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INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

INTERNATIONAL DEVELOPMENT ASSOCIATION

PROPOSALS FOR AN ACTION PROGRAM

EAST PAKISTAN AGRICULTURE AND WATER DEVELOPMENT

VOLUME III

THE WATER PROGRAM

July 17, 1970

Special Projects Department

CURRENCY EQUIVALENTS

US$ 1.00	=	Rupees (Rs) 4.762
Rs 1.00	=	US$ 0.21
Rs 1 million	=	US$ 210,000

WEIGHTS AND MEASURES

1 Acre (ac)	=	0.405 hectare (ha)
1 mile (mi)	=	1.609 kilometers (km)
1 square mile (sq mi)	=	640 ac
	=	259 ha
1 foot (ft)	=	30.5 centimeters (cm)
1 long ton (lg ton)	=	1.016 metric tons (m ton)
1 acre-foot (ac-ft)	=	1,234 cubic meters (m^3)
1 cubic foot per second (cusec)	=	0.028 m^3/sec

(Local Units)

1 maund (md)	=	0.0367 lg ton
1 maund	=	82.2 lb

INITIALS AND ACRONYMS

EPADC - East Pakistan Agricultural Development Corporation
EPWAPDA - East Pakistan Water and Power Development Authority
IRRI - International Rice Research Institute, Philippines
PARD - Pakistan Academy for Rural Development (at Comilla)
SIDA - Swedish International Development Authority
TIP - Thana Irrigation Programme
UNDP - United Nations Development Programme
USAID - United States Agency for International Development
USGS - United States Geological Survey

GLOSSARY

aman - rice planted before the monsoon and harvested in November or December

aus - rice planted in March and harvested in June or July

boro - winter rice planted in October or November and harvested in March or April

khal - small natural water course

kharif - summer (wet) cropping season

rabi - winter (dry) cropping season

EAST PAKISTAN AGRICULTURE AND WATER DEVELOPMENT

PROPOSALS FOR AN ACTION PROGRAM

VOLUME III --- WATER PROGRAM

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CHAPTER 1

INTRODUCTION

1.01 Chapter 6 of Volume I contained a description of the water development program. In this Volume III the same program is described but in greater detail. Several of the larger projects (Pabna, Barisal, Little Feni and Comilla-Noakhali) have been divided into two phases and in Volume I the first phases of these projects were described. This volume contains further descriptions of these phases as well as particulars with respect to the later phases of these projects. In addition, this volume gives information on long-range aspects of water development and on specific studies needed in connection therewith.

Geographical Setting

1.02 East Pakistan, Pakistan's eastern province (area 55,000 square miles), is surrounded on the west, north and northeast by India, on the southeast by Burma, and on the south by the Bay of Bengal. Within the Province, the Brahmaputra-Jamuna, Ganges-Padma and Meghna Rivers join and flow into the Bay of Bengal. Over the centuries, these three rivers have built the largest and one of the most fertile deltas in the world. Ranging generally from sea level to 100 feet in elevation (with over half lower than 50 feet), this delta covers most of East Pakistan.

1.03 The drainage area of the three rivers covers 600,000 square miles but only 7.5 percent of this lies within East Pakistan. There are unfortunately no storage sites within East Pakistan that could assist in flood or low-flow regulation although feasible sites may exist within upstream riparian countries. The long-range technical problem is further complicated by the great magnitude of the peak flood flow (5 million cusecs or about twice the historical peak flood of the Mississippi River) and the enormous sediment load of the combined rivers, which is about 2.4 billion tons annually or greater than that of any other river system in the world. The enormous transporting power of the Ganges and Brahmaputra has resulted in major shifts of their channels in recent centuries.

1.04 Because East Pakistan depends on agriculture for economic survival, her flood and drought problems are particularly significant. In the last few years, floods caused East Pakistan to import about one million tons of rice per year to feed her population. In the future, flood control and irrigation will be even more important because, at the present population growth rate of about 3 percent per year, East Pakistan will have 120 million people by 1985. They will consume twice as much rice as they do now.

1.05 The cultivable area of the Province (excluding rivers, streams, roads, towns and villages) is about 22.5 million acres. About a third of this area (from 8 to 10 million acres) is flooded annually on the average by spills from the main rivers to the land and from the fact that local runoff from the heavy monsoon rains is backed up by flood levels in the main rivers; see Map 1. Some flooding is also caused by tributary streams draining hilly areas either within India, or within Pakistan but near the border.

1.06 In the coastal belt, a zone covering 3 million acres is subject to flooding from oceanic tides and tidal surges from typhoons. Depending on the time of the year and the flood flows in the rivers, the inundations vary greatly as regards the degree of salinity.

1.07 A total of 17 million acres (two-thirds the cultivable land) is subject from time to time to one of the foregoing types of flooding although the area flooded in any single year never has reached such a total. Because of floods, 1.7 million tons of rice were lost between 1954 and 1956, and 1.2 million tons were lost in 1962. The rice lost in 1962 had a value of $220 million.

1.08 Besides direct damage to crops, floods hamper rice production in other ways. In deeply flooded lands (over 15 feet as in the Meghna valley) farmers cannot grow any rice at all. In lands that are flooded from 3 to 12 feet, they can grow only low-yielding braodcast aman rice. Where flooding is from 1 to 3 feet, farmers grow higher-yielding aus and transplanted aman rice but they must accept risks from occasional higher floods or from drought and they cannot generally use fertilizers or improved seed effectively. The effect of flooding on land use is shown graphically on Map 1.

1.09 Rainfall in the Province averages 85 inches of which about 58 inches fall during the rainy season from May to October. The southeast monsoon brings rainfall averaging from 48 inches in the west to more than 100 inches in the Himalayan foothills. However even during the monsoon period because of irregular rainfall there may at times be insufficient water for crops. During the dry season, about 60 percent of the cultivated land is left fallow because of insufficient water. Residual moisture is the basis for the cultivation of the remaining 40 percent with relatively low-yielding pulses and cereals (mainly millets).

1.10 With water control (flood prevention, drainage and irrigation) coupled with modern agricultural inputs, the present agricultural production could be more than tripled.

Regions

1.11 One can divide East Pakistan into four roughly equal regions, based on hydrologic differences. The Brahmaputra-Jamuna, Ganges-Padma, and Meghna Rivers form the boundaries of the four regions: the Southwest, the Northeast, the Southeast and the Northwest. All four regions have severe winter droughts, and summer and early fall floods. In the Northwest, droughts are more serious than floods whereas in the Northeast the reverse is true. Both droughts and floods are serious in the Southeast and Southwest regions; the floods in these cases are mainly tidal in nature.

1.12 The Southwest Region, which covers almost 10 million acres, consists of Kushtia, Jessore, Faridpur, Khulna, Barisal and Patuakhali Districts. Each year, cyclones produce high tides in rivers emptying into the Bay of Bengal; tidal surges from typhoons sometimes reach up to 25 feet above sea level.

1.13 In the past, tidal floods especially hampered the agricultural output in an area of 3 million acres approximately contiguous with the latter three Districts and resulted in extensive salinization of the soil. Farmers planted transplanted aman rice in the wet season after the rains had partially leached the residual salts from the earth. In the winter, the drought and soil's excess salinity prevented farmers from growing any crops. For these reasons, only a single crop had been grown in these Districts (see Map 1). During the past 10 years considerable progress in the construction of embankments (see Coastal Embankment project described in Chapter 3) has protected an area of about 1 million acres from saline inundation with resulting increased yields in the transplanted aman crops. Within this zone, further increase in yields as well as the introduction of dry season crops by means of irrigation, to the extent that water can be made available, will come as a later stage. The remaining area of 2 million acres still suffers from tidal inundation but with the important difference that the flooding is from fresh rather than saline water. It seems likely therefore that dry-season irrigation should in this case come first and flood prevention as a later stage (see Chapter 3).

1.14 Although river and rain flooding are not as serious in the southwest as tidal inundation, they do harm much of this region's agriculture especially in the Faridpur and parts of the Barisal Districts. Distributaries from the Padma flow, such as the Arial Khan, periodically flood the latter two Districts. Because of these floods, Faridpur's yield of rice is only 75 percent of the East Pakistan average. Consequently, Faridpur's large population consumes more rice than her farmers can produce and the Government has had to import rice to feed the local population.

1.15 Drought rather than flood is a problem in Kushtia and Jessore Districts where ground elevations are higher. Cropping intensities average about 130 percent with considerable areas in rabi crops (pulses and sugarcane) that utilize (in late fall and early winter) residual moisture stored in the soil. Aus rice is another widespread crop in these Districts but yields are low due to dry conditions in the early part of the growing season. The Ganges-Kobadak irrigation project (Kushtia Unit) covers 0.35 million acres in Kushtia and the northern part of Jessore District (see Chapter 3 for detail). The Ganges-Kobadak development at its ultimate stage would cover a total area 2.6 million acres. The Government's intention has been to base this irrigation almost entirely on diversion of water from the Ganges River. The Government has in fact proceeded with design of a major barrage one of whose functions would be to facilitate such diversion. However, whether such an ultimate plan is technically and economically feasible is not yet clear. For one thing, an agreement with India would probably be needed with respect to water releases at the Farakka barrage and there are many other technical complexities to be worked out with respect to other effects of upstream diversions (includes increased saline water intrusion, reduced navigation depths and reduced yields from fishing) and with respect to possible counter-measures (such as use of return flow in downstream areas from upstream irrigation, possible closure of tidal estuaries and development of groundwater). (For further detail see Chapter 5 and especially the proposed special studies of the Ganges barrage, the Southwest region and the Brahmaputra-Ganges-Meghna Complex.)

1.16 The Southeast region (gross area 7.7 million acres) includes the Districts of Comilla, Noakhali, Chittagong and the Chittagong Hill Tracts. Tidal inundation is one of this region's major water problem. Much of this inundation is saline but some of this has been prevented by the Coastal Embankment project (Chapter 3) which extends in part to the Southeast region.

1.17 River and rain flooding and droughts also have harmful effects. The Meghna and Gumti Rivers flood large sections of Noakhali and almost all of Comilla. The Karnafuli, although in parts under control, and the Sangu River flood parts of the Chittagong and the Chittagong Hill Tracts Districts. The Southeast produces a large crop of broadcast aman in the summer and early fall when floods in some places reach depths of 12 to 15 feet. Because of droughts, farmer only produce a small winter rice crop and some rabi crops (from residual soil moisture). They also grow a small crop of transplanted aman in less flooded areas.

1.18 The high elevations in the Chittagong Hill Tracts and parts of the Chittagong Districts prevent floods from occurring, although winter droughts are still a problem. The soil here is sandier and has a different composition from the rest of East Pakistan, thus enabling farmers to grow citrus fruits and tea on the hills and cotton on the lower slopes.

1.19 The Northeast region (gross area 9.2 million acres) covers the following districts: Mymensingh, Sylhet, Dacca and the northern tip of Comilla. This region's topography, climate and rivers all contribute to East Pakistan's worst flood problem. The region includes the Sylhet Basin through which the Brahmaputra River flowed before it changed its course during the latter part of the eighteenth century. Much of the Sylhet Basin lies between elevations 10 to 20 feet as a result of 30-40 feet of subsidence that has occurred over the past several hundred years. Because of the plain's low relief, channels and basins are not deep enough to drain the Brahmaputra-Jamuna and Meghna Rivers' overflow during the monsoon season. Nor can they drain the monsoon rains averaging between 220 inches in northeastern Sylhet to 70 inches in Dacca.

1.20 Floods and droughts slow down agricultural production in this region. Meghna River Valley farmers cannot grow any variety of rice because floods rise to 20 feet here. Floods damage crops in Sylhet and Mymensingh. In Dacca, agricultural workers can double crop only 40 percent of their land. Dacca's large population consumes much more rice than the flood burdened District can produce. In the last few years, the Pakistan government imported rice to satisfy this population's needs.

1.21 Farmers in these zones adapt their agriculture to drought and flood conditions. Where flooding is infrequent, farmers grow jute, aus, and transplanted aman during the monsoon season. Where floods do not exceed fifteen feet, they plant broadcast aman. On the moist low lands, farmers grow boro in the winter. But in other areas, the drought prevents a boro crop. Sylhet's hills are not flooded and the hill soils have a different composition, thus permitting the East Pakistanis to grow tea and citrus fruits.

1.22 The ultimate solution of the Northeast region's water problems involves serious complexities. Aside from the areas of the Dacca Southwest, Dacca North projects and several small tributary projects in the extreme Northeast (total area about 0.7 million acres) plus some areas totalling perhaps 0.1 million acres suitable in the near future for groundwater development, the best method of proceeding in the rest of the region is uncertain at this time. A possibility that has been considered for many years but needs a great deal of further study is the diversion of a portion of the flow of the Brahmaputra River into its former channel (designated "Old Brahmaputra River" on Maps 1 and 2) and thence to the Sylhet depression; see Chapter 5 on description of the "Brahmaputra-Ganges-Meghna Complex".

1.23 The Northwest Region (gross area 8.5 million acres) includes the districts of Dinajpur, Rangpur, Bogra, Rajshahi, and Pabna. Drought is this region's most serious problem since the monsoon season is shorter here than elsewhere in the Province. The drought lasts seven months, and prevents farmers from growing a winter crop of rice except in a small portion of the lower-lying lands.

1.24 Floods are also a problem in the Northwest. While the right bank of the Brahmaputra-Jamuna has now been largely protected by an embankment (completed in 1968) the Teesta and Atrai Rivers continue to overflow. A large section of southeastern Pabna District suffers flooding from the Ganges each year (see Maps 1 and 2). As a result rice production is low and in the last few years the Government has imported rice to satisfy Pabna's needs.

1.25 Northwesterners adapt their farming to flood and drought conditions. In higher lands they grow only transplanted aman as there is not enough moisture to start an aus crop before the monsoons. In intermediate lands farmers grow aus or jute alone or double-cropped with aman or sugarcane. In low-lying lands they plant a mixture of broadcast aman and aus or broadcast aman alone (where flooding is deep).

1.26 As is generally found to be true in East Pakistan, the zones of flooding are also the zones where surface water is available for irrigation. In the Northwest region this applies particularly to the eastern part of Pabna District. Elsewhere in the region, surface water is scarce and irrigation will have to be based largely on groundwater. Fortunately, the outlook is favorable in a considerable part of the Province. A tubewell project (Thakurgaon) for the irrigation of a concentrated zone of 70,000 acres was completed in 1967. The Agricultural Development Corporation intends soon to proceed with a project for 3,000 tubewells at dispersed locations, mostly in the Northwest region; see Chapter 4.

CHAPTER 2

HISTORY OF WATER DEVELOPMENT

SUMMARY

i. Important construction efforts have been successfully carried out in East Pakistan but mainly with respect to single-purpose flood prevention projects. The achievement to date in this type of project amounts to about 1,000,000 acres protected against tidal flooding and a similar area protected against river flooding. Construction progress, while slow at first, has improved in recent years. The use of labor-intensive ("head basket") methods for the extensive earthworks involved are well suited to the local conditions of climate and labor supply.

ii. The execution of multi-purpose projects, involving three functions -- irrigation and drainage as well as flood prevention -- began about 15 years ago but has not made the rate of progress that had been hoped for since the achievement to date amounts to only about 60,000 acres enjoying benefits from all three functions. The disappointing results obtained thus far from this type of project has been due to a combination of factors among which probably the most important has been a lack of understanding of the the particular requirements of such projects under East Pakistan conditions. This understanding has however made important progress in the past few years and there is now keen realization that two key ingredients for success are: (a) a well integrated project organization capable of dealing with the farmers (the establishment of such an organization involves cooperation among several agencies including EPWAPDA, the Department of Agriculture, the ADC and the BD & LG Department) and (b) adoption of a method of irrigation distribution suitable to the conditions of small, fragmented landholdings that prevail. Several projects aggregating 450,000 acres have been prepared on the basis of these concepts and either are under construction or at the stage of final engineering design.

iii. Experience with the low-lift pump program of ADC (paragraph 2.14) indicates that East Pakistan farmers do in fact respond quickly when irrigation water is provided in the dry season. The area irrigated (mostly boro rice during the winter months) has grown from nil in 1962 to about 200,000 acres in 1966/67 and 700,000 acres in 1969/70. The areas irrigated by this means to date have been located along perennial streams where conditions have been relatively favorable. The stage will soon be reached when medium-scale civil works (i.e. EPWAPDA-type projects) will be needed so as to increase water availability and thereby greatly extend the area that can be irrigated by low-lift pumps. Such civil works will at the same time give major benefits through flood prevention, drainage, navigation and improved fish culture.

iv. The use of tubewells has resulted thus far in the irrigation of about 100,000 acres. A project for an additional 150,000 acres is just starting. It is noteworthy nevertheless that the exploitation of groundwater for irrigation has barely started in East Pakistan. As discussed later in this volume, as further knowledge and experience are gained, groundwater development is likely to grow in relative importance in the years ahead.

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2.01 Small-scale irrigation in the form of primitive lifting devices has a long history in East Pakistan in view of the lack of rainfall during the winter months. As these devices are inefficient and can lift only small quantities of water, the area cultivated in winter through such means has however remained small. The use of diesel-driven pumps, obtaining water from perennial streams, began in the early 50's and by 1955, 40 such pumps were operating. The East Pakistan Agricultural Development Corporation (ADC) was established in 1961. While its primary functions are the procurement and distribution to farmers of agricultural inputs (seeds, fertilizers, pesticides and agricultural machinery), ADC has also a highly important secondary function, namely the promotion of the development of small-scale irrigation by means of low-lift pumps and tubewells. ADC has been a main supplier and organizer since 1962 of portable, diesel-driven low-lift pumps which generally have a capacity of 2 cusecs and are almost entirely used only during the boro season being removed from the field at the end of this season. By 1966/67 a total of about 4,000 such pumps were supplied by ADC. In the 1969/70 season this increased to 18,000 pumps and the Government has plans to increase this up to 40,000 for the irrigation of about 1.5 million acres at scattered locations througout the Province. This is about the upper limit of area irrigable by low-lift pumps, unless assisted by larger scale civil works (see below and in Chapter 4).

2.02 Since a typical low-lift pump of 2-cusec capacity serves up to about 50 acres and since, with the small landholdings prevalent in East Pakistan this area can involve as many as 50 farmers, a key element is the organization of groups of farmers for the distribution and utilization of irrigation water. To assist in this objective at least insofar as the low-lift pumps are concerned, the Government a few years ago established the so-called Thana Irrigation Plan (TIP) 1/ under which the responsibility for forming pump groups, for providing and paying pump operators, for providing fuel and for collecting pump rental charges has been the function of the Basic Democracies and Local Government (BD & LG) Department utilizing the existing Union and Thana Councils. ADC's sole responsibility is thus the provision and maintenance of the pumps.

1/ See: Volume I, Chapter VII; also paras 4.05-4.09 below.

2.03 ADC in recent years has also become involved in the construction and operation of tubewells and has constructed 800 wells of 1.5 to 2-cusec capacity during the past 3 years. These are at dispersed locations rather than in a concentrated zone such as those of EPWAPDA (described below). As for the low-lift pumps, distribution to farmers' field channels is being handled under the TIP. IDA is processing a credit for 3,000 ADC tubewells to be constructed during the next few years; see Chapter 4 for further details.

2.04 Large-scale water development in East Pakistan began in the early 1950's. At that time after several years of studies, a team of UN experts proposed the Ganges-Kobadak project covering 1.9 million acres in the Districts of Kushtia, Jessore and Khulna. 1/ Continued assistance was provided by the Food and Agriculture Organization of the UN for this project, the Kushtia Unit of which was then started with aid in the form of foreign exchange provided by Canada and the United States. In 1954, 1955 and 1956 severe flood damages occurred and the Government of Pakistan again sought the assistance of the United Nations. A team of experts headed by J.A. Krug, former Secretary of Interior of the U.S.A., visited East Pakistan in late 1956. Their report known as the "Krug Mission Report" dated 1957 recommended the creation of an autonomous corporation to deal with water and electric power development. Such a corporation, known as the East Pakistan Water and Power Development Authority (EPWAPDA) was established in 1959.

2.05 Since EPWAPDA's establishment in 1959, six agricultural water projects have had primary importance, as follows:

<u>Completed projects</u>

Brahmaputra Right Embankment
Northern Tubewells (Thakurgaon)
Dacca-Demra

<u>Partially completed projects</u>

Coastal Embankments
Ganges-Kobadak, Kushtia Unit
Chandpur

The main emphasis thus far has been on single-purpose flood prevention projects, especially in the coastal area.

2.06 Among the six existing projects listed above, the coastal embankment project has constituted by far the largest effort. A sum of $200 million (total equivalent) has been invested since the project started in 1959. The principal source of financing has been rupees generated by the US PL-480

1/ Later increased to 2.6 million acres (ultimate); see Chapter 1.

program. The project will ultimately provide protection against inundation from oceanic tides in an area of 3 million acres sub-divided into 102 separate polders. Inundation is of two main types: saline and non-saline, with various gradations thereof.

2.07 Phase I of the project consists of 86 polders with an aggregate area of 2.0 million acres. To date 61 polders have been completed providing protection to an area of 1.0 million acres; the remaining 25 polders in Phase I are partially completed. Construction has consisted primarily of earth embankments. These have an average height of about 12 feet and their aggregate length is over 2000 miles. Numerous sluices have been provided through the embankments to provide outlets for interior drainage.

2.08 Although the project has provided important benefits through elimination of saline flooding, there have also been cases of negative benefits since farmers in some of the polders had previously been accustomed to using non-saline flood waters for irrigation. As a next stage of development, water management in the interior of each of the polders, coupled with agricultural inputs, would provide sizable benefits at relatively low cost. A program for such development is described in Chapter 3.

2.09 The second most important endeavor by EPWAPDA has been the GK-Kushtia project in which the total sum invested since 1959 has been $60 million total equivalent. Financing has been mainly from GOEP resources but with substantial foreign assistance from Canada and the United States. The purpose of the project is to provide irrigation and drainage and eliminate flooding in a gross area of 350,000 acres (120,000 acres in Phase I and 230,000 acres in Phase II -- only Phase I is in operation at present). Although the project is providing benefits, these have fallen short of expectations since irrigation is being provided for only 40,000 acres and even this occurs only at the end of and immediately following the monsoon season. This is because the project has suffered from several serious technical difficulties and because the type of irrigation distribution (conventional gravity system) adopted may not be suited to East Pakistan conditions (very small and badly fragmented landholdings). On the other hand, GK-Kushtia can still provide substantial benefits. The serious technical difficulties mentioned are in fact gradually being corrected; a stepped-up effort is needed however as discussed in Chapter 3.

2.10 The Brahmaputra Right Embankment project was constructed in the years 1964-68. This project for which IDA provided a credit of $5 million consists of an embankment 135 miles long and 12 feet high (average) and appurtenant structures consisting of drainage sluices. Protection against floods from the Brahmaputra River have been provided for 580,000 acres and important benefits are being realized, mainly through higher yields from transplanted aman rice rather than the lower yielding broadcast aman previously grown (see para. 5.04). As a next stage the protected area will require irrigation facilities probably by means of tubewells; see para. 4.30.

2.11 IDA has so far financed three water development projects in East Pakistan with a total of US$24.25 million of credits. Besides the Brahmaputra Embankment project these have included the Dacca-Demra and Chandpur projects. An IDA credit of US$1.0 million for Dacca-Demra was provided in 1961. The project provides partial flood protection and irrigation in an area of 15,000 acres. It was substantially completed in 1967 and benefits are now being obtained.

2.12 The Northern Tubewell (Thakurgaon) project was substantially completed in 1967. It consists of 365 electrically-driven relatively large-capacity (3 cusec) tubewells that will ultimately serve an irrigated area of about 71,000 acres. The project cost was Rs. 155 million and was assisted by two German loans totalling DM 22.2 million. As part of the project, a brick-lined canal generally several hundred feet long has been provided leading from each well. Since completion, additional expenditures for lining of field channels that take off from the brick-lined canal (the region is sandy) are being found necessary. Even after full development, the project will be costly whether measured in terms of cost per well or per acre irrigated. The long and narrow configuration of the project area and the dispersal of the well sites, coupled with the desire of providing social benefits through rural electrification are the apparent explanations of the high cost. EPWAPDA is now conducting studies that could lead to a more rational use of the electric transmission system through the addition of more wells. Irrigation and improved agriculture are being developed through cooperation with the Pakistan Academy for Rural Development at Comilla which has provided an extension director since mid-1966 and the crops that have been developed in the project area are generally good.

2.13 In 1963 IDA granted a credit of US$9.0 million for the Chandpur project, a combined irrigation and flood protection scheme covering 127,000 1/ acres. The irrigation features were dropped in late 1965 and the credit reduced to US$5.25 million. Work proceeded on the flood control features but these too were halted early in 1967 and the remaining proceeds of the credit were used to engage new consultants (in 1968) to assist in the preparation of a revised project which would restore irrigation as a primary feature of the project but on a substantially modified basis as compared with the original project. Whereas, under the original project, irrigation distribution was to have been accomplished by means of canals elevated above the terrain (which involve high construction costs and extensive land acquisition), the revised project would make use of natural drainage channels requiring the acquisition of very much less land. Water would be lifted from the drainage channels by means of portable low-lift pumps. Finally, flooding within the project area would be eliminated gradually over a period of several years to allow farmers time to adjust to the new cropping conditions provided by water control (see para. 5.04). In April 1970 IDA granted a credit of US$13.0 million to assist in financing completion of the Chandpur project, as revised.

1/ Later changed to 140,000 acres gross (75,000 acres net).

2.14 The idea of using low-lift pumps for irrigation distribution within polder-type projects such as Chandpur is a recent development since, as indicated above, low-lift pumps have been used on a significant scale in East Pakistan only during the past four or five years. The layout of field channels for water distribution within a typical 50-acre area served by a low-lift pump, while impeded by the fragmented holdings and small plots, is far less complex and less land consuming than what would be required for a conventional gravity system. 1/ Primarily because of quick benefits obtainable during the dry season, low-lift pump irrigation is catching on quickly in East Pakistan. Without sizable engineering works for primary pumping from the larger rivers however, the scope of low-lift pumping using perennial low flows of the smaller rivers is limited (the present estimate is about 1,500,000 acres). Besides simplifying land acquisition, the use of low-life pumps and natural channels for water distribution has several other important advantages.

> One advantage concerns conservation of water supply. Take Chandpur as an example. An embankment will completely surround the project area thus forming a "polder". Water will be introduced into the polder either by gravity (when river stages are high) or by means of a large primary pumping station (when river stages are low). Water thus introduced will be distributed throughout the polder via the natural drainage channels from which it will be relifted by the low-lift pumps. The waste water (water not actually consumed by crops) will return to the drainage channels but will never leave the polder. Water will thus be recirculated within a "closed system". (Waste water is very high -- as much as 75 percent of the water that is actually supplied to farmers' fields. The high wastage results from the fact that it is impracticable to install a rational distribution system because of the unusually small and fragmented holdings. In the Chandpur project area the average holding is 2 acres and this is fragmented into as many as 10 pieces.) The "closed system" differs from an "open system" of the gravity type (such as that of Ganges Kobadak project) wherein waste water leaves the project area.

1/ In the long run, once the value of irrigation is fully understood by the farmers they will gradually realize that not only can they irrigate and cultivate more efficiently if their holdings are consolidated but also that the system of water distribution can be simplified. Such simplifications would include: (a) more rational layout of field channels, thus reducing maintenance costs and water wastage; (b) replacement of some of the portable pumps by fixed installations of larger capacity serving a larger area, with resulting economies of scale (to accomplish this might require some gravity canals).

In the "closed system" the low-lift pumps recirculate waste water so that only "make-up" water needs to be supplied. The primary pumping station serving the closed system does not need to supply waste water as does one serving an open system. The make-up water equals in volume the crop requirements ("consumptive use") plus minor losses such as evaporation from the water surfaces of the drainage channels, seepage at the periphery of the polder and lockage losses (at navigation locks). While precise data are not now available it is certain that the aggregate of these minor losses is far less than the operating wastes associated with an "open system".

A second advantage is that farmers pay operating costs of the low-lift pumps including fuel. Subsidies to defray the cost will be heavy at first but will be gradually eliminated. The operating cost will thus act as an incentive to reduce water consumption.

