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# THE CHOICE OF TECHNOLOGY IN DEVELOPING COUNTRIES:

## The Case of Irrigation Tubewells in Bangladesh

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# THE CHOICE OF TECHNOLOGY IN DEVELOPING COUNTRIES:

## The Case of Irrigation Tubewells in Bangladesh*

By John W. Thomas

Development analysts have often suggested that the developing countries share one advantage which the high income nations did not enjoy: they have a whole range of technologies from single to complex, from low to high cost, from labor intensive to highly automated, from which they can select those best suited to their needs. In practice, however, this implied freedom of choice may be seriously constrained by a variety of factors which impinge upon the decision-making process. In this paper the question of the choice of technology in developing countries is explored through a detailed examination of the case of irrigation tubewells in Bangladesh. The paper evaluates the technological alternatives available to the Government, determines the factors influencing the choice of technology for tubewells, analyzes the decision in terms of priorities of the national development, and interprets the implications of this case study for other emerging nations.

By the late 1960's, the Government of East Pakistan, foreign aid donors and those knowledgeable about the area were agreed that high priority should be placed on the installation of irrigation tubewells in order to

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* The name Bangladesh is used when referring to the area in general terms. The name East Pakistan is used when referring to specific events before March 25, 1971 and the formal creation of Bangladesh.

This paper has been substantially improved by the comments and suggestions of Stephen V. Allison, Eric Griffel, Walter P. Falcon, Carl Gotsch, Edwin Smith and Peter Warr. Their contribution is gratefully acknowledged.

provide an impetus to agricultural growth.[1/] There remained, however, important decisions concerning the type of well and the method of installation. The choice of tubewell technology would determine the number of wells that could be financed, their location and the way in which the benefits would be distributed throughout the country. Thus it would have significant social as well as economic consequences.

## I. Agriculture, Irrigation and Development

The population of Bangladesh was estimated at 75 million at the end of 1970. Over 90 percent[2/] lived in rural areas, and most of these derive their income from agricultural activities. Seventy-five percent of the labor force is in the agricultural sector, and unemployment is estimated at 30 percent of total available man days.[3/] The economy of the region is based on agriculture, and there are no important natural resources other than water and land. Since 57 percent[4/] of Gross Domestic Product is derived from agriculture and 95 percent[5/] of export earnings are from the agricultural sector, the dominant role of agriculture in the economy is clear. If economic growth is to take place, it must, in the short run at least, come from agriculture.

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1/ Throughout the 1960's the rate of population growth in East Pakistan was 3 per cent, exceeding that of the growth of agricultural production which averaged 2.2 per cent, and thereby increasing the area's chronic food deficit.

2/ The 1961 Census of Pakistan indicated that 94.6 percent of East Pakistan's population was rural. This is assumed to have declined somewhat in the intervening ten years.

3/ Government of East Pakistan, Statistical Digest of East Pakistan, (Dacca: 1968), Table 3.3, p. 40.

4/ Government of East Pakistan, Economic Survey of East Pakistan, (Dacca: 1969-1970), Table I, pp. 102-103.

5/ Ibid., Table 19, p. 24.

Facilities for irrigation would permit substantial increase of agricultural production in Bangladesh. Only with irrigation is a boro (November - May) crop in the sixth-month dry season possible, and recent estimates indicate that between 10 and 15 million acres or 50 to 75 percent of total crop land may be suitable for irrigated cultivation.[6/] With its continual sunshine and the absence of the recurring floods and storms that damage crops in other seasons, this period is potentially the most productive season of the year.[7/] In addition to making a third crop possible, facilities for supplemental irrigations allow marginal shifts in the planting and harvest times of the two other annual rice crops thereby reducing the risk of crop loss in the peak flood season in August and the loss of productivity due to drought at the end of August to November (amon) season.

Because of this potential, the Government of East Pakistan decided in 1969 to give tubewell development high priority in the Fourth Plan (1970-75) and established a target of 20,000 tubewells to be installed in that period. It budgeted a generous Rs. 1,400 million, ($274 million), Rs. 70,000 ($14,750).[8/] To meet this target, more than half the funds would have had to come from external sources.[9/]

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6/ Based on unpublished estimates made by the Ganges Brahmaputra Basin Study Group of the Harvard Center for Population Studies.

7/ During the period 1965 to 1970 boro (November-May) rice averaged 18.2 maunds (1 maund 82.3 pounds) per acre. Aus (May-July) harvests yielded 10.1 Maunds and amon (August-November) production averaged 12.4 maunds per acre. Agricultural Production Statistics, Department of Agriculture, (Dacca: mimeo, issued annually).

8/ Government of Pakistan, The Fourth Five-Year Plan, 1970-75. Islamabad, 1970, p. 275 and p. 311.

9/ The Government of Bangladesh, after independence, also placed a priority on tubewell development. Its first annual plan for 1972-73, contains provisions for the installation of 6,400 irrigation tubewells of varying depths. Planning Commission, The Annual Plan, 1972-73. (Dacca: 1972) pp. 27-28.

