of this type of maintenance is to keep the facility at or near the original condition.

Periodic maintenance
This type of maintenance are taken after a time gap or at periodic interval. The damages are assessed and repair work is done where necessary. In this type of maintenance the damage encountered may not be uniform all through; some portion may not require any maintenance at all.

Rehabilitation
When major components deteriorate or wear out to such an extent that further preventive maintenance or repair is no longer economical, then complete replacement/rehabilitation becomes necessary. This type of maintenance are taken up due to exigency of the circumstance to bring it back to near the original condition. Rehabilitation is related to the condition of structure; without any relation to the time interval.

Emergency maintenance

This is the corrective work which must be done when unexpected deterioration or destruction of project facilities occur. This takes place suddenly & previous forecasting is not possible in such case.

4.2 History of O&M in Bangladesh

The history of construction and maintenance of flood control embankment dates back to historical time (BANCID, 1992). One of early recorded event dates back to the time of Sultan Ghyasuddin Iwaz Khilzi (1213-1227 AD). Sultani regime was followed by Mughal rule. The Mughals maintained and promoted the system. The Mughal provincial government maintained an independent department for O&M of the embankment, roads etc. It was called *pulbandi daftar* or *pushtabandi*. There was separate budget for this department. The functions of the *pulbandi daftar* war delegated to the local zaminders who received a budgetary allocation from the government in the form of deduction from land revenue collected by them. To keep constant watch there was a class of field workers called *pausban*. They were also called *astapahari* or *atgariahs*; because they were on duty for 24 hours by turn. The zaminders alerted the *gramsaranjami* or the village establishment for taking timely action in case of any breach. The *gramsaranjami* was a body of village officials and volunteers in charge of construction and O&M. **Fig. 4-1** shows the construction and maintenance hierarchy:

During the colonial period the British rulers abolished the *pulbandi daftar* and withdrew the state support. The zamindars were relieved of their traditional *pulbandi* duties. The whole system of embankment along with irrigation systems fell into neglect. The embankments were being cut randomly for entry of irrigation water. Through a notification in 1831 the control of embankments were vested on the District Collectors. But that system did not work. The then Government by another letter in 1847 nullified the executive authority of District Collectors and emphasized the rights of the zaminders over the embankments. The cumulative result of negligence resulted in frequent floods in the region. The Government assumed control over some of the embankments by promulgating Bengal Embankment Act 1873, The Bengal Embankment Act 1882, The Bengal Embankment Act 1915 and The Assam Embankment and Drainage Act 1941.

After the independence in 1947 the Government's attention was drawn to the situation. The Bengal Embankment Act 1951 and The East Bengal Embankment and Drainage Act 1952 (E.B Act I of 1953) were promulgated. By the Acts the Government took control over the public embankments. The Acts stipulated that the Government shall repair/remove, alter or construct any new embankment that may be necessary. The Acts had explicit provision for public hearing with scope of appeal in the intended future interventions. There was provision for expression of public desire for modification or alternation of the embankment in public interest. The Acts prescribed penalty for illegal injury to the embankment. The Irrigation Department of the Government used to look after the embankment. After severe floods of 1954 & 1955, the Krug Mission gave it's report in 1957 for development of water resources in this part of the country. On the basis of Krug Mission's recommendations "East Pakistan Water and Power Development Authority (EPWAPDA)" - a statutory body was created for integrated water resources & power development. In 1972 this body was bifurcated and "Bangladesh Water development board (BWDB)" was entrusted with the responsibility of development and O&M of water resources.

4.3 Review of O&M Manuals

O&M manuals are set of instructions for proper operation and maintenance of projects infrastructures. The ideal manuals contain guideline to meet all eventualities and exigencies. The purpose of the manuals have been spelled out as assistance to field officials in accomplishing systematic and timely operation and maintenance programme. One manual requested that it should be followed and used by all concerned in their day to day project activities. One of the manuals has expressed the purpose of manuals as (EPC, 1988):

"An O&M manuals is of use only if it is in use".

The following manuals were reviewed for evaluation purpose:

i. BWDB Manual of Works (BWDB, 1963).
ii. G.K. Project O&M Manual (Harza, 1982).
iii. Bara Manikdi Sub-project O&M Manual (EPC, 1986).
iv. CEP Polder 67 O&M Manual (EPC, 1988).
v. Sukaijuri Bathai River Sub-project O&M Manual (NHCL, 1992).
vi. Fourth FCD Project O&M Manual (DDC, 1993).
vii. Cyclone Protection Project-II(FAP-7),O&M Manual(Kampsax,1992).
viii. Systems Rehabilitation Project (SRP) O& M Plan, (Halcrow, 1994a).
ix Second Small Scale Flood Control Drainage & Irrigation (SSSFCDI) Project; Model O&M Manual (NHCL, 1987; 1995).

The list of manuals cover from the earliest one of 1965 to the latest one of 1995. The manuals cover different types of projects located at different regions of Bangladesh covering inland as well as coastal region. The manuals gave detailed technical instruction for normal maintenance as well as instructions for protection of embankments in case of imminent failure. To standardize the O&M procedure, BWDB commissioned Halcrow et. al., in connection with the Systems Rehabilitation Project (SRP). The Operation and Maintenance Plan (Halcrow, 1994) was prepared in 1994. BWDB approved the plan and instructed for implementation of the plan in all its completed projects. The O&M Plan identified the followings as main reasons, which necessitate rehabilitation for BWDB projects:

- lack of maintenance;
- project construction not fully or properly completed;
- changes in hydrologic and hydraulic conditions since initial planning; and
- inadequate training of operation and maintenance personnel.

Some other manuals also observed that in the past many large and costly project of BWDB failed to produce desired results due to lack of attention on operation and maintenance requirements by project management (DDC, 1993). According to the manuals the domain of O&M covers among others:

- O&M Organization of BWDB;
- participation of local bodies, officials and beneficiaries in operation and maintenance;
- training;
- monitoring and evaluation; and
- O&M financing.

O&M organisation of BWDB

The manuals stated that formal transferring of a project form construction phase to O&M phase must include handing over of papers like" As built drawings", "Proper Completion Plan", "O&M Manuals" etc. The manuals gave detailed set-up of O&M personnel and stated their responsibilities and line of command.

Participation of local bodies, officials and beneficiaries in O&M

The manuals recognized the role of Beneficiaries and Officials of other local bodies and departments towards materialization of project objectives.

Training

Some of the manuals gave programme of training of personnel in proper O&M of project facilities. It was argued that training motivate and raise moral of workers.

Monitoring and evaluation

Monitoring is done to overview the performance of the facilities. Evaluation of the monitoring results are done for concurrent adjustment of priorities for further improvement of performance.

O&M financing

The manuals stressed the necessity of getting the requisite financing in time for proper operation and maintenance. Some manuals gave methodology for annual budget preparation. The necessity for cost recovery from beneficiaries also has been stressed in the manuals. According to the manual (Halcrow, 1994a), the long term aim of achieving sustained satisfactory system performance with the minimum expenditure will require:

- improved planning and budgeting;
- shifting part of O&M responsibilities to the beneficiaries;
- reorganization and training of personnel for their active participation and that of the beneficiaries; and
- employment of land less people (particularly women) in maintenance.

The constraints to achieve an acceptable level of project's operation and maintenance are (DDC, 1993; Halcrow, 1994):

- fund shortage;
- organisation, staffing and institutional difficulties;
- lack of other resources like transport, equipment etc.;
- unsatisfactory performance of some of maintenance crews in performing their duties;
- maintenance crews in discharging their duties; etc.

The major causes of failures of embankments as identified in the manuals are:

- wave erosion;
- river erosion;
- settlement;
- rain cut/galley formation;
- overtopping;
- seepage and percolation;
- undercutting;
- sloughing;
- leak or ghog;
- boil;

- slip failure;
- damage to turf and revetments;
- unauthorized encroachment;
- intentional removal of fill; and
- excessive growth of shrubs and trees.

The manuals gave much importance on regular inspection and reporting in order to communicate problems and needs of work to a level, where a proper response can be decided. There should be random and surprise visits of supervisory personnel in addition to routine inspections. During monsoons and at times of high river flows embankments should be patrolled frequently. Normally emergency occurs with advance symptoms. Observation of these symptoms and timely precaution helps in reduction of damage and planning of emergency repairs. The manuals have given a check list for routine inspection. The items are:

- seepage through the embankment;
- sloughing of slope;
- leaks, rat holes or ghogs;
- slippage or settlement;
- rain cut or surface erosion;
- wave erosion;
- bank erosion;
- shoot current in the borrowpit;
- cutting of slope or removal of fill;
- unauthorized encroachment;
- condition of grass cover;
- growth of weeds, bushes or trees;
- condition of borrowpit;
- condition of road; etc.

The manuals prohibited growth/plantation of trees on the embankment slopes because of:

- trees, shrubs can induce side slope erosion by concentrating rain runoff;
root system sucks moisture from the embankment reducing cohesive strength, inducing crack even resulting in uneven settlement;
- roots allows seepage of water through the micro-tunnel around it;
- dead root system of a tree may result in piping exacerbating seepage;
- trees blowing over in a storm may dramatically reduce the effective width of an embankment; etc.

Some of the manuals (Halcrow, 1994; NHCL, 1995) have recommended O&M staffing pattern and training for BWDB personnel. The manuals also gave details of equipment, supplies; and budgeting procedure for O&M works. Preventive maintenance works to retain the design profile of the embankment, prevention of leaks etc., were recommended. According to the manuals basic requirement of embankment maintenance are:

- retention of design profiles;
- prevention of erosion;
- prevention of leaks; and
- maintenance of inspection roads.

Retention of design profile

- repair/prevent rain cuts;
- fill low pockets;

- establish cause then appropriately repair slopes;
- prevent encroachment.

Prevention of erosion

- maintain and cut grass cover and/or maintain other approved vegetation on slopes and crest;
- eliminate un-approved shrubs and trees from slopes and crest;
- prevent concentration of water run off;
- stabilize and prevent erosive flows along borrowpits.

Prevention of leaks

- fill animal holes and ghogs;
- remove roots from slopes and back fill with earth;
- establish cause and appropriately stop seepage at ground/embankment base interface;
- prevent seepage around structures.

Maintenance of inspection roads

- grade crest to maintain camber and even water run-off;
- drain and fill cuts;
- encourage creeping grass on surface.

The works of annual preventive maintenance has been recommended to be assigned to Earthwork Maintenance Groups (EMGs) formed from among the landless women head of households. The ongoing activities of preventive maintenance were to be awarded to the EMGs on annual contract basis. BWDB was to be responsible for the quality of work.

Periodic maintenance for retention of design profile, prevention of anticipated erosion and repair of breaches and public cuts etc., has to be done periodically depending on the condition of the embankment. The time interval for this type of maintenance is neither definite nor fixed. Periodic maintenance has to be programmed according to actual requirement giving priority to the sections considered to be in most urgent need. Resectioning has to be done by engaging Landless Contracting Societies (LCSs) or contractors. Periodic maintenance works include:

Retention of design profile

- resection after settlement and erosion;
- retirement of embankment.

Prevention of erosion

- major river training works including embankment slope.

Prevention of leaks

- repair of major breaches and public cuts.

Maintenance of inspection roads

- major repair, rehabilitation or improvement of road.

The aim of emergency maintenance is to handle the emergency situations arising due to ghogs, leaks, slips, piping or breach & such other unexpected damage. These works have to be got done by contractors on emergency basis. Emergency repair involves:

i.	Ghogs, leaks or cavity	:	resulting from substandard compaction or from animal holes.
ii.	Slip	:	sliding failure of embankment slope due to scour at base, saturation of soil or wave action.
iii.	Piping	:	a leak under an embankment carrying sand with water.
iv.	Breach	:	failure of a portion of embankment admitting water into the protected/poldered area.

Ghog, leak or cavity should be blocked on the riverside. The causes of slips are poor compaction, over steep slope, erosion of base or side of the slope, or too close location of the borrowpit. The temporary protective measure of the slope is providing additional resistance with bullah or bamboo piling. Widening of country side slope, retiring the embankment, filling the borrowpit and river training works are the long term solutions. The manuals contained detailed methodology of breach closing. The main causes of breach are mentioned as :

- river erosion;
- embankment overtopping;
- ghogs, leaks, cavities, piping, rain cuts;
- seepage by the side of the structures;
- access path;
- public cuts; etc.

One manual (Halcrow, 1994a) mentioned of the recent years successful embankment maintenance works by BWDB, LGED and other agencies' by employing Embankment Maintenance Groups (EMGs). It suggested organization of EMGs through NGOs and to award the annual maintenance contracts to them. Maintenance work of embankments has to be got done by the EMGs and LCSs under the technical supervision of departmental personnel. The EMG/LCS members were to give labour only while officials were to supervise and monitor progress as well as quality of work. However, large scale works and emergency works were to be taken through contractors.

4.4 Review of Researches/ Studies on O&M of Embankment

Research / study on O&M has been going on since the initiation of construction activities. Some of these have been taken on a very limited scale, some have been taken institutionally.

4.4.1 General Studies

"Methodology of Preparation of Operation and Maintenance Manual for Water Development Projects with Some Illustrations" is one of such manuals prepared during the early stages of implementation of water development projects in this country (Rahman, 1976). The manual gave general instructions about operation and maintenance of flood control embankments. The interesting contents of the books are the copies of letters of Chief Engineer, Bengal, (Govt. of British India) containing detailed operating instructions. It also contained general instructions about probable emergency situations and the remedial measures.

A study of Pathakhali-Konai Embankment Project (RIT, 1992) concluded that inadequate operation and maintenance not only impede the realisation of project objectives but may also contribute to enhancing negative environmental impact. It observed the embankment to be in a pathetic condition due to :

- subsidence;
- sliding;
- rain cut and erosion;
- river erosion;
- holes caused by rats and snakes;
- depression on crest due to movement of bullock cart;
- public cut to remove drainage congestion.

It was observed during a review of planning approach for rehabilitation of water development projects in Bangladesh (Ali, 1993) that, over staffing eats away the maintenance budget. As a result preventive maintenance are not executed regularly. It was further observed that rehabilitation is only done after major damages; that too is dependent on the availability external borrowed fund. It was also observed that maintenance work, whatever is done, through food for work or such other fund are not properly supervised.

FPCO's FCD/I Agricultural Study (FAP-12), had one of it's objectives to develop guidelines and criteria for planning, design, implementation, operation and maintenance of FCD/I projects (Hunting , 1992a). 12 projects were selected for evaluations. Some of the selected projects were found to be very poorly documented. Original feasibility studies, project proforma (PP), designs, as-built drawings etc., could not be located in many cases. The observations of the study regarding planning, design and construction of embankment were :

- alignments were poorly planned leading to frequent failures requiring retirements;
- multiple use was rarely considered;
- drainage congestion and subsequent public cut was not too uncommon;
- regulator gates were found leaking every where;
- compaction was often inadequate;
- though design were generally sound, on several occasion projects were not constructed as designed. Reasons for the variations could rarely be identified.

The study concluded that inadequate O&M was the most frequent immediate constraint of effective achievement of FCD/I goal. The reasons of inadequate O&M was attributed to :

- resource constraint;
- poor quality of maintenance; and
- absence of public participation in O&M

Pilot operation and maintenance programme for improvements of O&M of small schemes projects was taken by BWDB. The report (Halcrow, 1986) mentioned that although a few project suffered from poor planning & design or construction or had social problems or/were victims of physical changes since construction; the neglect to carry out remedial measures or repairs at right time was responsible for failures or abandonment of water control structures and facilities; with consequent progressive decline and deterioration of project and corresponding reduced benefits.

The report attributed the poor O&M to :

- shortage of fund;

- shortage of transport, equipment and supplies;
- shortage of field personnel; and
- lack of training, resulting in faulty or injudicious operation.

The study suggested expansion of agricultural extension & rural development as well as consolidation of agricultural cooperatives in the project area; as credit and marketing activities are the pre-requisites of cost recovery. It stated that formation of farmers' associations is important to ensure farmers' interest and participation in BWDB's projects and related cost recoveries. These association can act as forum to bring up farmers' needs or grievances. It strongly recommended training for all concerned. The study set the following conditions as pre-requisite for transfer of a BWDB project to other organization for O&M:

- the project's O&M system should be in good order & functioning effectively; and
- there is an active farmer's group with resources & ability to operate & maintain the project.

The study emphasised the necessity of regular field inspection and supervision for monitoring purpose. According to the report daily rainfall and daily water level data have to be collected and compiled regularly for monitoring the effectivity of the water control facilities. It suggested the following activities to be part of operation and maintenance of embankment:

- maintenance of design levels for checking of settlements to avoid overtopping;
- protection against slip, erosion, wave action, dry season shrinkage, holes by burrowing animals etc.; and
- preparation for emergency repair of breaches.

According to the study an O&M manual should contain :

- summary and description of the project;
- different aspects of project operation;
- different aspects of maintenance of the project facilities;
- particulars of organization and project staffing;
- data collection program; and
- annual O&M program of the project.

The study was of opinion that regular maintenance, periodic maintenance and emergency repairs have to be done by departmental personnel. Special maintenance works of large volumes or works beyond the capacity of departmental employees have to be taken by contractors annually. Annual repair works of the contractors have to be supervised by experienced and trained departmental employees.

"Pilot Operation and Maintenance Programme" for BWDB Small Schemes Project was prepared by Halcrow in 1986, to improve operation and maintenance activities of BWDB projects. The study mainly emphasised on policy re-orientation. Technical matters were given less emphasis as without proper policy, technicality can not be effective.

"Procedures for Guideline for Preparation of Operation and Maintenance Manual" (NHCL, 1987) prepared in connection with small scale water control structures of BWDB considered commencement of O&M phase before completion of construction as one of the inherent difficulties of O&M with BWDB projects. The study suggested that completed projects should be handed over formally with all necessary papers. It pointed out that no special care is taken for selection of soil in construction of embankments in Bangladesh. The embankments are also not properly compacted during construction. As a result, they remain vulnerable to river erosion and flood damage. So the weak sections of an embankment have to be identified and special vigilance has to be taken during flood time. It identified the followings as threats to embankment and gave details of remedial measures:

- ghogs;
- slips;
- public cuts;
- encroachments; and
- breaches.

The report stressed on formation of beneficiaries committees, close inspections and regular monitoring as essential elements of proper maintenance. The report discouraged plantation on the embankment slopes but encouraged plantation of threes on the berm.

4.4.2 Improved O&M in Water Management Project

The Technical Report No. 33 of BWDB Systems Rehabilitation Project prepared for BWDB (Euroconsult, 1994a) observed that one time rehabilitation does not yield sustainable benefit. Systems Rehabilitation Project initiated the study of Improved Operation and Maintenance to address the underlying shortcomings which lead to less optimal performance and ongoing deterioration of projects. Prevailing O&M fails to address the beneficiary needs. This in turn causes lack of willingness among beneficiaries to share the O&M needs. The reason lies in the historically grown constructions bias of the development organisations, where O&M has to continuously compete with non-O&M activities. Systems Rehabilitation Project (SRP) aimed at addressing the underlying short comings rather than solving the technical and financial problems of O&M. They identified 4 major O&M issues, which are complimentary to each other and essential for successful, sustainable O&M of a project. The concerned issues are:

Basic scheme data
Reliable and regularly updated data reflecting the actual status, other relevant information including scheme inventories are essential for any proper planning undertaking.

Budgeting procedure
For protection of beneficiaries interests and project infrastructures; proper O&M activities are necessary. Proper O&M activities requires requisite and timely release of O&M funds. For that well defined short and long term budgeting procedures must be in place at the national and field level O&M agencies.

Planning procedure
Timely, efficient and transparent planning is required to ensure that management priorities are met, beneficiary requirements are adequately taken care of and maintenance activities can start on time. The procedure for planning O&M must ensure the critical participation of the system users and protect their interests.

Monitoring and supervision aspects`
Effectual monitoring and supervision procedure must be there in place to monitor the fact

that quality, efficiency and cost effectiveness of operations and maintenance works are ensured as well as beneficiaries interests are safe guarded. Beneficiary participation has to be there in all 4 issues as integral part of providing the services. So beneficiary participation is not required to the considered as a separate issue.

The basic scheme data of the embankments are the longitudinal sections and cross-sections as per design. After construction the data has to be updated as per actual field measurement. Similarly after relocation/retirement, the data has to be again updated. The owners organogramme, job responsibilities, organisation of Embankment Maintenance Groups (EMGs), their responsibilities, project proforma and such other secondary data form the resource data of the scheme. List of maintenance works and their costs are the historical data. Clear and transparent budgeting procedures are required:

- to support short and long term decision making and O&M policies;
- to secure adequate O&M funds;
- to monitor cost-effectiveness and efficiency of O&M; and
- to allocate fund on the basis of actual priorities.

The operation and maintenance activities have to be planned at early stage in consultation with the beneficiaries and based on the field requirement. The project activities planning has to incorporate all the concerned agencies and the beneficiaries. Beneficiary participation in operation and maintenance will also express itself in smooth cost recovery. The 3 steps of maintenance planning are:

- identification of work;
- general timing of works; and
- physical planning of maintenance.

Embankment Maintenance Groups (EMGs) will carry out the preventive maintenance works under the supervision of departmental people. The EMGs will have to be paid in time units. Periodic maintenance like re-sectioning of embankments are intended to bring the system elements back to design standards. Periodic maintenance follows from the annual performance of the system and identification of bottlenecks, determined through monitoring and O&M check list. The periodic maintenance work is to be carried out by the contractors and Landless Contracting Societies (LCSs). For that design has to be available and tender preparation has to be done in time. For a long term O&M plan, standard cycles of maintenance are necessary.

O&M comprises two distinct types of implementation. These are implementation of system use (operation) and implementation of maintenance plan (maintenance). The 2 types have got different level of involvement of various parties. Maintenance work can not interfere with the activities of system users. So it has to be synchronised with users needs and practices.

Monitoring implies collection of data, processing them and reporting the results. Data, themselves are not information. Data when processed becomes information. System managers, policy makers each have their own specific requirement of information. The requisite of different groups may not be the same. Monitoring is related to implementation but not a part of it. Monitoring can be summarised as observing and reporting with specific objectives in mind. Field level data collection, their processing and reporting comprises the Management Information System (MIS).

4.4.3 Operation and Maintenance Study (FAP13)

After the flood of 1988 Government of Bangladesh initiated series of studies to the coordinated by the Flood Plan Coordination organisation. Operation & Maintenance Study (FAP-13)was one of such studies done for FPCO in 1992(Hunting, 1992b).The study aimed at:

- identification of the main constraints to effective operation and maintenance (O&M) of FCD and FCDI projects in Bangladesh;
- development of guidelines to overcome the constraints; and
- recommendation for maximizing beneficiary participation and mobilization of local resources.

The consultant reviewed many BWDB projects and projects of other organisation as well as conducted series of detailed discussions with concerned officials and beneficiaries. RRA were conducted for 17 related projects. A literature review of O&M in other countries was undertaken. Workshops to discuss preliminary findings were organized. The O&M is collectively termed by them as management of completed projects of system. Operation reacts to changing environmental circumstances in order to achieve the target of serving the interests of the beneficiaries. The working definition of individual terms as accepted by them are:

- operation is the planning of, and execution of the project at the system and subsystem level; and
- maintenance is the action taken to keep the physical components of a system in a state in which it can operate as desired.

During the feasibility study as well as detailed engineering of a project; the consideration of O&M is important. If the system can not be operated as intended then it will not be sustainable and benefits will either never be achieved as intended or will be achieved initially and then either decline as the project falls into despair or be suddenly lost when it fails. It is also important to ensure that the O&M requirements are compatible with social and institutional circumstances in the project area. Unjustified difference from the original plan or inadequate construction may also subsequently result in maintenance problem. The report considered Thana Council, Union Council, LGED, DoF, DAE, BRDB & NGO contribution fruitful and essential for good O&M. However their contribution cannot be fully effective for want of well defined or established linkage or liaison between the different organizations. They found inadequate resource a major constraint to effective O&M. Similarly whatever training arrangement is there; that is given to the middle and senior level staff. In general there is no training for field levels staff or the beneficiaries. Review of previous assessment of BWDB O&M have concluded that operational difficulties occur as a result of:

i. unsuitable planning and design;
ii. incomplete or poor construction practice; and
iii. failure to undertake routine maintenance and inadequate management of O&M.

The weakness of O&M is often ascribed to O&M fund shortage. There is a general belief that beneficiary participation will generate increased resources and will improve quality of O&M. RRA of 17 projects representative of the different types of FCD/I projects spread throughout Bangladesh revealed that:

- operational requirements and problems were not considered during the design e.g. wooden full board is a total failure;

- committees proposed for operation have not always been established or are not active;
- the operation of water control structures are mainly dominated by local influential people, leading to conflict of interest;
- khalashi meant to operate structure were either not present or had unholy alliance with influential groups. They were untrained and received little guidance or supervision from higher officials; and
- frequent conflict of interest over operating practices were not anticipated or taken care of during the planning stage of the project.

Table 4-1 shows the general condition of embankment and **Table 4-2** shows the economic and financial performance of the study projects. Trees & bushes are being cultivated on the embankments. The squatter housing is another serious problem. Poor state of maintenance and unregulated uses resulted in the poor general condition of the embankment. Breaches were associated with:

- overtopping;
- river erosion;
- public cut; and
- poor construction.

Considerable number of public cuts were found to have been made by the inside resident because of drainage congestion. There are instance of cutting embankment by outsiders to remove impedance to drainage in their locality. In either case public cuts indicate poor planning. The table mentioned before indicates that construction failures were relatively less important factors, although they are instrumental in retirement of the BRE and are important contributors to the low performance of three projects. However the various problems involved in O&M are inter-linked and it is difficult to generalize a single cause or even a key symptom of poor O&M. The study revealed that:

- there is general lack of systematic accounting of O&M costs on project basis;
- the O&M expenditure averages 3.3 % of capital cost. This is rather more than the standard percentages and yet the maintenance of the project studied were of below minimum requirement. In number of cases O&M expenditure being incurred were even higher;
- many staff were found not directly engaged in O&M, who appeared to be surplus. The staff get their salary irrespective of performance and there is no incentive for improving efficiency or project performance;
- BWDB is not empowered to mobilize resources for its own use;
- local resources are not raised even for technically and economically viable projects on the expectation of getting it done by BWDB.

The study was of the opinion: *"Hence it is not clear from the projects studied that availability of resources were the critical constraint on O&M. In general a combination of high demands for resources due to planning problems, flood damages and bank protection; plus a lack of efficiency in resource use was found implicated. O&M could be improved within the funds available although some additional resources might still be necessary at least for some projects".*

Resource constraint is not an independent issue, it is a part of a more complex problem.

Other O&M issues revealed by case studies are:

- There is general lack of public consultation in planning, design and implementation. Decisions are dominated by engineering and not local opinions, needs or plans. (Zilker haor and Protappur are exceptions where peoples opinion were given cognizance and the result is good EIRR).
- Construction overrun in time and cost occurred in several projects and in some were associated with sub-standard construction. This can lead to an incomplete projects or defective components which then can not be operated or maintained effectively.
- O&M manuals are supposed to be prepared by engineers concerned for a project during first two years after the project is commissioned. No locally produced practical manuals were found. Some of the projects have O&M manuals prepared in English by the consultant. The study team to its utter disappointment found:
  - none of the manuals were in Bangla;
  - none could be considered to be effective field guides to practical O&M;
  - none appeared to be used or implemented; and
  - in no case manuals were found to be available with field staff.
- The task, responsibility and accountability of those charged with O&M are not clearly defined. BWDB O&M officers have programme of work laid down which are complex and time consuming. As a result there are minimal checks on the lower ranks directly involved in O&M. Streamlining of reporting, monitoring and administration might improve supervision of O&M although it would not address the lack of incentives. Training programmes and O&M guidelines would need to be prepared with such improvements.
- Many of the projects did not take into account the full range of socio-economic and environmental impact of the project, (both inside and outside) in the planning stage. As a result the actions of the adversely affected people obstruct in achieving operating target and increase in maintenance requirements.

