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BANGLADESH

# IRRIGATION DEVELOPMENT OPTIONS AND INVESTMENT STRATEGIES FOR THE 1980'S

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Water Management Synthesis Proje
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# PREFACE

Great emphasis is being placed worldwide on effective and efficient use of irrigation water. The direct result of improving yields and extending irrigated land area is increased food production.

Conserving the quality and quantity of irrigation water deserves more attention to expand agricultural production. Improving on-farm water management directly benefits most rural poor and landless laborers by increasing income and employment.

The Water Management Synthesis Project is a program that is funded and assisted by the United States Agency for International Development through Consortium for International Development. Colorado State University and Utah State University serve as lead universities for the project.

The key objective of the project is to provide services in irrigated regions of the world for improving the design and operation of existing and future irrigation projects and provide guidence for selecting development options and investment strategies for the 1980's.

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# FORWARD

1. Purpose of the study or report
2. What was done
3. Why
4. By whome
5. Acknowledgments

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BANGLADESH

# IRRIGATION DEVELOPMENT OPTIONS AND INVESTMENT STRATEGIES FOR THE 1980'S

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# SECTION I

## INTRODUCTION AND BACKGROUND

The government of Bangladesh has established an objective of food grain self-sufficiency as soon as possible and no later than 1985. This will require an essentially doubling of production. There is ilittle if any, new land to cultivate, hence the increased food must come from intensifying production by significant improvements in the control of excess water, irrigation expansion and improvement to permit multiple crops per year, more and better use of fertilizer and high yielding varieties, pest control and in general an improved agricultural husbandry. The GOB has recognized the benefits that can come from irrigation and has indicated irrigation will play a major role in meeting the goals established in the second five year plan.

The country is blessed with an abundance of renewable surface and groundwater throughout most of the land. Irrigation can provide crop insurance during periods of drought in the wet season and extend the crop growing season over the entire year. It also increases the potential for increased yields from high yield varieties, greater benefits from fertilizers and allows for a greater variety of crops which can greatly contribute to better nutritional diet for the malnourished.

Thus, we feel the policy of AID should be to participate in the irrigation development. The projects supported should be of such a size and nature as to be manageable by AID and the GOB. These

projects should fit into the master plan for the development of irrigation for the country and supported by many donors.

The country of Bangladesh has a population of approximately 88 million (1980) and 24 million acres of cultivable land. This is roughly 3.2 persons per cultivatable acre. The population density is over 1400 per square mile making Bangladesh the most densely populated country in the world. Over 90 percent of the total population are rural and 75 percent are actively engaged in agriculture. The average annual rate of population growth is esimated to be between 2.4 and 2.7 percent. By the year 2000 the population is estimated to reach approximately 130 million with an accompanying decline at the rate of growth to approximately 1.6 percent.

Generally, except as limited by water, year round cropping is possible. Annual rainfall varies from 50 inches in the southwest up to 220 inches on the northeast. There are typically three cropping seasons (1) the early monsoon (aus), (2) the main monsoon (amon) and (3) the winter dry season (boro). The great majority of the rainfall comes during the monsoon season. During the winter dry season (roughly November through mid-April) the rainfall over most of the country is between 2.5 to 4.5 inches.

In total, the quantity of water which flows through Bangladesh is tremendous. Counting the river inflow from the Ganges, Brahmaputra and Meghna Rivers and average rainfall, there is typically enough water each year to cover the country to a depth of some thirty

feet.* In fact large sections of the country (some 6 to 10 million acres) are flooded during a normal rainfall year.

Cropping patterns and paddy varieties have evolved to adjust to the climatic conditions (Figure 1). Nevertheless, crop production throughout the year is threatened by problems associated with (1) water shortage during the early monsoon months due to insufficient quantity and poor distribution of rainfall, (2) abnormal flooding and the occasional cyclone during the main monsoon, (3) in some years drought during the main monsoon season and (4) very low rainfall in the winter months.

This is emphasized by the data in Table 1 for five stations. The data were compiled by Utah State University from the thirty year record from the World Meteorological Organization. The most striking fact is that at some time in the thirty years of record there was zero precipitation in each month at all of the five stations. The data emphasize there has been serious droughts in the wet season and a general lack of rain in the dry season making rainfed cropping extremely hazardous in the winter and spring seasons.

The water resources of the country are (1) ground water which is substantial over the vast majority of the nation, (2) river inflow from India, (3) natural rainfall, (4) numerous oxbow lakes left behind by the ever wandering Ganges-Brahmaputra and Megha Rivers and (5) residual.

The water resources which are available for exploitation by agriculture are (1) river flow, (2) ground water, (3) oxbow lakes

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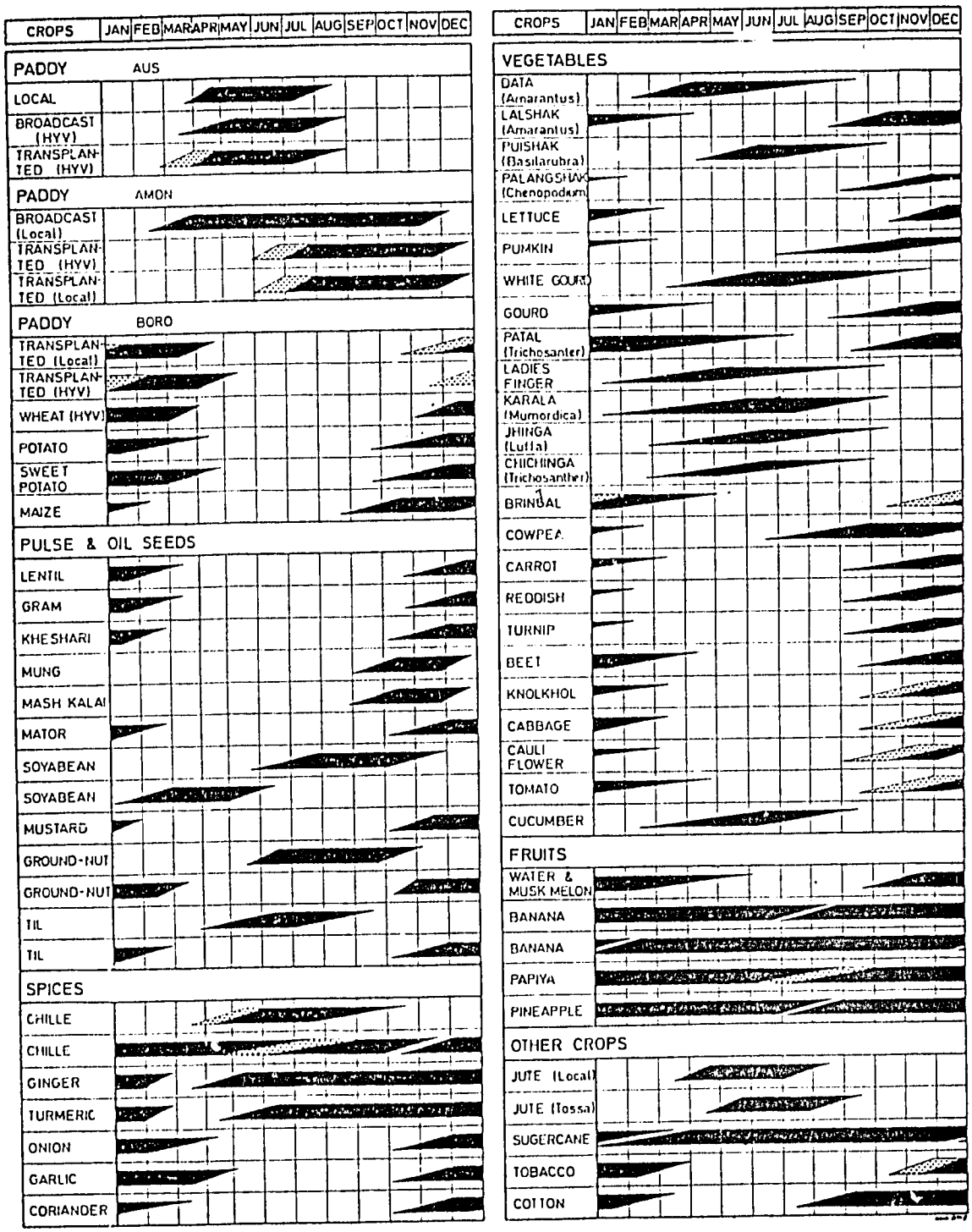
*Based on 870 MAF from river inflows and 703 MAF from rainfall. In contrast average annual evaporation is approximately 132 MAF.

Figure 1.