A wide variety of technical alternatives for tubewell irrigation exist. In choosing among these, the high rate of unemployment had to be considered. The labor force of 23 million in 1969 is expected to grow to 35 million by 1983, compounding the unemployment problem. Therefore, in both the installation techniques and in the degree which the technology chosen would create new rural small industry employment creation had to be considered.[10/] In addition, 91 percent of the rural population consists of small farmers with holdings of seven acres or less, who hold 62 percent of the total cropped land. Agricultural landholdings which average 2.6 acres per owner are also fragmented, 69 percent are subdivided into four or more parcels.[11/] In these circumstances, Government initiative in well installation in a manner conducive to shared use of water is essential if well development is to be widespread and its benefits distributed with some equity. Government initiative also means a way would have to be found to expand Government's very limited administrative capacity.

In considering tubewell alternatives, primary importance had to be attached to these objectives, along with more standard calculations such as economic return and engineering efficiency; for the technology selected would have an important bearing on both the nature and extent of tubewell development and on other policy goals.

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10/ Robert Dorfman, "Framework for Economic Planning in East Bengal," (mimeo, 1972), Cambridge, Massachusetts.

11/ Government of Pakistan, Census of Agriculture, A Summary of East Pakistan Data, Lahore, 1960, p. 11.

## II. Tubewell Operations, Alternatives and Plans

A.) Operations. At the time the initial choices of tubewell technology were being made, planners, agricultural sector administrators, and aid donors had the experience of two pilot tubewell projects in East Pakistan, representing widely differing technologies. They provide an illustration of the range of choice available: in Thakurgaon, in the northwest part of the country, a high-cost tubewell field was constructed and operated under the auspices of the Water and Power Development Authority (WAPDA). The feasibility study, design, including the choice of well location, and construction were done by German engineers under a German supplies credit. The project was located in an area known to have an excellent groundwater supply. Three hundred eighty 4 cusec (cubic feet per second) wells were installed. And an electric generating plant was constructed to provide the power. The wells, which were sunk by power drilling rigs, utilized steel screens and turbine pumps, all from West Germany. The total installation, including the generating plant, took five years, and the well field became operational in 1965.

The cost of these wells was very high, approximately Rs. 260,000 ($54,750) per well or Rs. 87,000 ($18,300) per cusec of water. Just over half the cost was for electric generation and transmission facilities.

Two major problems have arisen in Thakurgaon: location of wells on high ground along a ridge or on soils that proved inefficient for irrigation, and failure to prepare or organize farmers to utilize irrigation water which resulted in only 31 percent of the irrigable land being cultivated in the dry season four years after completion of the

project.[12/] However, neither of these failures is directly related to the high-cost well technology chosen.

The other pilot project was in Comilla, in east-central Bangladesh, where wells were sunk by the Kotwali Thana Central Cooperative Association (KTCCA), which adapted for local conditions two low-cost, labor intensive techniques for installing wells: Percussion and jet drilling.

The 211 diesel-powered wells, of two-cusec output design, utilizing locally fabricated, brass screens, were installed between 1962 and 1969. The cost of the wells, Rs. 23,700 ($5,000) per well or Rs. 11,850 ($2,500) per cusec, was borne by KTCCA and the East Pakistan Government. Although water utilization has been inefficient, resulting in less than optimal coverage, the wells have proven highly profitable from both a private and a social perspective.[13/]

Depite the profitability of irrigation in Comilla, there has been little private investment in tubewells. The general level of rural poverty has meant that only a very small proportion of the farmers have an investable surplus and there are reasons why even these few well-to-do farmers have not invested in tubewells: first, government subsidy policies have prevented private tubewell development, even where the value of water is understood.

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12/ EWAPDA, Irrigation Extension Activities in Thakurgaon Tubewell Project, 1969, mimeo. Appendix A, pp. i-v.

13/ Farmers benefits from a 2-cusec well are estimated at Rs. 38,000 annually, enough to pay the full costs of well installation in one to two years. See Appendix 5, page 6.

Based on markets costs in Dacca in 1970, a Comilla-type well would have cost Rs. 32,000. In Comilla, farmers had only to meet a share of the operating and maintenance costs; in Thakurgaon, water was free. Given the Government's widely announced plans to undertake a major new well installation program, even farmers who had an investable surplus had little incentive to invest in wells. Second, the cost for pioneers in sinking wells would have been much higher than the average cost. With supplies located almost exclusively in Dacca, trained drillers only in Comilla and no maintenance or service facilities, the problems of attempting to install wells privately were large.