A third advantage is that the closed system provides maximum flexibility enabling its use for a wide variety of crops. It can be expected that at least in the beginning high water-requirement crops such as boro rice will be introduced. Excessively large canals would be required with an open gravity system whereas, with a closed system, the natural channels (which supply only make-up water) can more easily supply the high-water-requirement crops.

2.15 Since its formation, EPWAPDA has devoted much effort to project preparation. Feasibility studies have been completed for more than 40 projects and are underway for about another 10 projects.

2.16 Following a request made in May 1968 by GOP to the Bank, the East Pakistan Agriculture and Water Development Bank Group conducted a review of 32 projects that EPWAPDA indicated should be considered for inclusion in the Fourth Five Year Plan (1970/75). This review involved an examination of feasibility reports for the 32 projects supplemented by field trips to most of the project sites and discussions with EPWAPDA and its project consultants. 1/ The review, which was completed in August 1969, confirmed an earlier judgement that had been reached by the Bank Group 2/ namely that, while the feasibility studies prepared by or for EPWAPDA up to that time contained much valuable information, there were certain deficiencies needing correction. Besides the problem of irrigation distribution,

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1/ Summarized in report entitled "Observations on Water Development Projects, Fourth Five Year Plan", October 23, 1969.

2/ Report of November 1967 Mission, May 21, 1968.

two matters that generally had not received adequate treatment were: economic analysis and project organization especially as regards agricultural inputs. (For more detail see Chapter 4 under Multi-purpose Projects.)

2.17 An opportunity to solve these questions in an integrated manner arose in 1968 in connection with the Chandpur project (para. 2.13). The consultants engaged at that time worked in close cooperation with the East Pakistan Bank Group in revising the project as regards irrigation distribution and organizational aspects. In connect with the latter, the consultants, following discussion with agencies other than EPWAPDA (e.g. the Agriculture Department and the ADC), recommended an organization that could deal with project implementation at the farmers' level. A revised feasibility study along these lines, which was completed in September 1969, formed the basis for an appraisal by IDA of the second construction credit for this project in the amount of $13 million (see para. 2.13). This credit will enable completion of construction (by EPWAPDA) as well as the establishment of a project implementing organization which the Government has decided will be the responsibility of the Department of Agriculture. The organization will include personnel for agricultural extension; plant protection; installation, operation and maintenance of pumps; and assistance to cooperatives. All such personnel will be deputed from existing Government agencies and will be under the control and supervision of a Project Director appointed by the Secretary of Agriculture. (For further detail on the Chandpur project see Chapter 3.)

2.18 A second case arose in mid-1969 in connection with the Dacca Southwest project (net irrigable area 270,000 acres). A feasibility study for this project, which covers an area about three times that of Chandpur, was completed in March 1968. The Bank after detailed evaluation of the available information concluded that Dacca Southwest was basically a technically and economically sound project, but that further work on organizational aspects, on the repayment problem and on certain technical features (especially as regards design of the flood embankments) would be needed prior to appraisal of a credit for capital investment. The Bank therefore proceeded to appraisal of an engineering credit which would allow the project to proceed to final engineering while concurrently revising the March 1968 feasibility study so as to eliminate its deficiencies. An IDA credit was granted in December 1969 in the amount of $800,000 for this purpose on the basis of which construction could begin January 1971 provided that financing can be arranged.

2.19 A similar IDA engineering credit in the amount of $2,400,000 covering the Karnafuli and Muhuri projects was granted in June 1970. The net irrigable areas are 67,000 and 42,000 acres respectively.

2.20 Besides the three construction credits (paras. 2.10, 2.11 and 2.13), the engineering credits for the Dacca Southwest project (para. 2.18) and the Karnafuli and Muhuri projects (para. 2.19), and the formation of the East Pakistan Bank Group (para. 2.16), there has been one further important item of assistance to EPWAPDA by IBRD/IDA. This has been the financing to the extent of US$2.0 million which together with $1,947,300 from the United Nations Development Program will pay for the foreign exchange cost of general consultants to EPWAPDA during an initial two-year period starting in early 1969. General consultants to EPWAPDA during the previous eight-year period (1961-68) had been financed by USAID. Advice on management aspects 1/ had been provided by a group of three specialists from the Department of Water Resources, State of California; this assistance, from 1965 to 1969, was also financed by USAID. The scope of work for the new general consultants, which is similar to that of the former one, includes assistance to EPWAPDA with respect to basic policy, plans and programs related to water and power development; also the development of an efficient organization to plan, finance, construct, operate and maintain water and power development projects. The General Consultants' assistance is divided into three parts: services to the Water Wing of EPWAPDA, services to the Power Wing and services to all parts of EPWAPDA in the field of management (the scope of work thus covers what had formerly been the concern of the California team). A highly significant part of the General Consultants' work is in the field of project preparation and final engineering. The General Consultants do not do this directly but rather through separate project consultants whose work the General Consultants assist in monitoring. The General Consultants also assist EPWAPDA in the drawing up of specific terms of reference for the project consulting firms, in their selection and in review of qualifications of the specialist personnel actually assigned.

1/ Included: development of program and project controls; improvements in accounting procedures and inventory controls; and improvements in organizational structure and in personnel development including staff training.

CHAPTER 3

INCREASING OUTPUT FROM EXISTING PROJECTS

Coastal Embankments

3.01 Among the six principal existing projects, the Coastal Embankments is by far the largest. A sum of $200 million (total equivalent) has been invested up to now. The project has thus far concentrated on flood protection against oceanic tides. Despite benefits obtained from such protection, much larger benefits could be obtained through interior water management and provision of agricultural inputs. Water management would have several facets including: (a) introduction into the polders of non-saline river water and its distribution by various means; (b) conservation of natural rainfall mainly through adoption by farmers of proper cultural practices; and (c) development of deep as well as shallow groundwater to the extent available. Preliminary information is available with respect to the extent of areas that could be developed by the first means -- it might cover 1.5 million acres or about half the total area of the coastal embankments. Closure of some of the tidal estuaries might extend this area considerably but the feasibility of such schemes can be determined only after detailed study (see water study of the Southwest region, described in Chapter 5). The extent to which the other two methods are applicable is not known at the present time.

3.02 Because of its size (3,000,000 acres of which 1,000,000 acres now have flood protection with the embankments for an additional 500,000 acres partially completed), remoteness, and various technical and sociologic complexities, the Coastal Embankment area will require special treatment and effort. Such special effort appears well justified in view of the large potential of the area and the relatively low capital investments required. The speed with which the potential of the area can be realized will depend primarily on the resolution of organizational and institutional problems. The Bank is prepared to send to Pakistan a special mission to assist the Government in formulating, in the first instance, the institutional framework needed. Concurrently, "pilot polders" for demonstrating the value of water management and agricultural inputs can be advanced as well as technical studies for their gradual extension to a major part of the entire coastal embankment area.

3.03 Phase I of the Coastal Embankment Project consists of 86 polders enclosing an aggregate area of about 2 million acres. As of July 1970, 61 polders will have been completed, enclosing about 1 million acres. Of the remaining 25 polders, some construction has been started on 17. "Group A" designates the Phase I polders which are either completed or started (78 polders covering 1.5 million acres) while "Group B" designates the 8 remaining polders (covering 0.5 million acres) not yet started. The Group A polders are scheduled for completion by EPWAPDA in 1970-71 and 1971-72 at a cost of $40 million. These polders have had public acceptance in varying degrees.

3.04 The Group A polders need additional project planning and water management to mitigate the loss of beneficial fresh river overflow in some areas and to increase the water supply and management in all the polders. The Group B polders have been deferred due to unacceptance by the public primarily because they would interfere with freshwater inflows during October and because intensive polder planning will need to be completed before construction can properly resume. For these reasons construction expenditures will be minimal in Group B for the next three years with emphasis on project planning as is indicated in Table 1.

3.05 Phase II construction would be deferred to permit polder by polder project planning and management studies to be completed with a construction start scheduled for 1972-73. An overall management assistance program, including all facets of implementation from management of water supply, operation of physical works, agricultural extension through advisory services at all levels has been programmed for the entire Coastal Embankment project as indicated in Table 1. The management assistance program, together with the project planning studies now proposed, would be directed toward solving the many problems of project implementation including the development of a viable overall organization to direct the project.

3.06 The following paragraphs described each of the foregoing items in greater detail.

3.07 Phase I, Group A: This designates the 61 completed Phase I polders (area 1.0 million acres) and the 17 that have been started but not completed (area 0.5 million acres). Generally these polders have been in zones of saline or brackish water. Important benefits have resulted from elimination of this type of flooding. Construction forces are already mobilized (mainly manual labor recruited locally) and EPWAPDA is anxious to complete the 17 polders during the 1970/71 and 1971/72 seasons. Whether or not "water management" (see para 3.11) can be applied rapidly to the Phase I Group A polders is in doubt pending further study. The costs in Table 1 provide for (a) completion of the embankments in these polders (cost $40 million total equivalent) and (b) studies of interior water management (cost $1.4 million total equivalent) but no capital investments for this purpose pending the results of the studies.

3.08 Phase I, Group B: These 8 polders, which cover 0.5 million acres, are in zones of relatively fresh water. Since farmers now depend on these fresh water inflows and since there has been opposition to construction of these polders, it seems clear that for their development "water management" (para 3.11) will have to be planned concurrently. Funds programmed for Group B in Table 1 ($40.0 million total equivalent) would be utilized primarily for polder-by-polder planning for the first two years (170/71 and 1971/72) and for construction which would start about January 1973 and might be completed in 1978/79. The actual rate of implementation would depend largely on the resolution of organizational and institutional questions (see para 3.13). In Table 1 programming has been assumed as follows:

	Start	Complete	Cost (millions)
Polder by polder planning	1/7/70	30/6/72	$ 3.3
Stage 1 construction	1/9/72	30/6/75	18.3
Stage 2 construction	1/7/75	31/12/78	18.4

3.09 Phase II: Considerable parts of the Phase II area are known to be in freshwater zones. It is likely therefore, as in the case of the Barisal region (see Chapter 4), that low-lift pumping should constitute the initial stage of development with embankment construction coming later. Table 1 indicates an initial period of project planning during the years 1971 to 1974 ($1.5 million total equivalent) with capital investment starting September 1972 and extending (in two stages) until June 1978. As for the Phase I Group B polders, water management would be concurrent (or might precede) embankment construction. The sum of $60.0 million (total equivalent) is estimated to be enough to cover the full capital investment cost for about two-thirds (i.e. 670,000 acres) of the Phase II area including interior water management as well as flood-prevention embankments.

3.10 Overall management assistance: An overall management assistance program, including all facets of implementation from management of water supply, operation of physical works and agricultural extension through advisory services at all levels has been programmed for the entire Coastal Embankment area as indicated in Table 1 ($7.7 million total equivalent). The management assistance program, together with the project planning studies described above, would also have as an objective the development of a viable organization to direct the overall activities needed for development of the entire 3 million acres in the Coastal Embankment area.

3.11 Water management: As has been indicated in para 3.01, "water management" and the provisions of agricultural inputs are needed to realize the full potential of the Coastal Embankment area. 1/ Water management

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1/ This has been the opinion of several technical groups including the consultants engaged by EPWAPDA (Leedshill-Deleuw) and the ECAFE Advisory Group on Development of Deltaic Areas; see their report of February 1966 "Appraisal of Some Aspects of the Coastal Embankment Project of East Pakistan".

would have several facets including: (a) introduction into the polders of non-saline river water and its distribution by various means; 1/ (b) conservation of natural rainfall mainly through adoption by farmers of proper cultural practices; and (c) development of deep as well as shallow groundwater to the extent available. Preliminary information with respect to the extent of areas that could be developed by the first means indicate that it might cover 1.5 million acres or about half the total area of the coastal embankments. Closure of some of the tidal estuaries might extend this area considerably but the feasibility of such schemes can be determined only after detailed study (see water study of the Southwest region described in Chapter 5). The extent to which the other two methods are applicable is not known at present but would be determined in the course of the planning studies described in paras 3.07, 3.08 and 3.09 above.

3.12 Organizational and institutional problems: Although the problem of water management is in part technical, it also has important organizational and institutional aspects since to solve it will require close cooperation among EPWAPDA, the Department of Agriculture, the Basic Democracies and Local Government (BD & LG) Department, the ADC and the Thana Irrigation Program (see Volume I, Chapter VII).

3.13 Organizational and institutional problems are involved not only with respect to the implementation of water management but also as regards the provision of agricultural inputs. These matters may be somewhat more complex than elsewhere in East Pakistan owing to the remoteness of the area and generally poor communications. Land-tenure factors may also be a complicating feature as there are many relatively large holdings and share-cropping is quite prevalent. The study given thus far to the organizational problem (mainly by Leedshill-Deleuw) has indicated, as a possible approach, the setting up of a series of "Working Units" and "Task Forces" which would deal both with water management and agricultural inputs. Space does not permit a full description of the scheme, which still needs further discussion and acceptance in any case. A summary of the scheme is as follows:

a. A "Working Unit" would deal with 2000 acres at a time and would consist of a Planning Unit, a Construction Unit and an O & M Training Unit (total personnel 32 of which, 3 professional level, 8 sub-professional and the rest clerical and/or unskilled).

1/ By manipulation of gates on drainage sluices, fresh water can be allowed to enter most polders during high tide. This is however not as easy as it sounds. There are many variations and combinations of factors involving characteristics of the tidal cycle, amount of fresh water discharge, degree of salinity and local topography. Thus each polder will require detailed study.

b. A "Task Force" would supervise the work of 5 Working Units. The Task Force would be composed of 7 officers as follows:

1 Leader
1 Assistant Engineer
1 Thana Agriculture Officer
1 Thana Irrigation Officer
1 Thana Cooperative Officer
1 Circle Officer (Development)
1 Representative of Pakistan Academy for Rural Development (Comilla)

c. The 5 Working Units under the Task Force would deal with only 10,000 acres initially but each year they would move on to new areas and eventually (during a period of perhaps 10 to 15 years) would cover 150,000 acres.

d. There would be 5 Task Forces and 25 Working Units initially. This would be expanded gradually to 20 Task Forces and 100 Working Units so as to cover eventually the entire 3.0 million acres in the coastal embankment area. The total manpower required would thus be:

140 Officers (for 20 Task Forces)
300 Professionals (for 100 Working Units)
800 Sub-professionals (for 100 Working Units)
2,100 Clerks and unskilled (for 100 Working Units)

e. The initial 5 Task Forces and 25 Working Units would employ "Pilot Polders" as a training and demonstration device. One such pilot polder is already in existence.

3.14 Relationship with Southwest Region Water Study: The proposed Southwest Region Water Study would be carried out concurrently with the studies and investments described in the preceding paragraphs. Since, however, the water study would take about five years it would not greatly affect these studies and investments which would be well underway by the time the water study is completed. On the other hand, the studies and investments would produce a feedback of information that would be utilized in the water study.

3.15 Special Bank Mission: Work in the Coastal Embankment area thus far has been carried out almost exclusively by EPWAPDA and its consultant, Leedshill-Deleuw. From the foregoing discussion of organizational and institutional problems, it is clear that solution of these problems will require close and intensive inter-agency cooperation as well as continued use of expatriate consultants. The precise methods for achieving the needed inter-agency cooperation has however not been worked out. To assist in formulation of a possible framework for such cooperation, the Bank has offered to send to East Pakistan a special team that would be composed approximately as follows: an agriculturist, an agricultural economist, an agricultural engineer with knowledge of irrigation and drainage, a rural sociologist and a public administration specialist. The tasks of the team would be: (a) to conduct a reconnaissance in the field; (b) to conduct discussions with the various GOEP agencies concerned and to obtain their preliminary agreement with respect to the organizational and institutional setup that might ultimately be desired for the entire Coastal Embankment area; and (c) to draw up terms of reference for the consultants that would be needed to assist in the project planning, actual implementation and overall management as has been discussed above in paras 3.07-3.12.

3.16 The above three tasks would require a time period of about a month. Another month would be needed for preparation by the team (in cooperation with the East Pakistan Bank Group) of a report setting forth conclusions and recommendations regarding the organizational and institutional setup, and the terms of reference for the consultants (items (b) and (c) in the preceding paragraph). In view of the previous discussions that the team will have had in East Pakistan, it should be possible to reach final agreement regarding the conclusions and recommendations of the team's report in a fairly short time -- say, two months. Steps required for the engagement of the consultants as well as arrangements for their financing could proceed concurrently and it might be possible for the consultants to begin their work by the beginning of 1971 or shortly thereafter (a starting date of January 1, 1971 has been indicated in Table 1). As described above (paras 3.08 and 3.09), the major capital investments for Phase I, Group B and for Phase II would not be needed before January 1973 in both cases.

Ganges-Kobadak Project (Kushtia Unit)

3.17 As already mentioned (para 2.09), the investment made to date in the GK-Kushtia project has been substantially under-utilized. Although the technical difficulties that impede efficient operation of the project are gradually being solved, a stepped-up effort is needed as well in the organizational and management fields as in the technical field. It would then be possible on a progressive basis to achieve a substantially large increase in the area irrigated and thereby the benefits from the project. To accomplish this it would be necessary to employ a consulting firm to be charged with management of the project which would include a determination of how the project must be modified so as to improve the operational efficiency of facilities to prevent waste and losses of water, improve water deliveries to the farmers, improve use of water on the farm, train personnel and establish repayment for water deliveries on an equitable basis.1/

1/ Province-wide approaches to the problem of project-cost repayment would be part of the Comprehensive Study described in Volume I.

3.18 Agriculture in the area is in a transition period. Farmers are very slowly shifting from the old rainfed and risky subsistence farming to a more modern irrigation farming. Irrigation, drainage and flood prevention offer the possibility of replacing the old monsoon pattern of broadcast mixed aus and aman paddy on intermediate land -- and broadcast aman on low land -- by broadcast or transplanted aus, followed by transplanted aman. The following paragraphs contain further detail on the current problems concerning the GK-Kushtia project.

3.19 Phase I: The construction of Phase I was started in 1955 and the physical works are substantially completed. The essential components of Phase I (net irrigable area 120,000 acres) are:

(a) A pumping plant near Bheramara, consisting of a main and subsidiary pumping station together with a power plant.

(b) A canal system consisting of an intake channel, a main canal with appurtenant structures, and a system of secondary and tertiary canals and field distribution channels. At about 6.5 miles from the pumping station the main canal -- called the Ganges canal with a capacity of 5,400 cusecs -- bifurcates into a branch canal called the Kushtia canal (capacity 1,200 cusecs) which conveys water into the Phase I area. The other branch (4,600 cusecs capacity) is still called the Ganges canal initially and, further downstream, the Alamdanga canal; it conveys water to the Phase II area.

(c) A flood embankment along the Ganges and Gorai rivers protecting both Phases I and II from inundation by the Ganges river.

3.20 The major problems requiring solution with respect to Phase I are summarized as follows:

(a) Up till now the number of acres actually irrigated is around 40,000 acres of which the bulk consists of transplanted aman. The area irrigated during the dry season -- the winter months December, January and February and the summer months March, April and May -- remains very small (only about 4,000 acres). The main reason is that the farmers have no confidence regarding the reliability of the water supply and choose to grow rabi crops (mainly pulses and wheat) on residual soil moisture. During the early kharif season (April-June) the most suitable crop would be transplanted aus of an improved variety, such as IRRI aus from which a yield of over 60 maunds could be obtained. This is, however, a delicate plant and only the larger, more progressive farmers would be willing to risk planting it. The next most suitable crop would be a local variety of transplanted aus giving a yield of 35 maunds. However, the farmers, in general, prefer to stay with rice crops basically dependent on monsoon rains with only supplemental irrigation from the project. They are thus not prepared to plant rice crops, such as transplanted aus, that would be largely dependent on irrigation, at least during the pre-monsoon months of April and May. As already stated, this is because they do not as yet have confidence regarding the reliability of the water supply.

(b) The reasons for the unreliability of the water supply provided by the Ganges-Kobadak canal system are: first, the main pumping station is still not functioning properly and, second, the canal system is not able to operate at partial capacity. The current problems concerning the pumping station may be summarized as follows:

(i) Two pumphouses, the main pumphouse and the subsidiary pumphouse serve the Kushtia Unit. The main pumphouse, comprising 3 Hitachi turbine pumps each of 1,300 cusec capacity has a 10-year history of difficulties. Pump No. 2 was commissioned in May 1969 and Pumps Nos. 1 and 3 in March and April 1970 respectively. Structural settlement problems affecting the three pump units remain unresolved. Installation of some auxiliary equipment is till outstanding.

(ii) The subsidiary pumphouse comprises 12 Stork mixed flow vertical pumps each of 116.5 cusec capacity. This installation was originally constructed to provide temporary water to the developed sectors of Phase I on an interim basis whilst awaiting completion of the main pumphouse. It now suffers from frequent breakdowns, requires constant maintenance and is considered unreliable.

(iii) The power supply for the pumping station remains shaky. A report prepared October 1969 by EPWAPDA's general consultants suggested three alternative solutions, of which one involves obtaining power from a 90-mile long 132-KV transmission line which is however considered an unreliable solution. The other two alternatives involve installation of an additional generator at the Bheramara power station which is adjacent to the pumping station.

However, this may also be less than acceptable considering that the station is rather old and does not appear to be well maintained. One of the two existing generators has been out of operation for two years. If the Brahmaputra River interconnector were constructed the problem of power supply might be easier to solve; however, the status of this interconnector is now in doubt and in any case several years of construction time would be required.

(iv) The intake channel from the Ganges River, serving both pumphouses, is subject to heavy siltation and must be dredged between October and March annually. Annual deposits range from 12 to 18 feet in thickness, so that water supply to the Kushtia Unit must be regarded as unreliable during the dry winter season due to intake channel blockage by siltation. The dredging of the channel consitutes moreover a heavy annual operating cost and spoil disposal areas utilize valuable land. A special study of this problem is needed including a physical model of the intake channel to determine how best to reduce the existing serious siltation.

(c) The project canals (which are intended to distribute water to the project area entirely by gravity) have been designed in such a way that full command can only be obtained at full supply level. Basic to the canal design has been the introduction of "downstream water control" to be effected by self regulating hydraulic gates and lower category canal offtakes directly downstream of these gates. For a number of reasons this system has not been successful. Therefore, in periods of low demand, the project cannot be operated with partial supply, but has to be operated on a part time basis. This is considered unsatisfactory by the water users and moreover results in high operational losses. To run the project with partial supply would require raising of the canal banks. It would appear urgent to do this as otherwise it would be difficult to make a start in providing a reliable water supply especially during the summer months.

(d) Seepage losses in the major canal system have been very large. The situation has improved in the course of the years but accurate data on the canal seepage is not available.

(e) The detailed irrigation canal network shows certain deficiencies, in particular with respect to the capacity of the tertiary canal offtake-structures (outlets to the fieldchannels) which under development of a modern cropping pattern appear to be too small (see also (g) below). These have a capacity of only one cusec per 100 acres which is much less than what has been found (for example) to be needed for boro irrigation with low-lift pumps, namely 2 cusecs for 50 acres. Also the number of these structures may have to be increased to promote an efficient distribution of water amongst the farmers of an outlet unit.

(f) An assessing board, working in the years 1966 through 1968, estimated that the operation and maintenance costs of the project would be from Rs 70 to 80 per acre. The board recommended a water charge of Rs 3 to 21 per acre. No charges have been collected so far. The collection of water charges would seem to be important not only to provide revenue but also to provide an economic incentive tending to reduce water wastage and improve irrigation practices.

(g) Recent studies of cropping patterns and water requirements indicated that no more than about 60 acres can be irrigated during the "summer months" of April-June (also called "early kharif season") per cusec of main-canal capacity.1/ Since the capacity of the Phase I canal is only 1200 cusecs, this would limit irrigation during these months to about 72,000 acres. The canal capacity of 1,200 cusecs would however be ample to irrigate the entire Phase I area (120,000 acres net) at other times. This raises the question of whether tubewells might ultimately be a valuable supplement to achieve full summer irrigation. Tubewells might also provide an economic means of achieving re-use of water from the main pumping station which is now wasted either from canal seepage or from farm losses due to the flood-irrigation methods now utilized. Further detailed studies of soils, cropping patterns and water requirements are needed before

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1/ The number of acres irrigable per cusec of lateral-canal capacity is actually unknown and may be substantially less. This is a matter requiring further study. Farmers in the GK-Kushtia area, as elsewhere in East Pakistan, practice "flood irrigation" whereby individual plots are flooded and downstream plots often get no water until the water demand of upstream plots have been fully met. This kind of flood irrigation could theoretically be eliminated by installation of a rational system of field channels but in practice this is rarely attainable owing to the small, fragmented landholdings (not as bad however in GK-Kushtia as elsewhere in the Province): see also para. 2.14).

this question can be answered; it might however be practicable to obtain interim answers indicating that there should be no delay in installing tubewells in those parts of the project area that cannot be served by the canal system.

3.21 Phase II: A recent review of soils information has indicated that (a) some clearly defined areas should be excluded from irrigation e.g. the area designated as Bhairab association with a poor irrigation capability; and (b) some overall reduction of the remaining gross area should be allowed for, in particular, ridge-land association and small uneconomic water management areas. This reduces the net area to be irrigated for Phase II from 230,000 to 195,000 acres. If Phase I takes 1,200 cusecs and if the primary pumping station capacity is 3,900 cusecs (subsidiary station for standby use only) the capacity available for Phase II is 2,700 cusecs. Using 60 acres/cusec for early kharif irrigation as for Phase I, gives 162,000 acres irrigable in Phase II. (The balance of 33,000 acres could presumably be irrigated by tubewells.) However, as indicated above, the primary pumping station capacity is not yet firm. The extent of seepage in the Ganges and the Alamdanga canals (para. 3.19) as well as the other Phase II canals comprise further unknowns. The resolution of these problems as well as progress in organizing farmers' outlet groups may take some years to work out. A possible way to proceed could be to achieve at least partial use of the existing facilities by admitting water into the canal system even if only to ground level and then lift water out of the canals by portable low-lift pumps.

3.22 As of February 1970, the status of construction for the physical works of Phase II was as follows:

Main Canal (Start 1960-61)	75 miles	70%
Secondary Canals (Start 1960-61)	189 miles	40%
Tertiary Canals (Start 1961-62)	272 miles	14%
Field Channels	1606 Nos.	0%
Drainage Channels (Start 1961-62)	457 miles	6%
Hydraulic Structures (Start 1966-67)		
Regulators	203 Nos.	36%
Escapes	9 Nos.	59%
Syphons	236 Nos.	12%

3.23 The wide dispersal of effort over the entire Phase II area is noteworthy. On orders from the Chairman the number of Divisions assigned to complete the work was doubled (to 6) but commensurate funds to utilize this increased manpower capability were not made available. Consequently personnel have been substantially under-employed.

3.24 Agricultural extension: EPWAPDA now provides agricultural extension services in the GK-Kushtia area. EPWAPDA's extension service organization is headed by an Extension Director who is assisted by two Extension Officers. In addition there are two Agricultural Officers, and two Extension Overseers in each Thana and one Extension Overseer per 1,500 acres. Training of model farmers and managers of cooperative societies has been initiated. FAO established at Baradi in 1967 a training center for the purpose of training lower grade extension workers.

3.25 The change from traditional crop patterns is not being effected easily and it is acknowledged that education of the farmer is a prerequisite to success of the project. Cooperative societies have been given assistance covering all aspects of farming such as credit, irrigation and drainage. Cooperative societies, the organization of which has been started in a number of Thanas meet weekly and are guided by the Extension Overseers. These Overseers constitute the link between the farmer and the EPWAPDA operating and maintenance staff in the field. While recognizing the essential nature of agricultural extension to success of the project, it must also be recognized that until and unless a reliable water supply can be provided during the rabi and early kharif seasons, efforts in agricultural extension alone are likely to be considerably less than would otherwise be the case.

3.26 Conclusions on Phases I and II: These may be summarized as follows:

(a) It is important that benefits from the Kushtia Phase I Unit be substantially increased at an early date. It is likewise important to get at least a partial utilization of the Kushtia Phase II Unit.