# CROP CALENDAR OF BANGLADESH

## EXISTING CROPPING PATTERNS




EXISTING CROPPING PATTERNS:

1. AUS / JUTE + T. AMON
2. AUS + T. AMON + KHESARI (LATHYRUS)
3. JUTE + KALAI (PULSE)
4. AUS AND T. AMON MIXED
5. AUS + MUSTARD / PULSES / RABI VEGETABLES / TOBACCO / COTTON / POTATO
6. AUS AND ARHAR (CAJANUS) / TIL (SESAMUM) MIXED
7. B. AMON
8. AUS AND B. AMON MIXED
9. BORO
10. SUGARCANE
11. SUMMER VEGETABLES + MUSTARD / PULSES

Table 1. Climatic data for a thirty year period at five stations in Bangladesh.

BOGRA BANGLADESH EL= 20 LAT= 24 51 N LONG= 89 22 E KS=13.5

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM | 14. | 17. | 27. | 63. | 195. | 322. | 317. | 351. | 275. | 180. | 13. | 2. | 1776. |
| PMI | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1124. |
| P79 | 0. | 1. | 0. | 4. | 118. | 165. | 218. | 202. | 174. | 75. | 0. | 0. | 1329. |
| P60 | 2. | 7. | 11. | 30. | 166. | 240. | 282. | 297. | 220. | 107. | 0. | 0. | 1657. |
| PMX | 113. | 76. | 117. | 305. | 411. | 619. | 554. | 722. | 599. | 634. | 292. | 39. | 2594. |
| TMC | 18.3 | 20.4 | 25.2 | 28.9 | 28.9 | 28.4 | 28.8 | 28.8 | 28.8 | 27.1 | 23.0 | 19.5 | 25.5 |
| HM | 73. | 63. | 58. | 57. | 76. | 86. | 83. | 87. | 87. | 85. | 79. | 76. | 76. |
| SC | 70. | 82. | 87. | 59. | 66. | 51. | 56. | 49. | 49. | 52. | 62. | 66. | 65. |
| PD | 0. | 2. | 2. | 9. | 128. | 181. | 231. | 222. | 184. | 82. | 0. | 0. | 1398. |
| ETP | 95. | 115. | 175. | 209. | 198. | 171. | 184. | 165. | 145. | 125. | 103. | 91. | 1780. |
| ETDF | 95. | 113. | 172. | 199. | 70. | -10. | -48. | -57. | -39. | 47. | 103. | 91. | 733. |
| MAI | .00 | .02 | .01 | .05 | .65 | 1.06 | 1.26 | 1.35 | 1.27 | .54 | .00 | .00 | .79 |

CHITTAGONG BANGLADESH EL= 14 LAT= 22 21 N LONG= 91 50 E KS=12.5

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM | 10. | 23. | 58. | 116. | 285. | 507. | 642. | 572. | 344. | 228. | 56. | 17. | 2858. |
| PMI | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1851. |
| P79 | 0. | 0. | 9. | 39. | 131. | 371. | 368. | 361. | 210. | 120. | 0. | 0. | 2356. |
| P60 | 0. | 4. | 25. | 71. | 231. | 420. | 550. | 485. | 278. | 165. | 7. | 0. | 2704. |
| PMX | 69. | 117. | 276. | 355. | 635. | 950. | 1527. | 780. | 759. | 579. | 321. | 146. | 4277. |
| TMC | 19.9 | 23.6 | 25.6 | 27.7 | 28.3 | 27.8 | 27.5 | 27.6 | 27.8 | 27.3 | 24.1 | 20.7 | 25.7 |
| HM | 79. | 77. | 79. | 82. | 85. | 89. | 83. | 91. | 89. | 89. | 85. | 83. | 85. |
| SC | 57. | 60. | 57. | 53. | 48. | 41. | 41. | 38. | 41. | 41. | 48. | 52. | 48. |
| PD | 0. | 1. | 12. | 45. | 152. | 381. | 406. | 387. | 224. | 123. | 1. | 0. | 2429. |
| ETP | 95. | 111. | 146. | 158. | 167. | 150. | 153. | 141. | 133. | 119. | 99. | 89. | 1560. |
| ETDF | 95. | 110. | 134. | 113. | 15. | -232. | -253. | -248. | -91. | -11. | 97. | 89. | -180. |
| MAI | .00 | .01 | .08 | .28 | .91 | 2.55 | 2.66 | 2.75 | 1.69 | 1.09 | .01 | .00 | 1.56 |

JESSORE BANGLADESH EL= 7 LAT= 23 10 N LONG= 89 13 E KS=12.8

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM | 14. | 23. | 35. | 88. | 182. | 275. | 313. | 307. | 197. | 136. | 22. | 16. | 1603. |
| PMI | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 937. |
| P79 | 0. | 0. | 0. | 28. | 89. | 169. | 239. | 179. | 141. | 60. | 0. | 0. | 1257. |
| P60 | 1. | 7. | 17. | 43. | 140. | 248. | 281. | 258. | 162. | 90. | 1. | 0. | 1395. |
| PMX | 127. | 133. | 166. | 320. | 699. | 674. | 538. | 615. | 510. | 509. | 124. | 18. | 2275. |
| TMC | 18.2 | 20.7 | 25.9 | 29.6 | 29.9 | 29.3 | 28.5 | 28.6 | 28.7 | 27.2 | 22.7 | 18.9 | 25.7 |
| HM | 77. | 70. | 67. | 69. | 79. | 87. | 89. | 91. | 91. | 87. | 81. | 81. | 81. |
| SC | 61. | 70. | 74. | 71. | 59. | 46. | 42. | 39. | 38. | 46. | 56. | 56. | 55. |
| PD | 0. | 1. | 4. | 31. | 100. | 185. | 247. | 196. | 145. | 66. | 0. | 0. | 1285. |
| ETP | 93. | 110. | 165. | 191. | 190. | 164. | 159. | 146. | 130. | 124. | 101. | 86. | 1659. |
| ETDF | 92. | 109. | 162. | 160. | 91. | -21. | -88. | -50. | -15. | 57. | 101. | 86. | 683. |
| MAI | .00 | .01 | .02 | .16 | .52 | 1.13 | 1.56 | 1.34 | 1.12 | .54 | .00 | .00 | .78 |

NARAYANGANJ BANGLADESH EL= 8 LAT= 23 37 N LONG= 90 30 E KS=13.0

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM | 14. | 27. | 46. | 161. | 245. | 346. | 348. | 364. | 242. | 171. | 29. | 19. | 2012. |
| PMI | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1438. |
| P79 | 0. | 0. | 7. | 63. | 152. | 216. | 258. | 250. | 170. | 60. | 0. | 0. | 1740. |
| P60 | 0. | 14. | 30. | 103. | 206. | 270. | 292. | 323. | 200. | 113. | 1. | 0. | 1855. |
| PMX | 95. | 73. | 149. | 325. | 544. | 866. | 672. | 727. | 451. | 605. | 177. | 24. | 2630. |
| TMC | 19.8 | 22.2 | 26.0 | 28.7 | 29.1 | 29.0 | 28.7 | 28.4 | 29.2 | 28.2 | 24.5 | 20.9 | 26.3 |
| HM | 75. | 68. | 67. | 78. | 82. | 85. | 86. | 85. | 85. | 83. | 79. | 77. | 79. |
| SC | 65. | 74. | 75. | 61. | 55. | 50. | 49. | 50. | 50. | 54. | 60. | 62. | 59. |
| PD | 0. | 3. | 12. | 71. | 163. | 227. | 265. | 265. | 176. | 71. | 0. | 0. | 1764. |
| ETP | 99. | 116. | 169. | 173. | 182. | 170. | 171. | 168. | 150. | 136. | 108. | 95. | 1736. |
| ETDF | 99. | 113. | 157. | 102. | 18. | -57. | -94. | -98. | -26. | 64. | 108. | 95. | 481. |
| MAI | .00 | .03 | .07 | .41 | .90 | 1.33 | 1.55 | 1.58 | 1.17 | .52 | .00 | .00 | 1.02 |