The recommendations and guidelines of FAP13 study on:

Participatory approach
Different organizations are involved in FCDI projects. Inter-agency co-operation has to be increased, which needs policy decisions with macro as well as micro level options. There should be system level multi-agency decision making arrangement with beneficiary and local administrative participation. Variety of consultation techniques are expected to be useful at different stages of planning. At present there is relatively little experience of village level development programmes and a lack of cohesive social grouping centered on the village. Most experience is of single interest groups or at least of those with a common interest and it is likely that these would fit more easily within the existing frameworks of NGO and BRDB programme. Continuity and career structure guarantee of social organizers and specialists of different discipline are absent at present. So strengthening and working with other relevant government departments seems preferable.

Planning and designing
The choice of embankment type will naturally depend on local circumstances. Multiple use could easily the tested modifying existing projects or ongoing ones. Construction costs would increase but maintenance costs would be reduced.

Maintenance
Different types of work need different arrangements. The evidence is that in a well managed system improved maintenance can be linked with targeting benefits to poor/vulnerable groups and costs savings can be made. Preventive maintenance can be done by EMGs. SRP's programme of formation of EMG's as well as liaison with BWDB through BRDB has been approved by BWDB in 1992. It will be important to monitor the arrangement. Periodic maintenance may be done by LCS. In extreme events drainage congestion may tempt people to cut the embankment. The system management would agree with the water management groups, that they may cut the embankment in designated places or that farmers would accept a given level of water damage and not cut the embankment. Approval of cuts would be conditional of same water management groups repairing the cut once water level is acceptable and so restoring flood protection. The place of regular public cut would indicate the necessity of additional structures.

Monitoring
Knowledge about the latest condition of system facilities is necessary for identification of critical risks to components and to set priorities. Though details of checking procedures and reporting are given in O&M manuals, there is no proper enforcement of the requirement. That is another reason of poor linkage of maintenance resources to maintenance needs. Complex and too much comprehensive data base and proformas are itself is a deterrent to follow. Monitoring system is to be such that which can be easily followed by field staff and which does not generate excessive work during compilation. Formats for reporting flood embankment condition and EMG work are given in **Figs. 4-2 and 4-3** respectively. **Fig. 4-4** gives the format for improved O&M planning.

Resource mobilisation
The executing agency is to be empowered to generate resource. Contribution by beneficiaries would save government subsidies. When funding for O&M does not come from beneficiaries there is no incentive system or accountability, O&M staff can carry out their duties irrespective of project performance. In systems where beneficiaries contribute to O&M costs, poor performance leads to reduced income from service fee and improved performance can lead to increased resource mobilisation. Embankments, berms and borrowpits are places which can generate O&M expenses. Requirement of personnel in O&M phase is less than those required in implementation phase. So if people for implementation phase are employed on contract basis for that period only; then they will not be a liability on O&M budget.

Training
The rationale for greater emphasis on training would be to ensure that staff are able to carry out their functions and keep up with new ideas and changes in practice, to groom a professional and to achieve individual advancement. To achieve this a mixture of retraining and new appointments will be required to reflect changed emphasis and to replace skills which are less important. Clear division of O&M from implementation would create a career structure in system management in which different skills, those needed in O&M would be valued.

4.5 O&M Practise of LGED

The Local Government Engineering Department (LGED) is implementing the Infrastructure Development Programme (IDP). This is one of the component of Rural Employment Sector Programme (RESP) of the Ministry of Local Government, Rural Development & Cooperatives. The IDP involves construction and maintenance of earthen embankments for roads and water resources projects. "Operation and Maintenance of Small Scale Flood Control and Drainage Scheme", Intensive Rural Works Programme, 1986 of the Ministry contains details of O&M methodology.

Projects are initiated by local people or local government (MP or Thana Parishad). LGED's engineering & socio-economic staff initially visits the potential area. Planning and implementation involve participatory approach, although the procedure and techniques of different circumstances are still in the formative stage. It is intended to form local committees at the planning stage, to involve them in planning, detail design and prepare for O&M. In practice they are formed for the O&M phase following informal discussions with various groups and interests at earlier stages. The presently followed procedure is for the local authority to hold general meeting open to all and presided over by a local elite with LGED staff as facilitators. On the spot creation of representative at the meeting, creates representatives with no foundation of an interest group and lacks cohesion. Though the process is a bit top-down still it is done democratically. The LGED process involves a formal hand over of the scheme to the President, Secretary & Treasurer of the Operation & Maintenance Committee (OMC). OMCs are encouraged to raise their own resource by collecting a share of benefit from the scheme. The maintenance work is carried out by the following bodies according to the type of work:

- landless labour group;
- labour contracting societies; and
- local contractors.

The Landless Labour Groups are organized by project level LGED officials. The Earthwork Maintenance Programme provides employment to women and landless labour groups round the year. Labour Contracting Societies get work only during winter months for periodic maintenance and construction. The LGED provides 2 levels of training for those involved in Water Management Programme. Thana Engineers are trained in planning, design and O&M. In the second level training the Scheme Committees are given training in socio-economic aspects & O&M of the schemes. Though there is a provision for refresher courses 2 years after handover; there appears to have been lack of continued support and on-the-job training during the critical early phase of the scheme. The LGED O&M report provides detailed guidance on establishing an O&M capability but it did not recommend any long term advisory support. LGED projects are generally very small. If the approach adopted by LGED proves successful in the long run, it may not be replicable for FCD/I projects of BWDB; because of their bigger command area and wider coverage. But LGED model can be tested in the independent or semi-independent sub compartments of BWDB projects.

4.6 Summary

The recorded history of construction and O&M of embankments in this country dates back to 13th century, the time of Sultani regime. The system was improved during the time of Mughal rulers. The Mughals developed a system of construction and maintenance involving the officials and local volunteers. The system fell into neglect during the early

British rule. However the British started taking interest from 1830s. EPWAPDA was created in 1957 for development of water and power resources as a sequel to the floods of 1954 and 1955. The government of Bangladesh bifurcated WAPDA in 1972 and created Bangladesh Water Development Board (BWDB) for development of water resources. BWDB is constructing and doing the O&M of embankments since then. After the floods of 1987 and 1988, FPCO (presently merged with MPO and renamed as WARPO) was created to plan development and management of country's water resources. FPCO undertook studies relating to evaluation of O&M and studies relating to reorientation of O&M to make them effective. LGED is also taking up small scale water development projects recently. LGED is trying to introduce participatory approach involving the local people and local officials in their planning, construction and O&M.

RRA of 17 representative FCD/I projects in Bangladesh revealed that either operational requirements and operational problems were not considered during planning/construction stage; or committees proposed for O&M were not functioning and water control structures were under the domination of vested interest groups; or officials were not trained and did not attend to their duties properly. The RRA confirmed that breaches were mainly associated with river erosion, overtopping, public cut and poor construction. It stated that public cuts are made by insiders/outsiders to remove drainage congestion, which signifies planning mistake. The study found the absence of systematic accounting of O&M expenditure on project basis. It calculated average O&M expenditure amounting to 3.3% of capital cost, which is more than standard rate of O&M expense; and yet maintenance were of poor standard. The study found O&M resource constraint as part of a more complex problem involving lack of public consultation, construction time and cost over-run, non-availability of proper & suitable O&M manual in the field level; tasks, responsibility & accountability of concerned officials not being defined/poorly defined etc.

The study suggested participatory approach involving beneficiaries and concerned local officials of other department in planning, construction and O&M. It emphasized multiple use of embankment as well as maintenance by EMGs and LCSs. It suggested that monitoring of project activities and training of personnel be made effective. The study was of opinion that authorizing the executing agency to generate fund from the beneficiaries will ensure accountability. The study proposed that there should be consensus to the effect that, local people would accept certain level of damage prior to any public cut. If water level exceeds certain level, then embankment would be cut by water management groups. The cut will be closed again when water falls to accepted level, restoring the flood protection embankment to its original position.

Operation is the planning and execution of the project at system and subsystem level. Maintenance is the action taken to keep the physical component at or near the original condition as possible in a cost effective way. Maintenance of embankments are grouped as preventive maintenance, periodic maintenance and emergency maintenance. Preventive maintenance are the routine daily continuous process of maintenance. This has to be done by EMGs and the work involves retention of design profile, prevention of leaks, seepage & erosion. Periodic maintenance involves periodic resectioning/retirements, major river training works, repair of breach/public cuts and upgrading of inspection road. These works are to be done by LCSs or contractors. Emergency maintenance are repair of unexpected ghogs, leaks, slips, piping, breaches etc. These have to be done by engaging contractors. The domain of O&M covers participation of beneficiaries, local bodies & officials in O&M; training; monitoring & evaluation; and O&M financing. Basic requirement of embankment maintenance are retention of design profile, prevention of erosion & leaks, and maintenance of inspection roads. The constraints to the achievement of an acceptable level of project operation and maintenance are fund shortage, lack of motivation, organizational & institutional difficulties.

O&M manuals are to provide direction for maximizing benefit out of the project. These are basically reference book for the beneficiaries, the operators and the managers for effective operation and maintenance of the project. The O&M manual should contain summary & description of the project, different aspects of operation & maintenance of project facilities, particulars of project administrative organization and stuffing pattern, data collection program and details of annual O&M program.

CHAPTER V

METHODOLOGY

5.1 Introduction

Flood embankment is one of the earliest civil engineering structure to have been built by the mankind. Probably after the building of dwelling houses people built embankments. There size, shape, etc. varies through infinite combinations; so is the level of maintenance. There are individually built flood embankments for protecting one's farm land from inundation by the overflow from neighbouring field. The coastal embankments of Bangladesh is cumulatively one of the biggest embankments built by mankind.

For practicability the scope of study has been limited to institutional embankments. The other major reason for this limiting is the dissemination of findings and their effective use. In case of institution embankments collection of information may not be totally impossible.

5.2 Development of Evaluation Criteria

It is necessary to develop some criteria for evaluation of performance. The ideal case is to compare the post project, performance with base line data and a comparison with control data. In this case the performance of the embankment will be compared with the expected result. Affectivity is the achievement of target over time. In this case a balance had to be maintained between the precision, time and spatial data. In addition to the analysis of collected information, evaluation also included in-depth studies of the assumptions in data collection and analysis. Major considerations for evaluation of the O&M of embankments are:

a) The design criteria vis-à-vis maintenance requirements;
b) The fulfillment of design requirement related to constructions and
c) The operation and maintenance that is being exercised.

5.3 Selection of Case Study Area

Case study describes the report of one particular case event or project which is a valuable item for study as a guide or an example. Because of the field limitation it allows in depth examination by fewer investigator with limited time and financial resources. However the dedication, caliber and professionalism of the investigator is important in this case. Case study is particularly appropriate when high analytical control of information is required (Casley, 1982). Because of vastness of subject and limitation of time and money the case study of a project will be done. Meghna-Dhonagoda Irrigation Project of Bangladesh Water Development Board is a suitable project for case study. It has documented design records, construction data and subsequent maintenance records. It is not too big for complete physical observation of the researcher.

5.4 Rapid Rural Appraisal (RRA)

Data collection involves taking of counts and measures and/or interviewing selected respondents. Measurements can be taken at various level of accuracy. Interviews can be conducted in a variety of ways, ranging from a free flowing conversation to a more structured question/answer session. Choice of appropriate level of technique is important. The general principle that should guide the choice are as follows:

- the information gathering process should be tailored to the respondent. It should be acceptable to them and demand on them should be kept as low as possible; and
- the data should be collected and recorded in such a manner that subsequent analysis is facilitated.

Random increase in sample size may increase in cost and processing time but may not increase precision. Because greater precision due to a larger sample size may be more than offset by an accompanying increase in bias. The Rapid Rural Appraisal (RRA) approach is a suitable modern day technique for data collection (Mohammad, 1990). The RRA can provide a cost effective method of quick data collection, without too great a sacrifice in terms of data quality and comprehensiveness. Experiences of previous researchers have shown that though RRA fails to detect relatively minor changes but it can reliably be used to identify quantitative impacts. It gives stress on over all experience and observation of the concerned people rather on the answer of a set of structural question. Dissemination of observation takes place between the concerned people and the researchers in RRA.

Even for a RRA a set of well designed check list/questionnaire may be of great help to the researcher. A well designed check list contains a set of appropriate questions, suitably sequenced in a practical layout. This will steer the researcher in his field interviews and observations and will assert in interpretation of the values of the variables of interest. The focus of interviews should be on the items of direct concern and kept within bounds of time.

5.5 Land Survey, Field Visit and Consultation with Local People

Land survey to determine the field situation will be able to give a comparative picture of maintenance. This will also give the present state of other uses of the embankment. Field visits and consultation with local people and RRA will make the local situation clear.

5.6 The Methodology

The study will be conducted in three stages, involving desk study, field data collection data analysis and report preparation.

5.6.1 Desk Study

This phase involves collection and dissemination of all available information. This stage includes conceptualization of the study and its methodology; literature review etc. The work involves:

- collection and review of books, reports etc. relevant to the study;
- development and modification of methodology; and
- development and modification of RRA check list/questionnaire.

A sample questionnaire is enclosed in **Appendix**. The questionnaire will be filled from primary source data. The information will be collected directly from the local people as well as through personal observation of the researcher.

5.6.2 Field Data Collection

This phase includes actual field survey to determine the present state of embankment maintenance. The field survey will also give an idea of present state of other uses of the embankment. Field visit will also be made to conduct RRA. Group discussion and individual discussion during the field visit will expose the state of affairs and peoples perception of O&M. It will also inform the involvement and thinking of the local people about O&M. Ideas will come out how the beneficiaries can be involved in the management.

5.6.3 Data Analysis and Report Preparation

This stage involves desk work. The field data collected in the previous phase of activities will be processed synthesized, analyzed. On the basis of literature review and collected field data the summary conclusions, recommendations and suggestion for further study will be made.

5.7 Limitations of the Study

Every effort will be made to make this study an in-depth one. Limitations and constraints of time, fund and manpower is always associated with this type of academic studies. The limitations mentioned above makes a researcher dependent on secondary data of consultants and institutions.

CHAPTER VI

CASE STUDY OF OPERATION AND MAINTENANCE PRACTICES OF MEGHNA-DHONAGODA IRRIGATION PROJECT EMBANKMENT

6.1 Evaluation Criteria

Evaluation aims to determine whether project objectives set in terms of expected outputs, effects and impacts are being or will be met. Output levels are a measure of the result of the input utilization by the beneficiaries. Moreover a case study based on an intensive investigation would provide an insight that is not possible in case of sample survey scale of operation. Moreover sample survey requires huge resource and time. Hence this case study of Meghna-Dhonagoda Irrigation Project (MDIP) has been taken up to study the O&M aspects of a flood control embankment. The evaluation criteria are:

- present condition of the embankment as compared with the designed section and its effectiveness;
- present approaches to O&M of the embankment;
- beneficiary participation in O&M of the embankments;
- source of financing for O&M; and
- constraints to better O&M.

6.2 The Project

The Project Location and Description

The Meghna-Dhonagoda Irrigation Project is a combined flood control, drainage and irrigation (FCDI) project. It is situated in Matlab thana of Chandpur district. The gross 17,584 ha area of the project occupies the major portion of 14 out of 22 unions of the thana. It is located in an island like land, surrounded by the Meghna River on the north and west; and the Dhonagoda River on the south and east. The project is a low lying flat area, with general elevation ranging about 2.1 - 3.7m above PWD Datum. Yearly flooding depth was 1.8 - 2.7m. The project area is surrounded by 60.87 km ring embankment for protection against river flooding. There is a network of canals for irrigation and drainage purpose. 2 pump stations are there to supply irrigation water or to drain out the excess water as the case may be. The canal system commands an area of 14,367 ha. The general layout plan and typical embankment sections are given in **Fig. 6-1** and **Fig. 6-2** respectively.

Feasibility studies

The project was first proposed in the 1964 Master Plan prepared for EPWAPDA (IECO, 1964). The first feasibility study was done by local consulting firm during 1966-67 (Techno-Consult, 1967). Development options were:

- partial flood control by submersible embankment, irrigation and drainage in phase-I; to be followed by full flood control, irrigation and drainage in phase-II; or
- full flood control, irrigation and drainage.

The feasibility study related to project implementation was done by a consortium of local and foreign consulting engineering firms during 1976-77 (CKC, 1977). Comparing the minor difference between the water levels of 50 years and 100 years return period; the

100 years return period was suggested to determine the design water level. The different water levels are shown in **Table 6-1**. The feasibility study noted that soil moisture in the project area varied directly with water level fluctuations in the bordering rivers, indicating high permeability and a danger of piping development through the embankment foundation (Hunting, 1992a). The same report informed that the project area is covered by a layer of silt which is about 5 to 9 feet thick. This will prevent eruption of ground water due to external hydraulic pressure, if excavation for the new drainage canals is kept confined within top silt layer. It also warned to keep at least 1 feet top soil undisturbed. The report suggested an annual O&M cost of US$ 564,000 which was approximately 2% of estimate total investment of US$ 27,959,000. About people's participation the feasibility study suggested turning over of regulation and control of irrigation to irrigation association after completion of the project construction. It argued that this process would greatly reduce administrative, operating expenses and simplify water charge collection.

During detailed design attached peripheral irrigation canal was incorporated, and crest width of a portion of the embankment was reduced to save expenditure. The set back distance was re-fixed. It was also decided to compact the embankment mechanically upto high water level and manually the rest (CKC, 1981). About borrowpit the design report (CKC, 1981) said: *"The surface layer of silt, depth 5-9ft is recommended for use as materials for flood embankment. The deeper strata under silt layer contains fine sand. It this layer of sand is excavated, in subsequent years seepage will occur resulting in boiling and piping, this threatening the stability of the embankment"*

* * * * * *

"An investigation of the silting process was undertaken in 1979 to record the degree of silting in the borrowpits. It was reasoned that if silting was considerable, a small amount of sand layer could be excavated without any adverse effect. However it was found that such silting of the borrowpits would be minimal".

Implementation

Physical work of the project started in 1977/78. The details of constructed embankment are given in **Table 6-2**. During construction in 1980 a portion of flood embankment from Mohanpur to Ekhlaspur, at the confluence of Meghna and Dhonagoda was retired due to erosion by the Meghna River although the polder was incomplete. Another portion of embankment from Ekhlaspur to Amirabad had to be retired due to same reason in 1986/87. The existing embankment is upto 3 km inside the original alignment. The embankment was closed in 1987. Thus the project had to undergo adjustments even before it was completed. Then the embankment was completed in 1987 and the project came into operation. Tragically immediate on commencement of the O&M phase on 28/8/97 the embankment breached at Majumdar Para (Durgapur). This was closed. Again the embankment breached at Rishikandi on 1/9/88. The locations of the breaches are shown in **Fig. 6-1.** The two breaches had many similarities, as for example:

- both the breaches were located very close to each other;
- in both the case the Dhonagoda River is very close;
- both had deep borrowpit nearly, which were made deeper and deeper during construction and subsequent maintenance by excavating earth;
- the river levels at the time of breaches were well below the designed water level. The water level at the time of breach in 1987 was about 1-in-2 year return period level and that of 1988 was about 1-in-18 year return period level (Hunting, 1992 b);
- in both the cases several thousand acres of land inside the polder was buried deeply by sand (personal observation);

- in both the case the failures occurred suddenly with loud noise. Even hours before failure the sites were apparently all right. There were no sign of seepage (personal discussion with BWDB officials and local people);
- in both the cases failure initiated approx. 20/30m away from the countryside toe of the embankment.

The BWDB's Project Completion Report (PCR) of 1988 questioned the low factor of safety in stability calculation during the detailed design of the project. (Hunting, 1992b). The Project Completion Report of ADB (ADB, 1990) warned that the river was flowing close to the embankment at may places. Regarding the cause of breaches the PCR (ADB, 1990) was of opinion that, piping through rat holes may cause boiling and eventual collapse of the embankment. Lack of maintenance, possibility coupled with poor compaction and absence of support for a flood fighting group were considered to be the major contributing factor to the breach. Seepage, boiling and piping through the too deep and too wide borrowpits was also another possibility. The deeper excavations had removed the protective leas pervious, blanket like materials and exposed the underneath sandy layers. The presence of less pervious overburden could have prevented excessive seepage (ADB, 1990).

Operation and maintenance

Consultants had prepared an operation, maintenance and water management manual for the project in 1985 (CKC, 1985), which was more or less a water management manual only. It contained very little information about operation and maintenance of embankments and other infrastructures.

The construction of MDIP was affected by persistent problems some of which reflect short comings in planning and design while others relate to the standard of construction and the quality of its supervision. The components most affected were the main flood control embankment and the main pump house (Hunting, 1992a). The report stated that during the period of 1988/89 to 1990/91 an expenditure of Tk. 46.74 million was made for establishment purpose and Tk. 240.60 million was spent for O&M works. The total O&M expenditure was Tk. 287.34 million. The rehabilitation work which started in 1988 was not completed even in 1991. The report stated that establishment cost of Tk. 1442 per net cultivated ha., of land was very high in any standard. The report concluded that the organizational problems of MDIP reflects the BWDB's technical approach of giving emphasis on physical targets over the social aspects of development. Long term sustainability actually depends on the beneficiary's participation in the decision making process. O&M has been handicapped by problems of project planning and implementation. The report pointed to the system of lack of liability on the bodies responsible for such failures to compensate those who are adversely affected either by loss of livelihood (fisherman /boatman) or by avoidable embankment failures. The report suggested leasing out of project infrastructure like borrowpit canals for fisheries to mitigate a negative impact (Hunting, 1992a).

During an evaluation of O&M of irrigation projects, a team of experts from BUET identified the following constraint of MDIP (IFCDR, 1992):

- the embankment breached in the past due to soil piping. The sections were not upto their designed specifications & the river was very close to the embankment;
- the quality of maintenance work were far from satisfactory due to lack of proper supervision, contractors inexperience, corruption etc.;

- the O&M and water management manual was not being complied with;
- there was little participation of beneficiaries in decision making process or in actual maintenance;
- collection of water rate was not being persuaded;
- fund for maintenance was being received too little and too late;
- lack of co-ordination among various project officials was one of the management problem; etc.

The study recommended :

- strengthening of flood embankment, erosion protection works, diversion of river flow;
- regular monitoring of project activities;
- training of all project personnel;
- compliance of O&M manual;
- planting of embankment is considered very beneficial in reducing embankment maintenance as well as creating some income. The landless groups (including those presently living on the embankments) can be used for this purpose; and
- officials of other departments who are working in the project has to be placed under the administrate control of the Project Director.

Rehabilitation

BWDB formed a committee to suggest remedial measure for protection of MDIP embankments. The committee submitted its report in September, 1989 (BWDB, 1989). The committee analyzed stability of slopes and found the following safety factors:

	Country side WL (m+PWD)	River side WL (m+PWD)	Head (m)	Safety Factor
River side	4.60	2.41	2.19	1.30
	3.63	1.25	2.38	1.20
Country side	3.60	6.10	2.50	1.20
	4.97	6.10	1.13	1.14

The committee observed the safety factor to be much less than the minimum requirement of 1.5. The committee expressed that the consultant had analyzed the seepage and boiling condition of the embankment with attached canal only. No. analysis was made for portion without attached canal. The committee considered that the turf protection of slope as insufficient for direct current attack and parallel flow attack from wave having long fetch length. The committee also observed that the design requirement of keeping at least 30 cm layer of silt undisturbed was not followed during borrowpit excavation. The committee also presumed that the embankment was not properly compacted at all places. It also observed that 14.70 km length of embankment from Mohanpur to Amirabad was designed to have top width of 6.10m. But in actual field only 0.19 km was built with top width of 6.10m & the rest hand top width of 4.27m. It also found boulder protective work in slope protection and 13 cross bars for breaking of parallel current. On physical inspection the committee found:

sliding of slope	:	14 places
piping	:	51 places
wave erosion	:	16 km

critical condition of embankment due to river erosion	:	At 4 places namely, Ekhlaspur, Amirabad, Gazipur and Shibpur.

About boiling due to underground seepage the committee reported: *"It is learnt that boiling has been observed at different places near the country side toe of the embankment due to underground seepage at the time of flood during last 2 years".* The committee identified one or more of the followings as causes for breach:

- overtopping
- piping of embankment
- underground piping
- sliding of slope

The committee suggested the following measures for protection of embankment:

(a) strengthening of embankment;
(b) protection against river erosion;
(c) regular maintenance;
(d) maintenance during flood season; and
(e) protection against damage by human & cattle.

Strengthening of embankment

The committee suggested widening of crest width to compensate for the lack of compaction as well as for protection against seepage through ruminant holes. It also suggested resectioning of whole embankment to take care of sloughing which is taking place because of ghogs. The breaches of 1987 and 1988 were raised upto ground level by dredged soil. In 1988 berm of width 1.82 m was developed in the portions of embankment which were without attached peripheral canal. The committee recommended dredge filling of the borrowpits and clay blanketing the required length of berm, in places where boiling is observed. It suggested boulder/c.c. block revetment at places where wave erosion is taking place. It recommended construction of cross dams to cut the flow of parallel current in the borrowpits. It also recommended close turfing to protect the side slope from gully formation.

Protection against river erosion.

It suggested construction of revetment at the places attacked by river erosion.

Regular maintenance

It suggested monitoring, data collection & survey work as part of regular maintenance. The depressions, ghogs, damaged turfing and revetments etc. has to be identified and repaired at the earliest possible time.

Maintenance during flood season

During flood time the embankment has to be kept under close surveillance. Stores and materials are to be readily available to meet emergency. Committees have to be formed in co-operation with the local people for regular patrol at the time of flood. It suggested placing of earth filled gunny bags if there is risk of overtopping. In case of seepage, piping, sloughing or slides; the affected place has to be covered by geotextile filter & then covered by layers of khoa filler & then earth filled gunny bag. In case of boiling if the previous measure fails; then surrounding the place with gunny bag for storage of water will reduce pressure head.

Protection against damage by human and cattle.
Much damage is done to embankment by human activities and cattle grazing. People have to be convinced of the destructive/damaging effect. If such sort of motivation proves ineffective then necessary legal action has to be taken. Public cut has to be prevented by joint patrol of law enforcing agency and village defense party.

Asian Development Bank (ADB) had reviewed the Meghna-Dhonagoda Irrigation Project in March, 1990 (Garg, 1990). To overcome wave erosion and gully formation ADB suggested covering with a layer of 6" to 9" clay , where the embankment soil is sandy. It was advised to try deep rooted Napier grass for better holding of soil in place of presently used Durba grass. They were of the opinion of handling wave erosion on case by case basis. For the worst affected reaches, boulder rip-rap was suggested. The various reasons of the breaches which were identified to be seepage of water through rat holes, and/or ready passage of water through the voids of less compacted embankment and/or boiling due to passage of water through the exposed sand layer. It was reasoned that: *"The observation that boiling occurred about 70 to 100 ft away from the country side toe of the bank indicates that breaches in the embankment were caused due to piping below ground level. It therefore, appears that due to removal of the upper less pervious silty clay layer for construction of the embankment, the lower sandy layer was exposed, this providing ready access to water from the riverside to the country side through the underlying pervious sand layer".*

The Expert from ADB did not fully agree with the MDIP Committee's suggestion of 24ft widening the whole length of embankment. He suggested widening of the embankment between 4 km and 34 km as seepage was mainly confined to this length. He also agreed to the costly blanketing as a secondary measure to control seepage. He designed and suggested 2150 feet revetment work for protection of MDIP embankment in the region of Ekhlaspur and suggested a provision of five percent of the amount spent in construction for maintenance purpose.

The MDIP division of BWDB prepared a proposal in 1992 to strengthen the embankment and develop the command area. The salient features of the proposal were:

- widening the 47 km of flood embankment;
- slope protection & bank revetment work with blocks and boulders for a length of 17 km;
- removal of sand and leveling of land at Majumdar Para, Nandalalpur and Rishikandi. These sands were deposited during the breaches.