(b) Terms of reference should be prepared for the engagement of a consulting firm covering the fields of engineering, agriculture, agricultural economics and project management. The firm would be charged with the studying of the project and expediting means of getting the desired results. In preparing these, the terms of reference in the Bank's November 1967 mission report as well as the comments made herein should be taken into consideration.

(c) Collection of water charges would promote efficient use of the project while providing needed revenue. See para. 3.20(f).

(d) The use of groundwater, if only on a supplemental basis, should be considered in both the Kushtia Phase I and Phase II Units; see para. 3.20(g) above. Use of groundwater in any part of the GK area should not be construed as indicating a lesser need for diversion of surface water from the Ganges River. This matter will have to be studied on a broad basis to include, for example, saline-intrusion effects. Such a broad approach would be followed in the proposed Southwest Region Water Study; see Chapter 5.

(e) The costs indicated in Table 1 are for the following:

(i) Part (a) involving $6.0 million total equivalent would cover about 1,000 low-lift pumps supplied from the existing canal system and 200 tubewells plus some improvements of the existing canal system to enable dry-season irrigation of about 50,000 acres within a few years.

(ii) Management assistance including engineering and agricultural aspects as outlined above; cost $2.0 million total equivalent.

(iii) Completion of Phase II at an estimated cost of $26 million total equivalent. This work would be scheduled to start July 1, 1973.

Chandpur Project

3.27 Some description of this project has already been given in paras. 2.13, 2.14 and 2.17. The major works of the project include a peripheral embankment 60 miles long, from 10 to 15 feet high and with a crest width of 14 feet (wide enough for vehicular traffic); an irrigation cum drainage pumping station with 6 units having a combined capacity of 1,135 cusecs; an outlet regulator (for drainage) containing four 30-feet wide by 15 feet high gates; and 2 navigation locks, one adjacent to the pumping station and one to the outlet regulator, each 100 feet long and 20 feet wide.

3.28 As already mentioned (para. 2.13), irrigation distribution will be accomplished by making use of the natural drainage channels. When exterior water levels are sufficiently high, these channels will be filled by gravity with water admitted by operating gates at the pumping station as well as the outlet regulator gates. When the exterior levels are low, the pumps at the pumping station will be operated. The water will be lifted from the drainage channels by diesel powered 2-cusec pumps operated by TIP irrigation groups (see para. 2.02).

3.29 Thirty-one miles of the peripheral embankment have been completed to date. Contracts were awarded in early 1970 for the pumping station and outlet regulator and for the mechanical and electrical equipment involved; these structures govern the overall construction schedule and are expected to be completed by the end of 1972.

3.30 The planning, design and organizational concepts that have now been embodied in the Chandpur project (paras. 2.13 and 2.17) are expected to find quick acceptance by farmers of the benefits resulting from comprehensive water control (irrigation, drainage and flood prevention). A principal reason is that with water actually available throughout the project area (via the drainage system), farmers will actually see water during the dry season; this should convince them rapidly regarding the reliability of the project's water supply -- a feature that has been lacking, for example in the Ganges-Kobadak project described above. (That farmers react positively to ready availability of water during the dry season has in fact already been proved by the success of the low-lift pump program; see para. 2.01.) A second reason is that the use of the drainage channels means that far less land acquisition will be required than for a system of gravity canals; this should also promote farmers' confidence in this zone of extremely dense population. Finally, the fact that flooding will not be eliminated too abruptly will give farmers time to readjust their kharif season cropping from broadcast to higher-yielding transplanted aman.

3.31 Chandpur has been able to gain in other ways from the Ganges-Kobadak experience. The pumping units in the Chandpur pumping station will be of relatively simple design -- perhaps a bit less efficient in a strictly technical sense than those of the Ganges-Kobadak project but on the other hand easier to maintain and operate and better suited to East Pakistan conditions. The Chandpur pumping station will also be located on a relatively stable water channel (the Dakatia River) and will not suffer the serious siltation problems that have afflicted the intake of the Ganges-Kobadak pumping station.

3.32 The appraisal report, on the basis of which IDA in April 1970 granted a credit of US$13.0 million and which is included in Volume IV, indicated that the economic rate of return of the project would be about 22 percent. In this calculation the cost of farm family labor was included; if omitted the rate of return would be considerably higher. The appraisal report also estimated that the net value of production per acre would increase from Rs 425 without the project to Rs 1,411 with the project, an increase of 232 percent. Despite the increase and considering that the average farm holding is only 2 acres per farm family, the fact remains that even with the project the standard of living of an average farm family will remain low.

3.33 With respect to recovery of project cost, under existing TIP procedures, the cost of operation, maintenance and replacement of low-lift pumps are to be fully recovered by a "rental charge" collected by the Thana associations. In agreeing to the IDA credit, the Government assured IDA that rental charges would be collected on a graduated scale rising to a level sufficient to ensure recovery by the tenth year of full annual operation, maintenance and replacement cost which will amount to Rs 47 per acre. The cost of fuel estimated at about the same amount per acre will be paid directly by the pump group members. The cost of operation and maintenance of the major project works is estimated at about Rs 15 per acre; the Government agreed that they would determine within an 18-month period how this charge could be collected.

3.34 With respect to repayment of capital cost, the Government agreed to give this further study. In actuality this question will form part of a Province-wide investigation to be assisted in part by the Comprehensive Study described in Volume 1.

3.35 The fact that the Chandpur project area is already densely populated and that the population will continue to rise present a problem which is not limited to the Chandpur area and is typical of East Pakistan generally. There will be continued pressure on the land not only for agricultural production but also for additional rural housing and for roads. These problems which have no easy solution will require further investigation and long-range planning as described in Volume I in the chapter on the Comprehensive Study.

3.36 The planning concepts involved in the Chandpur project represent nevertheless an important step forward. It should be borne in mind that a completed comprehensive project such as Chandpur does not yet exist in East Pakistan. Successful and rapid implementation of the Chandpur project thus has crucial importance since it will assist in bringing to light problems still requiring solution with respect to the many projects similar to Chandpur to be undertaken in the near future.

CHAPTER 4

NEW PROJECTS -- SHORT RANGE

Low-lift Pumps

4.01 The history of small-scale irrigation including low-lift pumps has been described in Chapter 2. To assist in the evaluation of the potential for low-lift pumps, the East Pakistan Bank Group in 1968/69 made an evaluation of the quantity of surface water available for such pumping. Two criteria were used: (a) a mileage criterion whereby 5 low-lift pumps would be placed per mile of suitable and accessible streambank (many portions of the streambanks, especially of the principal rivers, are not suitable for locating low-lift pumps because of sand accretions; these often have transverse dimensions of from several hundred feet to more than a mile, which is beyond the operating capability of the low-lift pumps. and (a) a flow criterion whereby no more than 60 percent of the dry-weather flow of the stream would be utilized at any one time with the other 40 percent reserved for other purposes, namely fishing, navigation and salinity control. The mileage criterion was the most important as it covered 82 percent of the cases. The estimate indicated that the placement of 32,000 low-lift pumps could be justified each with a capacity of 2 cusecs.

4.02 Typically, the low-lift pumps are used for winter irrigation of boro rice. The zones where perennial winter water is available are also generally zones of flooding and it is necessary therefore to remove the pumps before the monsoon season starts. The extent of supplemental irrigation for aus and aman rice is thus rather limited. If it were practicable to operate the low-lift pumps 24 hours a day during the months of peak irrigation demand (January and February) and to shift their location, and provided that water could be distributed with reasonable efficiency so as to minimize wastage, it would theoretically be possible to irrigate perhaps as much as 100 acres of boro rice with a 2-cusec pump. In practice however, because of the small fragmented landholdings and the practical difficulties in shifting pump locations it has not been found possible to irrigate more than 50 acres with a 2-cusec pump and the current average is actually about 40 acres.

> With a spacing of 5 low-lift pumps per mile, the width of the irrigated strip paralleling the streambank under the mileage criterion is about 4,000 feet. It would appear that in many cases, depending on terrain characteristics, the width of the irrigates strip could be doubled provided the pumps are operated 16 rather than 8 hours which would indicate that even irrigated per pump. However to do this a way would have to be found to cross the 50-acre area of the original pump group so as to make water available to the land of a second 50-acre pump group which is 4,000 feet away from the water source. Considering the right-of-way difficulties involved in earth canals and the high cost

and technical difficulties involved with concrete distance of 4,000 feet), it might be possible to develop instead a scheme 7 to 8 feet would be needed. The flumes would have to be carefully staked out in the field and various special problems such as crossings would arise. To handle thestechnical matters, it would be necessary to create some sort of a bureau of agricultural engineering under TIP. Rural roads have been constructed in recent years by the Rural Works Program and it might be possible to combine the construction of such brick flumes with rural roads with the construction of both carried out by the Rural Works Program. The Bank's East Pakistan Group intends to explore these matters further as it might be possible at relatively low cost to achieve a considerably larger area of boro rice cultivation; see para 4.04.

4.03 As has been explained in Chapter 2 (para. 2.14) the use of low-lift pumps as part of large-scale schemes (executed by EPWAPDA) now constitutes a principal feature of these schemes which are described in detail later in this chapter. The basic concept is to provide structures (called "regulators") or pumping stations to supply water to the natural drainage system from which it is then distributed to farmers' field channels by the low-lift pumps. The large-scale schemes are within specific geographic areas and the question arises whether or not the use of low-lift pumps can be extended elsewhere by means of such structures which need not always be of great size. For example in the large tidal areas of the Southwest Region (and to a much lesser extent in the Southeast Region) it is possible to close many natural channels by means of a small barrier (earthen plug or dam) equipped with a sluice gate. Water can be admitted during high tide and the gate then closed to retain water (as the tide level falls) thus facilitating low-lift pumping. Medium-size structures of this type have already been constructed by EPWAPDA (for example at the mouth of the Little Feni River) but as part of schemes to prevent saline tidal flooding; a valuable by-product has resulted in that stored fresh water has become available for low-lift pumping. The use of minor works to assist low-lift pumping seems particularly promising in the Coastal Embankment project area (see Chapter 3) and in the Barisal region, described below. Here, it might be quite possible to proceed with construction of some minor works along with low-lift pumps as an initial stage, with larger scale works coming later. It has been roughly estimated by ADC that 8,000 additional low-lift pumps could be made effective by the construction of such minor works.

4.04 With 40,000 low-lift pumps in operation, and assuming 40 acres per pump, 1/ the total area irrigated would amount about 1.5 million acres.

1/ This is the average area served by the 18,000 pumps now in operation. During the coming period of rapid distribution of pumps, the area served per pump may be expected to remain constant or even drop slightly and then should rise again if the pump program continues to be well managed. On the other hand, if the scheme described in the indented portion of para 4.02 proved to be practicable, the area irrigated per pump could be increased up to perhaps 80 acres.

It should be reasonable to attain such objective by the year 1974-75. Thereafter since the area served by the low-lift pumps is as already mentioned mostly in the flood zone, it is estimated that of these 1.5 million acres 1.0 million will gradually be encompassed within the areas of the EPWAPDA multi-purpose projects.

4.05 Low-lift pumps are supplied by the Agricultural Department Corporation (ADC). For each pump, the Union councils as part of the Thana Irrigation Program (TIP) 1/ organize farmers into a group of users before the pumps are supplied. Typically there are 20-25 farmers in each pump group though the number can be as high as 50. As indicated above, pumps are located along perennial streams with suitable streambanks. However in many cases natural drainage channels tributary to the streams can also be made use of. Under the TIP, members of the pump groups assist in mapping the drainage channels and to determine where, by means of minor excavation, they can be deepened so as to extend the availability of water. The excavation is performed by the local farmers with payment for their labor by the Rural Works Program (see Volume 1, Chapter 7). The farmers must sometimes give up some land because of the channel deepening but this is provided at no cost to the Government.

4.06 Field channels for water distribution within the typically 50-acre area of a pumping group are arranged and paid for in a similar manner.

4.07 Besides supplying the pumps, ADC also operates and maintains them. The pump groups pay a lump sum for rental of the pumps to ADC and also pay for the fuel. The rental increases each year from Rs 150 per pump in the first year to Rs 2,700 in the seventh year and thereafter.

4.08 In 1966-67 and again in 1967-68 the Thana Irrigation Program was carried out in various parts of the Province on a pilot basis. In 1968-69 it was first implemented on a Province-wide scale and was quite successful. By 1969, 11,181 low-lift pumps were put into the field for operation. Due to the late arrival of some of these from abroad, not all were actually used for irrigation. However, 10,852 pumps with a total capacity of 20,606 cusecs were operated, and they irrigated 424,798 acres. As a result of this expanded area under irrigation, boro rice production increased from 1,113,000 tons of cleaned rice in 1967-68 to 1,612,000 tons in 1968-69, an increase of 499,000 tons or 44.8 percent over the previous boro season.

4.09 The way in which the TIP low-lift pump program is organized is important because for the first time farmers are sharing in the cost of irrigation in East Pakistan. In 1968-69, Rs 1,574,100 were collected for pump rentals. In addition, pump groups purchased 2,771,543 gallons of diesel fuel at Rs 1.38 per gallon for a total of Rs 3,833,009 for fuel. Of this, 55 percent (Rs 2,108,154) represented duties and taxes paid to the Government

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1/ See Volume I, Chapter 7 for a detailed description.

indirectly. Farmers thus paid a total of Rs 6 million for the Program (excluding their contribution in constructing all the field channels) while the Government's expenditure was Rs 60,000,000. The fact that farmers bore 10 percent of the capital costs in the full first year of the Program is of importance because it is the first time that East Pakistan's farmers have made any direct financial contribution to a water development project. It also indicates that a system has been developed under which Government subsidies can gradually be reduced as farmers' incomes and repayment capacity rises.

4.10 There is no doubt that where surface water is readily available low-lift pumps provide the cheapest and most economical form of irrigation in East Pakistan. The cost of a low-lift pumping unit including pump, engine, accessories and spares is currently estimated at about Rs 8,000 of which about three-fourths is in foreign exchange (assuming the official rate of exchange). Using a figure of 50 acres per low-lift pump would indicate a cost per acre of Rs 160. In comparison the tubewell cost per acre is roughly Rs 1,350 (tubewell and appurtenances only with no allowance for drainage -- see discussion below of ADC 3000-tubewell project) wereas the multi-purpose projects may cost from Rs 1,500 to 1,800 per acre. It must of course be realized that these figures are not strictly comparable since they do not take into account: the true value and percentage of foreign exchange (much higher for tubewell projects); the true economic cost of construction labor; and the fact that the multi-purpose projects provide drainage, flood, navigation and possibly also fisheries benefits in addition to irrigation benefits. Low-lift pumping may moreover entail additional costs such as deepening of drainage channels and excavation of field channels. In the case of the Chandpur multi-purpose project where internal irrigation distribution will be entirely by low-lift pumps, the associated costs for such excavations, for engineering, for overhead and for contingencies indicated that the total cost per acre would be about Rs 250 (see appraisal report in Vol. IV). It is nevertheless still clear that provided additional structures are not needed as described in para. 4.03, irrigation by low-lift pumping is the most economical method. A preliminary analysis made by the East Pakistan Bank Group in 1968 (Appendix A.2 of the report of March 1, 1968) indicated a probable very high rate of return as even if initial costs are discounted at a 50 percent interest rate, they can be recovered in 3 years. The report therefore concluded that low-lift pumping should have high priority in the East Pakistan program but that water availability and implementation capacity could limit the rate at which low-lift pumps can be installed.

4.11 In view of the large spread between low-lift pumps and the alternative methods of irrigation and provided that the cost of the minor works is not too high, it appears that the additional 8000 low-lift pumps mentioned in 4.03 are economically justified.

4.12 Through the 1969/70 winter season, ADC had placed a total of 18,000 low-lift pumps throughout the Province. The ADC program has provided for an additional 9,000 pumps to be placed and in operation during 1970/71. The pumps to meet this program plus about 1,000 as spares and replacements, have been purchased and will be ready for distribution starting in October 1970. ADC then plans for 5,000 pumps to be fielded in 1971/72 and about 8,000 to be fielded in 1972/73 making an addition of 13,000 and a grand total of 40,000.

4.13 ADC requires financing for the additional 13,000 low-lift pumps. The first group of 5,000 would cost $14.0 million of which $7.0 million in foreign exchange. As indicated in Table 6.1, funds would be needed by January 1, 1971. There is a manufacturing capacity for both pumps and engines in East Pakistan, but this capacity is not adequate to supply all of the engines. The local manufacturing capacity, according to ADC, will be adequate to provide engines for the second group of 8,000 pumps, provided that materials can be imported. In addition, the plans provide for the importation of a small number of larger capacity pumps to be used to feed the 2-cusec pumps. It will also be necessary to construct additional storage and repair facilities, strengthen the management of the low-lift pump section of ADC and train service and maintenance personnel. The cost of this second project is estimated at US$25 million, of which US$5 million would be foreign exchange. Since the final increment of 8,000 pumps may run into some difficulties regarding water availability, the figures shown in Table 1 indicate a somewhat slower rate of disbursement for the project than that implied above.

Tubewells

4.14 Aside from the dry-season flows of perennial streams usable by small low-lift pumps, the large dry-season flows in the major rivers would appear prima facie to provide the most economical source of water for irrigation. A major surface-water project (Ganges-Kobadak) was started 15 years ago but for a variety of reasons as described above has not provided benefits to the extent expected. Feasibility studies for various multi-purpose projects incorporating irrigation from surface water have been prepared (see descriptions later in this chapter) but detailed reviews of these studies have revealed difficulties in implementation which only now are gradually being solved. Since results from tubewell irrigation are obtainable more quickly (but not necessarily more economically) than from surface-water projects, and in view of the urgent need to expand irrigation to realize the full potential of the new IRRI rice varieties during the boro and aus seasons, the East Pakistan Government has given the highest priority to tubewell development in the Fourth Plan period and has proposed the installation of 20,000 tubewells. Concurrent tubewell programs are underway by both EPWAPDA and ADC.

4.15 There is little doubt that East Pakistan has abundant groundwater resources whose development is barely getting started. At this stage however information is as yet insufficient to permit "intensive development" except in certain areas of limited size. The most systematic overall view taken thus far was that made by the United States Geological Survey (USGS) in early 1967 (report entitled "Groundwater Resources Investigations Program for East Pakistan", July 1967). As determined from this report an area with a total extent of about 28,000 square miles (51 percent of the Province) contains unconsolidated materials to depths of several hundred feet and should therefore provide good possibilities for development of large-capacity wells. Outside this area prima facie evidence indicates limited possibilities either because of the nature of the superficial geologic deposits or (in the coastal belt) because of the proximity of the sea.

4.16 A major part -- 16,000 square miles -- of the 28,000 square mile favorable zone is located in the part of the Province that is normally flooded. Since, in areas subject to normal flooding, surface water generally is readily available and since pumping will also be required for drainage (the same pumps can be used in the dry season for irrigation pumping) the use of irrigation tubewells in the flooded portion of the favorable groundwater zone appears doubtful. The non-flooded portion amounts to about 12,000 square miles but only about five-eights (7500 square miles) is cultivable (three-eighths are taken by rivers, streams, roads, towns and villages). A breakdown of the latter figure according to regions is as follows:

Northwest Region	4,400 square miles	(2.8 million acres)
Southwest Region	2,600 " "	(1.7 " ")
Northeast Region	500 " "	(0.3 " ")
Total	7,500 square miles	(4.8 million acres)

4.17 As was pointed out in Chapter 1 with reference to the Northwest region this is the driest part of the Province and is also the one where flooding is now considerably less serious than elsewhere, particularly since completion of the Brahmaputra Right Bank Embankment (para. 2.10). Since drought is also more serious in the Northwest Region it is the one where most groundwater development to date has taken place in the form of the Northern Tubewells project (para. 2.12). The ADC 3,000 tubewell project partially financed by IDA and several EPWAPDA tubewell projects (all described below) will also largely be concentrated in the Northwest region.

4.18 The area of 2,600 square miles in the Southwest region is located in the area of the Ganges-Kobadak development described in para. 1.14. As brought out in Chapter 3 (paras. 3.20 and 3.26), the exixting Kushtia Unit of this project, which is based on surface water, will most likely not be able to supply all irrigation requirements and tubewells for supplemental irrigation should therefore be considered at an early date.

4.19 In the Thakurgaon intensive-type development (see para. 2.12) over 3 relatively large capacity (3-cusec) wells have been operated successfully per square mile irrigated. Even if an ultimate figure only half this is used, it would appear that over 11,000 3-cusec (or 17,000 2-cusec) wells could safely be installed. It would seem prudent therefore to plan for such a goal while obtaining confirmation from concurrent investigations and on-going projects (see para. 4.23). When more complete hydrogeologic information becomes available, massive tubewell developments (large capacity wells of over 4 cusecs and over 500 feet deep) will also ultimately require consideration; see paras. 5.26 and 5.36.

4.20 Existing tubewells: The total number of tubewells in East Pakistan at the present time is about 1,360 of which 365, in the Northern Tubewells (Thakurgaon) project of EPWAPDA previously described (para. 2.12), are electrically driven, of relatively large capacity (3-cusec) and closely spaced (about 0.5 mile apart). A more comprehensive development (in the sense that agricultural inputs were provided concurrently) has been that of the Pakistan Academy for Rural Development (PARD) at Comilla where 160 wells have been installed since 1962. Since mid-1966 PARD has also assisted agricultural extension efforts at Thakurgaon. The Comilla wells range in depth from about 150 to over 400 feet, are 6 inches in diameter and have an average capacity of about 1.25 cusecs. Most have been constructed with hand-powered rigs and have utilized locally made brass strainers. The pumps are centrifugal rather than turbine type and are powered by both electric motors and diesel engines. The closest well spacing is about 2,000 feet.

4.21 The Agricultural Development Corporation (ADC), using its own forces and local contractors has installed about 800 tubewells in the past two years. The cost of these tubewells to date, which have been mainly 6 inches in diameter, has ranged from Rs 26,000 to Rs 40,000.

4.22 ADC tubewells project: ADC has just concluded negotiations for the financing of a 3,000 tubewell project with a total equivalent cost of $44.6 million or Rs 212 million (Rs 71,000 per well). The tubewells would be installed on a turnkey basis by contractors (approximately one-third local and two-thirds expatriate contractors). The wells will be 8-inch diameter and will be equipped with imported fiberglass screens, casings, deepwells turbine pumps and diesel engines. Sixty percent of the total cost will be financed both by IDA and the Swedish International Development agency including parallel financing up to about $7 million by the Canadian International Development Agency. Both engineering and agricultural consultants will be provided under the Credit and the consultants' terms of reference include preparation of an additional ADC tubewell project.

4.23 The ADC tubewells will be of lower capacity (1.5 to 2 cusecs) than the EPWAPDA ones described below and they will be dispersed (spaced a minimum of about 1.5 miles apart). Prime movers will be diesel engines. (Some of the ADC tubewells are and will be located in the same zones as the EPWAPDA tubewells but this is considered beneficial in that the ADC wells provide valuable information on the aquifer characteristics for use in planning the intensive EPWAPDA wells. On the other hand, it is obvious that coordination of the two programs is necessary.) Approximately 80 percent of the 3,000 will be located in the Northwest region and the remainder in the northwest corner of the Northeast region. At a spacing of 1.5 miles, all of the available area (4,900 squire miles -- see para. 4.16) would be utilized. It is contemplated that as development of the 3,000 tubewells proceeds, information will become available on aquifer conditions which will provide a basis for closer spacing of tubewells. (As has been mentioned, in the Thakurgaon area, the average spacing is about half a mile; there are indications that in this area wells can now be added thus reducing the spacing below 0.5 mile.)

4.24 Table 1 indicates the Tubewells I (ADC) project as starting December 1, 1970 with completion December 31, 1973. The total equivalent cost would be US$44.6 million of which $22.8 million in foreign exchange. The appraisal report containing further details on this project is included in Volume IV. Table 1 also shows the Tubewells II (ADC) project starting 2 years later, that is, December 1, 1972 with completion December 31, 1976. The estimated total equivalent cost is $84.0 million for 6,000 tubewells. It is expected that many of the tubewells in the second project would be located in the same areas as the first project and would therefore involve a closer spacing of wells. This is considered reasonable in view of the experience at Thakurgaon. It should be possible, following about one year of development, to obtain from the first project sufficient information on aquifer characteristics to enable proceeding with the second project; consultants engaged on the first project would assist in preparing the second project.

4.25 EPWAPDA tubewell projects: Four areas are proposed for early development by EPWAPDA. The areas, designated as "Tubewells I" in Table 1, are as follows (see Map 2 for locations):

Thakurgaon Extension
Tentulia Panchagarh
Rangpur
North Mymensingh

4.26 The first three areas are in the Northwest region while North Mymensingh lies in the northwest corner of the Northeast region. The EPWAPDA tubewell areas in the Northwest have some general characteristics in common; there are limited surface water supplies, monsoon rain flooding is minimal, and -- based on data of varying reliability -- good aquifers. A feasibility report has been prepared for the Rangpur area, a draft of a feasibility report is available for Tentulia Panchagarh, and a feasibility study is underway on North Mymensingh. Wells located in the Thakurgaon area yield data indicating that further development is promising. The principal recharge in Thakurgaon is directly from precipitation; however additional water balance studies are needed.

4.27 The existing feasibility reports contain much valuable information, however, they are inadequate in many respects and will require revision. Additional information is becoming available for existing wells. The ADC tubewell program described above as well as the United States Geological Survey-Assisted program (see below) will also provide information of value. The ADC program raises two points with respect to any EPWAPDA tubewell project to be considered in the near future. First, there should be coordination so that the ADC and EPWAPDA program are not in conflict. 1/ This means they should either not be in the same general area or where they are it should be recognized that the ADC tubewell program, which has the objective of achieving a rapid increase of agricultural production, is on the basis of a non-intensive exploitation of the ground-

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1/ The coordinating agency should be the Planning Department, GOEP.

water resource. 1/ Thus, as a second point, it should be recognized that the intensive development of the groundwater resource in a particular area will ultimately require a much closer spacing of wells and/or large-capacity wells.

4.28 As previously mentioned, the ADC tubewells will not exceed 2 cusecs in capacity. Experience with the low-lift pump program indicates that this is about the maximum that can efficiently be handled by a "pump group". Wells of larger capacity involve some sort of a distribution system (this involves land acquisition problems) and a larger number of farmers within a particular pump group which makes the problem of management more difficult. The tubewells proposed by EPWAPDA would have an average capacity of about 3 cusecs. The average cost per tubewell (including electric transmission and a 1,800-foot lined distribution channel for each well) would be about Rs 200,000 and the area served per well would be 200 acres. 2/ The estimated cost of an ADC tubewell including diesel engine is about Rs 71,000 (para. 4.22). The capacity would be 1.5 to 2.0 cusecs and the area served, based on experience with the low-lift pump groups, would ultimately rise to 50 acres (for a cropping pattern including boro and aus rice) and perhaps 60 acres for one not including much boro rice. The lower cost of the ADC tubewells raises some questions regarding the proposed EPWAPDA tubewells, first, regarding economic justification particularly of electric transmission and, second, regarding optimum capacity of the wells (since the wells will be in a concentrated zone and some lined distribution canals will be provided, perhaps 3 cusecs is too low a capacity) and third the area served per well.

4.29 The location, capacity of wells, type of motor drive (electrical or diesel) agricultural inputs, repayment, 3/ economics, 3/ organization and mangement of the Tubewell I development all need further study. However, based on current data EPWAPDA has tentatively sized the development as follows:

Thakurgaon Extension	300 wells	60,000 acres
Rangpur	300 "	60,000 "
Tentulia Panchagarh	510 "	102,000 "
North Mymensingh	300 "	60,000 "
	1,410 wells	282,000 acres

1/ An important additional benefit of the ADC tubewells is that, if properly monitored, they will provide invaluable information for the USGS-assisted study.

2/ From PC-1 form prepared by EPWAPDA for 1,000 tubewell project, May 1968.

3/ Needs treatment as for the multi-purpose projects; see paras 4.39 and 4.40.