SRIMANGAL BANGLADESH EL= 21 LAT= 24 19 N LONG= 91 48 E KS=13.0

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM | 13. | 34. | 84. | 225. | 437. | 518. | 340. | 340. | 380. | 192. | 43. | 3. | 2503. |
| PMI | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1911. |
| P79 | 0. | 1. | 19. | 123. | 324. | 367. | 236. | 239. | 186. | 79. | 0. | 0. | 2256. |
| P60 | 1. | 11. | 55. | 193. | 410. | 444. | 295. | 295. | 272. | 151. | 3. | 0. | 2426. |
| PMX | 76. | 142. | 249. | 514. | 663. | 823. | 530. | 605. | 411. | 424. | 205. | 22. | 3269. |
| TMC | 17.2 | 19.5 | 24.3 | 27.3 | 27.7 | 28.2 | 28.5 | 28.3 | 28.2 | 26.4 | 22.2 | 18.4 | 24.7 |
| HM | 90. | 81. | 76. | 78. | 84. | 89. | 90. | 90. | 91. | 91. | 93. | 92. | 87. |
| SC | 41. | 57. | 64. | 61. | 52. | 43. | 41. | 41. | 39. | 39. | 34. | 37. | 46. |
| PD | 0. | 3. | 27. | 146. | 342. | 383. | 248. | 251. | 204. | 94. | 1. | 0. | 2315. |
| ETP | 72. | 94. | 147. | 167. | 171. | 155. | 157. | 150. | 129. | 110. | 76. | 67. | 1494. |
| ETDF | 71. | 91. | 120. | 22. | -171. | -223. | -92. | -101. | -75. | 16. | 76. | 67. | -205. |
| MAI | .00 | .03 | .18 | .87 | 2.00 | 2.47 | 1.59 | 1.67 | 1.59 | .86 | .01 | .00 | 1.55 |

| Heading | Description |
|---|---|
| PM | Mean monthly precipitation in mm |
| PMI | Minimum monthly recorded precipitation (30 years) |
| P79 | The 79 percent probability of precipitation occurrence |
| P60 | The 60 percent probability of precipitation occurrence |
| PMX | Maximum monthly recorded precipitation |
| TMC | Mean monthly temperature in degrees Celsius |
| HM | Mean monthly percent relative humidity |
| HMC | Percent relative humidity calculated from sunshine (Eq. 5) |
| S | Percentage of possible sunshine |
| SC | Percentage of sunshine calculated from HM (Eq. 5) |
| PD | Dependable precipitation - the 75 percent probability of precipitation occurrence |
| ETP | Potential evapotranspiration (Eq. 6) |
| ETDF | Potential evapotranspiration deficit (ETP - PD) |
| MAI | Moisture availability index (PD/ETP) (Eq. 7) |

Best Available Document

and depressions, (4) tanks, and (5) residual soil moisture. Except for groundwater recharge, it is generally not feasible to store monsoon runoff because suitable reservoir and tank sites are not available.

Crop production can be greatly increased through proper irrigation and water control by: providing supplemental irrigation during the early monsoon (aus) season; flood control and supplemental irrigation during the main monsoon (amon) season; irrigation during the winter dry season (boro season); and growing a greater variety of crops including vegetables.

## Flood Protection and Drainage

The flood and drainage situation in Bangladesh is unique in the world. The entire country is virtually a large active delta, roughly half the country is subject to flooding. The flood supply water for monsoon and dry season crops in some areas as cultivation and varietal selection have been accommodated to the normal flood environment. Nevertheless, there is substantial abnormal flooding most every year which damages crops and property.

Given this flood hazard, embankments and drainage improvement appears to have a role in water resource development. Within the area protected by embankments (about 3.3 million acres as of 1977) farmers cultivate monsoon paddy crops with greater success and are said to be investing more heavily in HYV and fertilizer and other yield increasing practices.

## Irrigation and Increased Production

The effect of irrigation on yield is the result of both the water itself and the associated complimentary inputs which accompany it.

If these inputs are not provided, then the impact of irrigation will be less or possibly negative.

On the basis of information supplied by the staff at the Bangladesh Rice Research Institute, (BIRRI) the following yield increases accompany the use of irrigation. These estimates are a reflection of results obtained on farmers fields and do not represent a potential established on the experiment stations

Boro. In Boro season both local and HYV rice are grown under irrigated conditions. Two to three tons/acre yield at farmers field level can easily be obtained. It is not possible to grow Boro rice without irrigation.

Aus. Usually Aus is grown under rainfed condition and per acre yield is about 2 tons. With supplemental irrigation 25 percent increased yield has been recorded. Prolonged drought is unusual in Aus season (April to July) but it does happen as shown in Table 1.

Transplanted Aman. Usually this crop is also grown under rainfed conditions. But there is possibility of drought in September to October and critical growth stages (panicle initiating and booting) occur during that period. Yield reduction depends on the severity of drought. Under rainfed conditions 1.5 to 2 tons per acre yield can be obtained. Under irrigated condition (supplemental irrigation) 50 percent increases in yield have been recorded. With assured irrigation facility 2.5 to 3 tons per acre yield can be obtained.

The acreage which is under irrigation in Bangladesh is given in Table 2. The total rice crop by season is shown in Table 3 and

TABLE 2
ACREAGE IRRIGATED BY DIFFERENT METHODS
(Millions of Acres)

| | Gravity Schemes | Low Lift Pumps | Deep Tubewells | Shallow Tubewells | Hand Tubewells | Traditional Methods | Total |
|---|---|---|---|---|---|---|---|
| 1974/75 | .08 | 1.3 | .14 | .03 | | 1.8 | 3.4 |
| 1975/76 | .09 | 1.3 | .18 | .03 | .006 | 1.7 | 3.4 |
| 1976/77 | .09 | 1.1 | .18 | .03 | .015 | 1.4 | 2.9 |
| 1977/78 | .14 | 1.3 | .35 | .08 | .025 | 1.8 | 3.7 |
| 1978/79 | .16 | 1.4 | .51 | .11 | .027 | 1.7 | 3.9 |

TABLE 3

ACREAGE OF PADDY BY SEASONS
(Millions of Acres)

| | 1976/77 | 1977/78 | 1978/79 | 1979/80 |
|---|---|---|---|---|
| Early Monsoon (Aus) | 7.9 | 7.8 | 8.0 | 7.5 |
| Main Monsoon (Aman) | 14.4 | 14.3 | 14.3 | |
| Winter dry (Boro) | 2.1 | 2.7 | 2.7 | |
| Total | 24.4 | 24.8 | 25.0 | |

Source: Bangladesh Bureau of Statistics

TABLE 4

YIELDS PER ACRE BY SEASON
(Maunds per acre of rice equivalent)

| | 1976/77 | 1977/78 | 1978/79 | 1979/80 |
|---|---|---|---|---|
| Early Monsoon (Aus) | 10.3 | 10.8 | 11.2 | 10.2 |
| Main Monsoon (Aman) | 13.1 | 14.2 | 13.9 | |
| Winter Dry (Boro) | 21.3 | 22.6 | 19.8 | |

1 Longton = 27.22 Maunds
1 Maund = 82.2 pounds

Source: Bangladesh Bureau of Statistics

yields per acre per season in Table 4 and total rice production in Table 5.

The production of wheat over the past 20 years is shown in Table 6. There have been dramatic increases in per acre production in the past five years. These have been made possibly by HYV and irrigation. In many cases wheat is being grown (a dry season crop) on land that formerly was in rice, however, the soil texture and moisture regimes during that period of the year favor wheat production; irrigation requirements are less and returns are greater to the farmer.

Very clearly there is a substantial opportunity to increase production with irrigation given the abundant water resources. Irrigation must be considered a priority in the country's development.

## HISTORY OF USAID IN IRRIGATION DEVELOPMENT

What follows is a brief description of the irrigation development programs and projects in which USAID has apparently been involved. Also included are comments on the applicability of the projects and recommendations for future action.

There are no reliable records of all the irrigation projects in which USAID has been involved. This is likely the result of lost records during the war of separation and the fact that many AID records were maintained in West Pakistan.

### Ganges-Kobadak Project, Kushtia Unit, Phase I.

This is primarily an irrigation project completed in 1970 with flood protection and drainage improvement aspects. It covers a gross area of 210,000 acres of which 120,000 are irrigable. Irrigation

TABLE 5

RICE PRODUCTION BY SEASONS
(Millions of long tons of rice equivalents)

| | 1976/77 | 1977/78 | 1978/79 | 1979/80 |
|---|---|---|---|---|
| Early Monsoon (Aus) | 3.0 | 3.1 | 3.3 | 2.8 |
| Main Monsoon (Aman) | 6.9 | 7.4 | 7.4 | |
| Winter Dry (Boro) | 1.6 | 2.2 | 1.9 | |
| Total | 11.5 | 12.7 | 12.6 | |

Source: Bangladesh Bureau of Statistics

TABLE 6

PRODUCTION OF WHEAT

| Year | Total Acreage (Millions) | Total Production (Millions Long Tons) | Yield/Acre Maunds |
|---|---|---|---|
| 1960/61 | .14 | .03 | 6.2 |
| 1964/65 | .13 | .03 | 6.4 |
| 1969/70 | .30 | .10 | 9.5 |
| 1974/75 | .31 | .12 | 10.1 |
| 1975/76 | .37 | .21 | 15.8 |
| 1976/77 | .40 | .25 | 17.6 |
| 1977/78 | .47 | .34 | 20.0 |
| 1978/79 | .65 | .48 | 20.2 |
| 1979/80 | | .00[e] | |

One long Ton = 27.22 Maunds
One maund = 82.2 pounds
e = estimate

Source: Bangladesh Bureau of Statistics

is provided by pumping water from the Ganges into a gravity canal system. The main feature of the project includes 46 miles of main channel and pumps with a total capacity of 125 cusec.