ADB further carried out a study for Command Area Development (Phillips, 1994) anxiety was expressed about considerable number of vulnerable reaches of flood embankment due to eroding of buffer strip of land between the river bank and the embankment toe, damages due to rain cut, cattle grazing, general wear and tear not being addressed satisfactorily by regular maintenance. Concern were also expressed about probable impact of deep fish ponds of borrowpit on the embankment. The consultant suggested building up/maintaining berm on the riverside by dredged soil. He insisted on regular & proper maintenance of the embankment as well as maintenance of water in the main irrigation canal during flood season to minimize hydraulic gradient and to disturb the habitat of burrowing animals. He encouraged growing of Vetiver grass (Embrechts, 1993) on the slopes of embankment to address the problems of rain cut & wave action. He also suggested involving local women as Embankment Maintenance Groups (EMGs) and Water Users Groups (WUGs) in those activities.

6.3 Physical Observations and Survey Work

6.3.1 Field Visit of 1994

Field work was undertaken in 1994 to evaluate the condition of the embankment (BCAS, 1994). The main findings were:

Visual observation

The embankment was thoroughly visited from starting to its end. Discussions were made with beneficiaries, staff of Forest Department and Fishery Department , aquaculturists, concerned BWDB officials at different times and at different places. The information gathered from study of background materials along with physical inspections helped in getting a clear and total picture of the situation.

Originally two places in embankment were to remain without adjacent irrigation canal, from 15.6th km to 21st km and again around 42nd km. But now only a distance of about 5.5 km from 15.6th km to 21st km is without canal. The other gap has been converted into canal. The wave erosion affected areas are reported to be Mohanpur, Shibpur, Amirabad, Gazipur, Lalpur and Ekhlaspur. The Dhonagoda River bank erosion was reported at Gazipur and Shibpur. BWDB has dumped boulders in these two place on the river bank. Embankment slope has also been protected by boulders at Gazipur & Amirabad. The situation did not appear to be critical. BWDB has built earthen spurs for protection of embankment from shoot current of the borrowpit canal. These earthen spurs are lying exposed to washing away by current. Intensive plantation of swamp forest will protect the cross-bar as well as provide wood. The protective work of Ekhlaspur implemented under Flood Damage Rehabilitation Program has been found to be effective. But abrupt ending of the revetment was giving rise to eddy current which were eroding both upstream and downstream ends. BWDB did assorted block dumping. These have been found to be effective. But further lengths upstream & downstream appeared to be in need of protection.

Physical survey

Physical Survey was done to ascertain the actual present situation of the embankment. The total peripheral length of the Meghna Dhonagoda Irrigation Project area is said to be 59.80 km. But during the physical survey it was found to be 60.66 km. The detailed design record was available for the total 61.29 km as per original length of embankment. But subsequent erosion and twice retirement of peripheral embankment reduced the total length. The comparative position of physical survey is given in **Table 6-3**.

Fishery ponds

It has been found that at the initiative of Fishery Directorate, local people have formed co-operative societies and has taken lease of borrowpit areas for aquaculture. There were as many as 53 ponds of varying depth (even exceeding 3m) on the borrowpit canal. The excavation of ponds are intensive from 36th to 42nd km. **Table 6-4** shows the locations. These excavations will disturb the hydro-geological situation and create condition for blow-out during high flood when the critical gradient will be exceeded. These will cause unimpeded flow of seepage water through the sub-surface.

Tree plantation

During field visit it was observed that Forest Department has already planted about 33.6 km of embankment outside slope with trees. Even during July, 1994 new areas were being planted. The species used were *Shishoo, Babla*, Rain tree, *Pitali, Mahogany* etc. These are mainly timber variety growing to a big height. Trees planted 2/3 years before has gown quite big now. The position of plantation are shown in the **Table 6-5**. Of these *Pitali* is able to survive prolonged inundation. It is being planted at lower level of embankment slope. But that lower level is also above the berm level. It was seen that a considerable length of embankment around 37th km near Shatnol have been planted with Guava trees. Growing of fruit bearing trees is strictly restricted on or near embankment as these invite rats and other burrowing animals.

Erosion of embankment slope

Erosion of embankment slope was taking place due to wave and shoot current. The places which have been attacked in the past are Amirabad, Gazipur and Shibpur. BWDB has dumped boulders at Gazipur and Amirabad. These have protected the embankment well. Some of the boulders were taken away by local people for making landings in the canal.

Erosion of river bank:

The Dhonagoda is more or less a stable river. No appreciable overall erosion of its bank were observed in the past. Localized bank erosion were there at Gazipur & Shibpur. BWDB dumped boulder riprap. This has been found to be effective.

BWDB modified the design of expert from ADB (Garg, 1990) and constructed about 700m length of protective work at Ekhlaspur at a cost of about Tk. 110 million. In the changed design the low height boulder embankment was substituted by earthen embankment covered with 2 (two) layers of blocks. Since this was meant for wave protection only the lower termination point was extended to low water level only. No provision was made against undercutting by scour action. Subsequently scouring started on the upstream and downstream termination. BWDB made a design for assorted dumping of cubes without any filter layer. Assorted dumping upstream and downstream of the previously built revetment has been found to effective against local scouring by eddy current as well as wave erosion.

6.3.2 Field Visit of 1997

The Project was again visited in October, 1997 for the study purpose. The observations are given in the following paragraphs.

Visual observation

The slopes were found to be more or less all right. Only in one place marks of sloughing due to seepage was visible. Due to successive unplanned maintenance the embankment top has taken the shape of see-saw. Somewhere it is 24' wide, somewhere 20' wide and in some other place it is 14' wide. The pattern is repeated all along the embankment. The 24' wide places were made to have additional soil available to meet emergency repair during high flood. During subsequent repair portions were widened to 20'. At present repair is being done with 14' top width. This it self shows BWDB's lack of planning and lack of engineering consistency.

Length of embankment

Through the discrepancy in actual length and officially reported length was pointed out by the researcher in September, 1994; BWDB officially adjusted and corrected the discrepancy in late 1996.

Fishery pond

The fishery ponds were the same as it was in 1994. The present BWDB personnel, as the previous BWDB officials, have no idea about the restriction as to the depth of excavation near the embankment. This was also not mentioned in the present rehabilitation drawings. During discussion with BWDB officials, it was found that, they do not give much importance to the depth restriction.

Tree plantation

BWDB officials does not seem to appreciate the implications of tree roots on the embankment. The trees have grown to height of 30'-40'. They look like forest. BWDB had instructed to cut all the trees, but this instruction was not taken seriously. Department of Forest argued that in the coming years when the trees would be full grown, these would be worth crores of taka; cutting them at this stage would be national loss. However 12 km was cleared during resectioning work during 1996-97. This year BWDB has requested for clearing more 6.28 km for additional resectioning work. It seems they are not very serious about threat to embankment because of tree root system. BWDB officials do not understand that guava garden provide a good food source to burrowing animals like rats. They are talking of protection of embankment against burrowing animals, at the same time making guava garden on the embankment. The garden has now grown to full height.

Erosion of embankment slope

BWDB has done some block pitching work. These have been found to be effective. In some places wave erosion is still prominent.

Erosion of river bank

Sedimentation is taking place upstream, down stream and opposite to Ekhlaspur.

6.4 Formation of Groups for Project Management

For efficient management of MDIP a special type of institutional structure was suggested in the PP and in the O&M manual by the consultants (CKC, 1985). This aimed at:

- efficiency in O&M including collection of water rates; and
- close coordination of agricultural activities through farmers organizations within the project area.

The structure provided for a Project Coordination Committee at project level, an Upazilla Committee at Upazilla level, a Union Irrigation Association at Union level, and at the lowest level the Turnout Irrigation Association (TIA). The TIAs are the primary unit of beneficiaries with irrigation facilities, and were to be formed at each turnout Project Coordination Committee. The Project Coordination Committee (PCC) would be responsible for overall agricultural development, including water management, mobilization of resources, and input services. The committee was to meet at least once a month. The composition of the committee was to include heads of various departments posted at the project level who are directly related to agricultural development, input supplies and grass roots level institution building. It was made a broad-based committee under the chairmanship of a Project Director at the rank of a Superintending Engineer.

However, it has been gathered during field visit in October, 1997 that 4 tiers water users associations have been formed for smooth operation and maintenance of Meghna Dhonagoda Irrigation Project. The 4 tiers are:

- Project Council (PC)

- Water Users Associations (WUA)
- Water Users Committees (WUC)
- Water Users Groups (WUG)

The water users groups have been recently formed. They are yet to get themselves acquainted with the project and the system. It is too early to comment on their activities.

6.5 Financing of O&M

The Meghna-Dhonagoda Irrigation Project was completed in 1988 at a cost of about Tk. 1856 million, being funded by ADB. The project was originally programmed to be completed in 1993. Because of delay in completion the loan. was extended. To compensate the cost overrun and to repair flood damage a supplementary loan was sanctioned in February 1988 (ADB, 1990).

The system of cost recovery is yet to be introduced in the project O&M cost spent per hactre of net benefited area was Tk. 2417 at 1991 price (Hunting, 1992b). Electricity cost alone comes to about Tk. 626 per hactre of net benefited area. The annual benefit per ha is about Tk. 13,437. The chance of financing of O&M from the cost recovery is not very promising. Till to-date the project O&M cost is being financed from revenue budget and development budget. O&M expenses of some of the years are given in **Table 6-6**. From the Table the following statistics (unweighted) can be identified:

O&M cost as % of capital cost = 13 %

Establishment. cost as % of total O&M cost = 32%

6.6 Rehabilitation under Command Area Development (CAD) Project

In the past, the major civil works of irrigation projects were completed without simultaneous development of command areas. Because the government generally lacked or had inadequate institutions, mechanisms (legislation and policies), and other necessary participatory arrangements the irrigation investments were underutilized and cost recovery initiatives were not realized. Consequently the major physical systems have deteriorated and O&M budgets were not sufficient to meet the required needs of the system. In addition in appropriate beneficiaries participation in system management created problems with distribution of water. CAD project has been initiated to solve this deadlock by addressing the technical and institutional issues. The CAD project envisaged to be implemented with full beneficiary participation at all stages, included the following major components.

- design and construction of on-farm civil works;
- minor rehabilitation of the main system;
- support development of multi-tier water user's organizations;
- strengthening of institutions that operates the system and provide extension service; and
- implementation of cost recovery system.

The objectives of the project were, to expand the service area within existing large irrigation system, to improve water use efficiency by mobilizing beneficiary participation and to implement the institutional improvements and cost recovery mechanism necessary for sustainable operation and maintenance of the system. The Command Area Development (CAD) Project financed by ADB loan will be implemented in 5 years spanning 1995-2000 at a Project Proforma (PP) cost of Tk. 7128.68 lac. CAD proposes to add 7,436 ha to the present irrigation command area of 6,936 ha. The potential total area is 14,372 ha. Feasibility report for activities leading to CAD was prepared in 1994 (ARD, 1994). From a list of 11 potential sub-projects 5 sub-projects were selected for feasibility study. On each of these sub-projects a rapid social assessment (RSA) a social design study (SDS) an engineering cost analysis, an environmental impact analysis (EIA) and a financial and economical evaluation were performed. Out of the 5 sub-projects, Meghna-Dhonagoda Irrigation Project and Pabna Irrigation Projects are the 2 sub-projects which were found to be financially and economically feasible. The SDS produced helpful information for identifications of necessary information for facilitation of farmers participation in CAD projects. The institutional assessment concluded Directorate of Land and Water Use (DLWU) of BWDB to be the head agency in organizing the farmers. The CAD's long term aim is the development of irrigation authority for each project. The DLWU and BWDB O&M employees will become employees of the irrigation authority. CAD has conducted a staffing study to determine the optimal staffing pattern and organization for O&M of the sub-projects. CAD project aims to convert BWDB to a contracting agency to support the irrigation authorities of the projects. CAD identified the following advantages of Meghna-Dhonagoda Irrigation Project:

- easy availability of water;
- minor civil work requirements;
- active working of BWDB extension unit in the project area;
- farmers have developed mental setup because of flood protection and irrigation facilities; and
- active presence of fisheries development and extension; which would be beneficial to the project and possibly others.

According to the study 30 km out of 60 km flood embankment needed re-sectioning. It mentioned of modification of existing 4.27m crest width to 6.10 m by BWDB design office (ARD, 1994). But the drawing for resectioning flood embankment from km 8.4 to km 10.13 and drawings for similar other reaches shows the crest width to be 4.30 m. In the past some embankment were designed with crest width of 6.10 m. It also suggested some slope protection work against wave erosion. The CAD gave the estimate of yearly O&M expenditure as follows:

1.	Establishment cost		196.00
2.	O&M of vehicles		10.00
3.	Building maintenance		5.00
4.	Structure maintenance		20.00
5.	Canals & Embankment member		60.00
6.	Bank protection work		18.00
7.	Bridge, culvert, road maintenance		3.00
8.	Mechanical & electrical maintenance		24.00
9.	Electrical power consumption		105.00
		Total	Tk. 441.00 lac

Physical implementation actually started for 1996-97. Year wise programmes are being taken. The programme of embankment resections till to-date is 12.58 km in 1996-97 and 6km in 1997-98, totaling 18.58 km.

6.7 Discussion with Local People during Field Visit

The purpose of the field visit was to see the latest condition of the project as well as to find out if there is any silent disadvantaged group who are suffering as a result of the project. Another aim was to verify whether actually the project is delivering intended goal. If so, then to what extent? It not, why? structured data collection and discussion was aimed to have an idea regarding the perception of the local people about the project.

The reply to the basic question of whether the project is doing good to people was always dialectic in nature. Unconditional reply was not given by anyone. The questions and discussion was mainly kept confined to embankments and related affairs. Though the public were more concerned about the project itself and its irrigation aspects. The direct and indirect benefits of the embankment project was visible and accepted. The price of land inside the project area is now about 10 times higher than those of outside the embankment. Crop production has increased, cropping intensity has increased and crop failure from flooding has stopped. Protection from flooding has reduced the cost of internal road construction due to reduction in the design height of road embankment. Improvement in the general standard of living is visible. Because of flood protection, NGO activities and fishery departments experimental activities have multiplied in the locality. This is also a spin benefit of the project, which has neither been published nor understood by the people. The people strongly resent the high handiness of government officials particularly BWDB. There is insensitiveness in attitude and handling of local people and environment by BWDB. The recently formed committees and groups were more or less hand-picked by BWDB officials. The system of mass participation is lacking for which lack of active interest of general people can also be blamed. It is too early for any of their activity to be visible and too early for any comment. The people appreciate the flood protection by embankment. But they have resentment for lack of mitigatory measures. The disadvantages which should have been considered at planning stage and has not yet been taken care of are:

i. Obstruction to boat traffic

The commonly put forward suggestion of lock gate is an impracticable suggestion. People had difficulties in the winter season in pre-project days. Boat always did not reach each household. The post project situation is like the winter of pre-project situation. Development of internal road should have been a part and parcel of embankment construction (Grubber, 1992).

ii. Adverse impact on fisheries

Embankment has obstructed entry of open water fisheries. Department of Fisheries has recently taken initiative for pond/culture fisheries. This step should have been taken long ago immediate with construction of polder to mitigate the protein shortage. Pond fisheries has been found to be highly popular. It is spreading at a very fast rate. New ponds are being excavated inside the project area for fish culture.

iii. Pollution of deadends

People of the affected area strongly recent BWDB's inactivity for the polluted water at the 14 deadends. People are themselves also making some of the deadends polluted by constructing toilets. This is adding to the pollution of the deadends.

iv. Leasing of canals and obstruction to flow of irrigation/drainage water

The present system of leasing of canals for fisheries has given rise to clash between the lease holder and cultivators. The lease holders are mainly local mastans, not professional fisherman. They close the entry and exit point of their portion of canal by partition made of woven bamboo sticks. These does not allow movement of sufficient water during lean season. The farmers do not have the strength to oppose it physically nor they have any place to complain. If they approach the BWDB officials, they are asked to go to local UC Chairman. If they approach the local UC Chairman they are asked to go to BWDB.

v. Overall impression

People in general appreciate plantation of trees on the embankment slope and fish culture in the borrowpit. But when the technical aspects were explained to them, they blame BWDB for not taking timely action. Similarly they have sympathy for the squatter housing. When the effect of embankment cutting by the squatter and the safe refuse of burrowing animal in squatter house was explained to them, the opinion changed and they opined that, govt. should provide them alternate place of living in khas land. People in general are of impression of massive corruption in all stages of the project starting from land acquisition to recent rehabilitation. About payment of water tax, almost all evaded direct reply. The gist of the replies are BWDB is not giving sufficient water to all the fields. Some replied that water tax should be fixed on the basis of crop production. A part of crop many be fixed (These suggestions are clumsy and impractical from collection mechanism). Yearly flat rate was approved by almost all. They were very enthusiastic of embankment maintenance by embankment maintenance groups (EMGs) and berm plantation. But they requested government support at the initial stage, still the groups can survive on their own.

The general assessment of the people about the project is mixed, not an unqualified one. They majority said the project has benefited them. Those affected like the inhabitant of deadends, the fisherman, the boatman and those whose land has been acquired are bitter critics of the Project. If economic calculation is done about the total investment and total benefit; then definitely there would have been other places where the same investment would have given higher return.

6.8 Performance of BWDB

6.8.1 Planning & Implementation of MDIP

The soil of MDIP is very suitable for vegetable cultivation during winter. It was a very big still water pond like area surrounded by rivers on all sides. These type of area are very suitable for open water fishery development . Fish fries coming through speedy river water take refuse and grow up in such area. This was a very suitable place for growing vegetable in winter and fish in monsoon. Production only is not enough for well being of people; they must have a market. The metropolis of Dhaka is a very lucrative market for vegetable and fish. The planners of metropolis always consider to supply of vegetable fish and such other products for the resident. In British India, the then Government had a special train which used to start from Bogra in the evening and reach Calcutta at the early morning. The train was for carrying vegetables from Bogra and fishes from Chalan Beel area fro Calcutta city. Because of its easy riverine connection, Dhaka could have been a good market for the agricultural and fisheries products of MDIP.

The per hactre area, development cost and annual benefit of some of BWDB projects are given in **Table 4-2**. The expected EIRR of MDIP as per feasibility study was 16.4% (CKC, 1979), where as actually it has attained EIRR of 7%. As a customary practice no project is taken up with EIRR less than 12%. In the feasibility study the EIRR was inflated and shown as 16.4%. If the mitigatory measures like lock gate, drainage sluices etc., which even to-day are extremely necessary parts of the project, are considered; the EIRR would further go down. Construction of lock gate would have provided communication facilities. Similarly construction of drainage sluice would not have given rise to the water pollution at deadends. These were necessary integral part of project construction. But to show a high EIRR; these were abandoned creating suffering for the project people. There are many other places, where less investment would have given much higher benefit.

6.8.2 Design and Construction

Safety factor

The safety factor for embankment in the deterministic design process in taken as 1.5. (Terzaghi, 1967). According to the USBR practice a factor of safety of 1.5 is adopted for all condition. This is considered to be on the higher side. High dams have recently been designed with lower factor of safety upto 1.25 (Varshney, 1982; Sharma, 1992). The BWDB recognized that static factor of safety of 1.3 for global stability and bearing capacity were the state of practice. However they believed short term factors of safety may be appropriate, if combined with an effective inspection and maintenance programme (GeoSyntec Consultants, 1991). But the presently available probabilistic design approach differs in provision of safety factor. In this process the safety factor is solved implicitly statistically considering the uncertainty of loading & strength variables. This prevents unnecessary conservation in design, leading to cost saving (CUR, 1991). BWDB in connection with renovation of Modhumati Nabaganga Project, permitted relaxation of some of the safety factor related design criteria in case of embankment which has with-stood floods of many years. Safety factor can be a guide but not be controlling factor of design.

Blowout

BWDB's Master Plan (IECO, 1964) marked the Meghna Dhonagoda Irrigation Project as Project No. SE6. Their assumptions were, Crest width - 14', Riverside slope - 1:3 and Country side slope - 1:2. The 1st feasibility study (Techno-Consult, 1967) assumed crest width 14', river side slope 1:2 and country side slope 1:2.1/2 and found the safety factor 4.5. The 14' top width was assumed considering use of vehicle for inspection purpose. However for Amirabad - Shatnal reach the width was arbitrarily fixed as 24' considering the location of Meghna.

The feasibility study related to project implementation (CKC, 1977) assumed the crest width considering were action and stability as follows, Meghna side - 20', Dhonagoda side - 17'. They found minimum factor of safety to be 1.22. The consultants at the inception stage in 1979 reduced the crest width from 17' to 14' considering the difficulties of land acquisition. The designed crest width from Mohanpur to Char Machua was 20' and crest width at other places were 14' (CKC, 1981). The factor of safety for sudden drawdown of canal side was found to be 1.14. In that of river side was 1.11. Based on the stability analysis the river side and country side slopes ware taken 1:3 and 1:2 respectively.

The BWDB committee (BWDB, 1989) observed the factor of safety to be less than conventional minimum of 1.5. The committee observed seepage, piping & wave erosion at places. They also observed the compaction of the embankment to be not upto the mark. So they suggested to widen the embankment to minimum 24' (7.30 m) with 24' width with 1:3 r/s slope & 1:2 c/s slope. The safety factor was found by them to be 1:75. Following the this report, BWDB is widening the embankment to 24' (7.30 m). During field survey in 1994 minimum crest width was always found to be more than 14' and the embankment has remained stable in number of years with varying flood height.

The MDIP embankment breached first at Majumder Para and then near Rishikandi in a close proximity of less than 1 km. distance. Both the breaches occurred suddenly. The Researcher had discussion in 1987 immediate after failures with concerned officials and local people and again had discussions with BWDB officials who were in charge during 1988. Every body opined that the breach place was intact hour prior to the failure. There was also local rumor of sabotage due to the loud noise & sudden unexpected occurrence of the breaches. It was also significant that in both the cases the process of failure initiated at a distance of about 20 m to 30 m away from the country side toe of the embankment. This fact has also been confirmed by the consultant of ADB(Garg, 1990). These are typical cases of blow-out. BWDB Manual of works (1963) also confirms that underground leaks causes "Blow-outs" at a distance of 50' (15 m) to 200' (61m) away from the downstream toe of the embankment. The manual further points out the probability of blowout at places where the embankment crosses the dry bed of an old channel because of underlying sand layer. The chronological process of blowout may be explained as follows. As water seeps through the sub-surface soil, the pressure head is dissipated in overcoming the viscous drag forces which resist the flow through the small soil pores. Conversely, the seeping water generates erosive forces which tend to pull the soil particles with it in its travel under the embankment. If the forces resisting erosion are less than those which tend to cause it, the soil-particles are washed away and piping commences. The resisting forces depend on the cohesion, the interlocking effect, and the weight of the soil particles. Concentration of seepage flow and velocity inevitably develop even though the total seepage may be small and at the places where these concentrations emerge on the country side, the erosive forces on the soil particles are greatest. The removal of a small portion of the foundation by erosive action at any point accentuates the subsequent concentration of seepage and erosive forces there. The ultimate result is the subsidence & breach of the embankment. **Fig. 6-3** shows the schematic diagram of the situation at the time of blowout. This is actually what happened in the case of the above mentioned breaches. Due to removal of top layer in the borrowpit the water got an easy access to the permeable sandy sub-surface layer. This resulted in blowout in both the cases.

Fixation of top width

There is no hard and fast rule for top width of embankment. This has to be sufficient to keep the seepage line within the dam at designed flood level. It has to be of sufficient width to withstand earth quake shock. For small dam/embankment the top width is generally governed by minimum roadway width. Factor of safety was found to be 1.11 (in case of sudden draw down on the canal side) to 1.30 (in case of sudden draw down o the river side). But this sort of sudden draw down is unknown in the project area even today. From probabilistic method of design consideration the selection of the above mentioned factor of safety was not unjustified. Factor of safety calculation can not be a factor for widening of stabilized embankment.

Variation in the top width of on earth dam within conventional limits has little effect on stability so that determination of an economical top width is governed largely by whatever functional purpose the top of dam must serve. The followings are the various suggested method of top width calculation:

(a) Garg (1989) suggested the following formula for height lower than 30 m:

$$A = 0.55 \sqrt{H} + 0.2 H \quad \ldots (1)$$

, where

A = Top width
H = Height of dam

(b) Strange (after Garg' 1989) suggested the top width of 3.00 m for dam height 15-22.5 m).

(c) Varma (1989) stated that the width at the top of embankment should provide a road for supervision and transportation of materials for emergency works during flood.

(d) Varshney (1982) suggested the following formula for calculation of top width subject to a minimum top width of 4 m.

$$A = 5/3 \sqrt{H} \quad \ldots (2)$$

The economical top width is about 14% of height of dam (Varshney, 1982).

(e) Design Manual of Third Flood Control & Drainage Project suggests the following guide line.
- The crest width should not be less than 2.5 m.
- If the embankment is used as an inspection road, the crest width should be 4.25 m.0
- If the embankment is used as a rural feeder road the crest width should be 5.65 m.

(f) Design Manual of Local Govt. Engineering Bureau of Govt. of Bangladesh (LGED, 1983) suggests the width of small of small scale embankments to be 4.0 m.

(g) Design workshop on Small Scale Water Control Structures (NHCL, 1993) sponsored by BWDB & CIDA suggests; if embankment inspection by vehicle is considered, the crest width shall be 4.3 meter.

(h) The generally used top width of BWDB embankments for internal rivers is 4.3 m. (14 feet) all over Bangladesh (LDL,1965); as for example in Chandpur Irrigation Project, Muhuri Irrigation Project etc.

The highest design height of embankment can be taken as 6.m. for checking purpose (BWDB, 1989). The average height calculated from design report as well as actual field condition has been found to be around 5m. However for the present calculation assumption of 6 m. height will keep the calculation on the safe side.

As per equation (1) ... $A = 0.55 \sqrt{6} + 0.2 \times 6 = 2.55$ m
As per equation (2) ... $A = 5/3\sqrt{6} = 4.08$ m
For economy consideration ... $(14/100) \times 6 = 0.84$ m

These shows the design top with of 4.3 m to be in conformity with accepted practice. The above calculation shows that 14' top width of MDIP embankment is structurally justified, there is no technical reason for widening. The BWDB committee findings (BWDB, 1989) were correct, but suggestions were not supported by technical calculation. If the embankment top is to be widened to 20' for road purpose, then it is not necessary to increase the slope (1:3 or 1:2) from bottom. In practice road embankments are found to have slope of 1: 1 1/2 or 1:2. Widening the embankment top from the embankment crest to stable slope at the time of road construction has got its own justification.

Compaction
BWDB embankments are designed with impracticable relative density of 95% to be attained by manual compaction. SRP study (Euroconsult, 1997a) has showed that it is not possible to attain more than 70% - 75% by manual compaction. For 95% relative density mechanical compaction and moisture control is necessary. The embankment attains the same 70%-75% compaction within 3-4 years naturally, in whatever way it is built. It is an wastage of money to pay extra for manual compaction. In case of MDIP the embankment compaction was not taken care of during construction. However it has stabilized by now. The breaches were not due to lack of compaction. BWDB Design Directorate in the latest drawing has asked to keep the embankment width to 14'. Compaction is no doubt necessary, but that has to be taken care of at the time of construction.