4.30 The Tubewells II project would be an EPWAPDA project comprised of 1,000 tubewells located in an area protected by the existing Brahmaputra Right Embankment project (paras. 1.24 and 2.10). EPWAPDA is negotiating a contract for a feasibility study and final engineering for the project with a Yugoslav firm called Geotecknika. This area shows promise for a good groundwater development but the feasibility study should include consideration of all the elements and alternatives recommended for study on Tubewells I.

4.31 EPWAPDA proposed to have the feasibility studies revised for the Tubewell I areas, and have tendering documents and final engineering done by the same consulting firm. Table 1 indicates this work beginning July 1, 1970; revision of the reports for the first three areas would be complete by mid-1971 and for North Mymensingh by mid-1972. Construction starts are scheduled for all but North Mymensingh by mid-1971. The estimated aggregate cost of Tubewells I is $56.6 million (total equivalent) based upon preliminary data. The feasibility study and final engineering on Tubewells II are scheduled for completion in mid-1973 with construction scheduled to begin at the beginning of 1974 at an estimated cost of $42 million based upon preliminary data.

4.32 Rate of tubewell development: The principal constraints on accelerated tubewell development appear to be:

(a) The rate of formation of water-user groups (the tubewell equivalent of the low-lift pump groups, both of which are formed under the TIP program) though this might be rapidly overcome with the new emphasis on tubewell development and coupled with the TIP program (see Volume I, Chapter 7);

(b) The speed at which groundwater conditions can be verified in specific areas;

(c) Limited capacity of the farmers to pay for fuel and other operation and maintenance costs;

(d) Institutional capacity with respect to supervision, maintenance and proper irrigation distribution.

4.33 Financial resources and trained manpower are not major constraints. Both the Center and Provincial Governments as well as several foreign donors have indicated a readiness to make substantial additional funds available for an accelerated tubewell program in East Pakistan. During the construction period technical difficulties will no doubt arise (access to many tubewell sites may not be available during the monsoon season); after completion, operation and maintenance problems will grow in scope and complexity. However, it is judged that existing local contractor capacity, together with expatriate contractors and the limited but developing capabilities of ADC, EPWAPDA and the Comilla Cooperative should be sufficient to sink wells as rapidly as water-user groups can be formed and the necessary concommitant irrigation distribution facilities can be constructed by the water-user groups. A confirmation of this judgement should be available by about mid-1972 (the end of the 1971-72 construction season) when considerable progress should have been made on the ADC Tubewells I project and, to a lesser extent, on the EPWAPDA Tubewell I developments. The major constraints thus appear to be mainly institutional, i.e. TIP, Department of Agriculture, ADC and EPWAPDA. For the present, it is estimated that the present annual rate at which well groups can be formed and wells sunk would be about 1,000 to 1,500 ADC-type dispersed wells and 500 to 750 EPWAPDA-type intensive wells. This rate would increase as the key institutions -- TIP, Agriculture, ADC and EPWAPDA -- demonstrate a greater capacity to form groups; provide supervision and maintenance; construct, or have water-user groups construct, irrigation distribution facilities and as additional information on the underground aquifers is obtained.

4.34 United States Geological Survey-assisted study: A five-year exploratory program and study of groundwater in the Province is scheduled to begin July 1970 by the Groundwater Directorate of EPWAPDA with the assistance of a team of experts from the United States Geological Survey (USGS). The cooperative activities of this group will be scheduled on a priority basis so as to be as helpful as possible in providing data for the above tubewell developments. From a long-range point of view, the USGS study will be important -- in fact essential -- for determination of an overall water balance for the Province out of which will come an understanding of the long-range role of groundwater development and its integration with surface-water development. This is discussed further in Chapter 5.

4.35 Indigenous methods: As has been indicated above, the tubewells constructed by ADC and PARD utilizing local methods and materials have cost considerably less than either the EPWAPDA tubewells or the 3,000 tubewells now being undertaken by ADC. Recent experience in West Pakistan indicates that, of 83,000 tubewells installed during approximately the past decade, only 4,000 have been by public agencies and the remaining 79,000 by private individuals. Private tubewells are currently being installed in West Pakistan at the rate of 10,000 per year. The private individuals installing these wells have been relatively large landowners who have been able to obtain credits from local banks. The wells they have installed resemble considerably those at Comilla in East Pakistan. While the standard of such tubewells may be far lower than those now being proposed (there may therefore be a much larger percentage of non-productive wells) nevertheless in view of their far lower cost (even lower than the foregoing figures indicate if foreign exchange is shadow-priced since the Comilla wells involved practically no foreign exchange) and the fact that they have proved to be of success in achieving agricultural production would indicate a need for further study to determine more clearly the applicability of indigenous methods of tubewell construction in East Pakistan. Obviously, recognition would have to be given to the fact that the number of creditworthy individial farmers in East Pakistan is far less, proportionately, than in West Pakistan. Consideration should be given to a policy which would give direct subsidies to the private sector through the Agricultural Development Bank, which would be equal to the subsidies given to EPWAPDA and ADC.

Fractional pumps (capacity less than one cusec) and dug wells should also be investigated in this regard.

4.36 Now that several types of tubewell program have been successfully launched in East Pakistan, comparative data will become available that can become a basis of more intensive programs. It is recommended that a timely evaluation be made that will take into account the need for accelerated tubewell investment, rapid verification of groundwater conditions, and coordination of the various tubewell projects. The evaluation should also take into account: the organization of tubewell groups and irrigation distribution; tubewell operation and maintenance; and an economic analysis of comparative costs and benefits of different types and sizes of tubewells (considering also dug wells as mentioned above). Such an analysis must consider not only the need for accelerated tubewell program and technical questions, but also the need for labor-intensive projects in East Pakistan and the desirability of improving indigenous capacity, whether that of private contractors, cooperatives or governmental organizations. It may be possible for the consultants engaged on the 3,000 tubewell project of ADC (para. 4.22) to make the necessary analysis.

Multi-purpose Projects - Feasibility Studies Available

4.37 As has been described in Chapter 2, multi-purpose (irrigation, drainage, flood prevention and navigation) surface-water projects have been studied intensively in recent years and a strategy has now evolved that is suitable to the small, fragmented landholdings that prevail in most of the Province. The elements of this strategy are:

a. Use of labor-intensive methods (for the extensive earthworks involved) which are well suited to the local conditions of climate and labor;

   Experience with embankment construction has been good. In the Coastal Embankment project, over 2,000 miles of 12-ft. high embankments, which provide protection against tidal flooding, have been built by such methods. The Brahmaputra Right Embankment (135 miles long, 12 ft. high), which provides protection against river flooding, also used such methods plus supplementary compaction by machine.

b. A well integrated project organization for provision of agricultural inputs, including emphasis on rural infrastructure (see Chapter VII, Volume I);

c. Adoption of a method of irrigation distribution (i.e. use of natural drainage channels as distributaries plus low-lift pumps) suitable to the conditions of small landholdings; and

d. Careful phasing of project constructions and investments.

This is practicable since the projects involve relatively small-scale civil works. For example, a primary pumping station (cost $1 to $2 million) can be built in 3 years to serve 1,000 to 2,000 low-lift pumps (50,000 to 100,000 acres). As a second example, embankments can be planned for partial flood protection of a project area or left for a later stage. Careful phasing can reduce the long gestation periods previously associated with multi-purpose projects down to the point where they will be only slightly longer than the gestation period for tubewell projects. The multi-purpose projects will moreover provide important flood control, drainage and navigation benefits.

4.38 Experience thus far with multi-purpose projects is limited. Only one small project - Dacca-Demra, covering 15,000 acres - has been completed. A second - Chandpur, covering 140,000 acres - is now underway; this project has been assisted by two IDA credits totalling $18.25 million (see Chapter 3 for details). Project preparation is however almost completed for 8 projects with an aggregate gross area of 1.5 million acres (1.0 million acres net), as follows (see Table 2 for project areas and Map 2 for locations):

Dacca Southwest	Belkuchi
Karnafuli	Upper Kusiyara
Muhuri	Khowai
Pabna	Sangu

These projects are technically sound, have high rates of economic return and can be integrated into a long-range Province-wide plan for water development including flood control. (See paras. 4.174, 5.01, 5.03 and 5.07). The status of project preparation as well as the available information on these 8 projects indicates that it is safe to proceed - as a next step in their implementation - to final engineering followed by tendering for construction. The financing of final engineering for the first three projects has already been assisted by IDA credits totalling $3.2 million. Additional financing requirements for capital investments as well as for final engineering are in Table 1. Descriptions of the 8 projects are contained in the following paragraphs.

4.39 The cost of the final engineering for the above 8 projects would include in each case revision of the existing feasibility studies. (The cost of preparing these revisions would however be a minor part of the cost of final engineering most of which is for preparation of tender documents and design drawings.) As was pointed out in Chapter 2 (para. 2.16), while these studies contain much valuable and in fact essential information, in general they are incomplete in respect to the method of irrigation distribution, economic analysis, project organization (particularly as regards agricultural inputs) and project repayment. With respect to irrigation distribution, the low-lift pump method (see para. 2.14) needs consideration in each case. As regards economic analysis, the feasibility studies prepared up to now (except for Chandpur) need to be revised in the following respects:

(a) The true "opportunity cost of capital" should be used rather than interest rates adopted arbitrarily;

(b) World market price trends for farm products should be used rather than internal prices including subsidies;

(c) A distinction should be made between cost of items involving foreign exchange, and those that do not (the former should be shadow-priced);

(d) Time lags to full development should be realistic;

(e) Phasing of expenditures to maximize economic returns should be carefully considered; and

(f) On-farm development and agricultural inputs need adequate costing.

4.40 As regards project organization, a scheme has now been worked out for Chandpur (para. 2.17) and similar schemes -- although not necessarily exactly the same -- need to be worked out for all future projects. The problem of project repayment, both as regards operation and maintenance and recovery of capital costs, is an urgent question which must be examined not only on a project-by-project basis but also on a Province-wide basis; see chapter VIII on the Comprehensive Study in Volume I.

4.41 Detailed descriptions of the 8 projects are contained in the following paragraphs.

4.42 Dacca Southwest project: The Dacca Southwest Irrigation project would provide flood control, drainage and irrigation to a gross area of 390,000 acres (300,000 acres net) located near Dacca (see Map 2). Originally, the project included four polders with a total gross area of 490,000 acres. Two of these have been eliminated from the project because of questionable feasibility. Further study has revealed that the two polders in the remaining area of 390,000 acres can be best developed by combining them into a single polder.

4.43 The embankments, 167 miles in length, would eliminate flooding from the Brahmaputra River and its tributaries. The project area is flooded every year during the monsoon season to depths ranging from 3 to 15 feet.

Typically, farmers in the area now grow broadcast aus (summer rice harvested in June or July) in the areas of medium to shallow flooding and broadcast aman rice (autumn rice harvested in November or December) in the areas of medium to deep flooding; both varieties are often planted together in areas of medium flooding. These varieties are low-yielding and owing to flooding cannot be fertilized. The elimination of flooding and the provision of irrigation would enable the use of improved transplanted varieties and fertilizer and would result in a tripling of present rice yields.

4.44 Flood elimination must be carefully phased since farmers cannot shift from the broadcast to the transplanted varieties in only one season. This is due not only to the need for farmers to adjust to new methods (although cultivation of transplanted aman is well known in East Pakistan) but also because there are many logistical problems to be solved (such as provision of seed and fertilizer) and because the transplanted varieties often suffer from water shortages particularly at the beginning and end of the monsoon season. For this reason the gradual elimination of flooding is proposed whereby the water level inside the polder would be gradually lowered during a period of perhaps five or six years.

4.45 The other major features of the project besides flood prevention would be drainage and irrigation. For drainage, 8 primary pumping stations would be constructed at natural drainage outlets along the embankment paralleling the Kaliganga river. Some improvement of the natural interior drainage channels would be necessary to assist in accomplishing drainage. For irrigation, these same pumping stations would be operated in a reverse direction to pump water from the Kaliganga to the interior of the polder.

4.46 During the months from October through May there is very little rain in the project area and much of the area lies fallow. In addition, there are occasions when the monsoon rainfall is insufficient for paddy so that supplementary water is often required. A primary purpose of the project would thus be the provision of water for irrigation.

4.47 The density of the population in the project area is very high (about 2,500 per square mile) and the average size of landholding is very small - only about 2.3 acres. Landholdings are moreover highly fragmented so that the average plot size is only about one-third of an acre.1/ Under

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1/ Fragmentation has provided a form of insurance as farmers have tried to disperse their holdings with respect to land elevation. (In years of deep flooding the higher land still yields a crop while the lower land does not. The reverse is true in years of shallow flooding.) Land consolidation to correct fragmentation will be encouraged by the project as it will largely eliminate the flood hazard. Land consolidation will also be encouraged by the availability of irrigation; see para. 2.14.

these conditions the provision of a conventional gravity irrigation distribution system is impracticable. This is further complicated by the extreme shortage and high cost of land in East Pakistan. Fortunately, however, it is possible to accomplish distribution of irrigation water by making use of the numerous natural drainage channels. Water can be pumped from these drainage channels by means of small portable low-lift pumps of about two cusec capacity.

4.48 Another important benefit of the project will be the provision of interior navigation. Rural roads are lacking in the project area and moreover the economic level of the typical rural family is too low to be able to afford wheeled vehicles; native country boats on the other hand are available everywhere. The improvement of the numerous drainage channels will provide many new navigable waterways and the maintenance of a minimum water level inside the polders during the dry season as well as a maximum level during the wet season will greatly extend the availability of navigation. At some of the principal natural channels, navigation locks would be provided to permit boats to enter and leave the empoldered areas.

4.49 According to the existing feasibility study, construction of the major works would take five years; the main construction item would be 167 miles of embankment. The 135-mile embankment for the Brahmaputra project took five years to build although very little work was done during the first two years. In view of the experience gained, it should be possible to construct the project embankments in four years. On the other hand, even if a somewhat longer time is required, the economic justification of the project will not be in doubt. This will be due in large part to the phasing of the construction that is planned so as to obtain interim benefits, as follows:

> The first item of construction will be a primary pumping station in the northern (upstream) part of the project area. This station will be similar to what was described in para. 4.37(d) above. Irrigation in this part of the project area during the dry season will thus be available possibly even before flood prevention has been accomplished. If confirmed by detailed studies, the other 7 primary pumping stations may also be completed and operated in advance of the availability of flood protection.
>
> Construction of the flood embankments would be started at the upstream end and advance in a downstream direction, along both the Brahmaputra and Kaliganga rivers. During the second and subsequent construction seasons temporary closures running across the polders would be provided for interim flood protection to the extent feasible.

These temporary closures need be only about six or seven feet high (only about half that of the main embankments) and they can serve later as permanent rural roads similar to those being constructed throughout the Province under the Rural Works Program. The temporary closures would provide protection against about a two-year flood as compared with the main embankments which provide protection against a 100-year flood and are moreover conservatively designed to withstand wave action, settlement and erosion from various causes. While two-year protection would be insufficient to enable farmers to shift from broadcast to transplanted aman it would be enough to enable them to grow a greatly improved transplanted aus crop. This crop is harvested in June whereas the peak of flooding from the Brahmaputra does not come until late July or August.

As construction of the embankments advances further, practically complete protection will progressively become available. Thus almost complete development in the upstream part of the polder will be possible even before it is entirely closed. 1/

4.50 Costs of the Dacca Southwest project are sufficiently well-known to indicate that the unit costs per acre are likely to be smaller than for the Chandpur project. Since cropping patterns and economic and social conditions are similar to those existing on the Chandpur project, the benefits and therefore the rate of return should at least be equal to and probably exceed that of Chandpur which has been established at 18.5 percent. 2/

1/ Aside from construction phasing as described, it is not practicable to subdivide the polder so as to have an initial project of smaller size. There would be serious local opposition to such a plan, first by the large number of landowners located in the right-of-way of the additional embankment that would be required; secondly, by landowners in the area excluded from the polder. Thus it would not be feasible to get agreement on the limits of the reduced polder.

2/ The appraisal report for Chandpur shows 22 percent. However, an adjustment for "sunk" costs previously incurred reduces this to 18.5 percent.

4.51 Consulting firms have been engaged by EPWAPDA to revise the feasibility report of 1968 particularly regarding the matters mentioned in para 4.39 but including also a review of flood control features (embankment design) and design of pumping station intakes to minimize sedimentation. The consultants will concurrently prepare final designs and tendering documents for initiation of construction. It is anticipated that the feasibility report will be completed by September 1970, and that construction can be initiated by January 1971. Construction should be completed in four or five years at a cost estimated at about $60 million (total equivalent). This estimate was based upon preliminary information obtained from the 1968 report, and subsequent information obtained from studies now in progress.

4.52 The <u>Karnafuli project</u> includes four sub-projects of which two are proposed for early development. These are the Halda Unit with a gross area of 131,500 acres and the Ichamati Unit with a gross area of 16,000 acres. Feasibility reports on these two Units, both dated May 1968 were prepared by the consulting engineering firm, Justin-Courtney-Hohlweg-Watts. An IDA credit of $2,400,000 has been made to the Government of Pakistan for revision of the Karnafuli and Muhuri feasibility studies and for the preparation concurrently of tender documents and final designs. The scope of work under the credit also includes a reconnaissance of the Comilla-Noakhali and Little Feni project areas which have a total area of over 1 million acres (see detailed discussion later in this chapter). The work to be carried out under this credit thus comprises a major step forward in the development of the Southeast region,

4.53 While the May 1968 feasibility study of the Halda Unit contains much useful information, additional surveys and studies are needed before final design and construction can be undertaken. The report proposed that flood protection be provided by a dike system with a total length of 70 miles. There would be eight miles of dike with an average height of about eight feet along the right bank of the Karnafuli river. There would be 26 miles of dike along each bank of the Halda river with an average height of about 10 feet and with a maximum height of 12 feet. Finally, there would be 10 miles of dike averaging about eight feet in height along the two principal tributaries, the Sonai and Sarta Khals. These embankments would eliminate flooding from the streams mentioned.

4.54 Flooding occurs every year during the monsoon season when large portions of the area are inundated to depths of three to six but as much as nine feet. Typically, farmers now grow <u>aus</u> followed by <u>aman</u> rice in areas of medium to deep flooding and aman rice in areas of shallow flooding. 1/

1/ Aus rice is planted in March and harvested in June or July. Aman rice is harvested in November or December. The aman rice in the Karnafuli area is of the transplanted rather than the broadcast variety.

4.55 Since flooding does not ordinarily last more than a week or two, the farmers grow transplanted rather than lower-yielding broadcast rice. On the other hand, the transplanted rice is often severely damaged by flash floods. Rice yields, which are presently low, could be about tripled through elimination of flooding and provision of irrigation which would provide the basis for a modernized agriculture.

4.56 As proposed in the 1968 report, the embanked channel of the Halda river would have a discharge capacity of 22,000 cusecs with a three foot freeboard. The maximum flood flow observed to date has been only 12,750 cusecs; however, the consultants estimated that the higher capacity would be required because confinement of the river by embankments would eliminate natural valley storage and therefore increase the discharge as compared with natural conditions. The current studies will review the consultants' analysis particularly as regards scouring and resulting maintenance problems.

4.57 The other major features of the Halda sub-project, besides flood control, would be drainage, irrigation and navigation. For drainage, the consultants recommend excavation of a nine-mile long channel, called the West Main Drain. Some additional drainage works might be necessary for the large low-lying area in the southeast portion of the project and this is being studied under the current engineering project.

4.58 For irrigation of the Halda Unit, the consultants proposed a main pumping station (capacity 1,750 cusecs) which would lift water from the Karnafuli river into a main gravity canal at elevation 23 feet. After flowing in this canal for a distance of five miles, water would be relifted by a second pumping station (capacity 1,060 cusecs) to elevation 45 feet. The irrigable area would be 84,600 acres net and distribution would be by means of conventional gravity-type canals. The system proposed, besides being costly, would not be suitable under the conditions of small landholdings that prevail. The average farm holding is about 2.6 acres of which 2.1 acres are presently under cultivation. Conditions in this respect are similar to those at Chandpur where the average holding is two acres which is fragmented into as many as ten pieces. Also, as at Chandpur, the project area is crisscrossed by many natural watercourses (khals) and excavated drainage channels which are tributary to the khals; there is thus hardly any point in the project area more than a mile from an existing drain. It should therefore be practicable to irrigate a large part of the area by low-lift pumps taking the water from the khals and thus eliminating the need to take land for canals. (This is the system proposed for the Chandpur project.) The water would be pumped from the Karnafuli River and utilizing low-lift pumps it should be possible to irrigate a net area of about 55,000 acres located between elevations 7 and 25. The maximum static lift would be 18 feet and the average would be only about 9 feet -- much less than required by the pumping stations proposed in the 1968 report. Following further investigations it might be possible to extend the estimated area beyond 55,000 acres, either by additional pumping (relifting) or by development of groundwater, particularly in the higher foothill areas. For the latter type of development, groundwater surveys and explorations will be necessary but these will be carried out gradually without holding up the main, first stage development; the surveys and explorations will however be included as part of the current feasibility study revisions.

4.59 Still another important benefit of the project will be the provision of interior navigation. Rural roads are lacking in the project area and moreover the economic level of the typical rural family is too low to be able to afford wheeled vehicles; native country boats on the other hand are available everywhere. The improvement of the numerous drainage channels will provide many new navigable waterways and the maintenance of a minimum water level inside the project area during the dry season as well as a maximum level during the wet season will greatly extend the availability of navigation. At some of the principal natural channels, navigation locks would be provided to permit boats to enter and leave the empoldered areas.

4.60 The 1968 feasibility report on the Halda Unit of the Karnafuli project contains much useful information, particularly with regard to the flood control embankments which constitute the most costly project feature. The costs of other major project works (major drainage channels, pumping stations, regulators and navigation locks) will require revision taking into account the alternative approaches and designs described above. Of these the most important revision concerns the method of irrigation distribution within the project area. The report on the Halda Unit is also inadequate with respect to project organization (see para 4.40) and project repayment. Regarding the latter, an analysis is needed to establish repayment capacity, water charges and the time period over which they can be progressively imposed. 1/

4.61 Revision of the Halda feasibility report, as described in the preceding paragraph, will be needed before appraisal by the Association of a construction credit can be undertaken. On the other hand, the relatively advanced status of project preparation as well as the favorable judgment regarding economic justification indicate that the Halda project can proceed without delay to the stage of tendering and final design.

1/ In the case of the Chandpur project, these subjects were studied in a preliminary manner by the consultants. The province has agreed to prepare within 18 months a plan providing for recovery of operation and maintenance (O & M) costs of the major project works, estimated at Rs 15 per acre. O & M of the low-lift pumps (including fuel), estimated at Rs 97 per acre, will be collected from farmers on a scale rising progressively to full value in 10 years. Recovery of capital costs are recognized to be more difficult; the Province has however agreed to prepare a plan for recovery of as much as practicable of the capital cost. (See project agreement signed with IDA, Chandpur II Irrigation Project, May 15, 1970, Section 2.07.)

4.62 By proceeding now with engineering for the Karnafuli project (Halda Unit), it would be possible to initiate construction by about December 1971.

4.63 As proposed in the 1968 feasibility report the Ichamati Unit will have a gross area of 16,000 and a net area of 11,800 acres. In 1969 it was noted that 6,300 acres or a little more than half of the irrigable area were already irrigated by low-lift pumps. Water supplies for these pumps have been made possible largely by two regulating structures already constructed by EPWAPDA. These structures also prevent flooding from the Karnafuli river. The project area is still subject, however, to flooding from the Ichamati river.

4.64 The local farmers are anxious to expand their successful irrigation and believe they have sufficient water to install additional low-lift pumps. Interest was expressed in a 100 cusec high level canal from the Karnafuli river similar to that proposed in the 1968 feasibility report. However, as an alternative, additional development of the Khals, as has already occurred, including utilization of the Ichamati river as an irrigation distributary would be considered. Groundwater would also be considered. As a matter of fact, local residents have already made application to ADC for 40 tubewells.

4.65 With respect to the Ichamati Unit, extensive revision of the feasibility report will be required as has been indicated above. Tendering the final design for this small project should be deferred until after completion of the revised feasibility study.

4.66 An initial determination of the economic justification has been made for the Karnafuli project (Halda Unit) based upon a comparison with the Chandpur project. This comparison revealed that costs per irrigated acre on the Karnafuli project will be less than Chandpur, and that benefits will be greater. Thus it was concluded that a rate of return for the project is likely to exceed that computed at 18.5 percent for Chandpur.

4.67 Two consulting firms (one Pakistani and one expatriate as a joint venture) have been engaged by EPWAPDA to perform final engineering and revise the feasibility report. Based upon current schedules, the revised feasibility report should be completed by mid-1971, and making use of the final engineering work, it should be possible to initiate construction in January of 1972. Preliminary information indicates the project will cost $21 million. Construction should be completed in about four years.

4.68 Muhuri project: The gross area of the project is 101,000 acres. A feasibility report dated January 1967 was prepared by the consulting engineering firm Techno-Consult of Karachi, Lahore and Dacca. While this feasibility study contains much useful information, additional surveys and studies will be needed before final design and construction can be undertaken. Of these the most important concern the method of irrigation distribution within the project area and drainage. The report is also inadequate with respect to project organization (see para 4.40) and project repayment. Regarding the latter an analysis is needed to establish repayment capacity, water charges and the time period of which they can be progressively imposed (see paras 4.39, 4.40 and 4.60). As previously mentioned, an IDA credit of $2,400,000 has been made to the Government of Pakistan for the revision of the Karnafuli and Muhuri feasibility studies and for the preparation of tender documents and final designs.

4.69 As proposed in the 1967 report, the project would involve an expenditure of Rs 36.5 million including interest during construction or Rs 34.7 million if the latter is omitted. These figures were for a project including a limited amount of irrigation, in an area of only 8,700 acres, with water obtained from the Muhuri river by pumping and thence through a conventional gravity canal system. The small area irrigated was due to the limited water supply available from the Muhuri river during the dry season. The report also describes a project limited to flood-control and drainage only. This project would have a cost including interest during construction of Rs 33.0 million or Rs 31.5 million if the latter is omitted.

4.70 For flood control there would be about 92 miles of major embankments (crest width 14 feet, average height nine feet, freeboard above design flood 3.5 feet) including 21 miles along the right bank of the Muhuri, 19.5 miles along its left bank, 20 miles along each bank of the Selonia river up to the point where it discharges into the Kalidas Khal (an existing man-made channel) and 12 miles along the right bank of the Feni river. In addition, there would be 56 miles of smaller embankments along some of the tributary streams.

4.71 The expenditure of Rs 4.8 million proposed for channel improvement is mainly to eliminate bends in the Muhuri and Selonia rivers so as to increase their carrying capacities. With these improvements plus the embankments, the Muhuri river would have a discharge capacity of 25,000 cusecs. The consultants have estimated by synthetic methods that such a flood would have a period of recurrence of 10 years. Such a degree of protection seems reasonable under the conditions prevailing. The 1967 report contains no discussion on the velocities in the Muhuri and Selonia channels as related to their stability and the resulting maintenance problems. The width of channels provided seem ample to keep velocities low. Nevertheless, the flood hydrology and hydraulics of the Muhuri and Selonia embanked channels will be reviewed.

4.72 The Muhuri river embankments would terminate at the Dacca-Chittagong Highway bridge near Haripur which is about 10 miles upstream of the mouth of the Muhuri river. The consultants felt that the Muhuri river downstream of the bridge need not be embanked thus allowing spill to occur into the portion of the project area between Haripur and the outfall. It was thought that this zone would act as a detention reservoir.

However, there may be two reasons against such a plan. First, with the improvements upstream, there would be more flooding in this area than at present and this would probably not be acceptable to local residents. A second reason is that with the banks of the Muhuri river in the ten-mile reach downstream of Haripur quite high, it should be relatively easy with embankments no more than a few feet high to carry most of the flood flow to the mouth of the Muhuri river.

4.73 The report indicates an additional embankment is needed to form a closure between the existing right-bank Kalidas embankment and a coastal embankment at Sonapur. The cost of such a closure and whether this would be part of the Muhuri project will be explored.