At the present time the project is estimated to irrigate betwee thirty and sixty-five thousand acres.

Coastal Embankment Project, Phase I

The coastal-embankment project is located along the shore of the Bay of Bengal in the coastal districts of Bangladesh. By virtue of the land location and elevation and many water passages, the land is subject to periodic tidal inundation and monsoon floods. The project comprises 86 polders which will provide protection to about 2.7 million acres through construction of 2,250 miles of embankment and 800 sluices.

Country Master Plan

Development of a countrywide Master Plan for Irrigation, Drainage and Flood Protection.

This program completed in 1964 under contract by International Engineering Company Inc. of California, identified and described a total of 51 irrigation, drainage or flood protection projects which would result in increased agriculture production. There were canal diversion projects, deep tubewell projects, and embankment type flood control projects. Some of the projects were multipurpose associated with hydro development.

The overall objective of this Master Plan was to include an irrigation capability which would provide for food production requirements for 20 to 25 years (approximately 1985).

The Dacca-Demra Project

This project was reportedly undertaken by USAID in the 1960's. No project documentation exists in the mission. The team visited the supposed project site and obtained the impression of a multi-dimensional project which included a flood control/road embankment, land leveling and the provision of a pumping station and irrigation canals. The project may have included four villages.

Small Scale Irrigation

This active project will make available 40,000 irrigation hand pumps per year for sale to farmers. It is to be accomplished by providing funds to the Bangladesh Government for purchase of pump manufacturing raw materials; by providing a credit program with minima stipulation for loans; and by a program for advertising the availabili of credit and pumps. The pumps are targeted for rice and wheat irriga tion on farms of one acre or less.

In total the project will finance the distribution of 240K hand pumps for irrigation to farms, at a cost to the farmer of $70/pump and $3.45 for installation. There is reportedly a large demand for such pumps and 135K/year are manufactured at present by local industry.

Assuming a 120 day season, one-third acre of land will require 640 hours of pumping or 5.3 hours per day. The food energy produced will be 20 times the human energy for pumping. A financial analysis from the farmer's viewpoint was made and even with rice prices at an extremely low level, the farmer owning one-third acre or more would show a profit after three years.

A program of radio advertisements will be prepared to inform the farmer of the program.

It is expected that there will be a 13 percent interest rate on loans and a 29 percent default rate, although the latter may improve with the addition of more loan officers. Therefore, the BDG is subsidizing the distribution of these pumps. The Bangladesh Krishi Bank will require $1M/year to maintain credit operations. In the first year, the IRDP will borrow $1.38M worth of pumps from UNICEF, to be repaid in local currency, and in the remaining years it will borrow about $1M/year from the Bangladesh Bank. The interest and default rates will be the same for the IRDP.

The BDG will absorb all local costs of constructing the 120K additional pumps for which AID is providing raw materials.

Assuming (conservatively) a 5-year life for the pumps, the B/C for the project is 2.2 at 15 percent and the IRR is 85 percent.

Terms for farmer loans are: no down payment; repayment in three equal installments after each dry season harvest; 13 percent interest; and pledging of the farmer's land as collateral.

This project is currently more than one year behind schedule. Difficulties arose with pump design and with dealing with import procedures. Procuring all components of the pump and pipes proved to be a formidable task. As of June 1980, 6000 pumps had been procured. However, contracts have been let which should produce results in the near future.

Rural Irrigation Works

This project would construct and operate small scale irrigation systems (which would be developed to increase the command areas of

existing water supplies) through the Rural Works Program of the Government of Bangladesh. To date a consultant has selected thirty (30) projects from a list of 90 DTW's for planning and design. Any one of these thirty projects is referred to as a sub-project. "Sub-projects to be developed will serve as models of design and operation to MRD (Ministry of Local Government, Rural Development and Cooperatives) and to water users' groups. Therefore, economic justifiability was not considered to be a primary factor in the development of the questionnaire, also the social and economic background data about the beneficiaries is inadequate to select the projects.

Status.--To date, 23 subprojects have been designed. They are to serve as demonstrations for promoting command area development-ultimately for the country. Water distribution channels are standardized to carry 2 cfs flows which is the typical output of a DTW, to be lined with locally made bricks and to have a masonary turnout for each three to five acre block of farmland, water scheduling will be done in each block by roster which "will be published and updated from time to time and will be posted at the pumphouse or another convenient location."

The evaluation team does not understand how any single subproject structure could serve as a national model without meeting the test of a financial analysis and field evaluation. In particular water saving practices such as lined canals and masonry turnouts should be shown to pay. The design which has been selected for these subprojects block rotational irrigation has implicit within it a necessity for farmer organization. There is no evidence to establish that this is the design which will minimize distribution costs where

distribution costs equal expenditures on structures plus land taken out of production plus operation and maintenance charges plus organization and transactions costs.

The Nabaganga Integrated Land and Water Use Study

This project is in phase II of preparation for a target area 90,000 acres serving a population of 202,500. At present 2,700 acres are irrigated from the Nabaganga River. The primary goal of the project is to "significantly improve the income of farmers especially poor land owners, tenants and landless laborers in the project area."

Primary Components. (1) Irrigation of 20,800 acres (1/1 boro rice, 1/2 wheat) with lowlift pumps from Nabaganga Reservoir, (2) Fisheries development in the Nabaganga Reservoir, (3) village industries and (4) an agricultural practice program on nonirrigated land. Four (4) 100 acre pilot farms iw to be used to establish management and organization structure for the remainder of the project. The BWDB responsible for training and extension services. BWDB Executive Engineer is to be responsible for implementation of pilot areas.

Development groups with a manager who is responsible for pump maintenance and operation, cropping pattern selection, procurement of seeds, fertilizer, and other inputs; setting up irrigation water delivery schedule, and collecting of input costs.

# SECTION II

## DEVELOPMENT OPTIONS

The team has chosen to consider the so-called issues as outlined in the paper prepared by Dr. Lavine, copy appended, as a listing not of issues but of development options. It was anticipated from the start that a pure strategy for irrigation development would not likely be appropriate. Rather what would be required as a mixture of options consistent with current country needs, political realities, and AID capabilities.

### Irrigation vs. Rainfed

It is not possible with the data readily available for analysis to calculate the profitability of past investment in irrigation. What is clear however is that across all fronts, results have been less than planned. Major canal projects were completed late and those under construction are behind schedule. Irrigated average is almost always less than the potential command with the quantity of water available and irrigable area. Tubewells with but a few exceptions irrigate less than the planned for acreage (about one-fourth to one-third of expectations). Clearly a realistic analysis of the benefits from irrigation in Bangladesh cannot be taken from project planning documents.

A total social accounting of irrigation investment in the country has not been carried out. Very little systematic monitoring or evaluation of existing projects has been going on. No one would argue, however, that planned for output increases have been achieved.

On the other hand, over the last five years the availability of irrigation water for the winter dry season (boro) has resulted in an acreage annual output of 2,094,000 long tons of rice equivalent. Valued at 1978/79 farmgate prices, this is approximately 5.95 billion Takas (approximately 411 million U.S.).*

There is an accumulating body of evidence in Bangladesh to suggest that significant increases in paddy production in the rainfed areas is a real possibility. In the first place of the 25.0 million cropped acres of paddy in the 1978/79, cropping season a typical year in terms of planted acreage, 22.3 million acres of 89 percent were rainfed. These are the early (aus) and main monsoon (aman) paddy crops. Although yields may be limited in these seasons, compared to the winter dry season (which is irrigated) because of available sunlight, they represent a substantial production base. Secondly, on-going research at the Bangladesh Rice Research Institute with cropping systems suggests potential for greater rainfed crop production by way of new varieties currently under field testing. There are varieties bred specifically for characteristics which will be appropriate for these environmental conditions of the monsoon seasons. Field tests showed yields and income increases even though fertilizer and pesticides were applied below recommended levels.

The release of these new varieties, which are being developed to be complementary with seasons, can be expected within the next several years. In addition, strong evidence of substantial production increases from the application of zinc sulphate and sulphur in some

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*Based on 1 long ton = 27.22 mds of rice, and an average farm gate price for Boro paddy of 104.46 TAKAS/MD.

regions of the country is accumulating. Taking advantage of these production possibilities will require attention to the well-known packages of inputs and practices: fertilizer availability, credit, seed multiplication, demonstration plots and so forth.