6.8.3 Fishery Ponds

During inspection of Embankment it has been observed that there are as many as 53 (fifty three) ponds of varying depth on the borrowpit canal. There has to be serious concern about activities at DoF in creating deepened fish pond and an associated outer flood embankment along the river side parts of the eastern flood embankment. This work was apparently carried out with no formal assessment as to its impact on the main BWDB embankment. An assessment of the situation should be made and strengthening works carried out on the portions of the flood embankments exposed to the risk of rapid rises in water level, if the DoF embankments are breached (Phillips, 1994). The situation is all the more precarious because of 2.5% mica content in the soil composition of Meghna River Basin in general. Mica has the tendency of dilatancy/liquefaction under induced shear stress depending on the nature of its denseness or looseness (Haskoning, 1990). It has already been mentioned before that the nature of past breaches clearly shows the occurrence of blow-out due to flow of water through sub-soil in over-excavated borrowpit. In order to avoid the recurrence of another breach BWDB dredge-filled the risky borrowpits in Majumder Para and Rishikandi. The berm on the outside of the embankment were re-built with widening and raising of ground level.

6.8.4 Tree Plantation

During field visit it was observed that Forest Department has already planted about 33.6 km of embankment outside slope with trees. The slope plantation is still going on. It was seen that a considerable length of embankment around 37th km near Shatnol have been planted with Guava trees. BWDB's Manual of works (BWDB, 1963) clearly forbids plantation of trees in embankment. There is the danger of raising of seepage line and risk of erosion of bottom of country side slope. Instead of planting near the foot of the embankment the trees are being planted all along the slope. This can create significant potential for piping erosion and eventual embankment failure. The existing trees should be transplanted to the embankment foot only.

6.8.5 Erosion

Erosion of embankment slope
Embankment slope is being protected by boulder dumping, brick block with geo-textile and such other costly work. Side by side local people are protecting fish pond embankment by *Dholkolomi*. BWDB people are reluctant to try vegetative protection which does not involve spending of huge money.

Erosion of river bank:
River bank erosion may be gradual recession of the bank line or quick eroding away of the bank. River discharge, ground water flow, wind wave, bed topography, properties of bed & bank material, permeability, sediment transport each have their own role in the erosion process. During floods large quantities of water and sediment are exchanged between the lower bed and the flood plain. The water exchange occurs with large velocities especially where there are sudden changes in the bed topography, for example at the banks.

The morphological condition at the Padma-Meghna Confluence has been elaborately studied under the Meghna River Bank Protection Study (FAP 9B). The study pointed that a big char immediately upstream of the confluence influence the morphological conditions at the confluence and further downstream significantly. The chars move progressively downstream in the Padma, as these chars reach the confluence with the Meghna the eastern or downstream tip is progressively eroded so that the char eventually disappears. However these chars appear to form alternately near the right bank or the left bank of the Padma. When the char, nearest the confluence, is near to the left bank of the Padma, the major flow in the Padma passes to the right of the char, i.e. to the north, in this case the Padma flow directly attacks Ekhlaspur. As that char moves downstream it is eroded. The next char is generally nearer to the north bank so that the major channel is near to the south bank, in this case the Padma attacks Chandpur town and the attack on Ekhlaspur diminishes. This cycle appears to repeat itself over a period of about 15 years. The ideal condition could probably be to maintain both channels so that the intensity of erosion is less near both Ekhlaspur and Chandpur. The protective works of Ekhlaspur were too heavy for wave erosion and moderate for protection against Meghna river flow. However the river has been seen to form chars in front, by the side and at the end of the protective work; during 1997.

6.8.6 O&M Expenses, Staff Strength & Training

Resource constraint is always put forward as major reasons for poor O&M. Statistics shows that MDIP has spent annually 13% of implementation cost on O&M, still no maintenance was done; when standard O&M cost is 2% of implementation cost. The reason is excess staff strength. It has been shown before 33% of O&M money is spent for establishment, which should not exceed 17%. BWDB has personnel who are not suitable nor motivated for O&M work. They are construction biased. O&M need people who are mentally ready to work with people and for people. Very few BWDB official has got this attitude. Training whatever is available is given to wrong people. Trained people are always posted at unrelated, wrong places. For O&M training, it will be more cost effective to bring trainers instead of sending the trainees outside the country. Training should be imparted at field level, to officials who are engaged in field work. Particularly the lowest and lower level employees should be trained, because they are the people who actually does the work. The lower level employees are the people who have close interaction with the beneficiaries. The surplus staff should be absorbed else where, other them the projects. The responsibilities should be shared with the beneficiaries. Then the beneficiaries will develop a sense of belonging, operation and maintenance cost requirement will come down and cost recovery will be possible. Above all the bureaucratic mentality of BWDB officials has to be changed. Every official in Bangladesh condemns bureaucracy but tragically every one is a bureaucrat in his own office.

The activities of BWDB O&M vis-à-vis their relation to the beneficiaries is summed up by SRP as follows (Duyne, 1997): *"The study also confirmed that projects delivered by the BWDB basically respond to needs that are strongly felt among all sections of the rural society. However, due to the top-down approach that characterizes BWDB and its officers limited contact to the field and its people does not always allow this agency to deliver projects fine tuned to the specific needs of the people. Several of the initiatives identified by this study is aimed to adapt BWDB infrastructure to the local needs or problems. For example, the forceful operation of flap gates with its often rather detrimental effects on them, would not have been necessary if people's need to control water levels, rather than being in the mercy of tidal flows would have been considered".*

6.9 Application of Evaluation Criteria

6.9.1 Present State of O&M

The embankment constructed in 1977/78, has already faced many calamities and stabilized by now. During field visit the embankment appeared to be in good condition. Only in one place sloughing was evident. No routine maintenance is done. The deep rooted, 12/15m high trees planted on the slope by forest department are growing very good. There is a guava garden on the embankment slope.

6.9.2 Beneficiary Participation in O&M of Embankment.

There is no routine maintenance of the embankment. Periodic rehabilitation/resectioning are done by engaging contractor. BWDB has recently started involving beneficiaries and others in project committee which is project's overall coordinator. The are yet to play any effective role. No beneficiary is involved in embankment maintenance.

6.9.3 BWDB's Participation in O&M

BWDB is doing the maintenance by periodic re-sectioning. Once some portions of the embankment was widened to 7.3m to have earth available in case of emergency during flood time. A portion of the embankment was built 6.1m wide while the remaining was built 4.3m. CAD project has already widened portions of embankments to 6.1m during 1996-97. This year another 6km is going to be re-sectioned with 4.3m crest width. Through no routine maintenance is done, but periodic slope protection and bank protections are being done.

6.9.4 Source of Financing of O&M

O&M is being financed from Government's own money as well as ADB's loan. The expenditure to do the remaining work of incomplete implementation and O&M are difficult to separate. The vast potential of making the embankment maintenance self sufficient is yet to be given any consideration.

6.9.5 Constraints to Better O&M

The main constraint is organizational inadequacies of BWDB. Both the organization and its employees are yet to re-orient from construction bias to O&M mentality; technical high handedness to people friendly service oriented attitude.

CHAPTER VII

DISCUSSION

7.1 Introduction

Embankments are earthen structures built in place to prevent entry of water. Operation is the planning and execution of the systems and sub-systems of a project to achieve the target of serving the interests of the intended beneficiaries. Maintenance is the activity of preserving the facilities and related structures from deterioration while they are being used or in operation. The objectives of maintenance can be summarized as to keep the system in design/top operating condition and/or to obtain greatest use and longest life at most economic cost. Maintenance can be divided into 3 types:

- (i) Preventive Maintenance
- (ii) Periodic Maintenance/Rehabilitation
- (iii) Emergency Maintenance

Preventive maintenance

Preventive maintenance are the routine and continuous inspection to identify any deterioration due to normal wear and tear, and doing the necessary rectification concurrently. Defects are not allowed too develop to much. Basic concept of preventive maintenance is to keep the facility as near to the original condition as possible.

Periodic maintenance/rehabilitation

In this type of maintenance, the damages are assessed after an interval of time and necessary repairs are done. In this case the deterioration or the necessity of repair may not be uniform for all components. The time gap may also vary. The wear and tear/damages may reach to such an extent that, preventive maintenance may not be sufficient or economical. This is also called rehabilitation. This type of maintenance may also be necessitated by exceedence of design criteria or change in geo-morphic situation.

Emergency maintenance

These are the corrective measures which must be taken when unexpected, sudden deterioration or failure of project facility takes place due to uncontrollable circumstances.

7.2 Agencies Involved in Construction and O&M of Embankment

7.2.1 Local Initiative

Bangladesh being subject to frequent inundation, small or big embankments have been built at different times at local initiative for protection against flood. There was no design for these constructions nor there was any systematic maintenance. These were built by local people and maintained by them depending on the circumstances.

More or less a systematic maintenance system developed during the time of mediaeval Sultans & Mughol rulers for protection against high floods. But during the British rule these systems went into oblivion. With the growth of zamindary system; again embankments were built for localized protection with the support from the zaminders at different places. These were built as per local experience and were not so massive. As such the weaknesses of their construction were not exposed during floods. As these gave protection of small scale; their breaches also caused small damages.

7.2.2 Local Councils

At the time of British rule and early part of Pakistan, local govt. activities were institutionalized under the banner of Zilla (District) Board. They initiated some small scale embankment construction at different places. The Board used to get lumpsum grant from the Government. Around sixties these local government institutions were given a boost under the umbrella of Basic Democracy system. They built numbers of roads and embankments at different places of the country. During eighties Upazila Parishad was introduced with elected Chairman as head. The Parishad comprised of elected. Union Council Chairman and local officials as it's members. The Local Government Ordinance of 1982 entrusted the Upazila Parishad to take over all development activities of their locality except the foreign aided projects and projects covering bigger areas. These included the construction and maintenance of small embankments also. Subsequently the Upazila Parishad has been prorogued with cancellation of Upazila Chairman post. The Upazila Parishad has been re-named as Thana Parishad headed by a government official namely Thana Nirbahi Officer (TNO).

7.2.3 Local Government Engineering Department (LGED)

Local Government Engineering Bureau (LGEB) was created in 1984 to provide technical assistance to the District and Thana level for construction, operation and maintenance of local civil infrastructures. The LGEB has been upgraded to a full fledged department of government under a Chief Engineer and the its present name is Local Government Engineering Department (LGED). Small scale water resources development schemes including construction of embankments are being implemented as part of Rural Employment Sector programme. Previously this programme was known as Intensive Rural Works Programme.

7.2.4 Food-For-Work (FFW) Programme

In 1975 the National Food-For-Work (FFW) Programme for water and land development was started in Bangladesh with support from the World Food Programme (World Bank, 1987b). Under FFW Programme, flood protection embankments, rural road construction, excavation of irrigation/drainage channel and such other earthworks are done by local people for payment in the form of wheat. CARE (Bangladesh) monitors the Rural Maintenance Programme (RMP)'s FFW Programme. The objective of the programme is to provide employment opportunities for disadvantaged people as well as to construct and maintain rural earthen infrastructures and facilities. However FFW did not have the resources to finance construction of permanent control structure for full and effective functioning of the embankment. In 1977 Canadian International Development Agency (CIDA) made a grant for construction of permanent structures of FFW earthwork in area covering Rajshahi Division and part of Chittagong Division. Then Bangladesh Water Development Board initiated construction of permanent structures on the FFW embankments under IDA & CIDA credit in their 1st Small Scale Drainage and Flood Control (SSDFC) and 2nd Small Scale Flood Control and Drainage (SSFCD) project.

7.2.5 Bangladesh Water Development Board (BWDB)

This organization was first created in 1959 with a mandate to implement water resources development and power generation projects. It was known at that times as East Pakistan Water & Power Development Authority (EPWAPDA). After the independence of

Bangladesh the water development & power generation were separated and the authority for the water development portion was re-name as Bangladesh Water Development Board (BWDB). The Board is entrusted with planning, design, implementation, operation and maintenance of large and small flood control, drainage and irrigation projects in Bangladesh (World Bank, 1979). The work of BWDB is mainly conducted with assistance from foreign donors. BWDB also implements and maintains project with financing from Government of Bangladesh's own resources. A third source of support is World Food Programme (WFP) which supplies about US$ 14 million equivalent of wheat annually for construction and maintenance of earthwork of BWDB schemes.

BWDB is engaged in construction and O&M of embankments in massive scale. Other agencies embankment initiatives are very limited and their history of construction or O&M is also not well documented. Similarly in case of organizational matters BWDB can be considered as a representative one. Considering these aspects this study has mainly concentrated on BWDB's embankments.

7.3 Failures of Embankments

Embankments are supposed to fail only in case of exceedance of design criteria, like overtopping, or due to seepage/sliding because of unanticipated soil conditions. But in Bangladesh failure due to exceedence of design criteria is very rare. Reasons for failure of embankments in Bangladesh may be broadly classified into three groups (Amanullah, 1989; BWDB, 1989; EIP, 1992; IFCDR, 1992; Euroconsult, 1994a; Halcrow, 1994a) :

A. Failure due to improper construction

B. Failure caused by erosion due to river migration / borrowpit shoot current .

C. Failure due to lack of proper maintenance.

Failure due to improper construction

This includes hydraulic, hydrologic & structural failures. Failure of embankment may be caused due to non-conformity between design and actual construction. Because of various inbuilt factor of safety in the design procedure, the probability of under design is very less. Non-compliance of design guideline as to quality of material, degree of compaction; actual field construction as to height and/or slope less than the designed one may lead to failure of embankment. Sometimes unexpected poor quality of soil may be encountered during construction which may also lead of failure. These may result in one or a combination of the following reasons for failure:

- Overtopping,
- Erosion of upstream face due to wave or sliding,
- Erosion of downstream face due to wave, sliding or gully formation,
- Erosion of downstream toe due to seepage,
- Piping through embankment body,
- Piping through foundation,
- Foundation failure due to sliding of foundation layer/layers.

A conceptual diagram showing various construction related failures is shown in **Fig. 7-1**. This includes (a) overtopping (b) sand boils & hydraulic soil failures (c) saturation and loss of embankment stability, and (d) wave action. The corresponding lowest water levels triggering these phenomena are marked schematically as h_1, h_2, h_3 and h_4 in the figure.

Failure caused by erosion due to migration of river or shoot current in borrowpit

Rivers due to their gradual shifting nature may scour bank and approach towards the embankment base, subsequently attack the embankment proper. Development of shoot current in the borrowpit canal may also attack the embankment & cause erosion of embankment slope.

Failure due to lack of proper maintenance

Embankments are subjected to rain which creates gullies. Use of embankment by bullock cart, pedestrian, animals as road and/or landing place of goods from boats may lead to gully type formation. This type of minor depression may ultimately become big creek and lead to failure of embankment, if not maintained regularly. Embankment having undulations/depressions on the top and/or side-slope collect rain water. This rain water drains through the lower elevations. The passing water erodes the non-turfed areas. The passing rain water may also make its path through the weaker section of the embankment resulting in the formation of gullies. These gully formations are a continuous process. It starts in a minor way in the beginning. If left uncared, unattended; these goes on increasing with passage of time and/or with each successive rain. These gully may extend from one end of the embankment top to the other end jeopardizing the safety of the embankment. Even before failure, gully formation is a problem for other functional uses of embankment. As for example, use of embankment top as road becomes difficult if not impossible. Occasionally squatters cut the embankment slope for building houses on the embankment. The reduction in embankment section is schematically shown in **Fig. 7-2.** Similarly holes and burrowing made by rats, insects and other animals if left unattended allows seepage through the main embankment body leading to ultimate failure. Trees planted on the embankment top or side slopes may cause a single or combination of the following, because of its root system:

- gully formation by concentrated rain run-off;
- root system reduces the effective embankment section. This has been shown in the schematic diagram in **Fig. 7-3**;
- root system reduces moisture content in summer resulting in subsidence of embankment and/or formation of crack on the surface. Root system allow seepage by its side. Dead ad decomposed root system if left in place allow piping action due to tree water path. Movement of trees and root system by storm reduces the effective width of embankment;
- dense forest/fruit bearing trees provide habitat for rats and other animals;
- deep hole left by uprooted tree if not immediately filled up, lead to reduction in effective overall cross-section of the embankment.

Prior to 1987 the major cause of failure was river erosion. During 1987 and 1988 floods, overtopping and public cuts were the two main causes of embankment failure. The other prominent cause of embankment breach was inadequate maintenance. Some of the breaches due to erosion, overtopping and public cut were avoidable, if proper and timely maintenance of the embankments were done. Similarly many incidents of sliding, seepage etc., are also the results of poor maintenance. Major causes of failures of flood embankments in Bangladesh can be summarized as:

- erosion;
- overtopping;
- public cut; and
- lack of maintenance.

7.4 Erosion

Erosion is considered as one of the main reasons of embankment failures in Bangladesh (Amanullah, 1989; Islam, 1991). Some of the erosion processes may be explained as follows:

- wave action erodes the embankment slope;
- river current or shoot current erodes the embankment slope;
- river current erodes the embankment base and ultimately devours the embankment; and
- unplanned protective work obstructing a deflecting the river current which attacks and erodes the unprotected portion.

Any one or combination of above reasons give rise to direct erosion which is also called scour. Erosion washes away soil particles. Undermining of the toe of lower bank by scouring results in collapse of overhanging materials of the embankment. Erosion protection work may be classified as Direct protection and Indirect protection. Direct protection includes works done on the bank itself like slope protection and/or toe protection. Indirect protection works are built in front of the bank, not directly on it. The aim of indirect protection works are to reduce the erosive force of the current, groynes are typical examples of indirect protection. If the current is quite strong, then paving of slopes with materials that can resist erosion is necessary. In case of wave action, the paving has to resist the onrushing wave wash as well as suction force of the receding wave.

Interior embankments of Bangladesh, are not subjected to very strong wave attack. Vegetal cover like turfing are sufficient to protect the embankments from wave erosion. Plantation of riverside berm can very well act as wave breaker. Foreshore afforestation has been found to reduce wave height by 20-25% (Kampsax, 1992). **Table 7-1** shows the comparative critical tractive force of grass soddings. Use of geo-jute can ensure protection during the growing period of turf. Submerged plants planted in the borrowpits can reduce the shoot currents. Rooted floating plants planted the borrowpit can reduce the shoot current as well as reduce the wave intensity. Sedges, meadows and reed swamp planted on the river bank, borrowpit bank are ideal for breaking wave energy. Fresh water swamp forest can safely protect the embankment from wave when properly grown on the berm.

7.5 Overtopping

Overtopping is related to the design height. In almost all the case the design has served the purposes defined by the planners. In Bangladesh design height are considered on the basis of 20 years return period of flood for the protection of agricultural properties (Amanullah, 1989). MDIP, BRE, as exceptions, were designed with a return period of 100 years. Coastal embankments have been found to have return period of 50 years.

The IBRD's Bangladesh and Water Resources Sector Study, Vol. II, Report No. PS-13, December 1, 1972 has given a comparative study of flood depth and related flooded area of Bangladesh. This is given in **Table 7-2**. The table shows that construction of embankment of design height 6ft (plus necessary freeboard) could save 84% of cultivable land from flood. Existing road, railway, other embankment as well as natural barriers; if converted into flood protection embankment, the requirement of capital for investment as well as clash with environment will be reduced.

Flood Hydrology Study of Bangladesh has shown the difference in height of flood peak due to different return period of flood (Kruger, 1992). This is given in **Table 7-3**. The table shows that because of flatness of terrain the difference in peak water level for 100 years return period flood and 25 years return flood is less than 1 m. **Fig. 7-4** shows the differences in peak water levels of different rivers of Bangladesh at some of the measuring stations . So the convention of 20 years return period deserves re-consideration. Specifically infrastructures like road, telephone, electricity water supply, gas network should be built considering flood return period of 100 years.

7.6 Public Cut

The capacity of discharge through a regulator is determined by flood routing depending on planning of overall drainage system. In some regions the construction of embankments results, while giving benefit to some areas; in considerable adverse effects on river levels and drainage conditions. The lower Atrai basin presents a clear example. Inhabitants of such adversely affected areas in many situations have reacted in cutting the embankments in order to prevent damages to their crops and homesteads. By doing so, they destroy the positive results of such project (EIP, 1992). FAP-12 Final Report (Hunting, 1992a) showed that public cuts are made either by insiders trying to remedy inadequate drainage capacity or by outsiders trying to dispose off water ponded against the outside of the embankment.

In some projects a few structures were located in inappropriate places and had to be abandoned subsequently. In some cases heavy siltation of the downstream channel reduced the conveyance capacity and caused water logging. All these faults can be attributed to improper planning, which should have been taken care of during planning. Some study considered public cut as functional and cost effective water management practice (Duyne, 1997). SRP Evaluation Study found some places where embankments are cut and closed by public systematically. In addition to cutting of embankment for drainage congestion, embankments were also found to be cut for entry of fish and facilitation of water transport. Public cut is even considered as a carefully planned indigenous water management practice - that is much cheaper and more appropriate than a regulator. Proper hydromorphological and environmental impact analysis is necessary so that such situation does not arise.

7.7 Maintenance

Maintenance of embankments gets less priority. Irregularly and inadequately maintained embankments are unlikely to provide protection against flood. They impede realization of project objectives and may even enhance negative environmental consequences. Sudden breaches are potentially more dangerous and more damaging to crop, life and property than damages by flood in a no embankment situation.

Operation and maintenance is technically related to planning, design & construction. In an well planned, properly designed and constructed to proper specification projects facilities; the O&M requirement is minimized. In case of planning defects maintenance need can necessitate rehabilitation or reconstruction. Similarly some design and construction shortcomings can be rectified where as some deficiencies are beyond the scope of maintenance. As for example, it is not possible to compact an under compacted embankment. The only way is to patch repair the under compacted sections by additional widening. Some of the major constraints to proper O&M are:

- non availability of sufficient fund. This affects the physical work programme; availability of required equipment, machinery and transport;
- failure to recover cost;
- non involvement of beneficiaries;
- deficiencies in BWDB's organizational arrangements, procedures and lack of training of field staff;
- incomprehensive planning;
- poor construction;
- compaction not being done upto required degree; and
- overlapping of construction and operation.

Actual O&M work requires fund, people to do the work. Sincerity and training of the worker is important for good O&M. Involvement of beneficiaries is also important, because beneficiary participation can help in good planning & proper implementation as well as on time O&M.

7.7.1 O&M Finance

The very frequently repeated cause of O&M constraint is lack of fund. **Table 7-4** shows the request, allocation and utilization status of O&M fund by BWDB. The table shows that BWDB got only 64% of its requisition. World Bank in its different reports mentioned of the adequate budget allocation (World Bank, 1985; 1987a: 1987b). Government of Bangladesh had to assure World Bank as to future allocation of necessary fund for O&M as a pre-condition of loan (World Bank, 1985: 1987a: 1990). To minimize the risk of inadequate O&M due to shortage of fund, there was provision of 2 years financing the O&M of completed sub-projects in SSSFCDI project (World Bank, 1987b). FAP-12 Final Report also mentioned resource constraint as one of the 3 main issues relating to O&M (Hunting, 1992a). O&M cost of public works are financed from the following sources (Hunting, 1992b):

- revenue budget;
- FFW programme;
- development budget; and
- cash foreign exchange budget.

The revenue budget is mainly used for establishment cost. A small percentage of it goes to the operation and repair of the completed project. FFW schemes are taken mainly for construction, reconstruction and/or rehabilitation of embankment, earthen road, canal etc. Spatial allocation of wheat is determined by world bank programme to a considerable extent on the basis of their target to provide support to thanas on the basis of population and distress level; rather on the basis of merit of the project. Quality of FFW work has to be occasionally compromised for different practical and circumstantial reason. World Food Programme, CIDA. Australian Govt. etc. are the main contributors to WFP.

But very few study have been made as to the justification of demand of BWDB for O&M purpose. BWDB requirements has never been co-related with projects implementation cost. FAP-12 made such a co-relation. **Table 7-5** shows the average yearly expenditure made on account of O&M as % of capital cost. The standard annual average O&M cost should be about 2% of total field cost (LDL, 1965; Harza, 1982). Even 5% is considered to be on the higher side (Garg, 1990). From the above it is seen that efficient utilization of O&M budget rather the increase in O&M budget is to be the aim.

7.7.2 Cost Recovery

Traditionally the implementation and O&M cost is borne by government in our country. Attempts have been/and are being made for cost recovery. The Guidelines for People's Participation (FPCO, 1993) says: *"Findings of O&M must be seen in the wider context of project sustainability and resource generation at the grass roots level. No easy solutions are expected and experimentation together with ongoing monitoring and evaluation will be needed for workable arrangement"*

* * * * *

"A system of government subsidies perhaps in the form of a matching grant, may be needed to stimulate local resource generation."

The World Bank thinks that the reason for dismal performance of BWDB's cost recovery (World Bank, 1987b) are, shortage of assessment and collection staff and insufficient and irregular supply of irrigation water. The World Bank in the above report further writes: *"Cost recovery from the beneficiaries of flood control and drainage work is a complex issue. GoB's ability to impose charges is limited by a number of practical considerations:*

- *firstly, flood protection in Bangladesh, as-in many other countries is considered a social service and no charges have been traditionally collected by GoB for this type of works;*
- *secondly, benefits from flood control and drainage works vary from one plot to another depending on their location, land level and soil quality.*

While it would be possible to determine aggregate benefits of the works (or average per ha benefits), it would be very difficult to design and implement a cost recovery scheme geared to individual farmers ability to pay. It is therefore GoB's view, accepted by IDA, that cost recovery on such projects is not feasible at this stage. Eventually some cost recovery may be attempted through the adaptation of a system of land taxes based on potential production".

The general belief of probable success in cost recovery by involving the beneficiaries was not supported by System Rehabilitation Project field trials. SRP's final evaluation study stated(Soussan, 1997): *"One specific economic issue which the evaluation has considered is the experience of SRP in introducing cost recovery as part of the management of embankment projects. There has been one sustained trial in cost recovery in KIP (Karnafully Irrigation Project). The experience of this trial is almost wholly negative, with great problems establishing a system and levels of payments into the BWDB which were low from the start and have declined to almost zero.*

The field research did find, however, that the farmers were paying a fee to the pump managers who were the designated collectors, but these collectors were not passing the monies collected on to the BWDB. These pump managers are meant to be the representative of users groups but this is a sham with no substance in reality. The local BWDB officials and SRP project staff were aware of this situation but have few channels through which to impose any sanctions.

As such the KIP experience on cost recovery provides no support for the wider introduction of such measures as a means to generate income to cover O&M costs. This is despite KIP being an irrigation scheme, where the benefits of acquiring water are more direct and material. At present the organizational base, social legitimacy and legal basis for cost recovery are all absent and it is likely that the costs of collection will be greater than the sums collected. The chances of successfully developing cost recovery in flood control and drainage schemes where the benefits are less direct and the means of collection less apparent, can consequently be considered minimal."

But people have been found to have the capacity to develop and implement effective strategies to finance relatively large water management initiatives themselves. The system was found to be quite flexible. Some were participating by money, less well to do people were giving their physical labour, marginally benefited people were getting exemption. *"The key to successful mobilization of material resources is local control, transparency and accountability"*(Dyne, 1997).

7.7.3 Peoples' Participation

People's participation in its traditional sense of the term means involving the beneficiaries and the affected people in planning, design, implementation, operation and maintenance of a project. The subject people's participation started to coming into prominence when the donors started imposing condition for involvement of beneficiaries and other agencies in O&M (World Bank, 1985; 1987b). People's participation in different stages of the project cycle-merits more attention than it has received so far. Findings of FAP12 and FAP13 confirm that lack of participation is one of the major reasons behind the poor performance of some of the projects (EIP, 1992).

Peoples participation involves multidisciplinary audience including the affected people. Agricultural and socio-economic benefits resulting from a development project can be greatly enhanced and its sustainability can be assured by integrating local people and their representative in all stages of the project activities. People must have the opportunity to articulate their needs, identify problems and work out solutions. It is essential that local people participate in full range identification, pre-feasibility, feasibility, design and construction, operation and maintenance, monitoring and evaluation (BANCID, 1995). The study says: *"Experience gained from development planning in Bangladesh demonstrates clearly that due to lack of an appreciable measure of peoples participation, programmed activities in social and economy development have had only limited success in achieving the desired objective and in sustained delivery of project benefits"*.