4.74 Although the 1967 report contains some discussion of the drainage problem, this will need further study first with respect to the low-lying area downstream of Haripur that has been mentioned above. Secondly, further analysis is needed with respect to other low-lying areas that cannot be drained during high levels in the main exit channels, namely the Muhuri and Selonia-Kalidas. It seems probable that pumping for drainage would not be economically justified. On the other hand, further knowledge is needed regarding the frequency and depth of flooding caused by inadequate drainage due to lack of exits. Also, suitable cropping patterns would have to be adopted for such areas. Thirdly, the drainage system should be designed taking into account its utilization for the distribution of irrigation as is discussed further below. Finally, use of the larger drainage channels for navigation will be considered as was found to be feasible at the Chandpur project where a highly important additional benefit was obtained. The provision of navigation is considered to be of great significance under the conditions that prevail whereby rural roads are lacking and are likely to be comparatively costly. Moreover, wheeled vehicles are scarce while country boats are plentiful.

4.75 The irrigation plan proposed in the report would provide irrigation by gravity to only 8,700 acres in the higher, northern portion of the project area. The small area irrigated would be on the basis of the available dry-season flow of the Muhuri river. A conventional gravity system is proposed which under the conditions that prevail (small landholdings) is probably not workable.

4.76 The report proposes sluices at the mouths of the Muhuri river and Kalidas Khal to prevent flooding and saline intrusion from high tides. The design would be similar to that of the existing EPWAPDA regulator across the Little Feni river whose drainage basin adjoins and is west of the Muhuri river drainage basin. This regulator has been successful in eliminating flooding from tides and saline water intrusion and, in addition, has in the past few years enabled the irrigation by means of low-lift pumps of about 5,000 acres. This area could be further extended if the water level upstream of the regulator could be raised but this requires some flood control measures upstream. 1/ (See description below of the Little Feni project.)

4.77 As of May 1969, 113 low-lift pumps had been installed by ADC along the Muhuri and its tributaries and the available water supply is ample for some additional pumps. The area irrigated per pump is about 45 acres or 5,000 acres total. It would seem that, as a next step, impoundment of water by the proposed Muhuri and Kalidas sluices (as at the Little Feni regulator) would permit further installation of low-lift pumps.

4.78 According to the area-versus-elevation curve in the 1967 report, there are 68,000 acres below elevation 25 and 11,000 acres below elevation 15, the difference being 57,000 acres. The bed of the Muhuri river at Haripur is at about elevation 6 whereas the existing banks are about elevation 20. The same elevations pertain in the Selonia river from its mouth at the Muhuri river to a point several miles upstream. The banks of each of these rivers are higher than the surrounding terrain. The high-water level proposed at each of the two major sluices (Muhuri and Kalidas) is elevation 15.5 (during the monsoon season). If a level of about 12.5 could be maintained during the dry season it should be possible to serve almost all of the 57,000 acres. (Data are not readily available to determine the corresponding net area. Assuming proportionality with the Karnafuli (Haldi Unit), the net area would be 42,000 acres.) Water would be distributed by means of low-lift pumps obtaining their supply from the drainage system. Since, however, the flow of the Muhuri river is insufficient during the dry season, another source of water would be required.

4.79 Import of water to the Muhuri project area, on the basis of available information, appears practicable. The source would be the Dakatia river which receives water at all times from the Meghna. From aerial reconnaissance and examination of available maps, it can be observed that the Dakatia has a wide navigable channel as far inland as Habiganj (14 miles east of Chandpur). The Dakatia is also navigable part of the year as far as Laksham (17 miles east of Habiganj - see IWTA navigation maps). Laksham is at the drainage divided between the Dakatia and Little Feni rivers. In view of the generally very flat topography it should be feasible to transfer Meghna water via the Dakatia to the Little Feni. Works needed to accomplish this might include a pumping station cum navigation lock on the Dakatia river. Obviously such a pumping station might ultimately have to serve a large part of the Comilla-Noakhali area (over 800,000 acres gross). However, such a pumping station

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1/ The Little Feni regulator has 20 vents each 12 feet in diameter. The regulator is capable of maintaining a water level of elevation 14 feet but upstream residents have objected so that the normal level reached (in October-November) now is elevation 12.5 feet. Low-lift pumping draws down the impounded water to about elevation 6 feet (in February/March).

could be developed gradually in stages. By making use of the existing regulator at the mouth of the Little Feni river as well as of the existing channels 1/ that connection the Little Feni with the Selonia it should be possible to transfer water from the Little Feni to the Selonia/Muhuri river system. Possibly some raising of the crest of the Little Feni regulator along with some ancillary works (low dikes) might be needed. To determine the practicability of such a scheme additional field information, particularly with regard to the profiles and cross-sections of the natural stream channels involved, are being obtained. (It will not be necessary to get complete topography of the areas adjacent to these stream channels. Actually most of this terrain is reportedly already mapped at a scale of four miles to the inch with one-foot contours.)

4.80 A report prepared by IECO in June 1964 entitled "Groundwater in East Pakistan" by H. V. Peterson, groundwater hydrologist, indicates (pages 57 and 58) that the prospects of developing groundwater seem favorable on the east side of the Muhuri valley but much less so on the west side. Since tubewells would provide water for irrigation of higher lands (above elevation 25), groundwater investigations will be included as part of the future feasibility study revisions.

4.81 As has been indicated above, navigation is an aspect needing further study not only with respect to the Muhuri project area but also in connection with the possibility of providing navigation links with the Little Feni and Dakatia rivers.

4.82 An aspect of the project that is scarcely treated in the 1967 report but is vital to success of the project is that dealing with organization. Although thus far only EPWAPDA has been carrying out the planning of this project, other agencies should be directly involved, even in the planning stage. Basically a strong project organization is needed headed by a Project Manager. The agency to whom the Project Manager would report is a matter that would have to be settled by GOEP. Personnel of the various agencies concerned should be seconded to the Project Manager and would form part of the project organization.

4.83 In the note on the Karnafuli project a preliminary determination of economic justification was made. Such a preliminary determination is not now possible for the Muhuri project because insufficient information is available with regard to costs of the three primary elements: flood control, drainage and irrigation. This will, however, be done by the time the proposed interim report described below is submitted. With the information developed in the 1967 report, as supplemented by the additional flood-control studies described above the cost of the flood-control items

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1/ EPWAPDA maps for Feni Sub-division, Noakhali District indicate two connecting channels: Gazaria Khal connecting Little Feni river and Kalidas Khal; and Madhupur Khal connecting Little Feni and Selonia rivers.

should be possible of sufficiently accurate determination after perhaps a few months of work. The drainage requirements seem more complicated and probably would require a longer time. The irrigation costs will depend on the practicability of importing water from the Meghna river via the Dakatia and Little Feni rivers and for this still more time would be needed; see further discussion below.

4.84 As regards benefits, the available information indicates that these would be relatively high in the Muhuri project area. Of the gross area of 101,000 acres, 72,500 acres are now cultivated, the principal crops now grown are as follows:

Aus/T Aman	36,000 acres
T Aman	20,000 "
B Aman	6,000 "
Aus/T Aman/Rabi	5,400 "
Miscellaneous1/	3,100 "
Total	72,500 "

4.85 The present average yield of the kharif rice crop is only 12 maunds per cropped acre but it is 19 maunds per cultivated acre. The latter is about the same as at Chandpur. The total area now cultivated during the rabi season amounts to only 10,300 acres (at Chandpur it is 44,000 acres). With complete water control it thus appears that the benefits at Muhuri would be substantially higher than at Chandpur. On the cost side, while information is deficient at present with regard to the three primary elements -- flood control, drainage and irrigation, in view of similarity of terrain and size of landholdings, it seems reasonable to expect that costs per acre will be similar to that of the Karnafuli project. These costs do not however include the cost of importing water via the Dakatia-Muhuri water transfer scheme. Since however this scheme would ultimately benefit substantial areas in the Comilla-Noakhali and Little Feni areas, the allocation chargeable to Muhuri would not have a serious effect on the rate of return of the Muhuri project particularly if the development of these areas proceeds as expected (see below in this chapter). In general, therefore, the outlook appears favorable as reagrds the economic justification of the Muhuri project. Substantiation of this preliminary conclusion should be possible at the time that the interim report (see next para) is issued in August 1971.

4.86 As now scheduled, the feasibility study revision would be completed April 1, 1972. An interim report setting forth the principal dimensions of the major project works would be completed August 1, 1971;

1/ Includes 2,700 acres of rabi only.

this report would also reach preliminary conclusions regarding the Dakatia-Muhuri water transfer scheme. Tender documents would be prepared beginning August 1, 1971 and these would be completed at the same time that the feasibility study revision is completed in December 1972. Tendering and preparation of final designs would go ahead immediately and construction could be initiated January 1, 1973 with completion 3 years later. Based upon preliminary data, cost of the project has been estimated at $12 million.

4.87 The Pabna project: The Pabna project is located along the left bank of the Ganges river between Abdulpur and its confluence with the Brahmaputra-Jamuna river; see Map 2. The project would provide flood protection and drainage for a gross area of 453,000 acres of which 316,000 would be irrigated. The project is being studied by a joint venture of two consulting firms. 1/ The consultants are considering various alternatives that have been suggested to them and it is expected that the report will identify the most practical plan of development.

4.88 Flood prevention would be provided by an embankment 188 miles long encircling the project. The embankment along the Ganges would be 49 miles long. Drainage of internal rainfall runoff during the monsoon season would be accomplished by a system of drainage channels utilizing the existing water courses as much as possible. The accumulated runoff, to the extent economically justified, would be removed by four pumping plants.

4.89 Many schemes have been considered for irrigation of the area. The one that the consultants now seem to be favoring would involve a main pumping plant on the relatively stable Karatoya river at Bera where backwater flow is received from the Brahmaputra-Jamuna. The Baral river would be used as a conveyance channel as would two rivers in the interior of the project, the Ichamati and the Atrai. The consultants are also considering use of existing drainage channels as irrigation distributaries (supplemented by low-lift pumps) as is proposed for the Chandpur and Dacca Southwest projects. It has also been suggested that groundwater might be an important water source, particularly in the western portion of the project area.

4.90 Phasing of the project is a crucial matter in view of its large size. Financial and organizational constraints needs are important considerations in selecting a first-stage project.

4.91 EPWAPDA and its general consultants are keeping in close touch with the project consultants to ensure that the feasibility report is adequate and that sufficient information is provided (for example) as regards the above issues and to see that adequate treatment is given to project organization and repayment capacity (see paras 4.39, 4.40 and 4.60). The feasibility report is expected to be available in mid-1970. The cost of

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1/ Sanyu Consultants International, Inc. of Japan and Associated Architects and Engineers Ltd. of Pakistan.

final engineering (preparation of tender documents and final design drawings) has been estimated at $4.0 million total equivalent; it could begin January 1, 1971, if financing can be arranged, and completed June 30, 1972. Construction of the first stage of the Pabna project (gross area 220,000 acres, net area 120,000 acres) could begin in about September 1972 and would require 3 or 4 construction seasons to complete.

4.92 Preliminary information indicates that a rate of return equal to or exceeding that for Chandpur (rate of return 18.5 percent) will result for this project. Based on information currently available, costs of Phase I of the project (gross area 220,000 acres, net area 160,000 acres) have been estimated at $50 million (total equivalent).

4.93 The Belkuchi project ares is bordered on the right bank by the Brahmaputra river and on the left by the Karatoya river in the Pabna District. Gross area of the project is 101,000 acres, 70,000 acres of which are proposed for irrigation. The Brahmaputra Embankment completed in 1968 protects the area from overbank spill of that river. However, the area is still vulnerable to flooding from the Karatoya-Hurasagar river and Brahmaputra backwater to an average depth of five feet. While there is always an abundant supply of water in the adjoining rivers, most of the land remains uncultivated in the winter months and agricultural yield is poor due to floods and droughts. A feasibility report in draft form dated September 1968 prepared by the consulting firm Techno-Consult of Pakistan is available.

4.94 Thirty-five miles of embankment are proposed for flood protection. Three pumping plants would supply irrigation water, and two of these plants would also serve to drain the area during the rainy season. Existing channels coupled with one sluice are planned for drainage, and the gravity irrigation plan developed by the consultants would require 58 miles of main canal and 101 miles of laterals to convey water to the irrigable lands. The water source proposed for the project is the Karatoya river which is said to be reasonably stable.

4.95 Since the area is traversed by numerous channels, it is believed that low-lift pumps might be utilized to convey water from natural waterways to the irrigable land and thus avoid the right-of-way problems and expense that would be encountered with a gravity system. Small farm holdings averaging two to three acres in size would make right-of-way problems acute on this project. Use and improvement of the natural channels would aid navigation by country boats, the only mode of transportation available to the greater bulk of the farmers.

4.96 Representatives of Techno-Consult said that tentatively they thought that six to eight months would be needed to study the low-lift pump alternative. While the economic analysis made in the 1968 draft report is better than that in many other reports in that discounting procedures were employed, further improvements in the analysis would be needed; see para 4.39.

4.97 The project appears to have good potential for development and costs should be reasonably low, considering that much of the needed flood prevention works already exist.

4.98 Organizational considerations are as for the Pabna project; see discussion above.

4.99 Based upon comparison with other projects (such as Chandpur) it appears that the project should have a favorable economic justification. Assuming that the same consultants that made the feasibility report of September 1968 are engaged, that their work is closely monitored by EPWAPDA and its general consultants and that the feasibility study revisions are completed by the latter part of 1970, it should be possible if financing can be arranged to start construction of the Belkuchi project in about September 1972. The cost of the project is estimated to be $24 million based upon currently available data. The cost of final engineering has been included with that of the Pabna project which is adjacent.

4.100 The Upper Kushiyara project is located in the northeastern corner of the Sylhet District, about 20 miles east of Sylhet Town. Agricultural production is considerably below what it could be if damaging floods were prevented, and if water could be made available to crops during the dry season. Improved drainage is also needed.

4.101 The Sylhet District is in the heaviest rainfall area of the Province. The average annual rainfall is 165 inches in the project area. Annual extremes range from 104 to 422 inches annually. The dry season, November through March, is normally two months shorter than most parts of the Province - a significant factor as regards irrigation requirements (see below).

4.102 Heavy rainfall and concurrent flood flows in the rivers cause extensive flooding from direct rainfall, reverse flows along the drainage khals, and overbank spills from the Kushiyara and Surma rivers. The project area is, however, above the influence of backwater flooding from the Meghna river.

4.103 The project area slopes from about 70 feet above sea level at the upper end, to 35 feet at the lowest. Farmers in the area say that the Kushiyara river overflows last from 7 to 15 days, that owing to inadequate drainage fields remain flooded 3 to 5 months a year and that severe crop damage during the past 14 years has resulted from an embankment along the Indian side of the Kushiyara. 1/ There have been some local Thana council efforts to reduce flooding and three khals have been closed to stop early flooding from the Kushiyara.

1/ The Kushiyara embankment would be about 25 miles long. The Kushiyara forms the international frontier over about half this distance.

4.104 A feasibility report dated May 1966 was prepared for this project by a study team made up of EPWAPDA employees under the general supervision of International Engineering Company. The 1966 report recommended a project covering a gross area of 87,000 acres. Flood protection of 78,000 acres would be provided by means of embankments; about 50,000 acres would be drained by gravity; and 40,000 acres would be irrigated by pumping from the Kushiyara and Surma rivers into a conventional gravity canal distribution system.

4.105 As the 1966 report brings out, prevention of flooding coupled with drainage are the primary needs of the area. The report recommends protection against a 100-year flood; however a lower degree of protection - against say, a 10-year flood may be more economic. The resulting lower embankments would not require as much right-of-way and would be less of an impact on the villages that occupy much of the higher ground adjacent to the rivers. Drainage outlets, acting as a complement to embankments, could reduce the duration of flooding on the rare occasions when the embankments are overtopped. 1/ 2/

4.106 Alternatives to the gravity canal irrigation scheme proposed in the report should be considered, particularly in view of the short dry season. Low-lift pumps and tubewells could provide attractive alternatives to gravity canals without the right-of-way problems created by the latter.

4.107 The project appears justified, at least for flood prevention and drainage. Additional studies should be made considering alternatives suggested above, and economic studies should be prepared in accordance with current standards established by EPWAPDA in cooperation with the East Pakistan Bank Group.

4.108 Terms of reference for revision of the 1966 feasibility study should be prepared and should cover, in addition to the alternatives suggested above, adequate treatment of project organization and repayment of project costs; see paras 4.39, 4.40 and 4.60. Landholdings in the Kushiyara project area, which average 15 acres in size, are considerably

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1/ Spillways would be needed to direct overflows and thus prevent erosion of the embankments. These might be located at the khal outlets where drainage structures (sluices) will also be required.

2/ The farmers' statement referred to above about the duration of overflow is confirmed by river-stage records. The fact that the duration of overflow is much less than on the main rivers of the Province means that, if only 10-year protection is provided, the duration of overflow resulting from a larger flood might be only a few days while the volume of water entering the protected area might be sufficiently small so as not to cause serious damage. In reviewing this aspect of the project design, economic as well as hydrologic factors should be considered.

above the norm for East Pakistan. Nevertheless, specific recommendations are needed on the magnitude and timing (probably on a progressive basis) of project repayment charges.

4.109 Once the terms of reference are prepared and considering the large amount of useful information in the 1966 report, it should be possible to prepare a revised feasibility study of adequate scope in about 12 months' time. If this can be accomplished by June 1971 it should be possible, provided that financing can be arranged, to start construction by early 1972. Based upon preliminary information, costs of the project have been estimated at $13.5 million.

4.110 Khowai project: A feasibility report on the Khowai project dated February 1968 was prepared for EPWAPDA by Associated Consulting Engineers, Dacca. Physical characteristics of the project divide it into two distinct areas; the Northern Area, composed of 39,800 acres which is flooded from late May to late October to a depth of 5 to 20 feet every year by backwater flow from the Dhaleswari Meghna, and the Southern Area encompassing a gross area of 40,200 acres with a net irrigable area of 33,000 acres which is flooded by the Khowai, Karangi, and Sutang rivers. The Northern Area development has been designated by the consultants as Phase I and the Southern Area development Phase II.

4.111 The Khowai river is a rainfed stream with most of the drainage area in India. There are at least 30 to 40 pronounced flood peaks every year. Normal annual rainfall averages about 100 inches annually, 86 percent of which falls in the six-month period April through September. As a result of flooding from the Khowai river and to some extent from the Sutang and Karangi rivers, and the rainfall pattern of the area, crop production is hampered by flood and drought.

4.112 Problems of flood prevention in the Phase I area below elevations 20 to 25 feet can be relieved in a minor way by some channel improvements and embankments but most of the flooding is due to the backwaters of the Meghna and should be studied as a part of the flood prevention plans for other areas also flooded by the Meghna. However, flood protection can be achieved by embankments in the Southern Area designated by the consultants as Phase II, and such a plan has been recommended.

4.113 The flood protection scheme for Phase II would involve construction of embankments along both banks of the Khowai river, a river reach of 16.5 miles, the right bank of the Sutang river for 26 miles and the left bank of the Karangi river for 17.5 miles and a diversion sluice and channel from the Khowai near Chunanighat to the Sutang river. The consultants propose protection against floods of a frequency of around 200 years. It is questionable whether this much protection can be justified; a review of the plans to offer a lesser degree of protection - perhaps for a 25-year frequency flood - is therefore recommended.

4.114 Provision of water supply for irrigation may prove to be very valuable in the Southern Area during the dry season. The consultants planned to provide water for irrigation from a conventional gravity canal system. They also proposed to build a barrage on the Khowai river and divert water into two main canals totalling 21 miles in length. Forty miles of laterals would be required to serve all the land under this scheme.

4.115 Gravity canal systems require considerable right-of-way and cause significant impact upon the densely populated areas of East Pakistan such as the Khowai area. The canals of necessity must be located on the higher ground where villages are usually built and as a result right-of-way costs are high, displaced people are very disturbed, and the process of obtaining land is time-consuming and frequently delays project implementation indefinitely. The alternative of releasing water for irrigation into drainageways and khals from which it can be lifted to the lands by low-lift pumps has many advantages and should be considered for the Khowai project. A second alternative that should be examined would be to use the borrow area adjacent to the outer embankment as the main canal locations so that less right-of-way would be required.

4.116 The Phase II project seems economically justified for flood prevention and irrigation. Additional studies should be made considering the alternatives suggested above, and economic studies should be prepared of adequate standard (see para 4.39). Terms of reference for revision of the 1968 feasibility study should be prepared and should cover, in addition to the alternatives suggested above, adequate treatment of project organization and repayment of project costs (see paras 4.40 and 4.60).

4.117 Once the terms of reference are prepared, and considering the large amount of useful information in the 1968 report, it should be possible to prepare a feasibility report in about twelve months' time. If this can be accomplished by June 1971 and if financing can be arranged it should be possible to start construction by the end of 1972. Based upon preliminary information including the 1968 report, the project is estimated to cost $11 million. It would appear practical to employ the same consulting firm on Khowai as will be used on Upper Kushiyara.

4.118 <u>Sangu multi-purpose project</u>: A report on this project dated January 31, 1965, was prepared by Sandwell & Company Ltd., under the auspices of the External Aid Office, Government of Canada. The project is located near Chittagong. The irrigation aspects are presented in a separate report dated June 1964 prepared by Associated Consulting Engineers (ACE Ltd. of Karachi and Dacca, Pakistan). The Sandwell report contains reviews of portions of the ACE report.

4.119 The main features of the project are a 190-foot high storage dam, a diversion dam (barrage) at Dohazari and a gravity irrigation system covering a command area of 100,000 acres. The main dam would include a power house with three 27,500 kw units. Average annual generation would be 229 million kilowatt-hours at 33 percent plant factor. The benefit-cost ratio for the hydro features was computed at 2.11; for the irrigation features it would be 3.79 for an "optimum program" and 1.35 for a "practical program"; for flood control it would be 2.43. 1/

4.120 The Sandwell report, states that more sedimentation data are needed to estimate the life expectancy of the reservoir.

4.121 Topographically, the irrigated area is low-lying; 80 percent of it is between elevations of 4 and 12 feet above sea level. It is of semi-bowl like shape with a depression in the center along the Chand Khali. The ACE report states that "this makes the task of canal alighment difficult and the system costly". Also there are "innumerable stream crossings".

4.122 The average cultivated holding is only 1.9 acres and with an average of 15.7 parcels per holding.

4.123 Rainfall in the area is relatively high. The average annual rainfall is 108 inches while the average October rainfall is 7.1 inches. Since these amounts of rainfall, particularly in October, could be ample for transplanted aman (provided proper cultural practices, e.g. diking of plots, are adopted by the farmers), relatively large benefits might be obtained from a first-stage project limited largely to flood control as described below.

4.124 From the map of the irrigable area, it appears that a considerable mileage of coastal embankments have already been constructed which may give some protection against tidal inundations. Maximum high tide conincident with high flood occurs in July and reaches 24.49 feet with an average maximum of 14.9. Average high tide during the low-flow months is between 4.3 and 6.1.

4.125 Considering the small farm size, the low elevations and the numerous natural channels in the irrigable area, an alternative project based on use of the natural channels as irrigation distributaries (supplemented by low-lift pumps) and, to the extent feasible, as navigation waterways, needs serious consideration.

4.126 A phased development of the irrigable area should be considered taking into account the extent of development that is possible preceding construction of the storage dam. For example, the project could be limited to flood control at first (to the extent possible without the storage reservoir) followed by supplemental kharif irrigation, which might be obtainable by operation of tidal sluices only.

1/ These ratios are considered illustrative only as the interest rate and foreign exchange rate, discounting procedures, etc., would need reconsideration.

4.127 The capacity of the hydro-electric installation should be reconsidered for a possible lower plant factor and higher installed capacity taking into account changes in the power system that have occured since the report was prepared. The possibility of pumped storage for peaking should also be studied making use of the Dohazari barrage for re-regulating storage.

4.128 Aspects of the project that are scarcely treated in the 1965 report but are vital to success of the project are those dealing with organization and project repayment. (Although thus far only EPWAPDA has been carrying out the planning of this project, other agencies should be directly involved, even in the planning stage). These matters need treatment as discussed above (paras 4.39, 4.40 and 4.60).

4.129 Further steps to advance this project should be considered on a reconnaissance basis before proceeding to detailed revision of the existing feasibility report. It has been proposed that a single consulting frim or group be engaged to carry out the studies for the nearby Karnafuli irrigation project as well as for the Muhuri, Little Feni and Comilla-Noakhali projects. It might be possible to arrange for the same firm to carry out the reconnaissance studies for the Sangu project and for a subsequent detailed revision of the existing feasibility study.

4.130 This project would appear to present no serious technical problems and might provide an excellent opportunity for a hydro-peaking plant to fit in with the East Pakistan power grid but adequate costs and benefits will not be available until further studies are completed. Assuming that the feasibility report and final engineering could be completed by the end of 1973, construction could begin early in 1974. Based upon preliminary information, the cost of the project has been estimated at US$50 million.

<u>New Multi-Purpose Projects -- Feasibility Studies Not Available</u>

4.131 Four projects, covering about 2.5 million gross acres (1.8 million acres net) appear to be viable projects from technical and economic aspects based upon information available and when compared with other projects that are now at advanced stages of preparation (especially Chandpur and Dacca Southwest). Conclusions regarding technical and economic soundness have been based upon knowledge of topographic, soils and hydrologic factors and of existing cropping patterns. However, feasibility studies have not been made and these must be completed before conclusions are made to proceed with construction. These projects are:

Dacca North
Barisal
Little Feni
Comilla-Noakhali

4.132 The projects listed above involve no serious technical constraints and would appear to fit well into long-range development needs of East Pakistan (see Chapter 5). It is concluded that feasibility studies should be undertaken as early as possible followed by final engineering and construction. (In most cases, since the outlook for economic justification is favorable, final engineering could proceed on the basis of an "interim report" which could precede the completion of the feasibility report.) However, the aggregate area of the 4 projects is large, and stage development should be considered where practical. At this juncture it appears likely that the initial phases would not involve more than 0.6 million acres (net) out of a total of 1.8 million (net); see Table 2.

4.133 The Dacca North project area is located in the Northeast region of East Pakistan between the Dacca-Joydebpur Sripur Road and the Banar-Lakhya River, north of the city of Dacca in Dacca District. The area extends from Dacca Demra Road in the south to Sripur Railroad in the north.

4.140 The gross project area is 218,000 acres and plans are proposed to irrigate 174,000 acres. Elevations in the project area range from 4 feet in the center to above 30 feet near Kapsia. Higher elevations occur generally along the river on the eastern side of the project and along the western boundary. The high area along the west is rapidly developing as an industrial area.

4.141 The East Pakistan Bank Group has had the opportunity to review a draft of an agreement on study of the feasibility of the project between EPWAPDA a consortium of three consulting firms: Pakistan Techno-Consult Ltd., Sir M. McDonald and Partner and Hunting Technical Services Ltd. The agreement would direct the consultants in the study of physical plans and economics for full development of project land and water resources to achieve flood prevention, irrigation and drainage. Several alternatives are suggested to achieve flood control including protecting the project area from Lakhya River flooding by embankments and a back levee and drain along the border with the jungle to the north. Gravity sluices and pumping plants would be studied for drainage. The source of irrigation water would be the Lakhya River through a pumping plant on the right bank. Study would be made both of a gravity canal system and of a system making use of existing drainage channels as irrigation distributaries with low-lift pumps to lift water to the lands.

4.142 The plan of development would include stages starting with partial flood protection with provision for increasing it, and the irrigation system developed in blocks to the extent practical. Gradual drawdown of flooding would be planned so that farmers would not be subject to sudden and drastic adjustments by complete elimination of flood water upon project completion.

4.143 As there is some relatively higher ground within the project area, which may not be flooded or may be subject to only shallow flooding, it might be useful to consider two additional alternatives. One would be a first-stage development limited to the high ground with water obtained from tubewells. The second would also consider tubewells for the high ground but as a final stage of the project.

4.144 The intent of the agreement is to make economic analyses using modern techniques. The terms of reference do not specifically mention repayment of project costs and this item should also be adequately studied in detail; see paras 4.39 and 4.40.

4.145 It was found in the study of Chandpur project that sample areas for study of detail plans and costs for low-lift pump implementation yielded valuable data. It would seem that the same approach should be followed on this project (see paragraph 2.14).