The general concensus seems to be that a substantial technology for rainfed paddy production is not yet available, but it is likely to be so, well within the next five year period. It is too early to determine (1) the yield and income potential of that technology and (2) the relative profitability of investments in delivering that technology compared to investments in irrigation. Existing rainfed agriculture leaves much of Bangladesh without the potential of year long agriculture and would limit production to those crops that can be grown in that period when moisture is available. The soil and climate resource therefore, goes unused for six months or more every year. In addition to increased production, irrigation affords a degree of insurance against unusual drought periods. Furthermore, one of the principal resources is a cheap and readily available water supply.

Wet Season vs. Year Round Irrigation

Typically, wet season or so-called supplemental irrigation has the following characteristics:

1. Water is provided through a river diversion or pump system with or without associated reservoir storage facilities. Storage facilities are often needed because river flow is lowest when the demand for water is highest, but this is not likely the case in Bangladesh.

2. For paddy, the per acre irrigation requirements are low even in the driest years compared to dry season irrigation.

3. The marginal productivity per acre inch of water declines over the full range of the supplemental water requirement. In the same way the marginal productivity per acre inch of system delivery capacity declines. This means that there are two reasons for spreading a given amount of water over a large area. (1) the per acre requirements are low and (2) average returns to water increase. The major factors which are acting to restrict the increase in the command area are cost incentives, cost of the distribution system and cost (management) of organizing for water control and incentive for those already reserving water to take the risks involved with expansion.

4. Very typically, paddy systems which have been designed for supplemental irrigation have a limited capability for year round i irrigation (which means irrigating a dry season crop). The reasons for this are both the availability of water compared to the total command area and the distribution systems are not designed to carry the larger quantity of water required per acre during the dry season.

In contrast, systems which are designed for many different crops and full season capability require greater water storage (reservoir or underground) and have the capability of transporting the higher per acre requirements. It is fair to say that a system which can supply the dry season command area can certainly provide supplemental rainy season irrigation--except in the case of wells as limited by falling water tables. That is, the supply of water is such that tradeoffs must be made between dry and rainy season irrigation.

In Bangladesh, 52 percent of the total irrigated acreage in 1978/79 was irrigated by pumps (low lift pumps, deep tubewells and shallow tubewells). Originally these pumps were only operated during the winter dry season (boro season). The reason was that fuel, maintenance, and operation organization which support the pumping operations were not set up to be available at other seasons of the year.

This situation appears to be changing. The last four rice crops in Bangladesh have suffered in some degree from drought. Experiments in supplemental irrigation at the Bangladesh Rice Research Institute during the early monsoon (aus) and main monsoon seasons showed a 54 percent and 10 percent increase in paddy yield from very limited supplemental irrigation. Water shortages had occurred during the very critical reproductive stages and therefore returns to small quantities of supplemental rainy season irrigation were high. This has been sufficient evidence for the Government to initiate the process so that wet season irrigation can be available when required from pump systems.

Pump Irrigation. There are, however, many unanswered questions. The probability estimates of when supplemental irrigation might be required in the various climatic regions of the country have not been made. There is no basis therefore for computing the economic benefits from investment in a supplemental irrigation capability. It is possible that an existing pump operations supplemental irrigation can proceed with no difficulties. On the other hand, several possible situations might well be considered:

1. Additional pumping at existing sites may adversely affect

the water table for pumping from shallow tubewells, particularly if full dry season potential is ever achieved.

2. Existing pump capacity, if not limited by topography, should be able to supply supplemental irrigation to a greater number of acres during the rainy than the dry winter season. New distribution systems and farmer organizations may be needed.

3. Irrigation can provide timely germination of crops at the beginning of the rainy season in order to take full advantage of the wet season for crop production.

In summary, at the present time the economic benefits of supplemental irrigation have not been thoroughly investigated. It is highly likely, however, that supplemental irrigation with existing pump operations is economically feasible especially under those circumstances where there is no competition between seasons for the available water supply There are no studies which compare the marginal benefit of limited water supply between seasons or between crops within seasons. For the most part, however, systems should be designed for operation in all seasons (year-round).

Traditional Irrigation. Traditional irrigation methods, doones, and hand pumps irrigate approximately 43 percent of the total irrigated area. This is recorded as dry season irrigation. It seems very unlikely that cultivators have not been using these same techniques for supplemental irrigation when the need arises.

Gravity Fed Canal System. Canal systems have been designed primarily for dry season irrigation. There are no comparative analyses

of full irrigation versus supplemental irrigation systems. Given river flows it is very likely that canal systems have the water supply for monsoon irrigation.

Clearly there is strong evidence that any system designed for dry season irrigation should be organized for full season irrigation. There is not sufficient evidence now available to advocate building systems with only a supplemental irrigation capability for paddy.

Expansion vs. Intensification

An expansion versus intensification development option for irrigation depends upon the existance of irrigation projects which have not achieved their design potential. The option clearly exists in Bangladesh. The history of irrigation investment is a continuous record of schemes which have failed to meet planned potential. But what is far from clear is to what extent this is because of incomplete planning and project execution, and implementation, and to what extent it is due to rational adjustments to economic, social and environmental realities. All of the reasons are most likely relevant to one situation or another.

Wells and Pumps. The areas typically being irrigated by deep tube wells, shallow tube wells, low lift pumps and hand tube wells are shown in Table 7. These acreages are well below planned-for irrigable areas. Deep tube wells for example with 2-3 cusec, pumps are said to have a capacity to irrigate from 90-120 acres. Deep tube wells of 4 cusec, capacity which were designed to irrigate a command area of 300 acres are averaging about 60 acres. This compared to a 5-year national average of 44.0 acres.

TABLE 7

AVERAGE AREA IRRIGATED BY TYPE OF WELL/PUMPS

| Type | Average Irrigated Area/Well 1978/79 | Average Over 5 Yrs 1975-79 | 5-Year Range |
|---|---|---|---|
| Deep Tube Well (DTW) | 54.1 | 44.0 | 54.1-36.8 |
| Shallow Tube Well (STW) | 10.4 | 7.5 | 10.4-5.8 |
| Low Lift Pump (LLP) | 40.0 | 37.6 | 40.0-36.1 |
| Hand Tube Wells (HTW) | .32 | .47 | .32-.64 |

Source: Bangladesh Water Development Board, Bangladesh Agricultural Development Corporation, Integrated Rural Development Program

*Program started in 1975-76, 4 year average and range-acreages estimated.

Deep Tube Wells (DTW's). These tubewells are six to eight inches in diameter and are drilled to a depth of over 160 ft. The wells are equipped with 1.5 and 2.5 cusec submersible turbine pumps, engines and pumphouses. Installed costs range from Tk 125,000 to Tk 225,000. Where possible electric pumps are preferred to diesel because they are simpler to operate and maintain, they also make REA more feasible. The reliability of an electric supply source should be considered before promoting a general plan to utilize electric pumps. A pump group or cooperative pays a rental charge (Tk. 1200) plus the cost of spare parts, fuel, oil and operator's salary.

Reasons cited for the failure of the DTW's to irrigate their potential acreage include:

1. Grossly inadequate distribution systems between the well and the land which can potentially be irrigated with the flow available.

2. Mismatching of well and pump capacity. Many pumps are suspected of pumping far less water than the pump ratings.

3. Improper Siting. Siting may be done on the land of the Manager and organizer rather than on the basis of topography. Irrigated acreage may therefore be limited by topography. Alternatively siting may be done on the basis of topography with no reference to the demand for irrigation water by farmers in the command area.

4. Ninety or 120 or 300 acre command areas are said to mean the organization of too many farms. (47.5 percent of all farms are less than 2 acres and 25.0 percent less than 1.5 acres.)

5. Farmers waste water (some claim because the cost of water is set too low to the cultivator).

6. Lack of uniformity in area irrigated (skipped plots).

7. No system of extension and agricultural development (supply of HYV fertilizer and other input) after wells are completed.

8. Lack of an integrated approach to water development and management i.e., failure to see irrigation as a complete physical, economic and social system and not providing the necessary inputs to integrate the total package.

9. Failure to run the pump more than four or five hours per day. There is a feeling that pumps must be rested!.

10. Failure of maintenance, fuel supply and availability of spare parts.

11. Lack of a capability to organize farmers to manage the total system water including efficient water application at the field level.

12. Large water losses in the canal system.

13. Fragmented holdings of very small sizes with no right-of-way for the water distribution system.

Low Lift Pumps (LLP). These diesel and electric powered centrifugal pumps, etc. (1 to 5 cusecs) are supplied to pump groups and cooperatives on an annual rental basis for pumping from streams, khals and ponds. Basic rental charges vary with the size of pump set. In addition repair charges are assessed and there are penalties for negligence and carelessness. The pump group also pays for fuel, oil and the operators salary. The Bangladesh Agricultural Development Council provides repair service.