The importance of people's participation is receiving major attention now-a-days nationally and internationally. The guidelines for peoples participation in water development projects prepared by FPCO (presently WARPO) has been endorsed by the Ministry of Water Resources, Govt. of Bangladesh in August, 1994. It is an accepted fact that people's participation is the key not only to sustainable flood mitigation and water development activities but to over all economic growth. The guide clearly spelled to award the regular maintenance of embankment to local groups including women's groups. It also suggested to do the earthwork and turfing by LCSs wherever appropriate. It says: *"Operation and maintenance: The operation and maintenance stage should directly involve the local population. However, the degree of direct local control and management will vary according to the nature of the infrastructural works to be built and operated. Operational manuals must be drawn up with this in mind including the legal responsibilities for ownership, labour and financial resource provision, day to day operation, routine and emergency maintenance and repair work. The criteria for deciding operational procedure must be drawn up with the consensus of local people"*.

FAP has prepared a comprehensive guidelines for people's participation considering the needs of the people at grass-root level. It suggests a flexible approach to the integration of knowledge, experience and insights of the people living in the project area with professional expertise, resource & efforts. This will help to address fully the needs of diverse interest groups and minimize the negative impacts as well as conflict of interest (BANCID, 1995).

Because of the elusiveness of the concept of participation, the number of groups formed has long been accepted as a valid indicator for monitoring the progress with introducing people's participation. A study for assessment of the role of water users organizations in participatory water management showed the followings (Euroconsult, 1997b):

- 80% members have never been consulted nor do know of anybody on their behalf being consulted about the systems O&M and rehabilitation needs;
- some of the BWDB officials still think peoples participation as unrealistic. They feel that BWDB does not need to interact with people, DAE should do this. The meaning of participation was different to different people.

Some of the inadequacies of the guide lines are (Euroconsult, 1997b):

- the guide did not specify concrete functions of the groups nor the groups have any authority to enforce actions/decisions made. The study thinks: *"in order to go beyond a void declaration of principles, a policy on peoples participation has to be congruent with the institutional and material capacity of the agencies in charge of their implementation and be reflected in a detailed implementation strategy to be conceived at the same time";*
- every body do not conceive participation as a process of joint management. Some were of opinion of division of responsibility, where people will do the operation and BWDB will do the maintenance, and so on.

The report (Euroconsult, 1997b) further said: *"The study confirms that within the BWDB there is no felt need for a change and no interest in a new mandate. Before drafting new guidelines, the more fundamental issues of whether it is at all feasible to force this new mandate on BWDB should be addressed first".*

7.7.4 Organizational Deficiencies

The historically grown construction-oriented planing and management style of the existing development agencies, O&M organization does not suit the real O&M objectives, i.e. is not geared towards serving the actual needs of the system users. Rather than financial or physical constraints, in fact the present orientation of the concerned agencies in itself is the main obstacle for the correct implementation of O&M and water management. Non technical system loss is very high in case of O&M works. The consultants' avoids going into confrontation for professional reasons. The donors' do not want to be bad donors for their own reasons. Some of the case stories are as follows:

Case Story - 1:
There was a drainage channel around a BWDB colony of Chandpur Irrigation Project. The overflow from adjacent paddy fields used to fall in the nearly river through the drainage channel. Every year some laces of taka were spent for protection of the colony from erosion by bullah protective spur works. Simply making a closure dam at the outfall of the drainage channel at a cost of some thousands taka saved recurrent annual expenditure of lacs of taka. The junior officer was criticized for taking the initiative instead of being appreciated.

Case Story - 2:
A regulator in Patuakhali was found to have been repaired in three consecutive years. The estimate of each year was for the same items of works, same quantity and for same amount. The estimates for the successive 2 years were carbon copy of the 1st year's estimate, with the financial year portion substituted using correcting fluid.

Case Story - 3:

The sluice gate of a canal in Satkhiria was suddenly opened with high water head. It was an operational mistake. The sudden outflow created a big hole on the river bed on which the canal discharged. The concerned officials wanted to close the scour hole by boulder dumping. The river water contained too much silt. The suggestion was to wait and see for 1 season. It was argued that, the river silt was expected to close the scour hole naturally. There was no apparent morphological reason of making a big scour hole in the straight reach of a river. This was most unwelcome suggestion for the concerned officials.

Case Story - 4:

A nice char was developing on the Ganges river adjacent to Rajshahi town. It was a highly welcomed event. There was still a narrow channel in between the town and the char. For closing the flow through the channel, it was logical to build a sill. The sill would have caused silt deposition closing the channel and making the char contagious to main land. But instead of sill a costly groyne was constructed. The resulting current and scour hole at the outer end of the groyne washed away the char instead of closing the channel.

Changing the objectives, management style and planning-base of the O&M organization should be the main target of improved O&M. As a result it will be possible to address the technical and financial constraints more efficiently and realistically in the future. The objectives of O&M must be based on the "system focus", that is the functioning of the water management system with agricultural performance as indicator rather than the "element focus", in which the condition of individual (physical) element is considered. In this changed concept the priorities for maintenance of the individual element should follow from assessment of system performance in relation to agriculture.

The long-term perspective of improved O&M should be to arrive at sustained and adequate scheme performance, where the O&M organization provides maximum service to the system users, the farmers, with minimal cost in terms of budget requirements and agricultural losses. From a construction orientation to a water management orientation, to effectively manage a water management system, with a view to maximize agricultural outputs at minimum cost requires a different type of managers. Changing the attitudes of system managers from construction orientation to water management orientation needs permanent emphasis. The systems were put in place to benefit the system users. Consequently the interests of the system users should be the central objective to focus on. Planning and decision making on water management and operation and maintenance by the system users should therefore be the main theme in the approach, and feed-back from the system users on the performance of the system should be a main source of information for planning. In this participatory process the field level staff has to form the key link between the system users and the BWDB. Participation in maintenance works by poor women and landless people is increasingly (although more by donors than by GoB line agencies) recognized as an important means to increasing acceptable employment opportunities for under-privileged people.

An essential task of O&M is to make a clear distinction between maintenance and rehabilitation (redesign and reconstruction). Before entering into any maintenance planning for a particular area the maintenance works and other works which may be required must be separated. Once this is done, planning for real maintenance can start. **Table 7-5** shows that BWDB spent more money on O&M then the standard requirement. Still the O&M obligations remained incomplete. BWDB's excess staff position is also responsible failure to fulfill the obligations. They are mainly construction oriented, who can not be efficiently utilized for O&M purposes. World Bank report stated that establishment cost amounted to 21% and 35% of O&M budgets in 1988 and 1989 respectively (World Bank, 1994). **Table 6-6** shows that on average MDIP spent 13% of capital cost as O&M expense, of which 32% were spent for establishment purposes; where as the establishment cost does not exceed 10%-12% of total expenditure the case of operation with normal efficiency (World Bank, 1990). The manifestation of organizational deficiencies are:

- construction bias and lack of commitment to O&M;
- non enforcement of systematic answerability;
- lack of training;
- technical people remaining busy with routine administration;
- system of centralized control of decision making process;
- non-technical system loss;
- stiff, non-comprehensive planning;
- poor construction;
- time and cost overrun;
- overlapping of construction and maintenance phase, etc.

The organizations has to be remodeled so that there is:

- transparency in all its actions;
- local people are also incorporated in the decision making process of projects which involves their lives and livelihood;
- there has to be answerability to local people as well as the line organization.

7.7.5 Training

The important aims of training of O&M field staff are:

- to develop their awareness of importance of O&M;
- to develop awareness of importance of beneficiary involvement in O&M;
- to acknowledge the importance of local knowledge about soil characteristic and flooding patterns;
- to train to deal with a problem in a multidisciplinary approach;
- to motivate for further studies to improve the O&M strategies being used;
- to acquaint them with the specialties and peculiarities of the project: and
- to introduce projects O&M manuals to the operators & maintenance personnel.

In service training in O&M has to (ADB, 1986) focus on 2 types of training for the project personnel:

- technical training and professional training for upper level staff; and
- practical training and field training for lower level staff.

7.7.6 Planning

In general people in all flood environments accept normal monsoon inundation but want the impact of flooding to be reduced. Flood related needs and interest of local communities depend on the characteristics of flood environment. People flooded by main rivers require protection from severe flood. Farmers in low lying areas are more concerned with modifying or reducing the rate of rise of floods rather than being fully protected from all floods. Local consultation is required to discern local support for flood mitigation measures (ISPAN, 1993).

There was no interaction with intended beneficiaries nor any consultation with the affected people in past projects planning. There ware no interaction with the officials of other departments. Even there are projects where region's hydro-morphological probable impact analyses was limited to the extent of easily available data. No serious attempts were made for comprehensive analysis. More comprehensive approaches to resource management, including multi-disciplinary planning and multi-measure interventions should be promoted. For increasing resource availability income generating activities should form a part of planning process. Project planning should initiate from desire of local people, not super imposed from top. The planning process should proceed through formal and informal participation of all affected people and concerned officials. Each opinion for/against the project has to be given due weight and taken into consideration.

There should be provision for adequate mitigation of all negative impacts. No issue should be pushed under the carpet to reduce investment in order to make the project viable. Giving benefit to some by creating disbenefit for other can not be considered as good planning. Past studies and opinions has to be given due weightage. The acceptable opinions of the past studies has to be included in the programme and those which can not be accepted must be discarded with justification.

Negative impacts have to be thoroughly identified & mitigatory measures taken. In the past, negative impacts were not properly analyzed nor enough mitigatory measures were provided. Some of the unattended environmental issues are decline in soil fertility due to diminished aquatic vegetation and micro biota, decline in open water fisheries, loss of land to project infrastructure often with inadequate compensation, loss of navigation facilities etc. In Meghna-Dhonagoda Irrigation Project like may other projects, the lock gate though present in the feasibility studies, was abandoned during detailed design to make the project economically viable. The locality being a low lying area had no developed land communication system. After closure of khals, the project authority did not consider any alternative communication system for the people.

Obstruction to navigation by closing of existing navigation routes is a very common and major disbenefit of flood control, drainage and irrigation projects. This is an unavoidable reality of flood control and/or irrigation projects. Construction of lock gates, though always presented, is not a viable option. Roads can be constructed in flood protected areas at a cheaper cost. Development of alternate communication system should be an essential and compulsory pre-requisite for closing of existing navigation route. Flood control embankments should be planned to be used as roads as much as possible. This will solve local transportation problem, mitigate the disadvantages of obstruction of navigation route and at the same time ensure better maintenance of the embankment itself. Development of embankment road will improve the quality of life of the residents of project area by providing them means of faster communication.

Land acquisition

The findings of the Panels of Experts of FPCO on completion time & cost overrun of existing projects are given in **Table 7-6**. In the same report it has been mentioned that the reason for delay of 8 projects out of 16 is land acquisition. In the SAR of BWDB Systems Rehabilitation Project (World Bank, 1990), it has been mentioned that: *"assurances were obtained from GOB during negotiations that (a) processing of land acquisition applications would start at least twelve months, (b) funds would be allocated at least six months, and (c) BWDB would obtain possession of the land at least one month, before construction would commence.*

Updating of plans

Due to rapid changes in cropping and land use pattern irrigation and drainage requirement may change drastically. The long implementation period of projects may witness hydro-morphological changes in the project area. Any of the above mentioned factor necessitate revised planning. **Table 7-7** shows the implementation time of some of the projects.

Close coordination with other organization can save a project from many inevitable unwanted adversities. One department builds a flood protection project while another is building road inside the project with pre-project flood height consideration. This is national wastage. Similarly construction of road without adequate flood passage creates drainage congestion. Interdepartmental liaison and coordinated planning is necessary.

7.7.7 Construction

Most of projects need for longer time to implement than originally specified was due to various internal and external reasons. At least some of delays are avoidable if care is taken at early stage. The delay causes overruns which in turn further delays the project & thus creates a vicious circle. Construction of embankment to proper specification as to section, compaction etc. are important. Poorly constructed embankment requires too much maintenance for too long period. The quality of construction has to be closely monitored both during the original construction and at the time of subsequent rehabilitations/retirements. Control of soil moisture is an integral part of proper compaction. Due to various reasons projects have been found not to be constructed as designed. Reasons for the change must be properly and adequately documented for records to be used in subsequent times. Some of the construction deficiencies are:

Deficiency	Possible consequences
Organic material not stripped from foundation	Differential settlement shear failure or internal erosion caused by seepage
Highly organic or excessively wet or dry fill	Excessive settlement, inadequate strength
Placement of pervious layers extending completely through the embankment	Allows seepage which may lead to internal erosion and failure
Inadequate compaction of embankment (lifts too thick; incomplete coverage)	Excessive settlement, inadequate strength

Excavation of required drainage channels, mitigatory road construction etc., should be a part of the project implementation. These types of works should not be abandoned during construction period due to price escalation or other financial crisis. Systematic methods of record keeping and storage of project documents, including feasibility study, technical reports, benchmark & evaluation studies, design reports, as built drawing etc., is to be considered as part of construction.

Soil characteristic

Failure to understand soil characteristic may result in disaster for which design can not be blamed. In MDIP the embankment breached twice in very close proximity due to boiling. The boiling was initiated by excavating too deep borrowpits inspite of clear warning in feasibility study and design sheets.

Berm & borrowpit

Often the designers considers the structure proper and the directly influencing factors only. For effective O&M, the design should also include the periphery as integral part of the structure. As for example the field engineers do not give due attention to berm or borrowpits. There are instances of cutting of earth from berm for embankment maintenance, which in turn damaged the embankment itself. Development of shoot current in the borrowpit and eroding the embankment is a very common experience. Keeping sufficient wide berm between the borrowpits at the time of embankment construction was sufficient to prevent development of cross current. The design vaguely says that there should be sufficient wide berm. The design should specify the width of berm between the borrowpits.

7.8 Compaction

Compaction is one of the most discussed topic related to embankment construction. It reduces the voids between the soil grains. This prevents the shrinkage and settlement of embankments. Compaction reduces permeability which in turn influences the hydraulic gradient of the saturation level of the embankment. BWDB Master Plan said that compaction of embankment is essential to the success of the embankment (IECO, 1964). World Bank suggested splitting of payment for embankment earthwork into 2 separate items. One item shall contain placement of earth in 15 cm layer and the other will be for breaking of clod, leveling, watering (if needed) and compaction. It even made specific certificate from concerned Executive Engineer as to the attainment of proper compaction mandatory condition for reimbursement (World Bank, 1985, 1987a). World Bank even arranged that the Consultant would monitor all construction work, particularly compaction of embankment in 3rd FCD Project and subsequent BWDB projects (Euroconsult, 1997a). Compaction is one of the factors those influence the strength of embankment. But there are difference of opinion also (Euroconsult, 1997): *"However the consultant did not encounter embankment failures as result of high permeability, in turn caused by poor compaction during construction and no reports of such failures have reached the consultant. The above discussion of the properties of earth fills indicates that compaction is not a very important factor in embankment deterioration failures".*

The embankment construction method evolved in Bangladesh can be identified as conventional method. In this method soil carried directly from borrow area by head basket is dumped in a strip about as wide as the crest of the embankment. This strip is brought to design level by walking up the previously dumped soil. Once a stretch of this strip has been completed soil is thrown from the crest to the areas on both sides of the strip to create the embankment slope. **Fig. 7-5** shows the conventional method of embankment filling order. Once the bulk of the soil has been dumped, the exposed clods are broken and the surface is smoothened. In actual practice placement of soils in uniform layers of 15 cm or breaking of clods in successive layers is practically neglected everywhere. To overcome the problems of conventional method BWDB introduced an improved method (Euroconsult, 1994a). In this method a layer of 15 cm of the whole width is built up and then compacted. In this way the entire embankment is built up layer by layer **(Fig. 7-6)**.

A comparative study of attainment of compaction in conventional method and the improved manual compaction method found that initially conventionally built embankment attains 60% to 65% maximum dry density and manually compacted embankments attains 65% to 70% maximum dry density. In about 40 to 50 months time due to natural action both stabilise at around 70% to 75% maximum dry density level (Euroconsult, 1997a). **Fig. 7-7** shows a typical case of comparison. On the basis of above: it can be concluded that:

- only two types of embankment should be considered in future. Compacted embankments and uncompacted embankments;
- compacted embankments are, per definition, mechanically compacted to relative densities of 90% or more. These are constructed under close supervision and the rate of compaction is verified for each layer through laboratory tests;
- uncompacted embankments are what has been termed as "conventionally constructed embankments" and no additional efforts or costs should be given for "manual compaction";
- the construction of uncompacted embankments with an over height and leveling out of unevenly settled sections after one rainy season should be standardized in earth work contracts;
- the design of uncompacted embankments needs to be based on relative densities of not more than 70% ultimately and not more than 60% initially. This is likely to have some consequences for the designed sections of such embankments.

The 90% relative density requires moisture controls, placement in layer etc. It is possible to attain 90% relative density when embankment is done mechanically. In conventional method with the present technical and economical back ground of the earthwork contractors and with the existing availability of earth work machinery it is next to impossible to get 90% relative density always. So, the embankments have to be designed with 60% relative density. There will be some shrinkage, settlements, erosion, rain cut etc., during the first monsoon. The construction of embankment should include maintenance and bringing the embankment to full section during the second season. Embankment so constructed will require minimum maintenance.

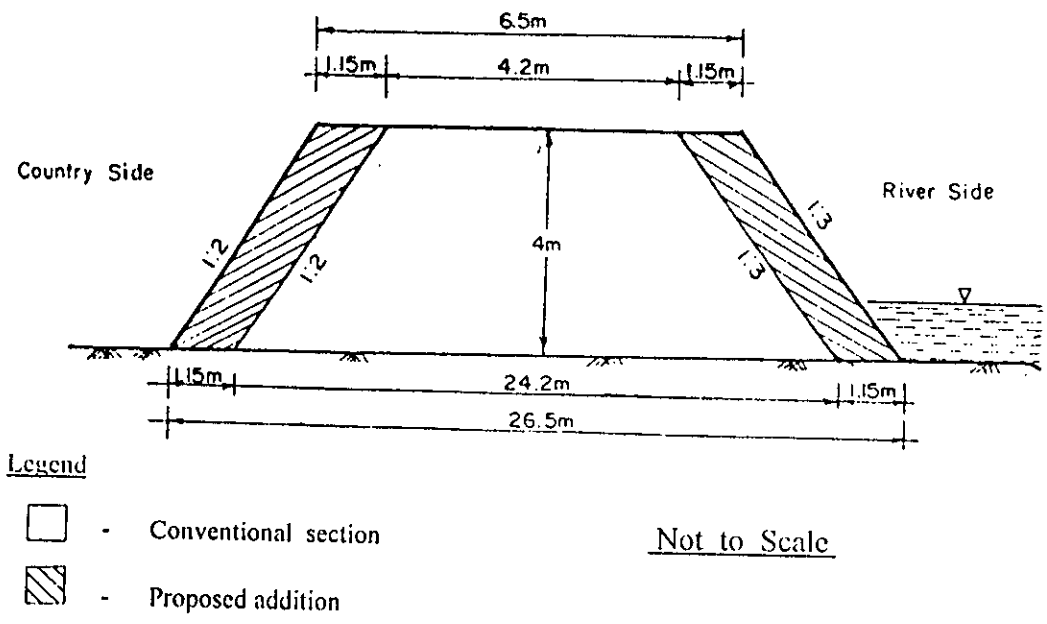
7.9 Multiple Use

Embankments are conventionally constructed for flood control purpose only. Top width of around 4 m is given for movement of inspection vehicle. Construction of embankment closes many khals and creeks. These closures disrupt the pre-project communication pattern of the locality. The adverse impact on local navigation is neither mitigated nor alternative communication system is developed. **Fig. 7-7** shows that there is no appreciable difference between the manually compacted and uncompacted embankments. Over and above, both the types attain the same degree of compaction in course of time due to natural action. The extra amount paid for manual compaction does not give the desired result.

Because of flatness of terrain, the difference in peak water levels of 100 years return period flood and 25 years return period flood is less than 1 m **(Fig. 7-4)**. The embankment with 25 years return period if properly constructed with 1 m free board can withstand flood of 100 years return period. However in extreme cases, some extra measures like floodwall of gunny bag etc., will prevent overtopping. FPCO's Flood Hydrology Study (FAP-25), 1992 shows the differences in flood peaks of different return periods as follows:

Return period	Highest difference with 2 years peak (m)	Average difference with 2 years peak (m)
25 years	1.22	0.85
50 years	1.45	1.03
100 years	1.67	1.21

Design of embankments with dual purposes of flood control and road communication can at least partially mitigate the adverse impact on navigation. Construction of embankment, also to be used as public road; will ensure constant use and more attention of local people. Widening the top to 6.5 m from the presently constructed 4.2 m can make the embankments suitable as roads in addition to their flood protection purpose. This will make the embankment structurally safe as well protect it against seepage and borrowing. The increased utility of the embankment will ensure better maintenance. The modified section has an envelope of extra earth around the minimum section required for flood control purpose (from seepage, sliding etc., consideration). This extra layer can be used for afforestation purpose without any risk of damage to the minimum required section. The conventionally designed section and proposed modification is shown below:



Not to Scale

Cost Comparison

A design height of 4 m (including freeboard, shrinkage allowance etc.) can be considered to be the representative height of embankments in Bangladesh. With a top width of 4.2 m generally required side slopes are 1:2 in countryside and 1:3 in riverside. Earthwork/meter length of embankment comes to 56.8 cu.m. For the purpose of comparison rates have been taken from BWDB's Schedule of Rates of Moulvibazar O&M Circle effective from July, 1996. The rates include labour cost of Tk. 25.67, royalty for earth of Tk. 5.89 and cost of Tk. 5.42 for compaction. The cost/cu.m of earth work comes to Tk. 36.98.

The modified section has top width 6.5 m and same slopes on both the sides as before. Earthwork/meter length is 66 cu.m. Cost/cu.m (including labour cost and royalty for earthwork) is Tk. 31.56. Average cost of land is Tk. 300,000 per ha. Comparison of cost/meter length of embankment is:

Cost as per conventional design

cost for earth work	=	56.8 x 36.98	=	Tk. 2100.46
cost for land	=	24.2 x 30	=	Tk. 726.00
		Total	=	Tk. 2826.46

Cost as per modified design

cost for earth work	=	66 x 31.56	=	Tk. 2082.96
cost for land	=	56 x 22.5	=	Tk. 795.00
		Total	=	Tk. 2877.96

- **% difference = (2877.96 - 2826.46) / 2826.46 = 2% increase.**

7.10 Transition Phase

A formal transition phase is necessary between construction and O&M. It has to span some years. During the transition period:

- defects or problems in the project should be identified and rectified. World Bank SAR (World bank, 1987a) stipulates that the project would be considered completed when the necessary measures are taken for ensuring that any deficiencies in design or construction of project facilities are identified and corrected within 2 additional years after construction;
- training of system staff and system users. Appropriate practical training and advisory service is needed for each level of users and managers, covering policy matters and technical matters.

System level operating rules should be established based on actual operation in the transition phase. Operation & maintenance rules and guidelines has to be updated accordingly. During this phase the "As built drawings" are to be verified and necessary additions/alterations has to be made.

7.11 Summing Up of the Major Issues

The flood control projects are not delivering their potential benefits. They often need rehabilitation. The projects could seldom attain credibility and general confidence in the beneficiaries. All these are due to lack of O&M. The constraints to O&M are clearly defined and often repeated. But there are myths as well as reality in the commonly expressed constraints.

The myths are:

- fund constraints;
- lack of compaction;
- willful damage like public cut; etc.

The real constraints are:

- deficiencies in organizational arrangements and procedures;
- non involvement of beneficiaries;
- failure to recover cost; etc.

There are other minor constraints. The minor constraints, often inter-related and inter-dependent, are not so important and their cumulative effect is also within the tolerable limit of technical system loss.

7.11.1 Fund Constraint

The most frequently expressed constraints to O&M is fund constraint. It is often stated that, for lack of fund necessary physical implementation, procurement of equipment and machinery etc., could not be done. Statistics are there as to availability of only 64% of BWDB's requisitioned O&M fund during the period 1989-90 to 1992-93. World Bank financed 2 years of O&M cost of SSFCDI project for this. FPCO's review (FAP-12) showed that majority of studied projects of BWDB spent 5% of capital investment per year for O&M. MDIP was found to have spent yearly 13% of capital investment on average for O&M. Where as, internationally accepted per year O&M cost is 2% of field expenditure. Efficient utilization of O&M money, rather the lack of fund is the constraint.

7.11.2 Lack of Compaction

Lack of compaction during construction is often put forward as a cause for additional O&M requirement. There is regular field laboratory testing for embankments compacted mechanically as to the attainment of relative density. So there can not be any lack of compaction in those cases. For manually compacted embankment properly compacted or not compacted, in any case, it attains the same relative density within a period of 4-5 years. Very few BWDB projects have been completed before that period. So lack of compaction during construction of manually compacted embankment; requiring extra O&M efforts is not supported by field observations.

7.11.3 Willful Damage Like Public Cut

Construction of embankment while benefiting some, may create adverse impact on some others. Public cuts are generally made by the inhabitants of a waterlogged area who are:

- either the insider of a poldered area, trying to remedy water logging due to insufficient or delayed drainage; or
- the outsider of a polder, trying to dispose off water ponded outside the embankment due to obstruction of natural drainage path or narrowing of drainage channel reducing the conveyance capacity.

It is an water management practice, executed by the waterlogged people to remedy negative hydromorphological/environmental impact of the embankment construction. Proper planning would not have created the situation, which necessitates public cut.

7.11.4 Organizational Deficiencies

Government agencies implement projects according to their own priority and planning. Their historical planning, implementation and management style are not geared towards serving the actual needs of the system users. The present orientation of the organizations themselves is the main obstacle to proper O&M, rather them financial or any other physical constraint. Changing the objectives, management style and planning base of these organizations is necessary to address the overall O&M constraint efficiently and realistically. The manifestation of organizational deficiencies can be expressed as:

- construction bias and lack of commitment to O&M;
- loose system of answerability;
- lack of training;
- non-technical system loss;
- non-comprehensive planning;
- poor construction;
- time and cost overrun;
- overlapping of construction and maintenance phase; etc.

Construction bias and lack of commitment to O&M

Construction and O&M deals with the same project at different stages. The aim and methodology of the two are totally different. The construction supervisors have got definite instructions and instruments to verify the correctness of performance. O&M involves in dealing with satisfying the demand of beneficiaries for whom the project has been constructed. O&M personnel has to assess the available resources and demand; and make compromise between the competing interests. Public organizations particularly BWDB has got very capable and experienced construction managers and supervisors, with knack in construction. But they are yet to get accustomed to deal with beneficiaries. In O&M, social aspects of project is more dominant then construction/technical aspects. O&M needs people who are willing to work with the people for the people. This needs commitment, which is yet to develop among many public officials.

Loose system of answerability

There are comprehensive office order covering almost every aspects of maintenance. But enforcement is loose; as for example BWDB has very clear and explicit office orders, manuals and instructions that; no big trees should be planted on the embankment slope. But trees like *Koroi*, Eucalyptus etc. has been planted and grown to a height of 10-12m on MDIP embankment slope. Either the BWDB orders should have been kept in abeyance or no tree should have been allowed to grow. There is no record of any official being asked so explain the non-compliance. Officials serve in a place for a period. Good/bad result depends on the individual character and integrity of the person. When that person is transferred; the liabilities of his past deeds are just wiped out. Institutional precedence of answerability of any official for his past mistakes are very far and few. There are exceptions but general practice is covering up of one past misdeed by another misdeed.

Lack of training

O&M management needs special type of expertise, with more emphasis on social, economic and extension aspects. These need separate type of training. As the projects could seldom be specifically identified to be in O&M phase; no such special training is organized nor person who needs training could be identified. It is a common experience that a person going on training in a subject on which he has no past experience nor will serve in a related post after the training. The training is a sort of benefit for the persons who could maneuver. There are instances of officials serving in an O&M projects, who have never consulted the available O&M manuals.