4.146 This project would appear to present no significant technical problems but adequate costs and benefits will not be available until the proposed feasibility studies are completed. However, the similarity of the project area to the Dacca Southwest and Chandpur project areas leads to the conclusion that similar benefits will be obtained and that the economic feasibility of the project will prove adequate.

4.147 Repayment and organization and management aspects of the project must be studied fully. Organization and management should be explored thoroughly and governmental responsibilities determined as has been done for the Chandpur Project.

4.148 EPWAPDA and its general consultants should follow the feasibility work closely to ensure that it is adequate. If this is done, and accomplished by mid-1972, it should be possible, if financing can be arranged, to begin construction of the project in 1973. Based on preliminary information, the cost of the project is estimated at $40 million (total equivalent).

4.149 The Barisal area comprises 1,500,000 acres in the southeast portion of the Southwest Region (see paragraphs 1.12-1.15, Map 2 and Table 2). It is a zone of ample sweet water and is subject to relatively shallow flooding. The soil and water resources of the region indicate that it is one of thigh potential and where major benefits can be achieved both in the shortrun and over a longer time period at relatively low cost.

4.150 The Barisal region is one wherein the installation by ADC of about 10,000 low-lift pumps has been contemplated and in fact, the estimate of water availability described in para 4.01 indicated that it would be feasible to install 10,000 such pumps in the region. Actual installation by ADC up to now has been only about 1,000 due to slack demand from farmers in the region. The cause of the low demand is somewhat complex. One reason is that the relatively large landholdings in the area give rise to considerable tenant occupancy. Another reason is that farmers already obtain an aus crop in about one-third of the area which, although low-yielding, would be competitive with the T aman crop that would result from low-lift pumping.

4.151 According to the UNDP soil studies as confirmed by questioning several farmers, much of the presently grown aman crop is not transplanted until late September or October when flooding in the area has receded. The depth of flooding nowhere exceeds two to three feet. Thus, flood prevention embankments would have to be only five to six feet high which is much less than (for example) Chandpur or Dacca Southwest.

4.152 It can thus be visualized that development of the Barisal region would have three stages: (a) low-lift pumps (to the extent of water availability); (b) further extension of low-lift pumping which would involve fixed primary pumping stations and possibly deepening of some of the natural channels (khals); (c) flood prevention embankments and appurtenant works including drainage sluices. It seems likely that drainage pumping would not be needed as the area could be drained during the low part of the tidal cycle. In some portions of the region, moreover, where tidal action is favorable, primary pumping might also not be needed for irrigation, thus eliminating stage (b) except for deepening of the khals. Natural levees exist along some of the streams in the region; in such cases, embankments could be omitted, at least initially, and only drainage sluices (supplemented by earth plugs to close off the khal exits) installed.

4.153 In view of the very large size of the Barisal area, it will have to be developed in phases. Phase I would cover 300,000 acres gross and 200,000 net irrigable. Project preparation, final engineering and capital investments for a Phase I project are outlined in Table 1. The cost of the project preparation is estimated at $4.0 million total equivalent. If this can start by January 1, 1971, it should be completed by June 30, 1973. The initial work of project preparation will have to include a reconnaissance of the entire 1.5 million acres in the Barisal region so as to delimit the 300,000 acres in Phase I. Final engineering is estimated as costing $5.0 million total equivalent. This would include the cost of final engineering for all three stages in Phase I. Stage (a) estimated to cost $6.0 million total equivalent would be for 2,000 low-lift pumps and some drainage sluices in an area of about 100,000 acres net. Stage (b) estimated to cost about $14.0 million total equivalent would be for 2,000 additional low-lift pumps and primary pumping stations to serve them. Stage (c) (cost $16.0 million total equivalent) is for flood control and drainage for the entire 300,000 acres (gross) in Phase I.

4.154 EPWAPDA and its general consultants have already prepared detailed terms of reference for consultants that will be required for project preparation and final engineering. These terms of reference which have been reviewed by the East Pakistan Bank Group include adequate treatment of economics and project organization (see paras 4.39 and 4.40). Effective inter-agency cooperation will be needed to ensure success of this important project. The East Pakistan Bank Group in its work program will endeavor to give particular attention to the development of the Barisal region in view of its high potential which is obtainable at relatively low cost.

4.155 The proposed Southwest Region Water Study (see Chapter 5) would be carried out concurrently with the project described in the preceding paragraphs. Going ahead with the Barisal project development need not, however, await the completion of the water study which it is judged will take about five years. The reason is that the Barisal region is in a sweet-water zone fed largely by the Brahmaputra River. The Barisal project would moreover have little effect on the water balance of the critical (western) part of the southwest region which depends primarily upon flows of the Ganges River.

4.156 Little Feni Project: According to the IECO Master Plan report of December 1964, the Little Feni project would have a gross area of 259,000 acres and a net area of 150,000 acres. The project is located in the Southeast region (see para. 1.16). In 1965, a large regulator structure (drainage sluice) was completed by EPWAPDA near the mouth of the Little Feni river to prevent tidal inundation and saline water intrusion. This structure, a preliminary design for which was contained in the IECO report of October 1961 entitled "Little Feni and Noakhali Regulators", has been described above in connection with the Muhuri project (see para 4.76).

4.157 As observed from the air, the Little Feni river contains many meanders. Some channel improvement work (cut-offs and low dikes) have been constructed during the past ten years by EPWAPDA. It appears that additional flood prevention works in the lower portion of the Little Feni river, just upstream of the existing regulator, might have good justification, particularly if planned in conjunction with a possible scheme for water transfer to the Muhuri river (see description above of the Muhuri project).

4.158 Irrigation of the Little Feni project area, like flood control, would probably have to proceed in stages. Much would depend upon further development of the possible scheme, just mentioned, involving transfer of water from the Dakatia river to the Muhuri river via the Little Feni river. In working out such a scheme, the long-range requirements for the Comilla-Noakhali project, which adjoins the Little Feni project area on the west would also have to be taken into account. The first step, therefore, in the study of the Little Feni project should be a study, on a reconnaissance basis, of the proposed Dakatia-Little Feni-Muhuri water transfer. As pointed out in the discussion of the Muhuri project (paras 4.79 and 4.81) a highly important benefit from such a scheme would be navigation. Such a study has in fact already been programmed as part of the Karnafuli-Muhuri engineering credit (see paras 4.52, 4.79 and 4.86).

4.159 The reconnaissance study of the water transfer is expected to be ready by about April 1971. A feasibility study for the first phase of the Little Feni project could be started about January 1, 1972 and, taking into that considerable information would already be available from the reconnaissance study, the feasibility study could be completed by the end of 1972. The final engineering could start July 1, 1972, that is, before the feasibility study has been completed. Using procedures as have been worked out for other projects, construction could proceed on the basis of outline drawings and it could start in December 1973. As indicated in Table I, a four-year construction period has been assumed. The capital investment required for a Phase I project covering a gross area of 140,000 acres and a net area of 90,000 acres, has been estimated at $30 million total equivalent.

4.160 The Comilla-Noakhali Project lies mainly in the Dakatia River drainage basin in the Southeast region of East Pakistan and covers a gross area of 892,000 acres (see para. 1.16). The area is bordered on the East by the Little Feni and Muhuri project areas and by the Chandpur project (now under construction) on the southwest.

4.161 Present agricultural practices in the Comilla-Noakhali project area are limited principally by flooding, which involves fresh as well as saline water. Cropping intensity is presently only 146 percent. Yields are low and B Aman is the principal crop occupying about 68 percent of the cultivated land. Judging from the recent studies at Chandpur and Dacca Southwest where cropping patterns and flooding conditions are similar, present yields at Comilla-Noakhali could be tripled through water control.

4.162 An IDA credit of $2,400,000 has been granted to the Government of Pakistan to finance revised feasibility studies and final engineering of the Karnafuli and Muhuri Projects and consultants have already been engaged by EPWAPDA for this work. Studies of water supply for the Muhuri project will involve investigation of the Meghna River as a source. The flat terrain and the presence of numerous natural drainage channels makes water transfer possibilities promising. On studying the water supply for the Muhuri project, the consultants will conduct a reconnaissance at the Comilla-Noakhali area to determine generally its water needs and its relationship to phased developments of water transfer schemes to serve as well the Muhuri and the Little Feni projects. Subsequent to such a reconnaissance it will be possible to determine what part of the project should constitute a first-stage development and should be the subject of a detailed feasibility study. Phasing of the project would be a crucial matter in view of its large size. Financial and organizational constraints would also need careful consideration before a first-stage project could be selected.

4.163 In planning flood prevention, the existence of the embankments of the Chandpur project in the southwest part of the Comilla-Noakhali project area could be taken advantage of. The drainage divide on the east between the Comilla-Noakhali project area and that of the Little Feni River is indistinct. Topographic surveys and hydrologic studies would be needed to determine whether flood spills are of significance and if so what preventive works may be justified.

4.164 Based upon a knowledge of the topographic, hydrologic, and agricultural aspects of the area, it would appear likely that a technically and economically sound project can evolve.

4.165 EPWAPDA and its general consultants should make use of reconnaissance findings for the project, and prepare appropriate terms of reference for feasibility studies. Table 1 indicates the possibility of a construction start December 1, 1973 following procedures as outlined above for the Little Feni project. Based on preliminary data, cost of Phase I of the project (gross area 220,000 acres, net area 160,000 acres) has been estimated at $50 million total equivalent. Project preparation and final engineering would cost $3 and $5 million (total equivalent) respectively.

4.166 Ganges-Kobadak Jessore Unit: A report on Phase II of the Jessore Unit of the Ganges-Kobadak project was prepared by Dr. Mubashir Hasan, consulting civil engineer, dated October 1966. There are three units of the

Ganges-Kobadak project: Kushtia, Khulna and Jessore. The Jessore Unit is further subdivided into six phases of which this project is the second or Phase II. The report proposes that the Nabaganga River downstream of the Magura River be used as a source of water supply for eastern areas; the Fatki River, the central area; and the Chitra River, the southern area. Six pumping plants are proposed and a series of canals from the pumping plants totalling 174 miles in length. Additional works are proposed to provide some flood control and drainage. The gross area is 140,000 acres of which about 105,000 acres is said to be irrigable.

4.167 The report points out that hydrologic data are extremely limited and that changes in flows brought about because of the existing Ganges-Kobadak works (see Chapter III) have made many historic records useless. Since water supply to the existing GK-Kuhstia unit is by no means solved as yet, the situation with respect to the Jessore and Khulna units remains obscure. Besides the Ganges as a source of supply, another major source that should be considered is groundwater. A third source could be return flow from upstream units, particularly in view of the high wastage of water that now prevails (Chapter III). A major part of the return flow from the Kushtia unit will flow to the Jessore and Khulna units. The hydrology of the whole Southwest region is rather complex and actions are needed (see Chapter 5) that will enable a gradual understanding of the problem. Concurrently, however, it should be possible to proceed with the development of portions of the area based on groundwater. Then, as reliable information is generated, surface sources could be utilized as well.

4.168 Quite possibley portions of the area will require drainage improvements including channel deepening and pumping and these facilities will also affect the water balance and therefore the sequence in which the various portions of the area can be irrigated and drained.

4.169 Whether a system of irrigation distribution based on use of natural channels supplemented by low-lift pumps rather than the gravity canal system proposed would also need investigation. Table 1 indicates preparation of a new feasibility study for the Ganges-Kobadak-Jessore unit (Phase II) at an estimated cost of $2.0 million total equivalent. The table also indicates start of such a study June 1, 1973 with completion a year later. An earlier start of such a feasibility study does not appear practiable in view of the need for previous progress on the Southwest Region Water Study (see Chapter V).

Manpower Requirements

4.170 Engineering: Manpower requirements to carry out the engineering for the projects listed in Table 1 (includes the special studies and basic data programs described in Chapter V) are likelv to present serious problems. A large number of expatriate specialists would be needed in the first three years 1970/71 to 1972/73. Even assuming that the home-office forces of the consultants will make up part of the work force and that there will be a maximum participation by Pakistani consultants and Government forces, the expatriates required to reside in East Pakistan, for the EPWAPDA projects alone, total about 125 in 1970-71 and would increase to about 225 in 1971-72 and 1972-73. Presently about 60 expatriate consultants are associated with EPWAPDA projects and this number would have to be retained; the total requirements for these two years is thus 285. Pakistani professional consultant needs will also be high with a 1970-71 demand estimated at about 200 increasing to about 350 in 1971-72 and 1972-73. Serious problems face East Pakistan in absorbing these personnel needs, particularly in regard to the expatriates. Experience indicates that such a large and sudden influx of expatraites will create public relations problems which must be dealt with carefully and at an early date. Housing needs must be met if recruitment is to be successful. Approval of consultants by the Government must be prompt and efficient. Salary scales must be realistic and attractive. Schooling and medical needs for families will have to be recognized. Equipment of all kinds such as automobiles, office machines and engineering instruments must be on hand when needed. While an effort should be made to locate consultants' offices outside of Dacca, practical considerations relating to location of Pakistani key agencies, facilities and information indicate that a large portion of the expatriates must be absorbed in Dacca. In addition to the need for consultants, EPWAPDA will face a large manpower need to assimilate the expanded program. Other agencies such as the Survey of Pakistan will also require increased manpower. EPWAPDA will need engineering staff, and a sizable body of sub-professional personnel for operation and maintenance as the program progresses although this need will develop more slowly than that which will develop with the planning and construction of projects. If recruitment of consultants is unsuccessful due to failure to meet all the essential requirements cited above, slippage in the program listed in Table 1 will inevitably occur. The starting and completion dates shown for project preparation, final engineering and construction for the various projects listed assume that all the actions described above will be carried out without delays. To speed up administrative actions concerned, such as approval of consultants' contracts and approval of individuals to be resident in East Pakistan, existing procedures need to be streamlined, which may involve granting EPWAPDA more autonomy in such matters. GOEP has indicated its willingness to consider the necessary administrative changes.

4.171 Agriculture: In Chapter 5 of Volume I, a discussion of agricultural manpower required for both irrigated and non-irrigated areas indicates a shortfall of both Union Agricultural Assistants and Thana Agricultural Officers. Present training facilities are inadequate and both shortfalls will get progressively worse (reaching a peak by 1974/75) unless a special training project is undertaken without delay. Such a project has been described in Chapter 5 of Volume I.

Agricultural Production

4.172 Table 3 contains a projection of the incremental agricultural production obtainable from the water development projects broken down according to low-lift pumps, non-intensive tubewells (constructed by ADC), intensive tubewells (constructed by EPWAPDA) and multi-purpose projects. The projection is given for the years 1971/72 through 1980/81, and an additional projection is shown for the year 1985/86. The projects included in making the projection are the three existing projects described in Chapter 3 (GK-Kushtia, Coastal Embankments and Chandpur) and the short-range projects described in this Chapter 4. As has been indicated in Table 2, portions of the later phases of the Coastal Embankments and of these short-range projects have been included in the projection to 1985/86 even though the capital investments indicated in Table 1 cover only the initial phases of the Coastal Embankments and of the larger multipurpose projects (Pabna, Little Feni, Barisal and Comilla-Noakhali). The areas irrigated and provided with flood protection may be summarized as follows (in thousands of acres) 1/:

	Irrigated	Flood Protection
Present (1969-70)	860	1,580 2/
1975-76	3,280	3,480
1980-81	5,960	5,730
1985-86	8,070	6,700
Ultimate	10,380	8,050

4.173 The assumptions used in making the projections were as follows:

a. The incremental area irrigated by low-lift pumps would be 300,000 acres by 1971/72 building up to 1.1 million acres in 1976/77. Thereafter it would decrease to 0.5 million acres in 1979/80 and would then remain constant. The decrease is to allow for the fact that an area of approximately 1.0 million acres overlaps with the EPWAPDA multi-purpose project areas.

b. The incremental area irrigated by non-intensive tubewells would amount to 50,000 acres in 1971/72 increasing to 800,000 acres in 1978/79 (this assumes 15,000 ADC tubewells by that date). Thereafter the area irrigated by these tubewells would decrease to about 300,000 acres by 1985/86. The reason for the decrease is because the area served would progressively be taken over by the intensive-type tubewell developments.

1/ Area presently irrigated of 860,000 acres (see footnotes 2 to 7 in Table 2) has been added to grand total in Table 2. Area protected against floods in Brahmaputra Right Bank project (footnote 6) has also been added.

2/ Includes 1,000,000 acres in Coastal Embankment area.

c. The intensive tubewell projects would have dates of start of construction as in Table 1. No area irrigated until 2 years after start of construction; thereafter full area irrigated reached after 3 years. The incremental area irrigated would build up to 1.0 million acres by 1980/81 and to 2.2 million acres by 1985/86.

d. The EPWAPDA multi-purpose projects include the 12 "new projects" in the short-range list and the 3 partially completed existing projects (Coastal Embankments, GK-Kushtia and Chandpur -- see Chapter 3). Dates of start of construction would be as in Table 1. No area irrigated until 3 years after start of construction; thereafter, full area irrigated reached from 3 to 7 years later, depending on size of project. The incremental area irrigated would reach 3.0 million acres in 1980/81 and 4.2 million acres in 1985/86.

e. The areas "effectively irrigated" in all cases except that of the low-lift pumps equals 30 percent of the incremental area irrigated during the first year, 60 percent the second year and 90 percent the third year. (Total elapsed period to reach 90 percent would thus be 5 years for tubewell projects and for multi-purpose projects it would be from 6 to 10 years depending on the size of the project area.) In the case of the low-lift pumps, the incremental area effectively irrigated would be 40 percent the first year, 80 percent the second, and 90 percent the third year.

f. For the multi-purpose projects, incremental production in tons was assumed equal to the area effectively irrigated times 3.0 tons. The latter figure was obtained from the Chandpur II appraisal report (in Volume IV), Annex 4, Table 4, taking future production at 341,000 tons (224,000 tons of paddy rice, which is equivalent to 150,000 tons of clean rice, plus 191,000 tons of short-season crops) and present production at 85,000 tons (42,000 tons of clean rice plus 43,000 tons of short-season crops). The difference is 256,000 tons for a cultivated area of 89,000 acres or 2.9 tons per acre. The irrigated area is however only 75,000 acres which would give 3.4 tons per acre. To be conservative, 3.0 tons per irrigated acre was used. For the intensive and non-intensive tubewells projects, these tonnages per acre were assumed 2.5 and 2.0 respectively. The latter figure was obtained from the appraisal report included in Volume IV. A slightly higher tonnage was assumed for the intensive tubewell projects since these would be located within a concentrated georgraphical area. For the low-lift pumps the tonnage was assumed at 1.2 tons per acre since the benefit is primarily from boro rice only.

Periodic Review of Projects

4.174 It is proper and indeed imperative to proceed with the water development projects "in the pipeline" as above outlined. These projects all have high rates of economic return, involve no technical difficulties and can be integrated into a long-range Province-wide plan of water development including flood control (see para 4.176). During the next few years efforts will be made by other agencies to prepare purely agricultural-input projects (improved seeds, fertilizers, pest control and credit). It is possible that some of these projects will have rates of return higher than the water development projects. Moreover some of these projects could be in competition for the same financial and/or manpower resources. On the other hand, as several of these possibilities are at this stage only speculative, there is no reason to delay proceeding with steps toward implementation of the water development projects as has been outlined above. At the same time, it must be realized that the overall cost of the water program comes to $932.1 million total equivalent (see Table 1), and that to carry out a program of this size and in accordance with the dates indicated in Table 1 would require an effort of unprecendented magnitude. The manpower constraint, has been discussed above and it was indicated that this contraint alone, as its effect is better understood, might have to require some shift (hopefully not more than a year or two) in the dates for start of construction of some of the projects in Table 1. In order to evaluate properly the combined effects of manpower and financial constraints and of the competition for these resources by other projects, the array of projects "in the pipeline" should be subject to periodic review on an annual basis. This should obviously apply to all projects and should be done in cooperation with the Planning Department, GOEP, whose staff would have to be strengthened for this purpose (see Volume I).

Short-Range Projects -- Summary

4.175 From Table 2 and 4.172, the short-range projects may be regrouped as follows (thousands of acres):

	Irrigation		Flood Protection	
	1985-86	Ultimate	1985-86	Ultimate
Low-lift pumps - Existing	700	700	-	-
- Future	500	500	-	-
	1,200	1,200		
Tubewells - Existing	110	110	-	-
- Future	2,500	2,500	-	-
	2,610	2,610		
Multipurpose projects - Existing	50	50	1,580	1,580
- Future	4,170	6,480	5,120	6,470
	4,220	6,530	6,700	8,050
Total - Existing	860	860	1,580	1,580
- Future	7,170	9,480	5,120	6,470
Grand Total	8,030	10,340	6,700	8,050

4.176 With respect to the tubewell area, it was assumed that this would increase by 1985-86 to 2,610,000 acres, an increase of 2,500,000 acres over the existing area. Although the figure of 2,610,000 acres is less than that of the favorable zone (para 4.16) and can therefore be used as a target, it is obvious that further investigations, as described elsewhere in this volume, will be needed before the figure can be confirmed. With respect to the multipurpose projects, there are a total of 18 involved: 6 existing (of which 3 are completed) and 12 new ones -- in other words 15 projects on which major works are in the future. With one exception, there are no technical constraints preventing full development of these 15 projects as ample technical data exist (topography, hydrology and soils) and there are no unresolved technical problems of consequence. The one exception is the Coastal Embankment project where full development (including water management) is clearly attainable only in half the project area (see para 3.11). Full development of the remaining half will probably have to await results -- as they become available -- of a special study of the Southwest Region; see Chapter 5. The ultimate irrigable area, with this adjustment, would be reduced from 10,340,000 acres to about 9.1 million acres. The ultimate area with flood protection would however remain at about 8.1 million acres.

4.177 As above outlined, the "short-range" projects cover 9.1 million acres of irrigation (of which 0.9 million existing) and 8.1 million acres of flood prevention (of which 1.6 million existing). Development of additional "long-range" projects are descrived in Chapter 5.

CHAPTER 5

NEW PROJECTS -- LONG-RANGE

5.01 For the development of additional water-control projects beyond those described in Chapters 3 and 4, technical constraints both with respect to unresolved technical problems and availability of basic data become crucial. To overcome these constraints, various "special studies" will be needed. However, before discussing these, it is useful to consider the two main areas of technical constraints -- the flood control aspects and the water balance aspects -- and to consider how these affect the four regions into which the Province can conveniently be subdivided.

Flood Control Aspects

5.02 As explained above, the 12 new and 5 existing multipurpose projects cover a gross area of 8.1 million acres. The Coastal Embankment project will provide protection basically against ocean flooding. Protection against other types of flooding (spill from the rivers and from excess rainfall backed up by high river stages) would thus amount to about 5.1 million acres.

5.03 The average area flooded in the monsoon season in East Pakistan is from 8 to 10 million acres but 17 million acres are subject to flooding from time to time. Thus even with 5.1 million acres protected, a flood problem of considerable magnitude would remain. The problem of protecting the remaining areas becomes moreover progressively more complex and involving considerable risks. East Pakistan consists of a large delta located at the confluence of the Ganges and Brahmaputra -- two of the world's largest rivers. They carry at maximum stage a higher flood flow than most rivers in the world and their sediment load (2.4 billion tons annually) exceeds that of any other river system in the world. Because of their enormous transporting power, the Ganges and Brahmaputra rivers have experienced major shifts of their channels in recent centuries. Attempts to contain these rivers by "double embankments" may be extremely hazardous because of the very real danger of overtopping and breaching of the containing embankments and the impracticability of quickly evacuating the densely populated zones in the areas protected by the embankments. (With one minor exception, none of the 17 projects mentioned in the preceding paragraph would involve double embankments. The one exception is the Dacca-Southwest project, the upper part of which would include over a stretch of about 8 miles an embankment paralleling the existing Brahmaputra Right Bank Embankment. However such limited extent of double embanking is not considered serious and in fact will provide a significant prototype to be observed carefully following completion of construction -- see below with regard to flood models and observations on prototypes.) The problem of flood control is further complicated by the lack of materials, principally stone and gravel, that are required in the construction of works for river training and embankment revetment (the need for such work becomes intensified once double embanking is embarked upon on a significant scale) and by the fact that little is known about the ultimate effect of upstream projects (in India) that involve embankments (and even some double embankments).

5.04 While elimination of flooding is clearly crucial to East Pakistan -- whether in human or economic terms -- it must nevertheless be remembered that the local farmers have over the centuries adjusted remarkably to the annual cycle of inundation. This is most evident with respect to the prevailing crops grown, especially long-stem broadcast aman (also called "floating rice") which, although low-yielding, not only tolerates flooding but actually depends on it. Higher yielding transplanted aman is also widely grown where flooding depths are shallow and rainfall is favorable. Water control, through elimination of deep flooding and provision of irrigation, will permit planting of higher yielding varieties but it must be realized that sudden changes may not always be acceptable to or manageable by the farmers. Three examples come to mind in this connection. One is the Coastal Embankment project; elimination of fresh-water flooding in some of the polders included in the project has forced consideration of "water management" in the interior of the polders. Another is Chandpur, where it is proposed that flooding be eliminated gradually over a period of several years to allow farmers time to adjust to the new conditions. A third example is the Brahmaputra Right Bank area where farmers have largely adjusted to elimination of flooding but where it is evident that further major benefits are realizable through introduction of irrigation.

Water Balance Aspects

5.05 During the course of the next 3 to 5 years, provided that the program of projects, studies and basic data gathering as outlined herein proceeds, a growing body of information on the hydrology of East Pakistan will become available. With this information "water balance studies" will become possible, first on a regional basis and ultimately on a province-wide basis. Such water balance studies will be essential to assist in establishing the priorities of further projects to be developed in the future and in evaluating their effects on water supply requirements for various uses including irrigation, navigation and fish culture.

5.06 The water balance studies will also be useful in considering the relative priorities as between the development of groundwater on the one hand (see description of the US Geological Survey-assisted study in Chapter 4) and major surface water diversions by means of major structures like the Ganges and Brahmaputra barrages on the other (see below under Special Studies).

5.07 Insofar as the 17 multipurpose projects are concerned, it is felt that allocation of water use during approximately the next decade or two will present no problem. The reasons are given in the following subparagraphs:

a. Of the 17 projects, those that depend on the flow of the Brahmaputra River are as follows: 1/

Chandpur	75,000	acres	(net)
Dacca Southwest (Polders 1 and 4)	260,000	"	"
Muhuri	42,000	"	"
Pabna (2/3 of area assuming 1/3 from groundwater)	200,000 2/	"	"
Belkuchi	70,000	"	"
Little Feni	150,000 2/	"	"
Upper Kushiyara	40,000	"	"
Khowai	33,000	"	"
Comilla-Noakhali	650,000 2/	"	"
Barisal	830,000 2/	"	"
Total	2,350,000	acres	(net)

b. To the above should be added the area irrigated during the dry season by low-lift pumps under the ADC program. The total area in that program may in a few years reach about 1,500,000 acres but a large part of this would be included within the areas of many of the projects listed above while another part would not be served by streams of the Brahmaputra system. Current information is inadequate to estimate how much area is in these two parts and how much in the remainder; as a rough guess it would be some 500,000 acres.

c. In the future other projects such as the Faridpur Unit of the Faridpur-Barisal project and the Sureswar project (total net area of these two projects about 800,000 acres) could be developed, possibly without flood control. It can thus be expected that in a time period of something like 15 to 20 years (allowing time for construction and attainment of full development) the total area requiring surface water from the Brahmaputra could reach about 3.6 million acres.

1/ Dacca North with 126,000 acres (net) has been omitted because it would obtain its water supply from the Meghna River downstream of Bhairab Bazaar. The low flow of the Brahmaputra is assumed equal to the sum of the flow of the Brahmaputra at Bahadurabad and the Meghna at Bhairab Bazaar (see para. h).