In 1976/77 28,224 LLP were fielded: 40,500 sets were available for use in the same year.

Reasons for lack of use and problems of the LLP program are cited as:

1. Grossly inadequate field distribution systems.

2. Lack of interest in irrigation due to low product prices and high input costs.

3. Unavailability of surface water for pumping in the drier years.

4. Conflict leading to dissolution of groups.

5. Pump life is too short (60 percent of potential) due to poor maintenance.

6. Lack of support for farmer groups.

7. Plus most of the other comments associated with DTW's.

Shallow Tube Wells (STW). The Bangladesh Agricultural Development Corporation sells STW to pump groups and farms at cost (approximately TK 19,500). The buyer pays 10 percent down and due remainder in five equal installments (zero interest). Buyers pay all operation and maintenance charges. Water yields are generally less than or equal to 1 cusec, and pumps are surface centrifical type powered by 5 to 6 H.P. diesel engines. STW's are cheaper, easier to install and maintain and require a much smaller pump group and distribution system for optimal utilization.

Hand Pumps. These pumps were discussed under the description of the USAID financed handpump project.

Canal Gravity System. It is difficult to determine the extent to which gravity systems are being operated up to either planned or

actual potential. There is evidence, however, that the record is less than 100 percent.

The USAID financed Banges-Kobadak Phase I project has cost more than 85 million US dollars since 1959. It was to have provided a net increase in irrigated acreage in the command area of 220,000 acres. As of 1978 this project was listed officially as irrigating 64,608 acres. Unofficial reports speculate that the actual irrigated acreage may be about half that amount. A variety of reasons have been cited to explain the lack of performance of the project. These include (1) heavy siltation at the intake and pumping station, (2) inadequate electrical supply for the pumps, and (3) design duty per cusec is too great, and (4) grossly inadequate field distribution systems, (5) plus most of the other comments which were mentioned in connection with DTW's.

Flood Control Project. The Coastal Embankment Project. The coastal embankment project consists of a system of dikes and drainage sluices to protect land in the coastal area from flooding by saline water at high tide. The program was begin in 1960. More than 2300 miles of embankment have been completed. According to World Bank reports only a fraction of the full potential of the embankment have been realized. What is said to be required are improved water management practices, agricultural support services, rural infrastructure and in short, a systems type integrated approach to development.

Summary. It is quite clear that the planned for potential of none of the irrigation alternatives, large or small, has been achieved. There are a long list of possible causes, but in all cases there are

either informed judgments, hypotheses or pure speculation. There have been no special study results to clearly document the difficulties. There have been no attempts to determine if the costs of increasing the irrigable area is less than the potential benefits. Indeed some consultants are claiming that it is cheaper to sink new tubewells than to bear the organizational costs and costs of increased water management on existing installations.

There is strong evidence to suggest an opportunity to increase irrigation from existing projects. There is no available information to evaluate the capital and operating (energy and management) costs and benefits associated with choosing that particular development option. The evaluation team recommends that investigations of these costs be undertaken in an organized professional manner. A project might be developed with this as its objective (giving special emphasis to energy use efficiency).

## Large Projects vs. Small Projects

A large irrigation project is one in which relatively large quantities of water are drawn from a single source and distributed by an extensive canal system over a large area. Canals are measured in miles rather than in meters. The area irrigated is often large enough that cultivators never visit the water source in their life time.

A project which is large in total investment but is a collection of many small projects in a geographical area (e.g., a project to sink 500 tubewells) is not what is meant here as a large project.

In summary, the possible benefits of a large project are:

(1) they are necessary to utilize a large but variable water source, (2) they permit more effective use of scarce managerial and technical skills, (3) they permit economies of size to be realized in operation and maintenance, (4) they are more easily financed through foreign donors, (5) they generate more benefits during the construction period. Some of the negative dimensions of large projects are (1) they inevitably require the use of external consultants, (2) they have major environmental impacts and (3) it requires extensive farmer user organization to utilize the water effectively. In addition, large projects have all the same on-farm water distribution and management complications as do small projects.

In contrast, small projects (including a large collection of small projects under a single large financing scheme) have the advantage of: (1) more rapid development, (2) more opportunities for mobilizing local resources, (3) minimal environmental impacts and (4) easier to organize for effective water management because fewer cultivators per unit are involved.

In Bangladesh, irrigation has been targeted as one of the major development activities for achieving food self-sufficiency by 1985.

Irrigation investment strategy in Bangladesh has been heavily influenced by the 1964 Master Plan funded by USAID. This plan with an originally estimated cost of US$2.1 billion called for some 50 major projects which would have jointly provided flood control and drainage for about 12.1 million acres. Irrigation was to be supplied at a later date to 7.9 million acres. Schemes completed so far (1979) provide full or partial flood protection for 3.37 million acres and irrigation for 150,000 acres.

Recently (April 1979) a joint team of the World Bank/Government of Bangladesh reviewed irrigation development in the country. The objective of the review was to facilitate and redirect water resources development strategy with a view toward meeting food grain self sufficiency by 1985. Overall the study team recommended that development should focus on immediate impact on food grain production rather than on long term flood protection and drainage.

It was determined that if food self-sufficiency was to be achieved a minimum of 4.85 million acres would need to be irrigated by 1984/85. This minimum requirement assumed a relatively high production response to irrigation. A more realistic requirement was felt to be 5.5 million acres. The types of irrigation facilities which would be required to meet the 5.7 million objective are shown in Table 8.

A large portion of the increase, 1,500,000 acres would come from primarily larger gravity pump systems and the remainder from smaller scale irrigation facilities. It was felt by the Bank review team that this high a level of development over the next five years is not achievable, consequently, they suggest a reduced target for gravity/primary pumping schemes of 800,000 acres for a total of 4.85 million irrigated acreages by 1984/85.

What has evolved since the 1964 Master Plan and its almost total emphasis on large scale projects is a joint strategy which recognizes the importance of small scale irrigation projects. In fact the role

TABLE 8

IRRIGATION FACILITIES PROJECTED FOR MEETING ESTIMATED NEEDS

| Types of System | Acreage 1975/79 (000) | Acreage 1985/85 (000) |
|---|---|---|
| Gravity/primar pumping | 110 | 1,660 |
| Low Lift Pumps (LLP) | 1,431 | 1,700 |
| Deep Tubewells (DTW) | 152 | 940 |
| Shallow Tubewells (STW) | 77 | 440 |
| Hand Pumps (HP) | 200 | 170 |
| Traditional | ,000 | 800 |
| Total | ,720 | 5,710 |

of small scale irrigation seems to be more limited by government uncertainty regarding ground water supplies and sites for low lift pumps rather than by a preference for the larger systems. This suggests the need for sufficient ground water survey data to delineate where STW's should be employed.

An interesting relationship is pointed to in the Bank report which is that in Bangladesh the rate of return from irrigation/flood control investments are inversely related to the per acre capital investment cost, which is found to be largely a function of flooding as well as utilization of man-made (railway and roads) and natural barriers as flood protection embankments.

What emerges then is a situation in which the higher returns

to investment in irrigation are from small scale projects in the less flood prone regions of the country.

A review of externally financed schemes by the World Bank demonstrates the relationship between size of scheme and cost and returns as shown in Table 9.

TABLE 9

COSTS AND RETURNS OF SELECTED IRRIGATION SCHEMES

| Type of Scheme | Sample Size | Capital Investment Per Acre (US$) | Internal Rate of Return |
|---|---|---|---|
| Small scheme | 10 | < 110 | 30-50% |
| Minor schemes | 3 | 110-170 | 28-30% |
| Medium schemes | 7 | 300-1000 | 14-16% |

Source: The Government of Bangladesh and the World Bank, Bangladesh Review of the Bangladesh Water Development Board, Report No. 2327-BD, April 2, 1979.

Another factor which appears to be opting strongly for small scale irrigation is the problem of farmer organization for water management. The organizational requirements for a deep tubewell are not likely significantly greater than thsoe at a turnout of a large gravity system. However, as the size of the water supply decreases with shallow tubewell and low lift pumps the organizational requirements for water management decreases.

The ultimate is the hand pump for which there is no organizational component for farm level water application.

This does not mean, however, that the organization necessary

to supply the farmer with the whole range of inputs and services necessary to achieve the potential of irrigation has decreased. It may in fact have increased for some services such as maintenance and repair and fuel distribution.

While the organizational costs and energy budget may favor hand pumps, shallow tubewells (and probably low lift pumps) appear to be less costly to operate on a per acre basis than hand pumps as demonstrated in Table 10.