Non-technical system loss

Non technical system loss is very high in case of O&M works. This has been explained in details in **Article 7.7.4** . The non-technical system losses inflates the O&M expenditure without doing any good to the project or people.

Non-comprehensive planning
Planning does not always cover the hydromorphological aspects or mitigatory measures. If comprehensive planning was done the necessity of abandoning structures or public cut would not have arisen in such large numbers as at present. These type of short comings necessitate additional O&M work. Closure of navigational routes should accompany lock gate or development of alternate communication system.

Barisal Irrigation Project is a typical case of non-comprehensive planning. People used to get water daily twice during tides. They used to lift water by low lift pump. BWDB built embankment and arranged steady water availability but secondary pumping was still necessary. This gave no additional benefit, rather blocked navigation route. Now BWDB taking extra measures to make the project acceptable in the name of O&M improvement.

MDIP was a very suitable place for winter vegetable and monsoon fish culture. The project is forcing people for rice cultivation, when the government is trying to diversify agricultural crop. There has been some improvement due to flood protection and irrigation facilities but at a cost which will not be economically justifiable. There are other areas where less investment would have given more benefit. Motivating the people of MDIP area in proper direction otherwise would have benefited them also without this massive investment.

Poor construction practice
Under specified, poor quality of construction work necessitate additional O&M work. Embankment when well compacted, properly turfed requires less maintenance. Rectification of construction defects inflate O&M cost requirements.

Time and cost overrun
Project completion for various reason takes much more than the scheduled time. The time overrun causes cost overrun and subsequent shortfall of project completion money. This in turn forces the authority to declare the project complete, leaving some of the component half complete or not done at all. The major cause of delay is non-availability of land in time. This factor has to be considered while planning the project. This delay in completion also creates O&M constraint.

Overlapping of construction and maintenance phases
The demarcation between construction and O&M is yet to be defined specifically in Bangladesh. This blurredness is generally made deliberately. Often projects are declared complete with many components remaining incomplete. This creates a situation where construction and O&M runs parallel to the annoyance of the intended beneficiaries. Because of this overlapping the O&M people can not take over from the construction people; at the same time the services of construction people are partially utilized. This taxes the project overhead. If the completed project is formally handed over to O&M people, then what has been done and what has not been done becomes transparent. New set of people, trained in new type of assignment could do their job better. This would have created a situation of transparency and accountability for the construction people as well as transparency and accountability in O&M functions.

7.11.5 Non Involvement of Beneficiaries

Beneficiaries are not involved in project construction from the conceptual stage. Because of various compulsions they are now-a-days unwillingly being incorporated in the later stage of the project. Because of elusiveness of the concept, the involvement of beneficiary carries different meaning to different people. Due to bureaucratic/autocratic attitude of officials the people do not feel the sense of ownership about a project. The project is termed either a BWDB's project or a govt. project. This sort of beneficiary aloofness gives rise to a carelessness about the maintenance of the project among them.

To make people's participation meaningful and effective, they have to be involved from the project identification stage, through implementation stage to O&M stage. Beneficiaries should be given responsible role in project implementation and O&M. This sort of empowerment will create sense of responsibility towards the project. Some of the pre-conditions of effective people's participation are:

- **Transparency**
  The process of decision making has to involve all willing participant at all levels and has to be transparent. So that people has the opportunity to review and influence decisions which affect their lives and livelihoods.

- **Comprehensiveness and meaningful choice**
  All involved willing participants should be taken into full confidence and given comprehensive information. All opinions, for and against, has to be given full weight. Final decision has to consider technical, social, economic, environment and such all other related aspects.

- **Accountability**
  The decision makers and project implementation authority has to be directly responsible to people/their committees at all time in addition to their line authority.

Involvement of people in the truest seance of the term would have transferred at least part of responsibilities, making O&M less costly and easier.

7.11.6 Cost recovery

Failure to recover cost is a major constraint to O&M. Because of various compulsion half hearted attempts are being made to involve local people. It was a general conception that if the beneficiaries could be some now involved in the process than, cost recovery will be easy. But SRP's experience with Karnafully Irrigation Project does not support this belief. The beneficiaries have been involved in the operation process, still the result of cost recovery is not satisfactory. The reason is "Loan Defaulting culture" of the society and practice of successive governments. The government has written off the defaulting loans without making compensation to the law abiding people who timely paid the loan. The government failed to recover loans of big loan defaulters. People are not convinced of government's sincerity as to recovery of any loan. The involvement of people at the late stage or during maintenance stage; or involvement of some stooges cannot be said to be effective people's participation. This does not allow the development of sense of ownership. Sense of responsibility can only be expected when there is authority. The lack of credibility of government and lack of sense of belonging do not encourage people to cooperate in cost recovery, rather it is considered to be smart not to pay. Because of very nature of the service, vast number of defaulters and fault in the collection system cost recovery is yet to be successful. This is also a major constraint to &M.

7.11.7 Multiple Use

The conventionally constructed embankments are designed for flood protection only. The top width is fixed to facilitate movement of inspection vehicles. Embankment closes khals and creeks, used by local people for boat traffic. The obstruction to riverine communication is seldom mitigated. Little attention is given to develop an alternate communication system. Embankment once constructed gets very little attention from concerned authority, other than in case of resectioning or rehabilitation.

If embankments are built considering 25 years return period with 1 m freeboard and 6.5 m top width instead of conventional 4.2 m top width, the construction cost increases by 2% only. The embankment can be used as public road in addition to its original purpose of flood protection. Some extra land is available for planted trees' root zone beyond the critical section required for flood protection purpose. If the embankment is used as public road, it gets more attention and better maintenance. Afforestation can be a source of O&M financing without any damage to the embankment. Multiple use makes the embankment self-sustaining, ensures constant attention and better maintenance.

CHAPTER VIII

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDIES

8.1 Introduction

The objectives of this study were to ascertain the actual field practice of O&M of embankments, find out the factors that contribute to improper practices and suggest effective non-structural as well as structural measures necessary for sustainable management approaches. During the study, it was observed that the topography, soil used in embankment construction as well as properties of the base, flooding pattern, construction method etc., had theirs own special characteristics in Bangladesh. Due to these reasons, O&M practices would also vary from location to location.

Embankments are constructed in Bangladesh by local initiatives, local bodies, LGED and BWDB. Among them BWDB is the main official agency involved in construction and maintenance of flood embankments. As such, one of the projects of BWDB was taken up for in-depth case study. The major findings of the study are given in the following sections.

8.2 Conclusions

Based on the study followings are the major conclusions:

i. Operation and Maintenance of flood embankments is a neglected issue. On the other hand, it has been found that organizations responsible for O&M are provided with adequate personnel as well as resources.

ii. It is only recently, that attention is being given on O&M issues. It is found, if due consideration is given from the time of conceptual planning, achievement of effective O&M practices is not unattainable.

iii. Assessment of environmental impacts was not carried in the past, in planning of polders/embankments. Measures such as alternate fishery development, alternate jobs training for fishermen/boatmen, alternate communication facilities (road development), sufficient gate opening for navigation of local country boats etc., should have been incorporated to mitigate the adverse impacts.

iv. In selecting the alignment of an embankment, the possible future hydro-morphological behaviour of the rivers both inside and outside the project area needs to be considered.

v. The whole process from planning to implementation and O&M has to be on participatory basis involving the beneficiaries, affected people, local officials of concerned departments and local people's representatives. Project committee comprising of peoples' representatives, local officials, beneficiaries, affected groups may be formed at the time of project inception. The project committee shall give top supervision of all project activities from inception.

vi. The process of involvement of people has to be transparent, comprehensive, meaningful and on the basis of accountability. The planning process has to be multi-disciplinary instead of being technically dominated.

vii. All projects should have in-built monitoring and feedback mechanism both during and after project implementation.

viii. Embankments have to be planned for multipurpose use, like road in addition to flood protection. This will ensure better O&M. The conversion of flood embankment to road-cum-embankment involves only very small increase in cost.

ix. Conventional system of manual earthwork compaction has been found to be ineffective. Compaction achieved under natural process within some years is considered to be adequate.

x. For maintenance of the slope, development of vegetal covers with grass may be encouraged. Care should be exerted in plantation of bigger plants.

xi. Location of borrowpits, too close to the embankment, may be reason for instability of the embankment. The borrowpit should not be continuous and there should be crossbars to prevent development of any flow parallel to the embankment.

8.3 Suggestions for Further Studies

Based on the present study, it is being suggested that the following topics may be taken up for further studies:

i. Feasibility of road-cum-embankment construction as boundaries for compartmentalization project inside the polders, deserves detailed study. These are likely to give early flood protection, manageable water control, efficient water use and improved communication facilities.

ii. Submersible embankments are very much environment friendly in *haor* areas. Presently it involves prohibitive annual maintenance cost. Detailed study may be done to determine the exact extent of maintenance requirement when the embankment is constructed to proper specification as well as protected by submersible trees and properly constructed spillways for over spilling.

iii. Berm and borrowpit plantation with plants and trees that can tolerate submergence may be a good substitute to the conventional slope protection work. Detailed study is necessary to determine the type, standard of plantation and their effectiveness.

iv. Fund constraint is always put forward as an impediment to proper O&M. Detailed study may be done to ascertain the actual utilization of available fund, O&M requirement and probable generation of fund from berm plantation and borrowpit psciculture. Study may also be taken up to see the possibility of making the embankment maintenance financially self sufficient through lease of borrowpits and berms.

REFERENCES

1) ADB (1986)
Appraisal of Khulna Coastal Embankment Project in Bangladesh, ADB.

2) ADB (1990)
Project Completion Report on the Meghna Dhonagoda Irrigation Project, PCR: BAN 21177, ADB.

3) Ali, A.Q.M. (1993)
A Review of Planning Approach for Rehabilitation of Water Development Projects in Bangladesh, M.Engg. Thesis, WRE Dept. BUET.

4) Amanullah (1989)
A Study on Failure of Flood Control Embankments in Bangladesh, M.Engg. Thesis WRE Dept. BUET.

5) ARD & EPC (1994)
Feasibility Study for the Command Area Development Project of the Peoples Republic of Bangladesh, Draft Final Report, BWDB.

6) BANCID (1992)
History of Irrigation Flood Control and Drainage in Bangladesh, Bangladesh National Committee of International Commission on Irrigation and Drainage (BANCID), DHAKA

7) BANCID (1995)
Non-structural Aspects of Flood Management in Bangladesh, Bangladesh National Committee of the International Commission on Irrigation & Drainage (BANCID), Dhaka.

8) BCAS and BETS (1994)
Socio-Environmental Assessment of Meghna-Dhonagoda Irrigation Project, ADB.

9) Beck, T. (1991)
Interim Report on Rural & Institutional Development Issues Related to Operation & Maintenance (SSSFCDI), BWDB.

10) BWDB (1963)
Manual of Works (with specification), BWDB

11) BWDB, Planning Schemes Dte. (1977)
Feasibility Report on Brahmaputra Report Flood Embankment Project (Rehabilitation & Drainage), BWDB.

12) BWDB (1984)
Feasibility Report on Bogra Polder Project, Vol. III, Annex C. BWDB

13) BWDB (1987)
Flood in Bangladesh-1987, BWDB, Dhaka.

14) BWDB (1989)
Recommendations for Protective Measures against Breach in Embankment, Meghna-Dhonagoda Irrigation Project, BWDB.

15) BWDB (1990)
Guide to River Training and Bank Protection, BWDB.

16) Casley, D.J. and D.A. Lury (1982)
Monitoring and Evaluation of Agriculture and Rural Development Projects. The World Bank. Washington, DC

17) CKC (1977)
Feasibility study on the Meghna-Dhonagada Irrigation Project in the Peoples Republic of Bangladesh, BWDB.

18) CKC, PSL (1981)
Design Report on the Meghna-Dhonagoda Irrigation Project, BWDB.

19) CKC, PSL (1985)
Meghna Dhonagoda Irrigation Project, Operation & Maintenance and Water Management Manual, BWDB.

20) CUR (1991)
Probabilistic Design of Flood Defenses, Report No. 141. Centre for Civil Engineering Research and Codes, Technical Advisory Committee on Water Defences, The Netherlands.

21) DDC, Howard Humphreys and Partners (1993)
O&M Manual, Fourth Flood Control and Drainage (Barnai) Project, BWDB.

22) DDP (1985)
Design Manual, Polder - 5, BWDB.

23) Duyne, J. (1997)
People's Initiatives in Water Management in the Context of Flood Control and Drainage System, First Draft, SRP Final Evaluation Study, BWDB.

24) EIP (1992)
Report of the Appraisal Mission 1992, DPS-IV (EIP), BWDB.

25) Embrechts, J.V.M. (1993)
Guidelines for Diversified Biological and Environment Friendly Protection of Embankments and Canal Slopes 1st approximation, UNDP, WFP

26) EPC, RDC (1986)
O&M Manual, Bara Manikdi Sub-project, BWDB.

27) EPC, Harza and Sir. M. Macdonald and Partners (1988)
O&M manual, CEP Polder 67, BWDB.

28) ESCAP, UNDP (1991)
Manual and Guidelines for Comprehensive Flood Loss Prevention and Management. ESCAP, Bangkok.

29) Euroconsult . Haskoning, DHV, BETS, BUP, BIDS (1994a)
Improved O&M in Water Management Projects, Technical Report No. 33, SRP, BWDB.

30) Euroconsult, Haskoning, DHV, BETS, BUP, BIDS (1994b)
Technical Report No. 43, System Rehabilitation Project, BWDB.

31) Euroconsult, Haskoning, DHV, BETS, BUP, BIDS (1997a)
The Effectiveness of Manual Compaction in Embankment Construction, BWDB, Systems Rehabilitation Project, Technical Report No. 53, (Draft), BWDB.

32) Euroconsult, Haskoning, DHV, BETS, BUP, BIDS (1997b)
An Empirical Assessment of the Role of Water Users Organisations in Participatory Water Management. SRP Technical Report No. 54, Vol. - I (Draft), BWDB

33) FPCO (1993)
Guidelines for People's Participation, FPCO, GOB.

34) Garg, S.P. (1990)
Report on the Erosion Problem of MDIP in Bangladesh, BWDB.

35) Garg, S.K. (1986)
Irrigation Engineering and Hydraulic Structures, Khanna Publisher, India.

36) GeoSyntech Consultant (1991)
Revised Remedial Design Approach, Dhaka Integrated Flood Protection Project (FAP-8B), BWDB.

37) GOB (1967)
The East Bengal Embankment and Drainage, Act, 1952 (E.B. Act I of 1953), GOB

38) Grubber, N.J. and M. Ahmed (1992)
Initial Environmental Examination and Rapid Social Assessment Report of MDIP, ADB.

39) Halcrow (1986)
Pilot Operation and Maintenance Programme, Small Schemes Project, Draft Final Report, BWDB.

40) Halcrow, BCEOM, DHV, DDC, Approtech (1994a)
Operation and Maintenance Plan BWDB Systems Rehabilitation Project, BWDB.

41) Halcrow, DHI,EPC and DIG (1994b)
River Training Studies of the Brahmaputra River FAP-I, Master Plan Report, BWDB

42) Haskoning, Delft Hydraulics, BCL and BETS (1990)
Final Report, FAP - 9B, BWDB.

43) Harza Engineering (1982)
O&M Manual, GK Project, BWDB.

44) Hunting TSL, BIDS, FHRC, Technoconsult (1992a)
FCD/I Agricultural Study (FAP 12), Final Report, Main Report, FPCO.

45) Hunting TSL, FHRC, Technoconsult (1992b)
Operation & Maintenance Study (FAP-13), Final Report, Main Report, FPCO.

46) Hussain, M.M. (1993)
River Engineering, WRE, BUET.

47) IECO (1962)
Feasibility Study of Brahmaputra Flood Embankment Project, BWDB.

48) IECO (1964)
Master Plan, Vol.II, EPWAPDA.

49) IFCDR, BUET (1992)
Pilot Programme to Improve Management of Flood Control, Drainage & Irrigation Projects, Final Report (Phase-I), BWDB.

50) Islam, M.Z. (1991)
Failure of Flood Embankments: Case Studies of Some Selected Projects in Bangladesh, IFCDR, BUET.

51) Islam, M.Z. (1994)
River Embankment Failure, Resulting in Sedimentation over the Flood Plain in Bangladesh and Their Model Experiments, "Final Report". Disaster Prevention Research Institute, Kyoto University, Japan.

52) ISPAN (1993)
Flood Response and Guidelines on Planning Flood Proofing, FPCO.

53) Kampsax, BCEOM, DHI, DDC (1992)
Cyclone Protection Project-II (FAP-7), Feasibility and Design Studies, Draft Project Preparation Report, Appendix-F - Operation & Maintenance, BWDB.

54) Kampsax, BCEOM, DHI, DDC (1994)
Cyclone Protection Project-II (FAP-7), Priority Works Programme and Coastal Embankment Rehabilitation Project, Operation and Maintenance of CPP-II Polders, BWDB.

55) Khanna, P.N. (1979)
Indian Practical Civil Engineers Handbook, New Sixth Edition, Engineers Publishers, New Delhi, India.

56) Kruger Consult and BCEOM (1992)
Flood Hydrology Study (FAP25), Main Report, FPCO

57) Lambe. T.W. (1951)
Soil Testing for Engineer, Wiley Eastern Ltd, New Delhi, India

58) LDL (1965)
Planning Memorandum No. 4, Brahmaputra Flood Embankment Project, BWDB.

59) LGED (1983)
Earthwork Manual, LGED,Dhaka.

60) LGED (1986)
Operation and Maintenance of Small Flood Control and Drainage Schemes, Intensive Rural Works Programme, LGED, Dhaka.

61) Mahalanabis (1930)
Report on Rainfall and Flood in North Bengal 1870 - 1922, Govt. of India, Calcutta.

62) Mohammad, A. (1990)
RRA Concepts, Methods & Applications, BARC, Dhaka.

63) MoWR, GoB (1988)
National Flood Protection Programme, Vol. II, GoB, Dhaka

64) NHCL (1987)
Procedure and Guidelines for Preparation of Operation and Maintenance Manuals, Small Scale Water Control Structures Project, BWDB.

65) NHCL (1992)
Plan of operation for Sukaijuri-Bathai River Subproject (Draft), Second SSFCDI Project, BWDB

66) NHCL (1993)
Design workshop; Small Scale Water Control Structure, BWDB.

67) NHCL (1995)
Model O&M Manual, Second Small Scale Flood Control Drainage & Irrigation Project (SSSFCDI), BWDB.

68) Nishat, A. (1987)
Brief Review of Planning and Design Principles Related to O&M Requirements: Training Course Operation and Maintenance of Small Scale Water Resources Project (LGED) WRE & IFCDR, BUET.

69) Nishat, A. (1998)
Report on Selection of Tree Species for Plantation of Inland and Coastal Embankment Slopes of BWDB, MoWR, GoB, Dhaka.

70) Panel of Experts (1994)
Institutional Development Programme, Interim Report No. 1, FPCO

71) Panel of Experts (1995)
Institutional Development Programme, Report No. 2, FPCO

72) Parvez, M.H. (1987)
Study on Brahmaputra Right Flood Embankment Project, M. Sc. Thesis, BUET.

73) Rogers, P. (1989)
Eastern Waters Study, ISPAN.

74) Philips, B. (1994)
Fact Finding Mission Report (CAD), ADB.

75) Punmia B.C. (1982)
Soil Mechanics & Foundations, Standard Book House, Delhi, India.

76) Rahman, S. (1976)
Methodology of Preparation of Operation and Maintenance Manuals for Water Development Project with some illustrations, BWDB.

77) Rahman, S. (1984)
The Brahmaputra Right Bank Flood Embankment its Problems and Probable Solutions, Bangladesh Academy for Rural Development, Bogra.

78) RIT, IFCDR (1992)
Environmental Examination of an Embankment Project in Bangladesh, A Case Study, Sustainable Use of Water Resources (SUWAR) Report No. B7, Sweden.

79) Rob, M.A. (1996)
Flood Hazards in Bangladesh Weekend Independent, 12th July 1996.

80) RPT, NEDECO, BCL (1989)
Jamuna Bridge Project, Phase II Study, Feasibility Report (Aug, 1989), GOB..

81) Shafiullah. A.M.M. (1977)
Performance of the Dhaka-Narayanganj-Demra Embankment, A research report of the Deptt. of Civil Engineering Dept. BUET, Dhaka.

82) Sharma (1992)
Dam Engineering Including Water Power Engineering, Oxford & IBH Publishing Co. New Delhi, India.

83) Shawinigan Lavalin, NHCL, EPC, BETS, IDEA, NCM (1993)
Wetland Resources Specialist Study, Northeast Regional Water Management Project (FAP-6), FPCO.

84) Siddiqi, M.H. (1996)
Floods: Problems and Prospects, Weekend Independent, 12th July 1996.

85) Soussan, J. (1997)
Systems Rehabilitation Project Final Evaluation Study, Summary of Progress, Results & Conclusion, (Paper read in Seminar). BWDB

86) Techno-Consult (1967)
Meghna Dhonagoda Project, Feasibility Studies, Project Report, BWDB

87) Terzaghi, K. and R. B. Peck (1967)
Soil Mechanics in Engineering Practice (2nd Ed), John Wiley & Sons, USA.

88) UNDP (1989)
The Flood Policy Study. UNDP. GoB.

89) USBR (1974)
Design of Small Dams, U.S. Department of Interior, Colorado, USA.

90) Varma, C.V.J. (1989)
River Behaviour Management and Training, Vol. 1, Central Board of Irrigation and Power, India Publication No. 204.

91) Varshney, R.S., S.C.Gupta, R.L.Gupta (1982)
Theory & Design of Irrigation Structure, Vol. II, Canal and Storage Works, Nemchand & Bros., Roorkee, India.

92) World Bank (1979)
Review of Bangladesh Water Development Board, Report No. 2327-BD, World Bank. Resident Mission Bangladesh (RMB), Dhaka.

93) World Bank (1985)
SAR Third FCD Project, Report No. 5428-BD, World Bank. RMB, Dhaka.

94) World Bank (1987a)
SAR Fourth FCD Project, Report No. 5916-BD, World Bank. RMB, Dhaka.

95) World Bank (1987b)
SAR SSFCDI Project, Report No. 6904-BD, World Bank, RMB, Dhaka.

96) World Bank (1989)
Bangladesh Action Plan for Flood Control. World Bank, RMB, Dhaka.

97) World Bank (1990)
SAR Bangladesh BWDB Systems Rehabilitation Project, Report No. 8093-BD, World Bank ,RMB, Dhaka.

TABLES AND FIGURES

Table 1-1: Areas affected by flood

Return Period (Year)	Affected Area (Percent of Total Area
2	20
5	30
10	37
20	43
50	52
100	around 60
500	around 70
Mean	22

(Source; World Bank, 1989)

Table 1-2: Flood affected areas of Bangladesh

Year	Affected Area (square kilometer)	Loss and Damage
1954	36,780	Tk. 1,500 million
1955	38,850	
1956	35,840	
1962	37,300	
1963	35,230	
1968	37,300	
1970	42,480	
1971	36,340	
1974	52,520	28,000 lives lost 30,000,200 people affected
1984	28,210	
1987	57,270	1,000 lives lost 41,000,000 people affected Tk. 35,000 million
1988	77,700	1,200 lives lost 50,000,000 people affected Tk. 50,000 million

(Source: Rob, 1996)

Table 1-3: The region wise distribution of flood affected areas

Sl. No.	Region	Total area (sq.km)	Flood vulnerable area (sq.km)	% of total area
1	The Brahmaputra	41,049	25,540	19
2	The Ganges	53,730	23,165	16
3	The Meghna	22,220	17,690	12
4	Flash Flood	25,778	6,566	5
5	Coastal	-	8,127	6
	Total	1,42,777	82,088	58

(Source: Rob, 1996)

Table 2-1: USBR recommended freeboard

Fetch km (miles)	Normal freeboard m (ft)	Minimum freeboard m (ft)
Less than 1.60 (1.0)	1.22 (4.0)	0.91 (3.0)
1.60 (1.0)	1.52 (5.0)	1.22 (4.0)
4.00 (2.5)	1.83 (6.0)	1.52 (5.0)
8.00 (5.0)	2.44 (8.0)	1.83 (6.0)
16.00 (10.0)	3.05 (10.0)	2.13 (7.0)

(Source: USBR, 1974)

Table 2-2: Freeboard by river type

Type of River	Freeboard, m
Major River (Brahmaputra, Ganges and Meghna)	1.52
Medium Rivers (Teesta and Similar size of rivers)	0.91

(Source: BWDB)

Table 2-3: Recommended Embankment Slopes

Type of material	R/S slope (H:V)	C/S slope (H:V)
Homogeneous well graded material	2.5:1	2:1
Homogenous course silt	2.5:1	2:1
Homogeneous silt clay or clay	3:1	2.5:1
Height <15 m	2.5:1	2:1
Height >15 m	3:1	2.5:1
Sand or sand and gravel with clay core	3:1	2.5:1
With R.C. core wall	2.5:1	2:1

(Source: Terzaghi, 1967)

Table 2-4: Recommended Side Slopes

Selection Criteria		C/S slope	R/S slope
River type:	Major and Medium river	1:2	1:3
Design based on:	Slip circle analysis and seepage gradient		
Performance :	Perfectly satisfactory		
Recommended for:	Fresh and remodeled embankment		

(Source: BWDB)

Table 2-5: Recommended riprap design criteria

Maximum wave height, (ft)	Minimum average rock size ,D50 (inches)	Layer thickness (in)
0-2	10	12
2-4	12	18
4-6	15	24
6-8	18	30
8-10	21	36

(Source: Amanullah, 1989)

Table 2-6: Minimum thickness of single layer filters under riprap blankets

Computed wave height (ft)	Minimum filter thickness (in)
0-4	6
4-8	9
8-10	10

(Source: Amanullah, 1989)

Table 2-7: Design criteria of upstream protection

Height of bund, (m)	Thickness of stone pitching, over graded shingle/spalls, (m)	Thickness of graded shingles/spalls, (m)
Upto 5	No pitching	
5-10	0.25	0.15
10-15	0.30	0.15
15-25	0.50	0.25
25-50	0.50	0.30
50-75	0.75	0.50
>75	1.00	0.75

(Source: Varshney, 1982)

Table 2-8: Types of embankments

Type	Description	Notes
Compacted	<u>Specify</u>: Water content range with respect to standard effort optimum water content. Losse lift thickness. Compaction equipment (sheepsfoot or rabber-tired rollers) Number of passes to attain a given percent compaction based on standard maximum density.	Embankment section occupies minimum space and is of low compressibility (as needed adjacent to concrete structures or with highway on levee crown). Requires strong foundation of low compressibility and fill material with natural water content reasonably close to specified ranges.
Semi-compacted	<u>Specify</u>: Compact at natural water content (no water content control). Lifts thicker than compacted fill (about 12 in). Compacted either by controlled movement of hauling and spreading equipment or by few passes of rollers. Compaction evaluated relative to 15-blow compaction test.	Most common type of construction used where: There is no stringement space limitation and compacted fill is not required. Relatively weak foundations weak foundations could not support compacted fill. Underseepage conditions require a wider embankment base than compacted construction requires. Water coment of borrow or rainfall during construction season do not justify compacted construction.
Un-compacted	Fill is cast or dumped in place in thick layers with little or no spreading or compaction, or Fill is hydraulic fill by dredge, often from channel excavation.	Cast or dumped fill used primarily for emergency work. Both methods used for berm construction Hydraulic fill used in some cases to build entire levee section: results in very that slopes with large space requirements.

(After U.S. Army, Corps of Engineers, 1978).

Table 2-9: Suitabie of soils for construction of earthen embankment

Relative suitability	Homogeneous sections
1. Very suitable	Clayey gravels (GC)
2. Suitable	Graveley clay (GL), clay of intermediate plasticity (CI)
3. Fairly suitable	Poorly graded sand (SP), silty sand (SM), Inorganic clay of high plasticity (CH).