2/ Ultimate development.

d. All of the polder-type developments within this area would presumably be based on the system conceived for Chandpur. This is a "closed system" and differs fundamentally from the Ganges-Kobadak type of system (large gravity canals) in that the return flow as well as waste water remains within the polder and does not leave the project area. Thus only "make-up" water needs to be supplied equal to crop water requirements plus losses for: (a) evaporation from the natural drainage channels used as irrigation distributaries (about 1 percent of the irrigated area) and (b) seepage at the periphery of the polder. 1/ The make-up water equals consumptive use plus losses less rainfall. Monthly crop water requirements would appear to be highest during April; however, February may be a more critical month as it is the month of lowest flow of the Brahmaputra River.

e. In order of their water requirements per acre, the principal crops that it is expected will be grown during February and April are as follows:

February	April
Boro rice, sugarcane, wheat, vegetables, pulses, oilseeds, fodder, fruits	Aus rice, jute sugarcane, fruits

f. Since the water requirement of boro rice is particularly high, the proportion that will be grown in the future is of great importance. In flood-prone areas, once floods have been prevented, the farmers can be expected to grow two rice crops consisting of aus followed by aman (both making maximum use of kharif rainfall). When

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1/ No allowance is made for operating waste and/or seepage in canals or field channels since -- unlike a conventional gravity system -- these wastes will all return to the drainage channels. There should moreover be no operating wastes even if the low-lift pumps operate only (say) 18 hours instead of 24 hours a day during the time of peak demand. This is because the fixed, primary pumps can operate 24 hours a day and there is ample space in the natural drainage system to store even up to 12 hours of primary pumping. An allowance for deep percolation loss is also considered unnecessary since under full year-round irrigation the water table can be expected to rise (IECO report page B VII - 32). An allowance of 0.5" per month should be adequate for the two losses mentioned.

this is done, boro rice will gradually be eliminated and replaced by a short-season rabi crop. If for present purposes (which is to estimate water requirements during the next one or two decades) it is nevertheless assumed that boro rice will increase in importance in the medium term, a conservative cropping pattern (again from the point of view of water requirements) might be as follows:

	February	April
Boro rice	30	-
Aus rice	-	68
Jute	-	10
Sugarcane	2	2
Other crops 1/	63	-
Fallow	5	20
Total	100%	100%

g. Consumptive use factors for East Pakistan is a matter requiring research. Approximate values can however be estimated from the Blaney-Criddle formula as was done in the IECO Master Plan report of 1964 (Supplement B, Table B VII-17). Using data for Dacca as representing average conditions gives weighted average requirements as follows (in inches):

	February	April
Rainfall		
Mean year	1.0	5.8
75% dry year	0.5	3.0
Consumptive use 2/	4.1	6.3
Loss 3/	0.5	0.5
Crop requirement		
Mean year	3.6	1.0
75% dry year	4.1	3.8

1/ Pulses, oilseeds, wheat, vegetables, fruit and fodder.

2/ K factors as in Table cited: K = 0.2 used for fallow area.

3/ See para. d.

The number of acres irrigable per cusec then become:

	February	April
Mean year	180	700
75% dry year	160	190

h. Use of the 75 percent dry year (1 year in 4) would seem reasonable if assumed to coincide with the low-flow year of record as regards the Brahmaputra. Using an average figure of 175 acres per cusec for both February and April would give a water supply requirement of 20,000 cusecs. In comparison, the minimum monthly flow of the Brahmaputra River 1/ in February is 133,000 cusecs and in April it is 208,000 cusecs. Thus the diversion requirement would be about one-sixth of the minimum February flow and one-eighth of the minimum April flow.

i. In para. f. it was mentioned that boro rice could eventually be replaced by aus. This would result in a higher percentage of fallow in February as well as a higher percentage of aus in April. If the fallow percentage for April is reduced to 5 percent and the aus area increased accordingly the diversion requirement for April would increase from about one-eighth to one-sixth. However, diverting one-sixth of the April flow (208,000 cusecs) would be far less serious than diverting one-sixth of the February flow (133,000 cusecs).

j. The foregoing analysis, although admittedly somewhat crude and subject to further refinement, indicates clearly nevertheless that the low flow of the Brahmaputra River is much more than ample to supply an aggregate area of 3.6 million acres. On the other hand, the diversions of the amounts indicated are bound to have some unfavorable effects with respect to navigation, saline-water intrusion and increased pumping lifts affecting the primary pumping stations of the projects mentioned. A possible factor tending to mitigate these effects would be the development of groundwater in upstream areas, as in the Northwest region, where advantageous use of storage within the underground aquifer might result in an increase in the available low flow of the Brahmaputra River. In any case there does not appear to be any prospective better use for the amounts diverted than to devote them to irrigation of the 3.6 million acres as described.

1/ Adding flow of the Brahmaputra at Bahadurabad and that of the Meghna at Bhairab Bazaar (IECO Report, Vol. 1, p. 80).

Floating Pumping Stations

5.08 Floating pumping stations have been suggested to provide a means of diverting water from rivers and waterways. Such pumping stations can be designed for a wide range of conditions and sizes but the complexity of design and construction, physical adaptability, cost and economics must be considered in each case, and compared with alternatives.

5.09 Detailed consideration is already being given to large floating pumping stations to serve the Sureswar and Faridpur projects. These are located on the right bank of the Ganges-Padma river on the opposite bank from the Dacca Southwest project (see Map 1). The floating pumping stations would be located in the Ganges-Padma and connected with the shore by large pipelines floated on pontoons. The General Consultants to EPWAPDA are also studying floating pumping plants designed to fit a range of East Pakistan conditions.

5.10 In comparing costs of floating pumping stations with conventional intakes it is most important to fully determine operation and maintenance costs as well as capital costs. Geomorphologic and sedimentary conditions are factors that must be fully understood in appraising the alternatives.

5.11 Floating pumping stations of large capacity involve many complexities of engineering design. On the larger rivers, transmission of water from the pump site to the land will involve a long, high-capacity conduit properly anchored, and/or floated on pontoons. Anchoring the pumping station and the conduit must be compatible with field conditions.

5.12 With respect to the 12 new multi-purpose projects for the short-range, there appears to be little likelihood for the applicability of floating pumping stations since these projects are all located adjacent to river or stream channels of relatively stable characteristics. Pumping stations of conventional design (these must of course be carefully sited and designed to minimize sediment problems) therefore appear to be better suited. 1/ For the longer-range projects such as Sureswar and Faridpur, the floating pumping station alternative appears to be worth considering.

1/ This is borne out by experience with the Dacca-Demra pumping station which is located on a relatively stable river and has suffered little or no difficulty from sediment problems as contrasted with the Ganges-Kobadak station which is located on the highly unstable Ganges River and has suffered seriously (see Chapter 3).

5.13 Terms of reference for feasibility studies of the long-range projects where irrigation is involved should therefore include study of floating pumping stations where conditions are such that this alternative appears to have practical application. The General Consultants to EPWAPDA should develop some practical guidelines for determining when and under what conditions this alternative should be included in terms of references for consultants making feasibility studies.

Regions

5.14 The four regions into which the province can be conveniently subdivided have been described in Chapter 1. The division into four regions is feasible because the hydrologic characteristics of each region is generally distinct. The Southwest region is discussed below under Special Studies.

5.15 For the southeast region practically no special studies will be needed. This is basically because all of the projects in the region are on rivers that are independent of the Brahmaputra-Ganges system. Flood prevention will generally present no technological difficulty (except for the relatively small -- 47,000 acres -- Meghna-Dhonagoda project) and water supply can be obtained mainly from the relatively stable natural channel of the Dakatia River which connects with the Meghna.

5.16 In the northwest region, except for the Belkuchi and Pabna project areas, groundwater rather than surface water may well prove to be a more desirable source of water supply. Of the 4 tubewell projects mentioned in para. 4.25, 3 are in the Northwest region. Further tubewell projects in the region can be expected to be identified. On the other hand, integration of surface and groundwater supplies may well prove advantageous in the long run; a gradual generation of knowledge on this matter would emerge from the proposed special study "Brahmaputra-Ganges-Meghna Complex," described below.

5.17 With respect to the northeast region, projects that are believed should go ahead as rapidly as possible are Dacca Southwest and Dacca North and several relatively small tributary projects such as Upper Kushiyara and Khowai. A tubewell development in the North Mymensingh area also appears feasible and is one of the four projects mentioned in para. 4.25. The so-called Brahmaputra Left Bank Embankment project is located in the Northeast region. It however presents serious technological difficulty and as a preliminary step flood models are needed as described below.

5.18 Most of the remainder of the northeast region is subject to deep flooding from the Meghna. Working out a practicable means of mitigating the effects of such flooding needs a great deal of study. A possible approach is that of submersible embankments as has been suggested for the Meghna Dhonagoda project in the southeast region. Alternatively, it could be accepted that the area of deep flooding be set aside for use as a storage reservoir with resulting benefits to flood control as well as low-flow augmentation. Such a scheme, which would be of rather grandiose scale and involving difficult technical problems, could be examined in a preliminary manner as part of the special study "Brahmaputra-Ganges-Meghna Complex."

Special Studies

5.19 The special studies needed for the preparation of long-range new projects are as follows:

Ganges Barrage and Southwest Region Water Study
Model of Southwest Region
Flood Models
Brahmaputra-Ganges-Meghna Complex
(Preliminary Planning Study)

(In addition, various comprehensive studies, which are described in Volume I, would be needed including (a) a study of financing and repayment of projects, (b) a manpower study, (c) a study of infrastructure, (d) systems analyses, and (e) an overall synthesis. Certain of the comprehensive studies, such as (a) and (b), are crucial for the short-range as well as the long-range projects.)

5.20 Ganges barrage and southwest region water study: By far the largest investments to date have been made in the southwest region. These amount to about US$200 million for the Coastal Embankment project and $60 million for the GK-Kushtia project. From the hydrologic point of view, the southwest region is by far the most complex (see paras. 1.12-1.15). This complexity results from the following physical characteristics:

a. There is a large tidal range -- of the order of 10 feet; tidal surges from typhoons may reach elevations 25 feet above mean sea level.

b. There are large tidal estuaries which vary in width from one to several miles. Closure of these estuaries would provide benefits through elimination of saline-water penetration and through flood prevention, but would entail major engineering works requiring careful study. The effect on fish ecology would also need to be evaluated.

c. Flows enter the area from the Ganges and Brahmaputra Rivers. The latter is much greater in volume than the former. When the Farakka Barrage in India is completed, the flow from the Ganges River may be reduced which would increase the saline-water penetration especially in the western part of the region. 1/

d. There is evidence of a large groundwater potential particularly in the western and higher part of the region but actual availability of groundwater needs quantification. The USGS groundwater study program would assist in this effort.

e. The region is interlaced with natural channels. These vary greatly in width, depth and state of enlargement or decay. Many control structures would be needed to enhance drainage, water distribution, capture of return flows from upstream areas, navigation and fisheries development.

f. EPWAPDA has the intention to proceed with the detailed structural design of a major barrage across the Ganges River. While such detailed design may be useful, it will be necessary to study the barrage from a functional as well as a structural viewpoint. To determine the functional requirements of such a barrage will require consideration of the above five features followed by an analysis of the regional water balance.

5.21 A period of a year should be spent in reconnaissance of the southwest region as soon as this can be organized, possibly by January 1971. 2/ The reconnaissance should be followed by an approximately three-year detailed technical study, making four years in all. The purpose of the reconnaissance would be to outline and get agreement on the terms of reference of the detailed study. The services of an agency with experience on large tidal deltas, should be sought to conduct both the reconnaissance and the detailed study. The cost of the 3-year study is estimated at $5.5 million (total equivalent). 2/ This is considered minimal and in the long run could be exceeded by a substantial amount.

1/ The present average flow during the three low-flow months (March, April and May) is about 66,000 cusecs. The minimum 3-month flow in 35 years of record (1934-68) was 55,000 cusecs in 1953. One year in 7 can be expected to have a flow of about 60,000 cusecs. (From "Ganes Barrage Project", Associated Consulting Engineers, Dacca, 1969.)

2/ Table 1 shows a starting date of January 1, 1972. The reconnaissance would start a year earlier as part of the Comprehensive Study (Chapter 8, Volume I).

Uncertainty regarding the cost estimate stems largely from current lack of knowledge regarding the extent of surveys, measurements and subsurface explorations required. By the end of the reconnaissance it should be possible to firm up the cost of the entire study. Except for the Coastal Embankments (Chapter 3) and Barisal (Chapter 4) projects it seems improbable that initial projects in the Southwest region could be formulated prior to about 1974, assuming that the detailed water study gets underway in 1972.

5.22 Model of southwest region: An indispensable analytical tool in carrying out the southwest region water study would be the setting up of a mathematical model. Such a model including its operation would cost about $2 million (total equivalent). Based on reconnaissance work that would have been carried out for the Southwest region as described in the foregoing paragraph, work on the model could begin July 1, 1971 as indicated in Table 1.

5.23 Flood models: Despite the technical difficulties described above, it is recognized that moving forward with a long-range program of flood protection should be expedited. 1/ It should also be recognized that since the problem is urgent there may not be sufficient time to collect all of the physical data normally required in the study of such complex technical problems. It may therefore be necessary to proceed with some works that would provide prototypes that can be observed in order to assist further planning and action. An example of such a prototype that might not involve undue risk is that to be provided by a part of the Dacca Southwest project. For projects such as the Brahmaputra Left Bank however (para. 5.17), the risk involved in construction of the prototype would be excessive. To assist in solving the technical problems for evaluating the risks for such a project two helpful steps would be the use of flood models and the establishment of a Flood Consulting Board (see para. 5.30). The flood models would be of two types: physical and mathematical. The physical model would consist of a scale model of a representative reach of the Brahmaputra River, probably in its upper portion between Bahadurabad and Sirajganj. (Other reaches of the river might be modelled also but at a later stage.) There are serious technical difficulties involved in the construction and operation of a physical model

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1/ This has been pointed out by various leading experts. See:
United Nations Water Control Mission, Water and Power Development in East Pakistan (the Krug Mission report), United Nations Technical Assistance Programme, New York, 1959.

J. Th. Thijsse, Report on Hydrology of East Pakistan, May/October 1964.

J. Th. Thijsse, Additional Report on Hydrology of East Pakistan, March/April 1965.

since, for example, it is unknown as yet whether the alluviums that constitute the bed and banks of the river can satisfactorily be reproduced in a model and the same applies to the very large sediment movements (bed load and suspended load) of the river. Nevertheless because of its crucial importance, it is considered that an attempt to set up a physical model is well worth the effort. (See also below regarding a physical model of a proposed barrage across the Brahmaputra.)

5.24 A mathematical model would also present formidable technical problems but here again, in view of the possible beneficial results and the very major works that might ultimately be considered for construction, the indicated investments shown in Table 1 for the physical and mathematical models are considered justified. Assuming that preparatory work will have been performed by the Flood Consulting Board described below (para. 5.30), it should be possible to start work on the flood models July 1, 1971 as indicated in Table 1. The proposed physical and mathematical models are estimated to cost $2.5 million.

5.25 Brahmaputra-Ganges-Meghna Complex: The construction of a complex involving a barrage across the Brahmaputra River near the international border with provision for diversion of flows to the Meghna Basin and to the Northwest and Southwest regions has been proposed from time to time. The purposes envisaged for this complex are: to provide partial relief of flooding along the Brahmaputra by diversion through the Old Brahmaputra River into the Sylhet depression of the Meghna Basin (see para 5.18); to divert irrigation supplies to serve water-deficient areas of the Northwest and Southwest regions; and to generate hydro-electric power which could conserve scarce fuel resources and also provide energy which may be required for pump drainage, particularly in the Northeast region.

5.26 Development of an adequate safe design for a barrage across the Brahmaputra River would involve complex problems, particularly with respect to hydrologic and geotechnical features. The design would have to incorporate extensive training works to ensure stable conditions so that the river would not change course. An alternative massive groundwater development (para 5.36) would have to be studied concurrently.

5.27 From a structural point of view, a barrage across the Brahmaputra would involve technical problems of great magnitude. The barrage would have to pass a very large flood flow (of perhaps 5 million cusecs) and it would have to be constructed on riverbed sediments of unknown depths -- perhaps several hundred feet. The prevention of seepage under such a barrage would require expensive cutoff construction or in lieu of this an extensive blanket probably of clay. To protect the blanket against wave action, rock or concrete blocks would be needed. Rocks and aggregate for concrete are either unobtainable or very expensive. A physical model of such a barrage would be needed to assist in determining the feasibility of any design proposed and also to develop a practical method for excluding sediments from an intake to a link canal on the right bank (required to transfer water to the Southwest region) and from an opening on the left bank (to divert excess flood flows to the channel of the Old Brahmaputra River as a flood control measure).

5.28 In addition to the model investigations, it would eventually be necessary, in order to make even rough construction cost estimates, to conduct extensive foundation and material investigations.

5.29 In order to define more specifically the various elements and functions and relate these to projected requirements, a preliminary planning study will precede the detailed investigations described in paras 5.27 and 5.28. This preliminary phase would have an estimated cost of $5.0 million total equivalent (see Table 1) and would be carried out concurrently with the related studies described in paras 5.20-5.24 as well as with the Comprehensive Study (Vol. I, Chapter 8). All of these studies would be guided by a Flood Consulting Group as described in the next section.

Flood Consulting Group

5.30 The scope and cost of the various investigations described above, particularly for the flood models and the Brahmaputra-Ganges-Meghna Complex, are so vast that they would have to be planned with considerable care. For this reason, it would be desirable to set up a Flood Consulting Group that would direct and review the investigations of the various related components. The Government of Pakistan recently requested the Bank to send a team of experts ("Flood Commission") to assist in the study of flood problems. It was felt that since this problem exceeds in complexity any situation of like character anywhere, world-renowned experts of the highest calibre would be required in the various technical fields involved including hydrology, engineering, sedimentology, geomorphology, and geography. While the need for such a group is still felt, it is now believed that its scope should be broader and not limited to the flood problem alone.

5.31 The setting up of a Flood Consulting Group is therefore proposed. It would consider not only the overall flood problem but also the question of flood models and how best to proceed with study of the Brahmaputra-Ganges-Meghna Complex. It would probably also be desirable for the Group to give some consideration to the effects of upstream developments in India (see paras. 5.03 and 5.20). Such a Group might consist of 5 or 6 experts that would include the fields already mentioned but in addition would include a broad-gauged economist with experience in water resource development. Suggested terms of reference and costs for such a Consulting Group, which would be needed on a part-time (about 1/3) basis during an initial 4-year period, are discussed in Chapter 8 of Volume I.

Basic Data

5.32 Much basic data are already available in East Pakistan on hydrology, topography, soils, agriculture and economics. 1/ These data are generally adequate in the short run for the planning of water projects, including those already underway which might start during the next few years (includes those for which capital investments are shown in Table 1). However, for further planning, including the various special studies described above, additional data will be needed in the near future. Reviews of needs for additional data have been made and are being continued by the General Consultants to EPWAPDA. Harvard University is also working on basic data requirements and inputs and is exploring establishment of a basic data bank for storage and retrieval of this information (see chapter on Comprehensive Study in Volume I). Need for additional basic data for long-range planning has long been recognized. A Bank mission of November 1967 observed that additional data are required particularly for study of flood control when double embankments are considered and that groundwater data are essential for study of an expanded water development program.

5.33 An expanded program of water resource development including agricultural implementation will also require an intensified program of aerial photography and mapping. Flood control considerations will be dependent upon additional photography and mapping also and will require basic data on sedimentology and morphology. Construction of river training works and barrages involve problems of finding suitable construction material (rock and aggregate for concrete are extremely scarce in East Pakistan). There is a void of information, laboratory facilities, and knowledge on geotechnical aspects of soils and bed materials needed for design of major structures. East Pakistan is situated on an active tectonic zone and data are lacking on seismology. Large hydraulic structures should be designed to withstand earthquake forces by making use of appropriate local data.

5.34 Data needs in surface water hydrology, groundwater hydrology, geotechnical information, construction materials, seismology, geomorphology, and sedimentology are discussed in the following paragraphs.

5.35 Surface water hydrology: Much data have been gathered by various groups and agencies and FAO has given valuable assistance with their program involving the training of Pakistani personnel to make gagings of streams. However much remains to be done in reviewing historical records to eliminate unreliable data, correct errors, establish procedures for recording records and retrieval of records when needed for use in hydrologic studies. There also is a need for additional training of Pakistani

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1/ The presently available data were obtained through programs of EPWAPDA, ADC, PARD and the Survey of Pakistan (with UNDP support) and through feasibility studies of specific projects, described in Chapter 4.

personnel in gaging large rivers and more modern equipment will be needed for this work. Accurate hydrologic measurements are also dependent upon re-calibration of measuring instruments at regular intervals. There is at present no operational facility in East Pakistan for accomplishing this objective. Funds must be made available to establish this facility and training provided for its use. The additional program for surface water hydrology must be undertaken now to supply data needed for long-range flood protection plans and to permit comprehensive planning as in the Southwest Region and for water-balance studies. The estimated cost over a 4-year period, as was indicated in Table 3.2 of Volume I, is $1.825 million total equivalent of which $1.5 million in foreign exchange.

5.36 Groundwater hydrology: Groundwater development in East Pakistan has proceeded and will soon be intensified (see Chapter 4). Data are adequate to proceed with the ADC tubewell programs (with dispersed well spacing) and may be adequate for first phases of the EPWAPDA tubewell projects. As more concentrated developments proceed, more comprehensive data will be needed both for project planning and for water-balance studies (see paras. 5.05 and 5.06). With progressive growth of hydrogeologic information, massive tubewell developments (large capacity wells of over 4 cusecs and over 500 feet deep) will ultimately require consideration, possibly as an alternative to a major barrage (paras. 4.19 and 5.26).

5.37 Hydro-geologic studies will include the determination of aquifer characteristics (such as area, depth, material, specific yield and recharge), well spacing and other factors pertinent to intensive groundwater development. Such studies have been programmed by U.S. Geological Survey (financed by USAID) to start in mid-1970 and to be completed in five years. The USGS studies will provide data for specific projects but, as the projects proceed, the USGS studies will also make use of data generated by the specific projects.

5.38 Aerial mapping: Work should begin as soon as possible on a quality aerial mapping survey of East Pakistan. This survey will be an essential source of basic data for flood protection planning and the more comprehensive regional and multiple purpose developments now being proposed. Information from this survey will be especially vital to the proper examination of double embankment flood control projects, regional studies such as that proposed for the Southwest Region and comprehensive study programs such as the Brahmaputra-Ganges-Meghna Complex. Intensified agriculture programs will also involve use of aerial photography.

5.39 Pakistani personnel should be trained and equipped to make necessary resurveys as needed in the future. As an essential tool in the study of embankments and river-training works, photographs of the main rivers both during the flood season and during the dry season will be needed so as to obtain information regarding the shifting of the riverbanks and streambeds. The survey will also provide basic data on topography, extent of flooding, location and width of waterways and land capability information.

5.40 While most of East Pakistan is mapped with one-foot contours at a scale of 4 inches to the mile, and some to large scales, the maps vary greatly in quality. The nature of the proposed projects is such that accurate locations and cross-sections (including elevations) of drainageways, and land ownership are of great importance. Topographic details and property boundaries have to be determined exactly for these reasons. It has been found necessary to map, by ground methods, project areas at a scale of 16 inches to the mile. The aerial mapping program being proposed would facilitate this work.

5.41 It is moreover desirable that the initial photography of the whole of East Pakistan be done in one season by a specialized aerial photography firm to establish a "bench-mark" year of quality mapping photo cover. Such a procedure would assure the availability of personnel and equipment adequate to meet the needs and the time schedule being projected for the East Pakistan development program. At the same time, the basis would be provided for future needs including sequential photography for continuing studies, prompt photographic reconnaissance and up-to-date photography for each year's mapping program. Besides providing a suitable aircraft, modern air cameras and other equipment, the program should also include training for Pakistani personnel as required to establish a permanent aerial photography and photographic unit based in East Pakistan and operated by Pakistanis. Such a unit could be located in a Government agency.

5.42 As such a proposal would involve services of a foreign survey firm it is recognized that the work must be done compatibly with national security policy. Consideration might be given to meet the needs of both security and development by adopting the following principles:

a. The foreign air survey company be, by nationality and reputation, acceptable to the Government of Pakistan;

b. A security officer be stationed in Dacca to monitor the operation, with discretionary authority to deal with security problems as they arise;

c. As required in controlling security, an officer or his deputy could travel in the aircraft at all times;

d. Exposed film processed at Survey of Pakistan, Dacca, would remain under his control and he would authorize release of prints to EPWAPDA;

e. He could interpret and administer security policy in respect to enumerated items of basic environmental data in East Pakistan.

5.43 Some months ago, a UNDP proposal was drafted in East Pakistan thru joint efforts of UNDP, EPWAPDA and the Survey of Pakistan, and a PC-1 form was prepared to support this program. However, aerial mapping experts from these agencies, and the General Consultants to EPWAPDA all agree that this program is inadequate to meet the needs for photography and mapping when consideration is given to the vastly expanded agriculture and water resources developments being proposed for East Pakistan.

5.44 As a result of conferences held in Dacca during April-May, it was agreed by representatives of UNDP, EPWAPDA, and The Survey of Pakistan that a new PC-1 form and application to UNDP should be drafted.

5.45 The aerial photograph and mapping program should proceed at the earliest possible date. This program will consist basically of the following:

a. The rephotography of the entire Province of East Pakistan at medium scale, principally for air photo interpretation purposes;

b. The photography at large scale of each area scheduled to be mapped at 16 inches to the mile for project purposes in conformity with the mapping schedule;

c. The supply of modern equipment and training of East Pakistan personnel to form an aerial photographic unit capable of meeting future requirements.

5.46 The estimated cost of the aerial mapping program over a 4-year period, as was indicated in Table 3.2 of Volume I, is $3.0 million total equivalent of which $1.6 million is in foreign exchange.

5.47 Geotechnical explorations: Soils testing and analyses used in design of project works is carried out by the materials testing section of the hydraulic research laboratory. A considerable increase in capacity will be needed to meet anticipated requirements. Training of personnel in modern techniques is essential, and additional equipment will be needed in the laboratory and in the field. Training of personnel should be accomplished in East Pakistan to a maximum extent. However, some engineers will require additional training in laboratories outside East Pakistan. Costs were indicated in Volume I, Table 3.2 ($800,000 total equivalent of which $600,000 is in foreign exchange).

5.48 Construction materials: Lack of suitable construction materials for river training works and control structures is one of the major problems facing the water development program. Presently available information suggests that concrete aggregates are principally found in North Bengal and along the Sylhet-Assam border. Supplies of suitable sand are also available at a number of locations throughout the Province. Apart from outcrops of near-surface bedrock in the Chittagong Hill Tracts, the only known potential sources of rock in East Pakistan are at a depth on the order of 600 feet in the Parbatipur-Rangpur area and even deeper in the coal and limestone deposit region of Jamalganj in the Bogna District.

5.49 An organized exploration for construction materials and through consideration of the processing, transport, and costs of providing materials at the job sites should be undertaken soon so that the knowledge gained can be made use of in the expanded development program being projected for East Pakistan. Information obtained should be of material value to the total construction industry in the Province. Studies would cost $600,000 total equivalent ($300,000 foreign exchange) as was indicated in Volume I, Table 3.2.

5.50 Seismology: East Pakistan is situated in an active tectonic zone. Limited data indicates that a large number of shallow and intermediate depth tremors have been felt within the Provincial boundaries since seismic data were first collected in the Indian sub-continent around the turn of the century. Historical evidence attests to the tremendous influence of the tectonic activity in the area with events like the avulsion of the Brahmaputra into the Jamuna some 200 years ago believed to have been triggered by an earthquake, and the tremendous landslide into the Brahmaputra Valley in Assam in 1950 which has caused considerable aggradation of the bed of the river and is probably still affecting the behavior of the Jamuna in East Pakistan. Large hydraulic structures must be designed to withstand earthquake forces, and without adequate pertinent information, overdesign for safety can result in increased costs. To provide rational criteria for design, it is proposed to obtain expatriate advice on analyses of data and the procurement of seismographs for strategic location in the Province. Presently, the only seismograph location is in Chittagong and it is understood that the data have not been fully analyzed. Study costs are estimated at $200,000 total equivalent ($100,000 foreign exchange) as was indicated in Volume I, Table 3.2.