TABLE 10

COMPARATIVE COST PER ACRE
HANDPUMP VS. SHALLOW TUBEWELL

| | Handpump | Shallow Tubewell |
|---|---|---|
| Capital Cost | Tk. 1000 | Tk 20,000 |
| Life of Unit | 5 yrs. | 5 yrs. |
| Amortized Capital Cost | 200 | 4,000 (?) |
| Operating Costs | 1,500 | 6,230 |
| Maintenance | 50 | 990 |
| Total cost/annually | 1,750 | 11,220 |
| Command area | 0.5 acres | 6 acres |
| Cost per Acre | Tk. 3,500* (US$233) | Tk 1,870 (US$125) |

*If the opportunity cost of family labor operating the pump is assuming zero, then the per acre costs are reduced to Tk 500 (US$33). This is probably not a valid assumption. Of course, increasing the efficiency of the pump would have a similar cost reducing effect.

Source: USAID Project Paper, "Proposal and Recommendations for the Review of the Development Loan Committee." Bangladesh: Small Scale Irrigation I, AID-DLC/P 2162 Annex B.12.

Summary. Bangladesh is committed to an irrigation program which includes both very large and very small projects (i.e., invidivual irrigation units). The available evidence to date shows that small scale projects in the less flood prone areas of the country have higher rates of return than large projects. Given USAID experience with larger projects and the evidence favoring small projects (and as well considerable support for the larger gravity-pump systems by other donors) USAID should not provide financing for large scale projects at this time.

Government vs. Private

The conventional wisdom in Bangladesh at the present time is that a number of the organizational and supply issues would be overcome if both the supply side and pump operation were turned over to the private sector. This may well be but there has been no systematic analysis of the most effective role of both government and the private sector in irrigation development.

Advocates of complete reliance on the private sector need to recall that there are two sides to the coin: (1) the efficiency argument which incorporates the "invisible hand" and (2) the distributional implications implicit in a private sector economy whcih may not be acceptable on (a) equity grounds and (b) political realities. More than likely a mixed strategy will eventually emerge in which the private sector will play an important but not the total role.

It is reported that private investment in water resource development activities has been hindered by ambiguities in national water laws.

Summary. The team recommends that USAID encourage development of the private sector when it appears consistent with their capability and the equity concerns of government. (In reality, it is likely that irrigation will be developed in the private and governmental sectors).

# SECTION III

This section discusses the investment strategies developed in the Levine paper. There is no attempt to devise a pure strategy but rather to point towards a mixture of options.

## INVESTMENT STRATEGIES

### Direct vs. Indirect

Up to this time USAID has had no experience in indirect investment in irrigation. Indirect investment refers to irrigation as a component of a larger systems approach to development. Typically, such projects are referred to as integrated rural development, integrated area development and so forth.

The general argument for indirect investment is that direct investment most often fails to meet output objectives because, as is well known, irrigation is only one of a vast number of inputs and services required to achieve development. The systems approach is generally accepted as the way to integrate activities so as to achieve development goals.

The evaluation team suggests that USAID avoid involvement with integrated projects which do not have a strong monitoring and problem solving capability. This may depend ultimately on the GOB commitment to facilitating projects of this nature. Integrated projects should reflect experience gained by donors who have been funding these types of projects.

Hardware vs. Software

The quantity of hardware (investment in physical facilities, plant and equipment) which is proposed for Bangladesh over the next five years is substantial. A very lage proportion of the financing for this development, particularly surface irrigation will be provided by outside donors (IDB, ABB, etc.) (See Table 11).

ABLE 11

IRRIGATION DEVELOPMENT IN BANGLADESH - 1980/85

| Type of Irrigation | Acres to be Irrigated | No. of Units |
|---|---|---|
| Surface Irrigation | 760,000 | |
| LLP | 57,000 | 23,000 |
| STW | 1,230,000 | 125,000 |
| DTW | 890,000 | 14,000 |
| HTW | 80,000 | 330,000 |
| Drainage/flood | 1,500,000 | |

Source: Bangladesh 5-year plan

Software. Software refers to research, training, and management modes of improved irrigation systems. The following recommendations dealing with irrigation in Bangladesh have been taken from the team's review of numerous reports, documents, conversations with AID and GOB officials, project managers, technicians of many organizations, and interviews with key farmer informants and extension workers. These recommendations are provided in summary form and should be viewed as ways to find solutions to problems raised in this report.

1. Research projects are needed on soil and water management which include:

a. Systems approaches to understand how the present systems work and what the priority problems are constraining increased agricultural production.

b. Distribution systems and their efficiencies, water supply management from the source of supply, and the management of the physical system on farms. This includes an examination of conveyance efficiencies, field application efficiencies and how on-farm improvements (conveyance channels, field outlets, and other farm structures) can improve the use of water.

c. Soil and water management and crop water use which gives focus to irrigation scheduling, timing, field application, irrigation practices, soil fertility, and water removal.

d. Crops and Rainfed farming. Soil moisture management, crop selection and crop quality to meet increased quantity and quality of food production.

e. Agro climatic. Improved recording and use of agroclimatic data and estimation of frequency and timing of supplemental irrigation requirements.

f. Economic analysis. Which have a farm management focus to ascertain costs and returns to irrigation by crops and of crops, cropping systems, research with a focus on agronomic practices for dry land and irrigated crops. Comparative studies on different types of irrigation systems, the demand for water and water control by farmers, hidden costs in

irrigation and the overall efficiency of alternative systems of management and control within the context of the present complex agrarian structure. Also analyses of the human and fossil fuel energy costs of alternative types of irrigation. Analysis of effectiveness of various methods to convey water to farmer's fields.

g. Social, legal, and Institutional Factors. Methods to improve the benefits of irrigation to small farmers, tenants, sharecroppers, and homesteaders. Water policy and codes related to land and water rights, and forms of farmer organizations which will work most effectively within the rural social structure. Constraints research to identify and remove constraints in the efficient use of water. An examination of the present water policy and codes for suggesting changes which will provide the incentives to water users.

h. Social organization to discover how, where and under what conditions farmers cooperate in the use of collective goods. Evaluations of the CARE, FAO, and other programs to ascertain what forms of cooperation are emerging. Assessment of the proposed costs of legal water user associations under the cooperative, societies, or other existing legislation. Study of linkages of farmers with organizations designed to serve them to ascertain quantity and quality of services provided. Studies of most effective forms of extension services such as conventional extension system, training and visitation approach, use of paraprofessionals or farmers in extension, and role of a farm water management advisor.

i. Water supply. Estimates of ground water supplies and recharge in order to develop a coordinated and rational pump and surface water use and management program.

j. Water Quality. Examination in selected areas the effects of pumping on salt water intrusion in the rivers and farm land. Study of consequences for fish stocks and effects of extensive pmping on ground water quality.

2. Difference approaches in farmer organization. The study of present effective farms and flexible experimentation with good evaluation to ascertain most effective approaches. Formal vs. legal, organization under various legal acts; centralized vs. decentralized; block organization vs. command area organization; single vs. multi-purpose, etc.

3. Planning and project implementation. A national water resource development strategy is needed which will provide commitment and guidance. Assessments of planning capabilities and management problems for project needs to be examined.

4. Institutional Linkages. Local institutions which conduct policy, applied research, and implement programs needed to be evaluated and improved. Universities and training schools which provide training in interdisciplinary methods are needed in universities, research institutes and training centers if the required manpower is to be available. An inventory of all organizations in Bangladesh should be made to assess the institutional capability for long-term irrigation improvement. At present, very few understand on-farm water management in its entirety because irrigation has been dominated from the 1950's with big structures and wells to simply deliver water to command areas

5. Training. If there is to be a long term focus on irrigation in Bangladesh to solve problems at the farm level, special training programs should be developed. Training should provide skills in priority problem identification, development of solutions, assessment of technologies, and planning, implementation monitoring, and evaluation of irrigation systems. The mode of training should be interdisciplinary and along with some graduate academic training for a few selected positions. A focus should be on short-term training for engineers, mechanics, economists, sociologists, and extension workers, to assist farmers.

Selection of trainees is important. Ideally selection criteria should include a period in the field for the first trainees with existing programs. Academic training initially should be for a selected number who will find positions in organizations committed to on-farm water management. A corps of initial trainees may need one year of overseas training in degree or nondegree training, where overseas degree training is involved the thesis should be done in Bangladesh on problems relevant to improving the irrigation system. Special observation training tours for selected individuals should be made available in third countries to learn what developments are taking place.

The opportunities for investment in the provision of software to support irrigation development appear great. In particular training and demonstration activities might be provided through short courses, grants to other agencies involved in institution building, fellowship programs, construction of schools and buildings, preparation of training materials specific to local conditions, sponsoring of country and regional seminars and workshops.