(Source : Islam, 1991)

Table 3-1: Bank movement of Brahmaputra during 1830 - 1963

Reach	Bank Movement in feet	
	Right Bank	Left Bank
Aricha to Dhaleswari river	20,600 W	1,000 W
Dhaleswari river to Sirajganj	11,500 W	6,900 W
Sirajganj to Gabragaon	8,800 W	13,200 W
Gabragaon to old Brahmaputra	24,300 W	11,300 W
Old Brahmaputra to Teesta river	31,900 W	22,600 W
Above Teesta river	13,600 W	10,100 W
Average	11,500 W	3,800 W

(Source : IECO, 1962)

Table 3-2: Bank movement of the Brahmaputra river between 1965-66 and 1983-84

BWDB Section No.	Distance from Section J#1	Change in Left Bank	Change in Right Bank
J#1	0	0	E3965
J#1-1	5.057	E150	E5490
J#2	11.316	E825	E1035
J#2-1	14.325	E1525	E2896
J#3	19.983	E1220	E1220
J#3-1	28.170	E1400	E3965
J#4	34.429	E6250	D6100
J#4-1	42.866	D2990	E5130
J#5	47.912	D3200	D150
J#5-1	53.932	E1400	D760
J#6	59.951	0	D760
J#6-1	65.127	D305	E305
J#7	72.591	E3810	D150
J#8	83.425	E1220	E610
J#8-1	87.398	E870	E430
J#9	91.732	E1340	E1830
J#9-1	95.343	E1950	D2320
J#10	100.400	E610	D5335
J#10-1	105.215	D30	E150
J#11	117.734	E1680	E1370
J#11-1	127.606	D2440	E1495
J#12	132.421	E3095	D320
J#12-1	139.644	E855	E1980
J#13	146.746	E1220	E460
J#13-1	152.042	D120	E2270
J#14	160.710	E760	D2135
J#14-1	170.340	D150	E1005
J#15	179.368	E5335	D700
J#15-1	188.157	E4725	D1677
J#16	196.463	D3355	E2895
J#16-1	202.722	E2060	D1070
J#17	211.390	E855	E1090

(Source; Parvez, 1987) Note: E indicates erosion, D indicates deposition

Table 3-3: Erosion rate

Reach (coordinate)	1953-73 (m/yr.)	1973-84 (m/yr.)	1984-92 (m/yr.)	1973-92 (m/yr.)
84500-83500	42.29	-43.37	-116.69	-14.48
83500-82500	-113.34	-29.69	-65.85	-80.01
82500-81500	-48.90	-39.21	-169.25	-70.86
81500-80500	-18.42	72.67	-147.87	-19.28
80500-79500	85.02	-84.56	-222.45	-25.86
79500-78500	90.37	-154.90	-145.35	-27.16
78500-77500	-46.95	-94.73	-19.12	-54.12
77500-76500	81.25	-168.23	-42.14	-14.43
76500-75500	-50.45	-115.12	-12.63	-60.93
75500-74500	-147.55	-87.84	-109.41	-122.89
74500-73500	-46.69	-166.25	-123.66	-96.20
73500-72500	-130.06	-56.19	-138.04	-110.86
72500-71500	-8.93	-77.33	-187.28	-64.81
71500-70500	-47.24	-24.08	54.72	-19.79
70500-69500	34.15	81.31	-196.08	0.22
69500-68500	19.10	5.40	-134.29	-16.23
68500-67500	-108.28	-112.62	19.73	-83.25
67500-66500	-62.32	-90.56	-79.21	-73.75
66500-65500	-31.76	11.30	-26.71	-18.58
65500-64500	-19.30	-67.29	-26.41	-34.29
64500-64400	-136.81	-11.43	-37.09	-80.99

(Source: Halcrow, 1994b)

Note: Positive sign indicates accretion, negative sign indicates erosion

Table 4-1: General condition of some BWDB projects' embankments

Sl. No.	Name of Project	Project Type	Completion Year	Functional Committee	Drainage Problem	Social conflict	Tree Plantation	Squatter Housing	% in poor condition	Erosion	Breaches	Cut by in-sider	Cut by out-sider	Key Problem: Planning Design	Key Problem: Construction	Key Problem: O&M	Length of embankment
1	Chalan Beel Polder-D	FCD	1988/89	no	yes	yes	yes	no	50%	no	yes	yes	yes	Important	0	important	132.28km
2	Kurigram(South)	FCD	1983/84	na	yes	yes	yes	yes	50%	yes	frequent	yes	no	important	severe	important	110km
3	MDIP	FCDI	1987	some	no	yes	no	few	20%	yes	yes	no	no	severe	severe	important	61.60km
4	Zilker Haor	Subme. emban.	1986/87	some	yes	yes	no	no	70%	no	no	no	no	0	0	important	full flood 15.8km, submersible 8.91 km
5	Kolabashukhali	FCD	1983	no	yes	yes	yes	no	50%	yes	no	no	no	moderate	0	moderate	85.50km
6	Protappur	FCDI	1977/78	no	no	no	yes	yes	most	no	no	no	no	moderate	0	important	10km
7	Nagar River	FCD	1986	no	yes	yes	some	no	85%	yes	yes	few	yes	severe	moderate	severe	27km
8	Sonamukhi Bonmander Beel	D	1978	no	yes	yes	-	Drainage	project	-	-	no	yes	severe	0	important	2km
9	Sakunia Beel	FCD	1985	some	yes	no	yes	no	70%	yes	yes	no	no	0	important	important	14.6km
10	Sitimpur Karatia	FCD	1983	no	no	yes	yes	no	15%	yes	yes	no	no	severe	0	0	28.5km
11	Katakhali Khal	FCD	1982/83	some	yes	yes	no	no	50%	no	yes	yes	no	moderate	0	severe	14.16km
12	Halir Haor	Submersible embankment	1983	yes	some	some	no	no	33%	no	yes	yes	no	0	0	important	submersible 53 km
13	Kahua-Muhuri Embankment	Flush flood control, irrigat.	n.a.	yes	yes	no	yes	no	80%	yes	yes	yes	no	0	0	important	10km
14	Konapara Embankment	Flush flood emankment	1983/84	na	some	yes	yes	no	60%	yes	yes	no	yes	important	0	severe	21.6km
15	Polder 17/2	FCD	1983/84	yes	no	yes	no	no	5%	no	no	yes	no	severe	severe	0	10.5km
16	BRE-Kamarjani	FCD	1970	na	yes	yes	yes	yes	70%	much	yes	yes	no	important	important	important	19.3km
17	BRE-Kazipur	FCD	1970	na	no	no	yes	yes	50%	much	yes	no	no	0	important	severe	16km

(Source: Hunting, 1992b) na = not applicable

Table 4-2: Economic & financial performance of the projects (1991price)

Sl. No.	Name of project	Net benefit area	Capital cost/ha (Tk)	O&M cost/ha (Tk)	O&M cost/ha (% of capital cost/ha)	Annual benefit/ ha	EIRR
1	Kahua Muhuri	2024	11512	235	2.0	12143	96
2	Sonamukhi-Bmander	7400	6284	314	5.0	10514	65
3	Halir Haor	6686	3671	191	5.2	2372	65
4	Konapara embnk.	3116	2634	132	5.0	10934	62
5	Protappur	4000	3419	224	6.5	5686	54
6	Zilker Haor	4238	17810	333	1.9	3964	40
7	Katakhai Khal	2520	7548	0	0	2722	30
8	KBK	18623	12041	624	5.2	3340	25
9	Kurigram (South)	50000	13672	776	5.7	5530	22
10	Silimpur Karatia	1012	10829	0	0	956	10
11	Sakunia Beel	4400	4787	28	0.6	584	10
12	Chalan Beel -D	37235	9196	129	1.4	914	9
13	MDIP	14367	129205	2417	1.9	13437	7
14	BRE Kamerjani	8783	6619	340	5.1	625	3
15	BRE-Kazipur	8788	5461	280	5.1	424	0
16	Nagar River	9312	7962	n.a	n.a	(-)1074	(-)10
17	Polder 17/2	2792	15136	440	2.9	(-)2224	(-)10

(Source: FAP - 13, 1992)

Table 6-1: Different water levels

Station	Water level (ft PWD)		
	100 yrs. return period	50 yrs. return period	Highest recorded
Shatnal	21.10	20.70	20.00
Matlab	18.70	18.40	18.15

(Source: CKC, 1977)

Table 6-2: Details of embankment

Item	As proposed in the feasibility study		As per detailed design	As built
	Techno-Consult	CKC		
Project area Irrigated area Embankment length	19,028 ha 15,101 ha 63.7 km	17,580 ha 13,765 ha 65 km	17,998 ha 14,474 ha 61.6 km	17,584 ha 14,367 ha 60 km
Top width Meghna side Dhonagoda side	7.3 m 4.3 m	6.1 m 5.2 m	6.1 m 4.3 m	5.2 m 4.3 m
Return period	100 yrs	100 yrs	100 yrs	100 yrs
Free board Meghna side Dhonagoda side	1.5 m 1.0 m	1.5 m 1.0 m	1.5 m 1.0 m	1.5 m 1.0 m
Side slope River side country side	1:2 1:1.5	1:3 1:2.5	1:3 1:2	1:3 1:2
Compaction	Manual	Manual	Mechanical	Mech.&Manual
Set back Naobhanga-Nabipur (Dhonagoda)	305 m	306 m - 400 m	122 m - 396 m	120 m - 400 m
Nabipur-Mahanpur - Naobhanga (Meghna)	300 - 1200 m	800-1000 m	823-914 m	800-1000 m

(Source: ADB, 1990)

Table 6-3: Difference in distances between BWDB pillars and actual field observations in MDIP peripheral embankment

Available BWDB Pillars		Distance as per BWDB (M)	Actual distance in the Field (M)	Difference (M)	Remarks
From	To				
0	Regular				Regulator Width 16m
0	1 km	1000	1000	0	
1 km	2 km	1000	990	-10	
2 km	3 km	1000	1000	0	
3 km	4 km	1000	998	-2	
4 km	5 km	1000	994	-6	
5 km	6 km	1000	994	-6	
6 km	7 km	1000	994	-6	Pillar No. 9 missing
7 km	8 km	1000	994	-6	
8 km	10 km	2000	1991	-9	
10 km	11 km	1000	995	-5	
11 km	12 km	1000	997	-3	
12 km	13 km	1000	998	-2	
13 km	15 km	2000	2040	+40	Pillar No. 14&15 missing
15 km	16 km	1000	1023	+23	
16 km	17 km	1000	991	-9	
17 km	21 km	4000	3950	-50	Pillar 18,19,20 missing
21 km	22 km	1000	996	-4	
22 km	23 km	1000	1054	+54	
23 km	24 km	1000	997	-3	
24 km	25 km	1000	995	-5	
25 km	26 km	1000	1117	+117	
26 km	27 km	1000	1024	+24	
27 km	28 km	1000	1087	+87	
28 km	29 km	1000	1040	+40	Pillar No. 29 broken
29 km	30 km		1034	+34	
30 km	31 km	1000	1080	+80	
31 km	32 km	1000	1060	+60	
32 km	33 km	1000	1090	+90	Regulator width at Kalipur is 21m
33 km	34 km		993	-7	
34 km	36 km	2000	2069	+69	Pillar No. 35 broken
36 km	37 km	1000	1026	+26	
37 km	38 km	1000	1089	+89	
38 km	39 km	1000	1057	+57	Pillar No. 39 missing
39 km	40 km		1003	+3	
40 km	41 km	1000	1011	+11	
41 km	43 km	2000	1978	-22	Pillar No. 42 missing 43 - broken
43 km	44 km	1000	996	-4	
44 km	45 km	1000	935	-65	
45 km	46 km		1004	+4	
46 km	47 km	1000	989	-11	
47 km	48 km	1000	906	-34	Pillar No. 48 underground
48 km	49 km	1000	1055	+55	
49 km	50 km	1000	1024	+24	
50 km	51 km		1029	+29	
51 km	52 km	1000	996	-4	
52 km	53 km	1000	1039	+39	
53 km	54 km	1000	1014	+14	
54 km	55 km		1024	+24	
55 km	56 km	1000	1002	+2	
56 km	57 km	1000	1001	+1	
57 km	58 km	1000	1003	+3	
58 km	59 km	1000	1003	+3	
59 km	60 (59.8) km	800	833	+33	
TOTAL		59600	60662	+813	

(Source: Personal physical survey)

Table 6-4: Location of fishery ponds

Location (km)	No. of Ponds
3	1
5	1
6	1
17	1
20	1
21	1
25	3
26	3
30	1
31	1
34	36
36-42	53
Total	53

Table 6-5: Length of embankment plantation

From	To	Total
0 km	7 km	7 km
18 km	24 km	6 km
37 km	38 km	1 lm
40 km	41.5 km	1.5 km
42.5 km	60.6 km	18.1 km
Total		33.6 km

Table 6-6: Year wise O&M expenses

Financing Year	Establishment Budget (Tk. in mil.)	Other (Tk. in mil.)	Total (Tk. in mil.)
1991-92	81.92	792.79	874.71
1992-93	93.94	170.38	264.32
1993-94	92.13	175.88	268.01
1994-95	149.75	154.62	304.37
1995-96	177.56	180.28	357.84
1996-97	158.61	158.22	316.83
Total	753.91	1632.17	2386.08

(Source : Personal collection from Chandpuar BWDB project office on 14.10.97)

Table 7-1: Comparative tractive force of protective cover

Type of construction	Critical tractive force (kg/m2)
Course sand between wattles	1.0
Grovels between wattles	1.5
Grass sodding	2.0-3.0
Wattles	5.0
Mattresses	7.0
Bruik paving	10.0
Stone paving	16.0
Random placed, riprap or large stone	24.0
Concrete pavement	60.0

(Source: BWDB, 1990)

Table 7-2: Flood depth of flooded area

Average Annual Flood Depth(ft)	Million Acres of Culturable	Percent
Less than 1	6.3	27
1 - 3	9.1	39
3 - 6	4.1	18
Over 6	3.6	16
	23.1	100

(Source: World Bank, 1979)

Table 7-3: Comparison of WL of different return period.

Return Period	Highest Difference with 2 year peak	Av. Difference with 2 year peak
25 year return period	1.22	0.85
50 year return period	1.45	1.03
100 year return period	1.67	1.21

(Source: Kruger, 1992)

Table 7-4: Fund requested and fund allocated

Financial year	Fund requested (Tk. in million)	Fund allocated (Tk. in million)	Fund utilised (Tk. in million)
1989-90	10913	6912	7437
1990-91	10106	7901	8388
1991-92	13796	8716	8716
1992-93	16956	9681	9949
Total	51771	33210	34,490

(Source: Panel of Expert, 1994)

Table7-5: O&M cost as percent of capital cost

Sl. No.	Project	O&M cost/ha (% of capital cost/ha)
1	Kahua Muhuri	2.0
2	Sonamukhi Banmander	5.0
3	Halir Haor	5.2
4	Konapara Embankment	5.0
5	Protappur Project	6.5
6	Zilker Haor	1.9
7	KBK	5.2
8	Kurigram South	5.7
9	Silimpur Karatia	No O&M expenditure
10	Sakunia Beel	0.6
11	Chalan Beel Polder D	1.4
12	MDIP	1.9
13	BRE Kamarjani	5.1
14	BRE Kajipur	5.1
15	Nagor River	n.a.
16	Polder 17/2	2.9
17	Katakhali Khal	No O&M expenditure

(Source: Hunting, 1992a)

Table 7-6: Time & cost overrun of some BWDB projects

Sl. No.	Name of the project	Time overrun years	Cost overrun % over original estimate
1	Tubewell Proejct	4	24.63
2	Coastal Embankment Rehab. Project	1/2	68.72
3	Naogaon Polder I	3	95.71
4	Pabna IRDP, Phase-I	13	44.59
5	Narayanganj Narsingdi Irrigation Project	0	8793.44
6	Madhumati-Nobaganga	3	39.05
7	Bhola Irrigation Project	4	182.47
8	Gumti Phase-I	1	68.41
9	Chandpur Irrig. Project	2	9.33
10	MDIP	2	63.30
11	KIP	1	26.57
12	Muhuri Irrigation Project	2	2.47
13	Dhaka Int. Flood Control	on going	1.28
14	Manu River Project	N.a.	103.28
15	Khowai River	11	26.08
16	Teesta Barrage Phase-I	5	1717.26

(Source: Panel of expert, 1995)

Table 7-7: Implementation period of some projects.

Sl. No.	Name of the project	Implementation period (years)
1	Kurigram South	10
2	MIDIP	12
3	BRE	10
4	Polder 17/2	13
5	KBK	7
6	Chalan Beel, Polder D	8

(Source: Hunting, 1992a)

Fig. 2-1: **Phreatic line for a homogeneous section**

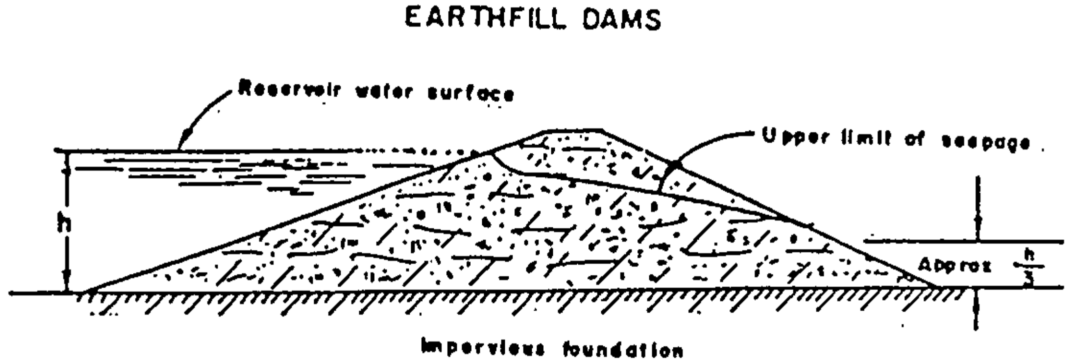


Fig. 2-2: **Phreatic line for a zoned section**

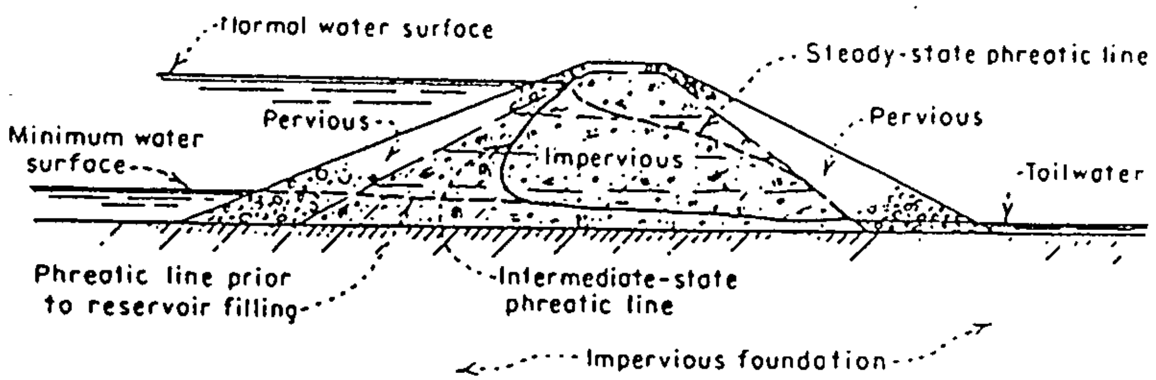
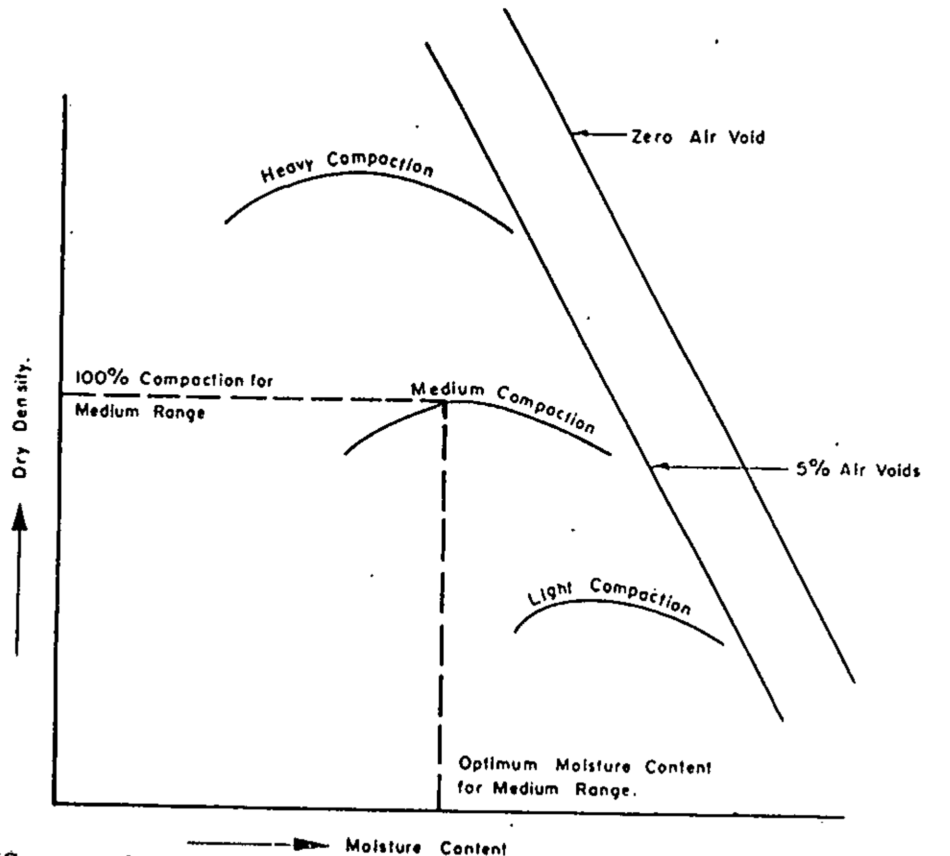


Fig. 2-3: Compacted density vs moisture content relationship



(Source: Lambe, 1951)

Fig. 4-1: Mughal hierarchy for construction and O&M of embankment (Source: BANCID, 1992).

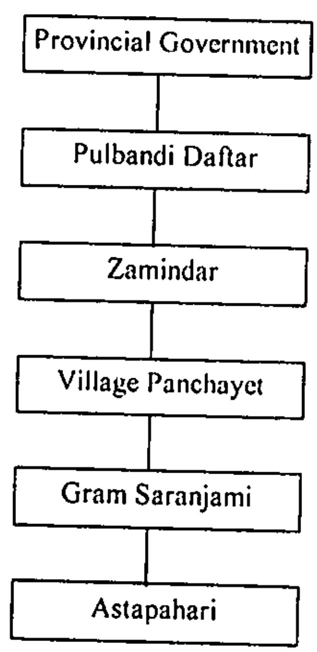


Fig. 4-2: **Report format for flood embankment**

REPORT FORM 1 : CONDITION OF FLOOD EMBANKMENT/ROAD

SECTION	CHAINAGE		RIVER LEVEL (m PWD)	TIME AM/PM	DATE
	FROM	TO			

Item Inspected	Observed Condition/Comments/Chainage	Maintenance Category		
		I	II	III
Seepage through embankment				
Seepage from berm				
Slipping				
Settlement				
erosion by wave/current action				
rain cut				
condition of grass cover on slope/berms				
growth of weeds, bushes and trees				
condition of borrow pit				
intentional cutting/ removal of fill				
encroachment by humans or animals				
road drainage/camber				
condition of brick pavement				
intentional removal of bricks				
local failures in brick pavement				
visibility - bush or tree growth				

Maintenance Category: I = urgent item - repair immediately;
II = repair within current programme;
III = include in next year's programme.

Submitted by: Signature .... Date ....

Comments/Action:

Signature .... Date ....

Fig. 4-3: Monitoring format for EMGs

Monotoring Form for EMG Works

This monitoring form is to be submitted XEN and the in-charge of the AA, within 2 days of the joint supervision visit.

01. Inspection visit paid by (state name and designation) :

BWDB: ____________________

AA: ____________________

Others: ____________________

02. Name of the EMG.

03. Location of work allotted to EMG: Km. .. to .. Km

04 Date of inspection visit

05. Date of previous visit.

06. Target of work during this week Km to Km = Km

07 Achievement of target during this week Km to km Km

08 Cumulative progress of this month Km

09 Check attendance register No of working days realized since last visit (including today) .. .. days

10. No. of crew members present at the site: ....

11 Information of crew members absent at the site.

Name of crew members	Reasons of absence	Remarks
1.		
2.		
3.		
4		

Fig. 4-3(cont'd): **Monitoring format for EMGs (cont'd)**

12. Replacement of crew members made after previous visit:

	Name of crew members	Date	Reasons
1.			
2.			
3.			
4.			

13. Equipment available at the site:

	Equipments	Unit	Workable condition	Non workable condition	Remarks
a)	Baskets				
b)	Spades				
c)	Mallet				
d)	Machete				
e)	Others (specify)				

14 Quality of work

Description of work activity	Quality of work				Remarks
	good	fair	poor	not done	
1. Repair of Ghogs, holes & other damages					
2. Repair of raincuts, cattle damage, etc.					
3. Cambering					
4. Vegetation cleaning					
5. Turfing					

Fig. 4-3(cont'd): Monitoring format for EMGs (cont'd)

Remarks:

15. Other related works:

Where from does EMG collect soil?
(Circle correct option)

Toe Borrowpit slope field Other (specify)

Does the EMG cover the full reach ?

Yes ☐ No ☐

Are there many damages noticed ?

Yes ☐ No ☐

Is EMG capable of working independently ?