5.51 Geomorphology and sedimentology: East Pakistan is traversed by large rivers carrying heavy loads of sediment. These rivers are constantly modifying their course and changing their cross section. Successful river training for flood control and construction of water regulating facilities is dependent upon properly identifying these conditions utilizing up-to-date techniques of analysis in the field of river morphology, sedimentology and fluvial hydraulics. While much information is already available from specific project studies (e.g. Dacca Southwest) and further data and advice will be available from the flood model studies (para. 5.23) and from the Flood Consulting Board (para. 5.30), basic research and long-term training of Pakistani personnel should be started at an early date.

5.52 Several universities have wide experience and staffing expertise to assist Pakistani staff in learning modern methods and techniques of analysis in sedimentology, geomorphology, and fluvial hydraulics. Their laboratories include facilities for testing and analyzing specific field conditions as necessary. These institutions are equipped also to provide educational training. A limited number of Pakistani engineers could receive fundamental training under this program. Costs are estimated at $100,000 total equivalent all of which is foreign exchange; see Volume I, Table 3.2.

Table 1
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EAST PAKISTAN -- COST ESTIMATES OF WATER PROJECTS

(Millions of US Dollars)

P R O J E C T S	Type of Investment	Remarks	Start	Completed	1970-71			1971-72			1972-73			Remaining Cost after 1972-73			Program Total		
					Local	Foreign	Total	Local	Foreign	Total	Local	Foreign	Total	Local	Foreign	Total	Local	Foreign	Total
EPWAPDA PROJECTS																			
1. Ganges-Kobadack, Kushtia Unit																			
Part (a)	Capital Inv.		1/7/70	30/6/72	0.5	2.5	3.0	0.5	2.5	3.0							1.0	5.0	6.0
Part (b)	Capital Inv.		1/7/73	30/6/75										19.0	7.0	26.0	19.0	7.0	26.0
	Mgt. Asst.		1/7/71	30/6/75	0.3	0.1	0.4	0.3	0.1	0.4	0.3	0.1	0.4	0.6	0.2	0.8	1.5	0.5	2.0
					0.8	2.6	3.4	0.8	2.6	3.4	0.3	0.1	0.4	19.6	7.2	26.8	21.5	12.5	34.0
2. Coastal Embankments																			
Phase I - Group A	Capital Inv.		1/7/70	1/6/72	29.0	1.0	30.0	9.0	1.0	10.0							38.0	2.0	40.0
Group A (Water Mgt.)	Proj. Prep.		1/1/71	30/6/74	0.2	0.1	0.3	0.3	0.1	0.4	0.3	0.1	0.4	0.2	0.1	0.3	1.0	0.4	1.4
Group B	Proj. Prep.		1/7/70	30/6/72	0.2	0.1	0.3	2.2	0.8	3.0							2.4	0.9	3.3
Group B - Stage I	Capital Inv.		1/9/72	30/6/75							3.8	1.2	5.0	10.0	3.3	13.3	13.8	4.5	18.3
Group B - Stage II	Capital Inv.		1/7/75	31/12/78										13.8	4.6	18.4	13.8	4.6	18.4
Phase II - Project Preparation	Proj. Prep.		1/1/71	30/6/74	0.1	0.1	0.2	0.3	0.2	0.5	0.3	0.2	0.5	0.2	0.1	0.3	0.9	0.6	1.5
Stage I	Capital Inv.		1/9/72	30/6/75							4.0	4.0	8.0	16.0	6.0	22.0	20.0	10.0	30.0
Stage II	Capital Inv.		1/9/75	30/6/78										20.0	10.0	30.0	20.0	10.0	30.0
Phases I & II Overall																			
Mgt. Asst. - Part I			1/7/71	30/6/74				0.1	0.1	0.2	1.0	0.5	1.5	1.4	0.7	2.1	2.5	1.3	3.8
Part II			1/7/74	31/12/77										2.6	1.3	3.9	2.6	1.3	3.9
					39.5	1.3	30.8	11.9	2.2	14.1	9.4	6.0	15.4	64.2	26.1	90.3	115.0	35.6	150.6
3. Chandpur 4/	Capital Inv.	IDA Credit	1/1/70	30/6/73	8.0	2.6	10.6	7.5	2.0	9.5	0.8	0.4	1.2		0.7	1.4	17.6	5.1	22.7
4. Dacca Southwest	Capital Inv.		1/1/71	30/6/76	3.0	1.0	4.0	8.5	2.5	11.0	9.5	4.5	14.0	24.0	7.0	31.0	45.0	15.0	60.0
	Final Eng.) Proj. Prep.) 1/	IDA Credit	1/1/70	31/12/70	0.6	0.8	1.4										0.6	0.8	1.4
					3.6	1.8	5.4	8.5	2.5	11.0	9.5	4.5	14.0	24.0	31.0	31.0	45.6	15.8	61.4
5. Karnafuli	Capital Inv.	IDA Credit	1/1/72	1/1/75				0.7	0.3	1.0	7.5	2.5	10.0	6.8	3.2	10.0	15.0	6.0	21.0
	Final Eng.) 1/		1/12/70	1/12/71	0.5	1.0	1.5	0.5	1.0	1.5	0.5	0.4	0.9				1.5	2.4	3.9
	Proj. Prep.)		1/7/70	1/5/71															
					0.5	1.0	1.5	1.2	1.3	2.5	8.0	2.9	10.9	6.8	3.2	10.0	16.5	8.4	24.9
6. Muhuri	Capital Inv.	Included in Karnafuli	1/1/73	1/1/76							0.7	0.3	1.0	7.5	3.5	11.0	8.2	3.8	12.0
	Final Eng.) 1/		1/8/71	1/12/72															
	Proj. Prep.)		1/2/71	1/4/72															
											0.7	0.3	1.0	7.5	3.5	11.0	8.2	3.8	12.0
7. Tubewells I																			
Thakurgaon Extension	Capital Inv.		1/7/71	1/6/74				0.7	1.9	2.6	1.2	3.8	5.0	1.2	3.8	5.0	3.1	9.5	12.6
Tontulia Panchagarh	Capital Inv.		1/7/71	1/6/75				0.3	1.1	1.4	2.0	6.0	8.0	3.0	9.0	12.0	5.3	16.1	21.4
Rangpur	Capital Inv.		1/7/71	1/6/74				0.2	0.4	0.6	1.5	4.5	6.0	1.5	4.5	6.0	3.2	9.4	12.6
North Mymensingh			1/7/72	1/6/75							0.5	1.5	2.0	2.0	6.0	8.0	2.5	7.5	10.0
	Final Eng. & Proj. Planning	All Tube-wells I	1/7/70	30/6/72	0.4	0.6	1.0	0.3	0.7	1.0							0.7	1.3	2.0
Total Tubewells I					0.4	0.6	1.0	1.5	4.1	5.6	5.2	15.8	21.0	7.7	23.3	31.0	14.8	43.8	58.6
8. Pabna Phase I	Capital Inv.		1/9/72	1/7/76							4.5	1.5	6.0	33.0	11.0	44.0	37.5	12.5	50.0
	Final Eng.		1/1/71	30/6/72	0.5	1.5	2.0	0.5	1.5	2.0							1.0	3.0	4.0
	Proj. Prep.	Completed in mid-1970																	
					0.5	1.5	2.0	0.5	1.5	2.0	4.5	1.5	6.0	33.0	11.0	44.0	38.5	15.5	54.0
9. Belkuchi	Capital Inv.		1/3/72	30/6/75							3.0	1.0	4.0	15.0	5.0	20.0	18.0	6.0	24.0
	Final Eng.) Proj. Pre. 1/)	Included in Pabna																	
											3.0	1.0	4.0	15.0	5.0	20.0	18.0	6.0	24.0
10. Little Feni Phase I	Capital Inv.		1/12/73	30/6/76							0.4	0.5	0.9	22.5	7.5	30.0	22.5	7.5	30.0
	Final Eng.		1/7/72	31/12/73				0.3	0.5	0.8 2/	0.4	0.5	0.9 2/	0.3	0.5	0.8 2/		1.5	2.5 2/
	Proj. Prep.		1/1/72	31/12/72				0.4	0.5	0.9 2/	0.4	0.5	0.9 2/				0.8	1.0	1.8
11. Upper Kusiyara	Capital Inv.		[illegible]	[illegible]				1.5	0.5	2.0	3.0	1.0	4.0	5.5	2.0	7.5	10.0	3.5	5
	Final Eng.) Proj. Prep.)		1/7/71	30/6/72				0.2	0.3	0.5	0.4	0.6	1.0				0.6	0.9	1.5
								1.7	0.8	2.5	3.4	1.6	5.0		2.0	7.5	10.0	4.4	15.0

Table 1
Page 2 2
(Millions of Dollars)

PROJECTS	Type of Investment	Remarks	Start	Completion	1970-71 Local	1970-71 Foreign	1970-71 Total	1971-72 Local	1971-72 Foreign	1971-72 Total	1972-73 Local	1972-73 Foreign	1972-73 Total	Remaining Cost After 1972-73 Local	Remaining Cost After 1972-73 Foreign	Remaining Cost After 1972-73 Total	Program Total Local	Program Total Foreign	Program Total Total
12. *Khowai*	Capital Inv.	Included in Upper Kushiyara	1/1/72	1/1/75				0.7	0.3	1.0	1.4	0.6	2.0	5.8	2.2	8.0	7.9	3.1	11.0
	Final Eng. 1/)		1/7/71	30/6/72															
	Proj. Prep. 1/)																		
								0.7	0.3	1.0	1.4	0.6	2.0	5.8	2.2	8.0	7.9	3.1	11.0
13. Dacca North	Capital Inv.		1/7/73	1/7/77										30.0	10.0	40.0	30.0	10.0	40.0
	Final Eng.		1/7/72	31/12/73							0.3	0.5	0.8	0.6	1.1	1.7	0.9	1.6	2.5
	Proj. Prep.		1/1/71	30/6/72				0.2	0.5	0.7	0.3	0.5	0.8				0.5	1.0	1.5
								0.2	0.5	0.7	0.6	1.0	1.6	30.6	11.1	41.7	31.4	12.6	44.0
14. Barisal Phase I																			
Project Preparation			1/1/71	30/6/73	0.3	0.7	1.0	0.5	1.0	1.5	0.5	1.0	1.5				1.3	2.7	4.0
Final Engineering		For all stages	1/1/71	30/6/73	0.3	0.7	1.0	0.5	1.5	2.0	0.5	1.5	2.0				1.3	3.7	5.0
Stage (a)	Capital Inv.		1/1/71	30/6/74				1.5	0.5	2.0	2.3	0.7	3.0	0.7	0.3	1.0	4.5	1.5	6.0
Stage (b)	Capital Inv.		1/1/73	30/6/76							0.7	0.3	1.0	10.0	3.0	13.0	10.7	3.3	14.0
Stage (c)	Capital Inv.		1/1/74	30/6/77										12.0	4.0	16.0	12.0	4.0	16.0
					0.6	1.4	2.0	2.5	3.0	5.5	4.0	3.5	7.5	22.7	7.3	30.0	29.8	15.2	45.0
15. Comilla-Noakhali Phase I	Capital Inv.		1/12/73	30/6/77										37.5	12.5	50.0	37.5	12.5	50.0
	Final Eng.		1/7/72	31/12/73				0.5	1.0	1.5 2/	0.7	1.3	2.0 2/	0.5	1.0	1.5	1.7	3.3	5.0
	Proj. Prep.		1/1/72	30/6/73				0.3	0.7	1.0 2/	0.3	0.7	1.0 2/	0.3	0.7	1.0	0.9	2.1	3.0
								0.8	1.7	2.5	1.0	2.0	3.0	38.3	14.2	52.5	40.1	17.9	58.0
16. Sangu	Capital Inv.		1/1/74	1/7/77										37.5	12.5	50.0	37.5	12.5	50.0
	Final Eng. 1/)		1/7/72	31/12/73				0.3	1.0	1.3	0.3	1.0	1.3	0.4	1.0	1.4	1.0	3.0	4.0
	Proj. Prep. 1/)																		
								0.3	1.0	1.3	0.3	1.0	1.3	37.9	13.5	51.4	38.5	15.5	54.0
17. Tubewells II	Capital Inv.		1/1/74	1/1/78							1.0	2.0	3.0	9.5	29.5	39.0	10.5	31.5	42.0
	Final Eng.		1/1/72	30/6/73				0.1	0.2	0.3		0.2	0.2				0.1	0.4	0.5
	Proj. Prep.		1/12/70	30/6/72	0.2	0.3	0.5	0.4	0.6	1.0							0.6	0.9	1.5
					0.2	0.3	0.5	0.5	0.8	1.3	1.0	2.2	3.2	9.5	29.5	39.0	11.2	32.8	44.0
18. Ganges-Kobadak, Jessore Unit (Phase II)	Proj. Prep.		1/6/73	30/6/74										0.5	1.5	2.0	0.5	1.5	2.0
Total EPWAPDA Projects					44.1	13.1	57.2	39.3	25.3	64.6	53.9	45.4	99.3	352.7	175.7	528.4	490.0	259.5	749.5
Flood Control Investigations 3/																			
1. Ganges Barrage and Southwest Region			1/1/72	31/12/74				0.5	1.5	2.0	0.5	1.5	2.0	0.5	1.0	1.5	1.5	4.0	5.5
2. Model of Southwest Region			1/7/71	30/6/73				0.3	0.7	1.0	0.3	0.7	1.0				0.6	1.4	2.0
3. Flood Models			1/7/71	30/6/74							0.5	1.0	1.5	0.3	0.7	1.0	0.8	1.7	2.5
4. Brahmaputra - Ganges-Meghna Complex			1/1/72	30/6/74				0.6	1.4	2.0	0.6	1.4	2.0	0.3	0.7	1.0	1.5	3.5	5.0
Total Flood Control Investigations								1.4	3.6	5.0	1.9	4.6	6.5	1.1	2.4	3.5	4.4	10.6	15.0
ADC Projects																			
1. Low-lift Pumps I			1/1/71	30/6/73	3.0	4.0	7.0	4.0	3.0	7.0							7.0	7.0	14.0
2. Low-lift Pumps II			1/1/73	30/6/75							6.0	2.0	8.0	14.0	3.0	17.0	20.0	5.0	25.0
3. Tubewells I			1/12/70	31/12/73	3.5	5.6	9.1	6.5	8.9	15.4	6.5	4.9	11.4	5.3	3.4	8.7	21.8	22.8	44.6
4. Tubewells II			1/12/72	31/12/76							6.3	6.3	12.6	35.7	35.7	71.4	42.0	42.0	84.0
Total ADC Projects					6.5	9.6	16.1	10.5	11.9	22.4	18.8	13.2	32.0	55.0	42.1	97.1	90.8	76.8	167.6
Grand Total					52.6	22.7	[illegible]	51.2	40.8	[illegible]	74.6	63.2	137.8	408.8	220.2	62?.0	585.2	346.9	932.1

1/ Revision of existing feasibility study.
2/ Same consultant as that engaged on the Karnafuli and Muhuri projects.
3/ Reconnaissance phases of these studies are included in the Comprehensive Study. See Chapter VIII, Volume I.
4/ 1970-71 figures include expenditure in 1969-70.

Table 2

AREAS IRRIGATED[1] AND PROTECTED FROM FLOODING[2]
(thousands of acres)

	1975-76		1980-81		1985-86		Ultimate		Remarks
	Flood Protection	Irrigation	Flood Protection	Irrigation	Flood Protection	Irrigation	Flood Protection	Irrigation	
Low-lift Pumps[3]	-	1,000	-	500	-	500	-	500	Peak 1,100 in 1976-77
Tubewells (Non-intensive)[4]	-	350	-	600	-	300	-	300	Peak 800 in 1978-79
Tubewells (Intensive)[5]	-	200	-	1,000	-	2,200	-	2,200	
Multi-purpose Projects[6]									
New Projects									
Dacca Southwest	260	130	390	260	390	300	390	300	
Karnafuli	100	20	150	70	150	100	150	100	
Muhuri	50	10	100	50	100	60	100	60	
Pabna I	220	40	220	160	220	160	220	160	
Pabna II	-	-	230	80	230	120	230	160	
Belkuchi	100	30	100	70	100	70	100	70	
Upper Kusiyara	80	70	80	40	80	50	80	50	
Khowai	80	20	80	40	80	50	80	50	
Sangu	20	10	120	80	120	80	120	80	
Dacca North	-	-	160	100	160	110	160	110	
Barisal I	-	50	300	160	300	200	300	200	
Barisal II	-	-	150	100	150	340	900	600	
Little Feni I	-	-	140	80	140	90	140	90	
Little Feni II	-	-	120	40	120	70	120	70	
Comilla-Noakhali I	-	-	220	160	220	160	220	160	
Comilla-Noakhali II	-	-	300	100	670	340	670	450	
Subtotal, New Projects	910	330	2,860	1,590	3,230	2,300	3,980	3,710	
Existing Projects									
Coastal Embankments	1,500	350	1,800	1,100	2,400	1,600	3,000	2,500	
GK-Kushtia[7]	350	130	350	220	350	220	350	220	
Chandpur	140	60	140	90	140	90	140	90	
Subtotal, Existing Projects	1,990	540	2,290	1,410	2,890	1,910	3,490	2,810	
Total, Multi-purpose Projects	2,900	870	5,150	3,000	6,120	4,210	7,470	6,520	
GRAND TOTAL	2,900	2,420	5,150	5,100	6,120	7,210	7,470	9,520	

1/ Net area commanded.

2/ Gross area protected.

3/ Not including existing (1969-70) area of 700,000 acres.

4/ Not including existing (1969-70) area of 40,000 acres.

5/ Not including existing (1969-70) area of 70,000 acres.

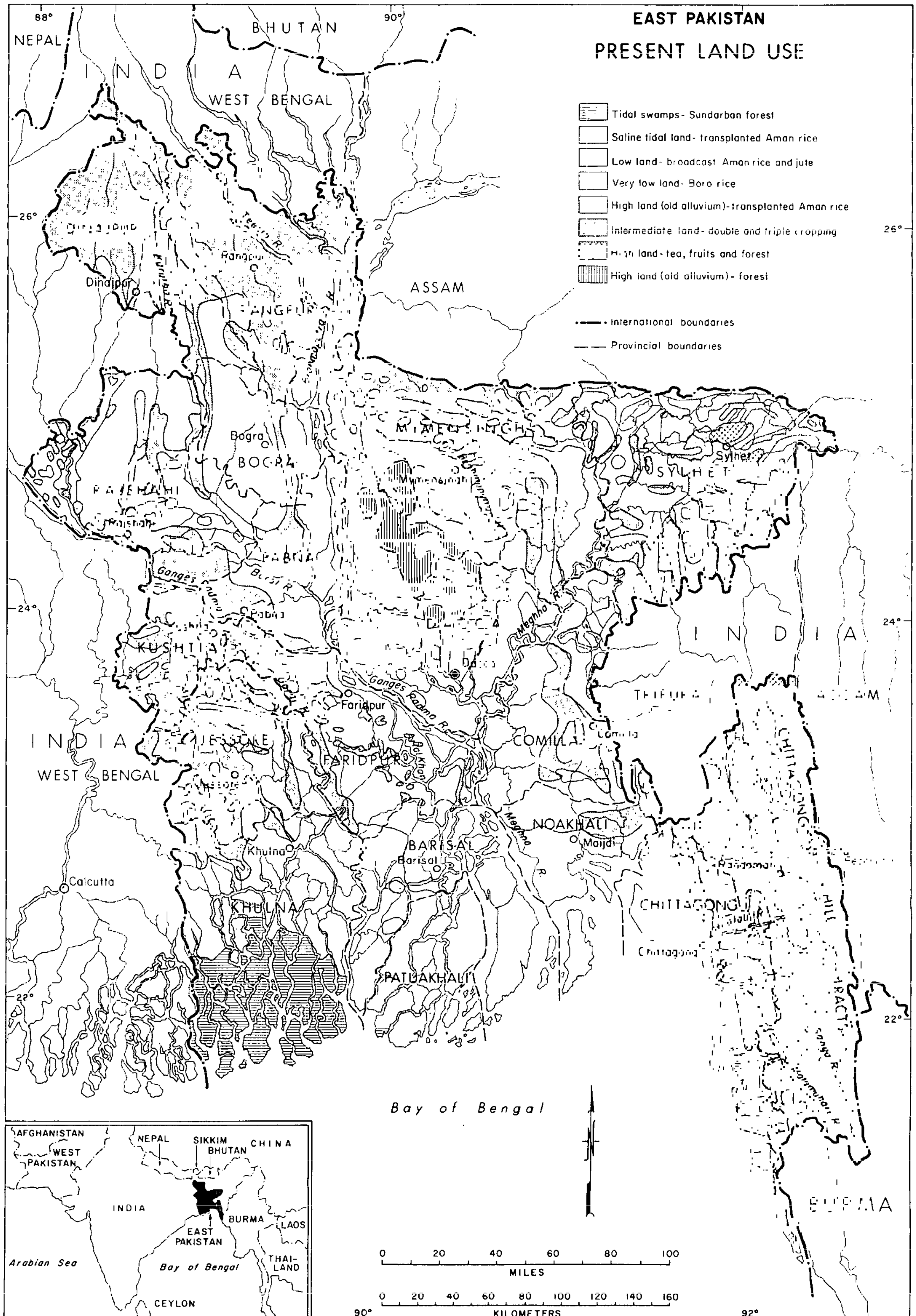
6/ Not including existing Dacca-Demra project (15,000 acres gross, 10,000 acres net) nor Brahmaputra Right Embankment flood protection project (580,000 acres gross).

7/ Includes 40,000 acres now partially irrigated.

Table 3

INCREMENTAL AGRICULTURAL PRODUCTION
FROM WATER DEVELOPMENT PROJECTS

	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	85/86
I. - AREA IRRIGATED (thousands of acres)											
Low-lift pumps	300	500	700	900	1000	1100	900	700	500	500	500
Tubewells (non-intensive)	50	100	150	250	350	500	700	800	700	600	300
Tubewells (intensive)	-	15	70	140	220	275	405	565	760	1000	2200
Multi-purpose projects	40	150	300	540	870	1130	1820	2330	2770	3000	4210
Totals	390	750	1220	1830	2440	3005	3825	4395	4730	5100	7210
II. - AREA EFFECTIVELY IRRIGATED (thousands of acres)											
Low-lift pumps	120	320	510	690	830	900	870	720	540	460	460
Tubewells (non intensive)	20	50	100	160	240	350	480	620	680	580	270
Tubewells (intensive)	-	-	20	50	110	210	330	470	610	760	2000
Multi-purpose projects	10	40	160	300	420		1170	1590	2090	2370	3800
Totals	150	410	790	1200	1600	2240	2850	3400	3920	4170	6530
III. - AGRICULTURAL PRODUCTION (thousands of long tons)											
Low-lift pumps	140	380	610	830	990	1040	1020	860	650	550	550
Tubewells (non-intensive)	40	100	100	320	480	700	960	1240	1360	1160	540
Tubewells (intensive)	-	-	50	125	275	525	830	1180	1520	1900	5000
Multi-purpose projects	30	120	480	900	1260	2350	3500	4800	6250	7100	11400
Totals	210	600	1340	2175	3005	4615	6310	8080	9780	10710	17490



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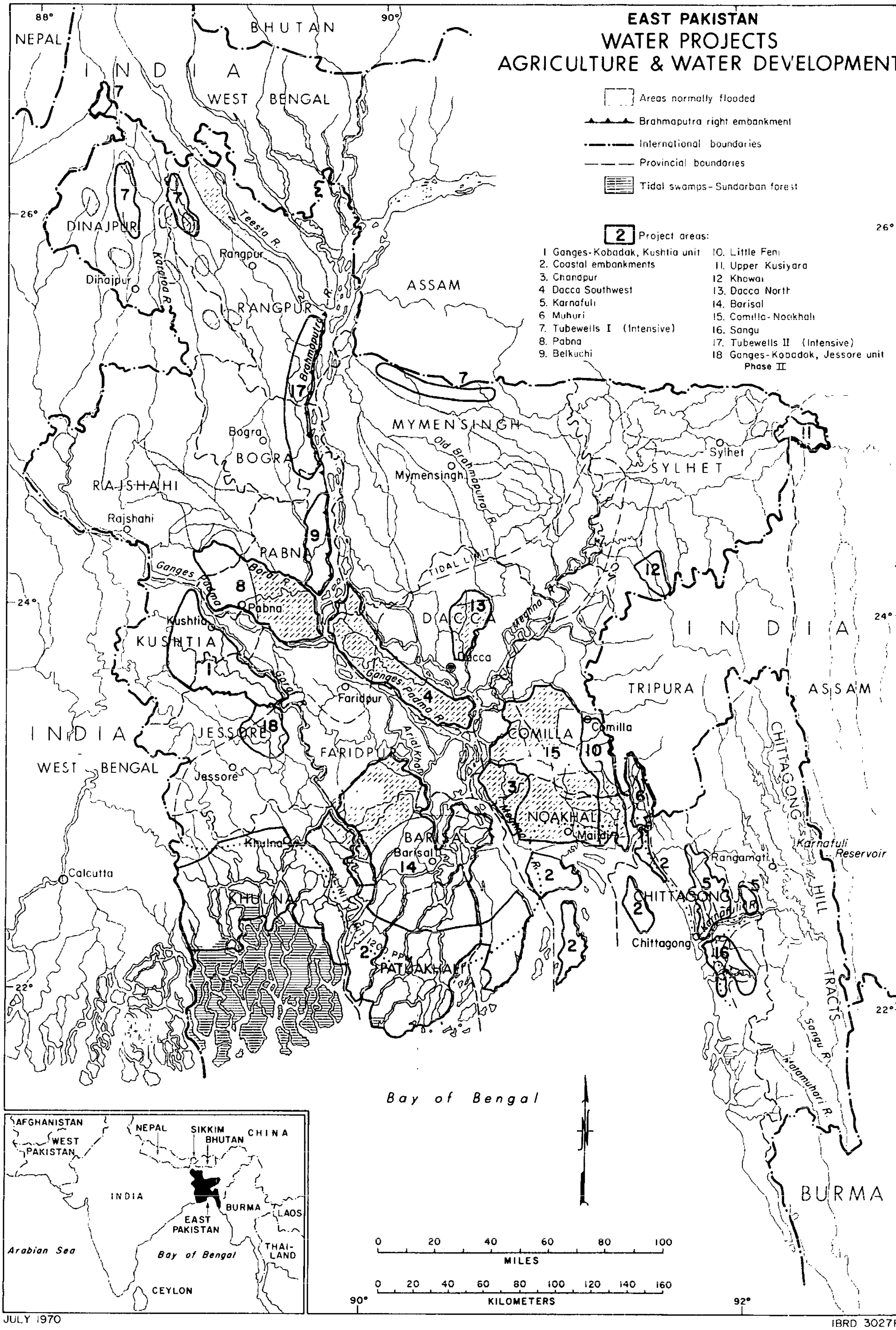
EAST PAKISTAN
WATER PROJECTS
AGRICULTURE & WATER DEVELOPMENT
Areas normally flooded
Brahmaputra right embankment
International boundaries
Provincial boundaries
Tidal swamps - Sundarban forest
2 Project areas:
1 Ganges-Kobadak, Kushtia unit
2. Coastal embankments
3. Chandpur
4 Dacca Southwest
5. Karnafuli
6 Muhuri
7. Tubewells I (Intensive)
8. Pabna
9. Belkuchi
10. Little Feni
11. Upper Kusiyara
12 Khowai
13. Dacca North
14. Barisal
15. Comilla-Noakhali
16. Sangu
17. Tubewells II (Intensive)
18 Ganges-Kobadak, Jessore unit Phase II
NEPAL
BHUTAN
INDIA
WEST BENGAL
ASSAM
DINAJPUR
RANGPUR
BOGRA
RAJSHAHI
PABNA
MYMENSINGH
SYLHET
DACCA
KUSHTIA
JESSORE
FARIDPUR
TRIPURA
COMILLA
NOAKHALI
BARISAL
KHULNA
PATUAKHALI
CHITTAGONG
CHITTAGONG HILL TRACTS
BURMA
Bay of Bengal
Karnafuli Reservoir
TIDAL LIMIT
MILES
KILOMETERS
AFGHANISTAN
WEST PAKISTAN
SIKKIM
CHINA
EAST PAKISTAN
LAOS
THAI-LAND
Arabian Sea
CEYLON