Main System vs. On-Farm

Lack of success of all types of projects, large and small alike, to meet project outputs are in part attributed to a failure of the on-farm delivery system. There are no studies which have carefully documented the exact course of failure and recommended changes on the basis of those studies. Nevertheless, there is an abundance of untested solutions to the "on-farm problem," ranging from land reform to field consolidation to collective farming to rotational irrigation.

The review team recommends that USAID emphasize on-farm delivery in any project which they might undertake. The team cautions against acceptance of any system, without first assessing the costs (per unit area which can practically receive water) and benefits including the organizational costs involved.

Early vs. Late

The early versus late investment strategy is not particularly relevant under present circumstances in Bangladesh. It is true that some of the very large projects have developed in stages. In those cases it is possible that lessons learned in the earlier stages might be applied in the second and later stages. This requires a capability of learning from earlier experiences and remembering the lessons. The evaluation process coupled with personnel changes mitigate against any possible advantage in entering a project at its later stages. Then too, the later stages of a large project are often quite dissimilar to the early ones and for all practical purposes are actually separate projects.

Easy vs. Difficult

There is clearly an order of difficulty in the USAID Irrigation projects currently under way and under consideration. From easiest to most difficult the team ranks the projects as:

1. Hand pump project
2. Small scale irrigation project (proposed)
3. Integrated land and water management project (proposed)

Here a degree of difficulty is seen to have a direct relationship with the management and organizational component of the project. To an extent the complexity of management and organization depends on how the project was formulated and not with differences in the overall development task in the project area. For example, the hand pump project never concerns itself with how the farmers can most effectively allocate the water from their hand pumps, the supply and use of complimentary inputs, the possible role of women in vegetable gardening and the pumps impact on that role and so on.

It is not at all obvious in this case that the size of the project payoff is postively related to the degree of project difficulty. The analysis provided of expected project benefits are not sufficiently great to estalbish any probable relationships.

Given the mission's lack of experience with complex and difficult projects in irrigation and the present restructuring of in-house supportive research and monitoring capability, the team suggests that the mission undertake difficult projects with great caution.

# SECTION IV

## GENERAL OBSERVATIONS ON USAID PROJECTS AND PROJECT PROPOSALS

The current round of USAID irrigation projects and project proposals seem to have given minimal attention to two important areas (1) the possibility of using irrigation water on crops other than paddy--particularly vegetables and (2) the role of women in agriculture and the impact of the new irrigation technology on that role.

### Vegetable Production

Vegetable production and consumption has a potentially very important role to play in raising the nutritional status of the people of Bangladesh, particularly the rural poor. Often vegetables are grown during the winter season on small plots tended by women. Provision for irrigation water and improved varieties and husbandry techniques have the potential of substantially contributing to nutritional status. Hand pumps in particular may be very appropriate for household vegetable gardening. In fact, the preproject survey of handpump users which was done to establish the benefits from hand pumps showed that 27 percent of the handpumps were being used to irrigate at least some vegetables. All of the projects both on-going and proposed have the potential for vegetable production. The survey team recommends that exploitation of this potential strongly be considered for incorporation into the project.

## The Role of Women

The effect of irrigation development on the roles of women has not been seriously considered in project planning and implementation. This seems an unfortunate oversight because undoubtedly they play important roles in decision making, organization, and are a part of the agricultural labor force.

The survey team recommends that the role and contribution of women in irrigation project planning and implementation be seriously considered. The team feels this will be to the benefit of all of the projects. To date attention to women's roles has been cursory at best.

## Nutrition and Irrigation

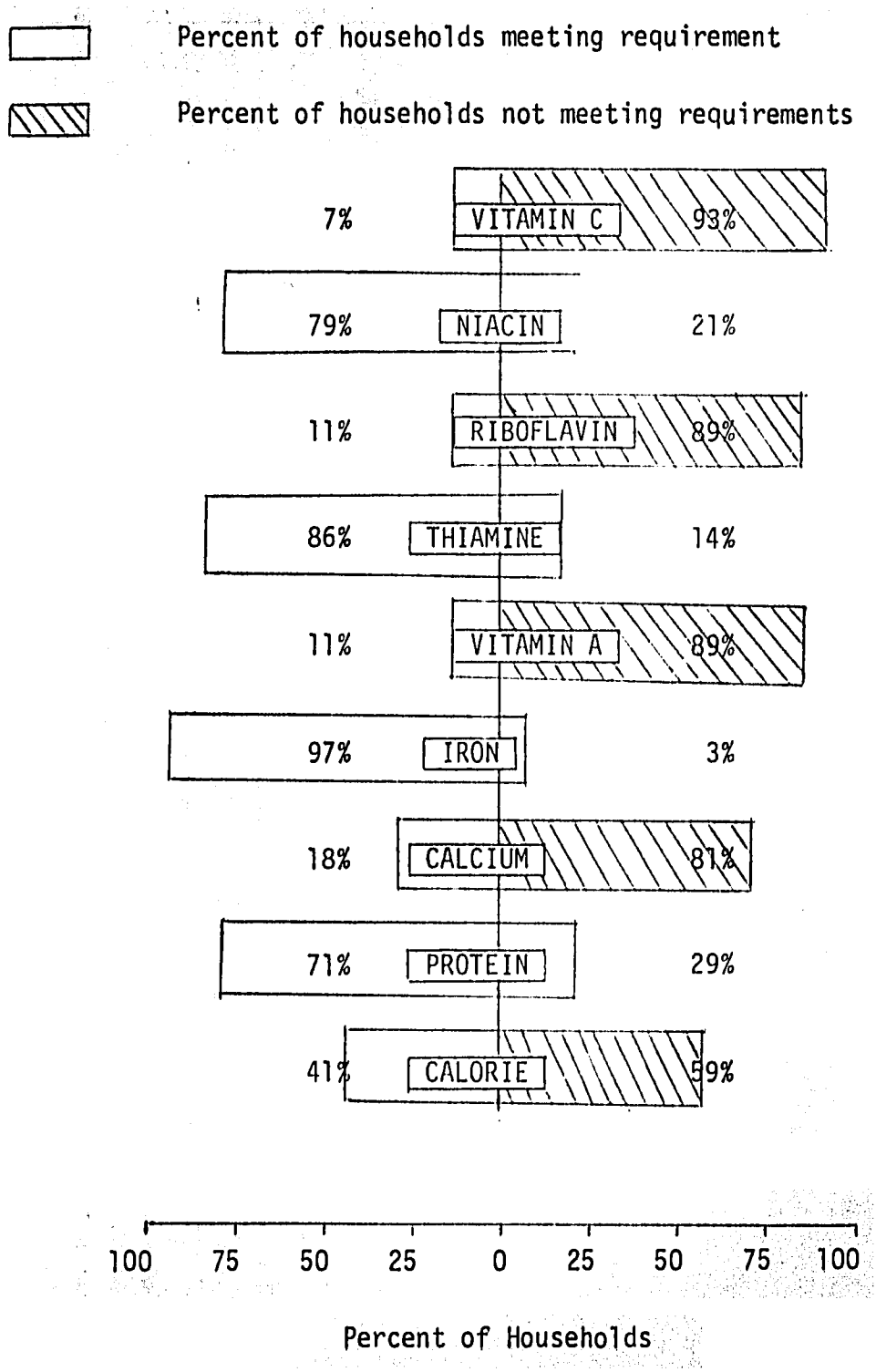
The problems of hunger and malnutrition in Bangladesh are well documented, Figure 2. Indicated in the Nutritional Survey of Rural Bangladesh 1975-1976 are some startling facts such as: the boys and girls of age groups of 1 to 15 are all receiving less than the minimu calorie requirement and the greatest deficiency is with the younger members. Lactating and pregnant mothers are deficient by 32 percent.

The calcium deficiencies are extreme for both sexes and at all ages, but most severe in the age group 1 to 3 years which receive only 32 percent of the minimum requirement.

A deficiency of Vitamin A is prevalent in all age groups and less than 50 percent of the daily requirement is consumed.

The consumption of Vitamin C is below the required amounts and much below in the younger age groups.

Figure 2. PERCENT OF HOUSEHOLDS MEETING AND NOT MEETING DIFFERENT NUTRITIONAL REQUIREMENTS



Surprisingly, all but the age groups 0-3 receive the minimum protein requirement or more. There is, however, a general deficiency of riboflavin.

An extended program of vegetable production should be included in any irrigation project design and improvement or extension. Vegetables offer the best means of providing a balanced diet for the rural family. A design of the systems should consider providing the family garden area with irrigation water for all seasons.

One way to measure the success of an improved irrigation project areas would be to monitor and evaluate changes in food consumption and nutritional status of deficient socio-economic strata in the villages to determine the division of benefits derived from the projects.

Summary. The rural population is grossly malnourished. This is particularly true of the young and pregnant lactating women. Irrigation can enable the growing of vegetables which can materially improve the nutritional status of the farm families.