Yes ☐ No ☐

Problems and warning reported by the EMG:

16 Problems identified by the supervisor ____________________

____

17 Instructions given to the EMG ____________________

____

18. Required follow-up by

BWDB: ____________________

BRDB ____________________

19. Issues brought up during previous supervision visit (by EMG, BRDB, BWDB) and not yet solved

a) ____________________

b) ____________________

c) ____________________

Fig. 4-3(cont'd): Monitoring format for EMGs (cont'd)

Agreed and signed on ________________________ date

For BWDB : Name and designation: ________________________

For BRDB : Name and designation: ________________________

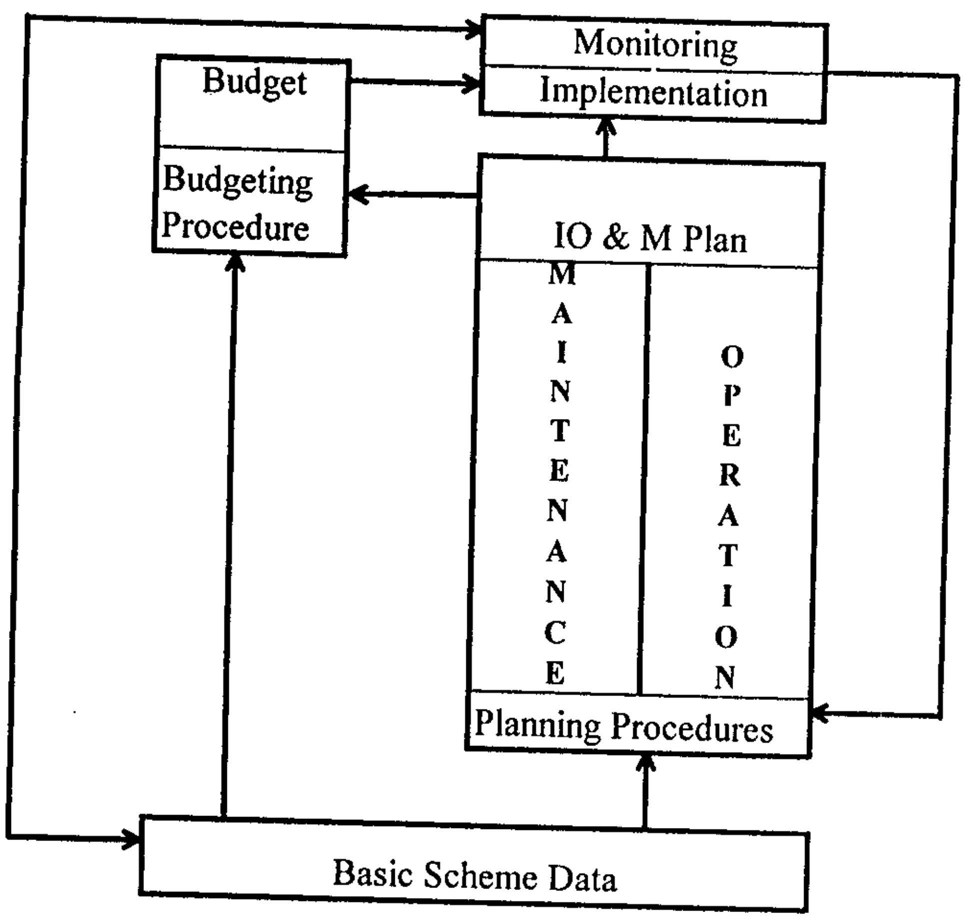
20. Comments of SDE: ________________________

____

21 Comments of AA Officer: ________________________

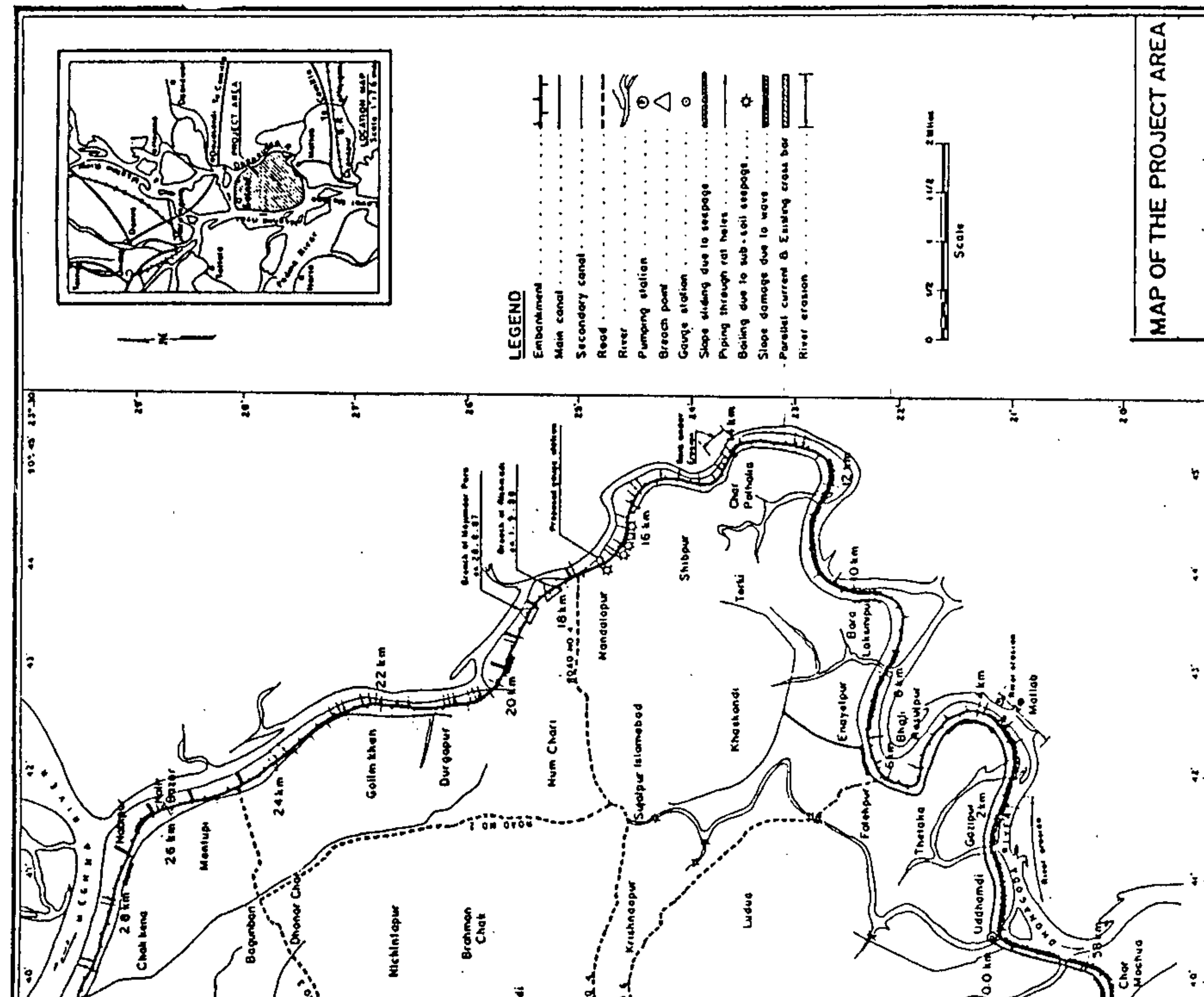
____

Fig. 4-4: Planning of improved O&M

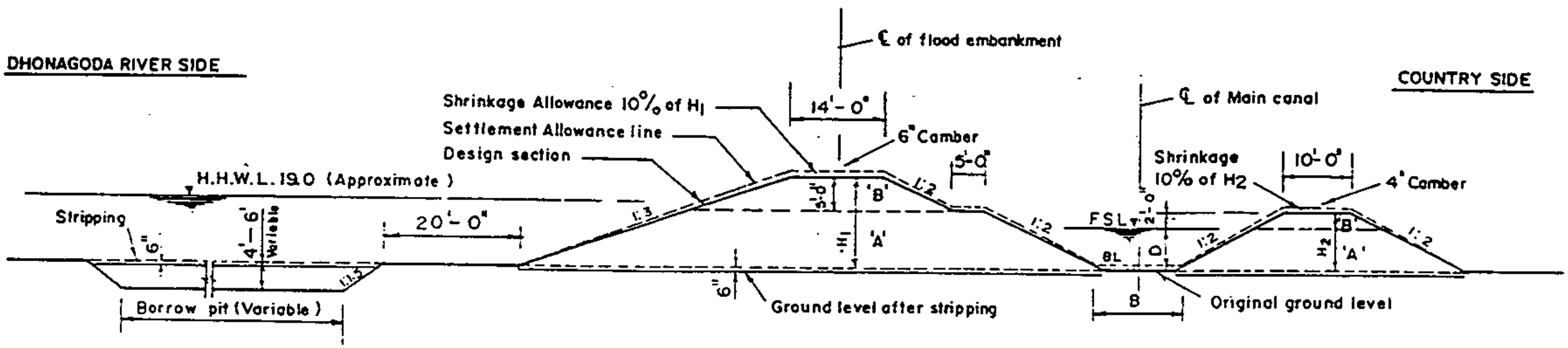


Frame work of Improved Operation and Maintenance

Fig. 6-1: General layout map of MDIP



TYPICAL CROSS SECTION OF FLOOD EMBANKMENT
AND IRRIGATION CANAL DIKE



NOTES

1. The drawings are to be used for the construction undertaken in the first dry season (Dec. 79 — May 80) fron Uddamdi to sibpur
2. The canal dike shall be constructed prior to the construction of flood Embankment unless otherwise directed by the Engineer.
3. Zone 'A' shall be compacted by havy compaction Machinery by owners forces as follows

	Layer Thickness	Pass Number
Bull dozer	8"	2
Sheepe foot roller	10"	2
Tire dozer	10"	2

   Above details shall be directed by the Engineer after the field compaction test.
4. Zone 'B' will not be compacted by Machinery; However cloos shall be broken manually by contractors forces
5. Borrow pit Materials shall be taken from the top soil (Silt layer). Sand layer shall not be disturbed during Excavation work in borrow pits. Borrow pits shall not Excavate continuously, Intermediate ramps of suitable width, as directed by the Engineer, shall be left.
6. The slope and crest of the Embankment and dike shall be Dressed with the stripped earth.
7. All slopes and crests shall be turfed Except wetted perimeter of the irrigation canal.
8. Abbreviations.

HHWL	: Designed flood water level
FSL	: Full supply level
BL	: Bed level of Irrigation canal
B	: Bed width of irrigation canal
D	: Depth of Irrigation canal
H_1 H_2	: Designed height of flood Embankment and canal dyke respectively after shrinkage from original ground to the crest.

Details of these values are shown in plan and profile of the Drawings (FE-01/1-FE-01/14)

Elevation are shown in Feet. (PWD)

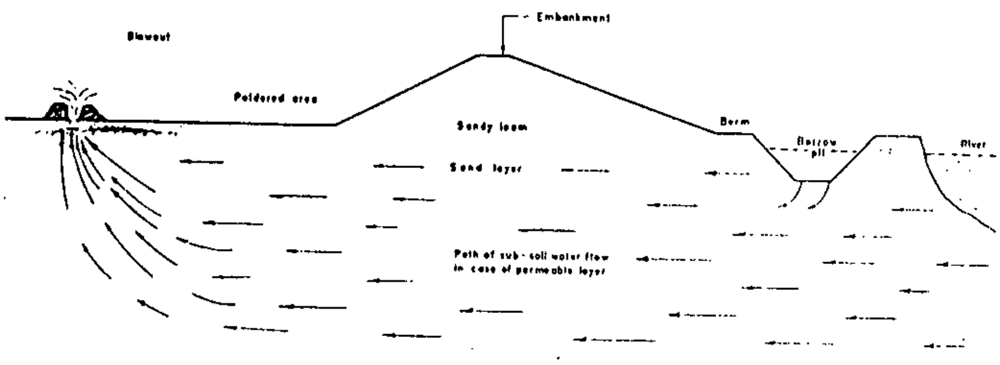
Scale - 1" = 10'-0"

Revision No - 1
Note - 3
Date 11-2-1980

BANGLADESH WATER DEVELOPMENT BOARD
MEGHNA DHONAGODA IRRIGATION PROJECT
TYPICAL CROSS SECTION OF FLOOD EMBANKMENT
CHUOKAIHATSU CORP. & PROKAUSHALI SANSAD LTD.

Fig. 6-2: Typical embankment section of MDIP

Fig. 6-3: **Schematic diagram of situation at the time of MDIP breach**



SCHEMATIC DIAGRAM OF A TYPICAL BLOW OUT

Fig. 7-1: **Failure criteria of embankment**

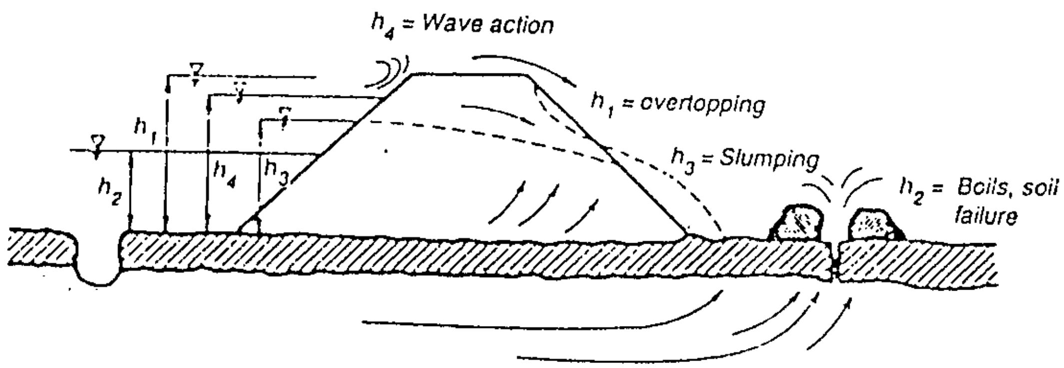
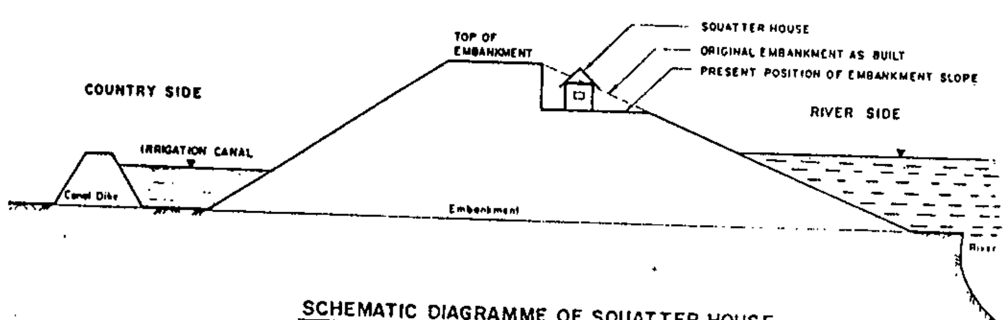


Fig. 7-2: **Schematic diagram of squatter housing**



SCHEMATIC DIAGRAMME OF SQUATTER HOUSE
AFTER CUTTING OF EMBANKMENT SLOPE

Fig. 7-3: Schematic diagram of trees in embankment

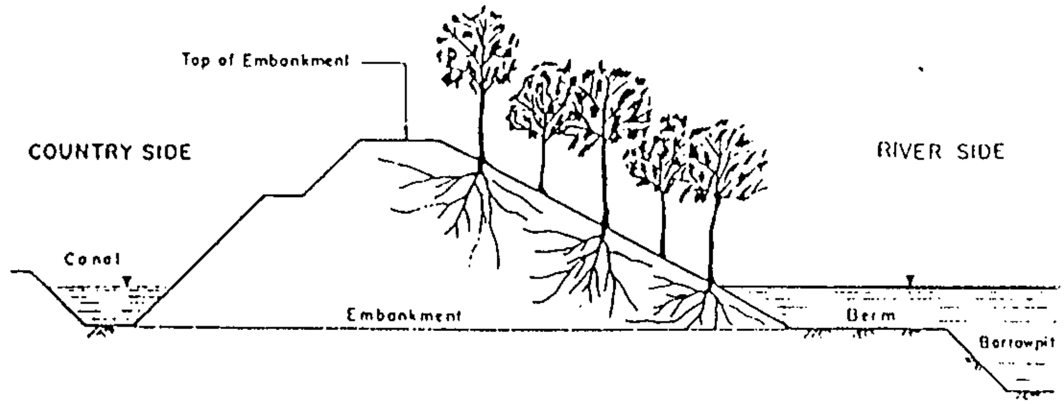
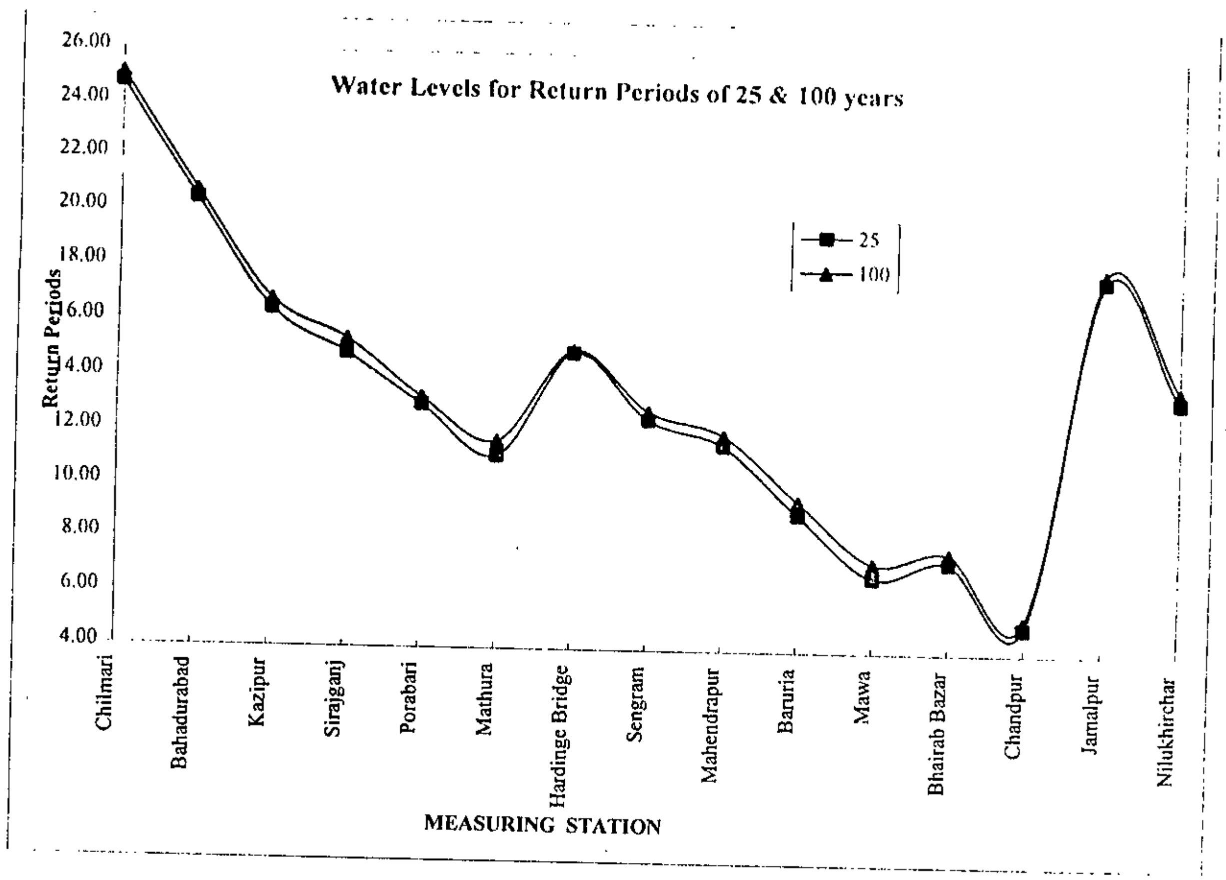
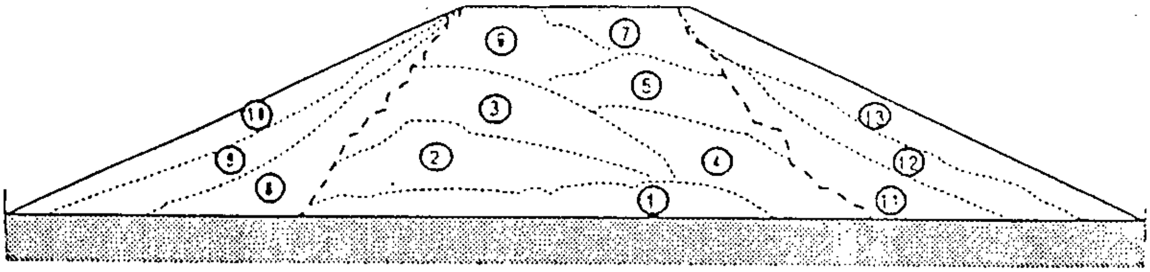


Fig. 7-4: Differences of 25 years and 100 years flood peaks at different stations on different rivers



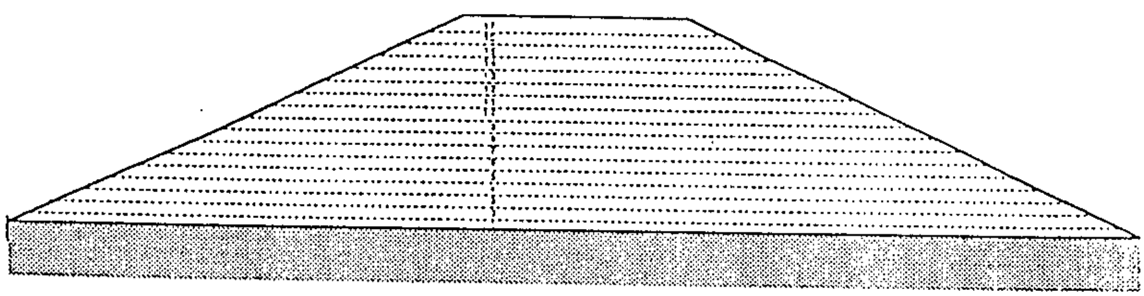
(Source : Kruger Consult, 1992)

Fig. 7-5: Order of embankment construction by conventional method



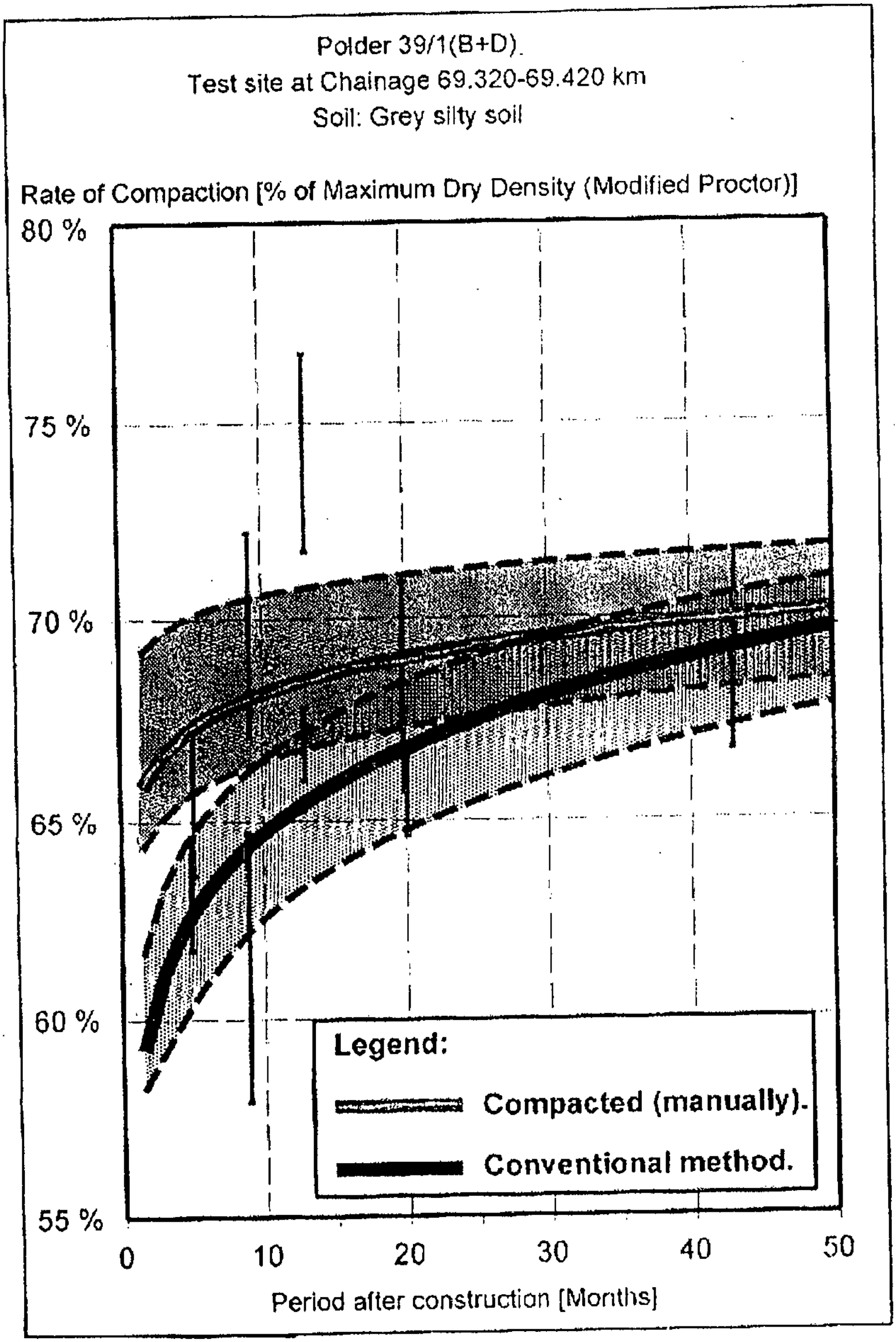
Filling order of embankments built according to the conventional method. First the core of the embankment is filled up by heaping soil quite haphazardly and without clod breaking or compaction. Next the slopes are built by throwing soil down from the top of the centre part of the embankment. Finally some clod breaking is done on the slopes and the top of the embankment, to create a smooth surface

Fig. 7-6: Modified sequence of embankment construction



Filling order of embankments built according to the manual compaction method. Soil is placed in layers not exceeding 15 cm in un-compacted height, starting from the riverside toe of the embankment and working towards the countryside toe. Immediately after the soil has been placed the clods are broken and the soil is rammed (manually compacted) to fill all the voids. After the first layer has been completed, the next layer is placed in a similar way, until the design crest level is reached. Finally, the surface of the slopes and the top of the embankment are smoothened.

Fig. 7-7: Comparative statement of compaction with time



(Source: Euroconsult, 1997b)

APPENDIX
Sample Questionnaire

SAMPLE QUESTIONNAIRE

1.0 PROJECT INFORMATION

1.1 Name of the project?

1.2 Location?

1.3 Rivers sorrounding the project?

1.4 Date of construction with length of completed embankment?

1.5 Details of embankment?

- (a) Crest height
- (b) Crest width
- (c) Slope inside
- (d) Slope outside
- (e) Materials used and their location
- (f) Flood frequency used
- (g) Freeboard

1.6 History of retirement?

1.7 Any unusual feature?

1.8 Erosion status and protective measures ?

1.9 Slope protective measures turf/afforestation ?

1.10 Details of water control structures ?

1.11 Area protected from flood ?

1.12 Details of irrigation ?

1.13 Crops grown during pre-project condition ?

1.14 Crops grown during post-project condition ?

2.0 PROJECT PLANNING.

2.1 When the project was initiated ?

2.2 Who initiated the project ?

2.3 Was there any pre-project meetting ?

2.4 Was there any discussion about Operation and Mintenance of the Project ?

2.5 Was there any discussion about income generation of local people ?

2.6 Was there any discussion about financing the Operation and Mintenance of the Project ?

3.0 BENIFITS AND DIS-BENEFITS OF THE PROJECT.

3.1 Is the project beneficial to the community ?

3.2 What are the disbenefits of the project ?

3.3 Who gets the benefits ?

3.4 Who are dis-benefited people ?

3.5 Is there any mitigation arrangement for the dis-benefited people ?

4.0 OPERATION AND MAINTENANCE OF THE PROJECT.

4.1 What are the present condition of the project components ?

4.2 Who does the operation of the project ?

4.3 Is there any committee for the the operation of the project ?

4.4 If so, who are the members of the committee ?

4.5 Is there any committee for the the maintenance of the project ?

4.5 If so, who are the members of the committee ?

4.6 Is there any other department involved in operation or maintenance of the project ?

4.7 If so, which function they are doing ?

4.6 Is there any NGO involved in operation/maintenance of the project ?

4.7 If so, which function they are doing ?

4.8 Who coordinates the activities of different organizations ?

4.9 In case of any conflict who resolves the conflict ?

4.10 Who pays for the operational expences ?

4.11 How frequently maintanance is done ?

4.12 Is preventive maintanance done ?

4.13 Is periodic maintanance done ?

4.14 Is emergency maintanance done ?

4.15 Who does the maintenance ?

4.16 From where the maintenance expenditure is borne ?

4.17 Do the beneficiaries pay for maintenance ?

5.0 INSTITUTIONAL FRAMEWORK OF THE PROJECT.

5.1 What are the organizations involved in the project ?

5.2 Is there any role of Deptt. of Fisheries ?

5.3 Is there any role of Deptt. of Forest ?

5.4 Is there any role of Deptt. of Livestock ?

5.5 Is there any role of Deptt. of Social Welfare ?

5.6 Is there any role of BRDB ?

5.7 Is there any role any NGO ?

5.8 Is there any role of local administration ?

5.9 Is there any role of elected representative ?

5.10 Is there any conflict between different organization ?

5.11 In case of any conflict, how solution is obtained ?