B.) Alternatives

There is a wide range of technical options for well installation and operation in Bangladesh. Comparisons of alternative well specifications can be made by utilizing costs per unit of output (measured in cusecs, cubic feet per second), since the product (benefits) of wells is standard and only the quantity varies. Important alternatives affecting cost fall in five general categories: (1) Drilling technique, (2) Power source and type of engine, (3) Type of pump, (4) Screen material utilized, and (5) Drilling agent. The details of alternative techniques are as follows:[14/]

(1) Drilling technique. The four drilling techniques used principally in Bangladesh are high cost, mechanically powered, rotary or reverse rotary rigs, usually mounted on truck bodies, and the low cost, labor intensive, cable percussion or water jet drilling. By

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14/ See Appendix A for more detailed specifications.

international standards, all four drilling techniques produce wells that perform equally well.

(2) Power source and engine.

(a) Power. If the power supply is constant, electrically-powered engines are more reliable and have fewer maintenance requirements than diesel enginers. However, to install generating capacity and distribution lines just to power a tubewell field is prohibitively expensive.[15/] Given the few electric transmission and distribution lines available in Bangladesh, diesel power will have to be the basis of any widespread tubewell development.

(b) Engine. The choice of engines for the medium size wells utilized in Bangladesh is between high and low speed diesels of 20 horsepower. Manufactured to close tolerances, high speed engines must be imported, are lighter weight and therefore more mobile, need high grade diesel fuel and if carefully operated and maintained are a high quality precision machine. Low speed diesel engines have been manufactured in Pakistan for about half the cost of high speed engines. They are heavy, operate on diesel fuel or kerosene, are easy to maintain, tolerant of misuse, but are less efficient in fuel consumption.

(3) Pumps. The two types of pumps generally used in Bangladesh are the centrifugal, vacuum and the submersible turbine pump. The output of the lower cost centrifugal pump begins to drop if draw down in the

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15/ In the Thakurgaon Tubewell Project, one-half the cost of the Project, or Rs. 130,000 per well was for electrification. IBRD, Thakurgaon Tubewells Project Extension, Appendix 1, p. 1.

well exceeds 18 to 20 feet. Existing wells in Bangladesh operated at about the efficient limits of the centrifugal pump. The turbine pump, which is about twice as expensive, can operate efficiently at draw down levels well beyond those anticipated in Bangladesh. The turbines extra power also allows well screen length to be reduced 25 to 50%.

(4) Screen material. Most of the materials used in wells are standardized, only the choice of well screen material, the most expensive component, provides important alternatives. In 1969-70 when initial decisions as to the appropriate tubewell technology were being made only brass and mild steel screens had been tried in East Pakistan and only brass had proven fully satisfactory. In addition, fiberglass and Polyvinyl chloride (PVC) had been used elsewhere and were believed appropriate for the area. PVC, which is susceptible to damage in heat or with rough handling, would, if proven suitable, be the least expensive and have life of approximately 15 years. Fiberglass, much more difficult to produce locally, is the highest cost and has an estimated life of 20 years. Brass screen was produced locally at low cost and had an average life of 10 years.

(5) Drilling agent. There are four categories of tubewell drillers: foreign contractors, domestic contractors, government agencies and local government bodies or cooperatives. Profit rates for domestic contractors are in the range of Rs. 3,000 to Rs. 5,000 per well.[16/] There is no basis

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16/ Obtained from analysis of bids of contractors and comparisons to Government well-installation costs. Contained in: ADC, Project Loan Application for 3,000 Deep Tubewells, Dacca, August 1969, pp. 91, 94, 95, 96.

for estimating the profits of foreign contractors. Clearly, however, their charges are much higher in actual cost terms and foreign exchange.

Foreign contractors provide the opportunity to install wells while domestic capacity for well sinking is created. Drilling agents do tend to prefer different drilling techniques; contractors have clear preferences for power drilling, while local level agencies would have capacity for jet or percussion drilling only. Domestic contractors and government agencies presumably could develop capacity for either or both techniques.

The best cost estimates of well components are compared in Table 1.

Although these alternatives provide more than 250 possible well designs, in practice they are used in combinations that allow them to be categorized as high (over Rs. 100,0 0), medium (Rs. 50,000 to Rs. 100,000), and low (under Rs. 50,000) cost wells. Although there is some overlapping of categories, in practice the categories provide a relatively accurate description (e.g. if the most expensive drilling technique is used, the lowest cost engines or screen materials are not and vice versa).

C.) Plans

Hope of meeting the plan targets for investment in tubewells was dependent on foreign aid. Of the Rs. 80 million budgeted for the first year of the Plan, Rs. 44 million was to come from foreign aid.[17/]

17/ Obtained from analysis of bids of contractors and comparisons to Government well-installation costs. Contained in: ADC, Project Loan Application for 3,000 Deep Tubewells, Dacca, August 1969, pp. 91-94, 95, 96.

TABLE 1.

Costs of Major Variable Items in Tubewells
(in Rupees)

| | Units | Costs | Foreign Exchange Component | Shadow Price | Source |
|---|---|---|---|---|---|
| Drilling | per foot(including depreciation) | | | | |
| Water jet | | 8 | 25% | 10. | KTCCA cost 1970. |
| Manual percussion | | 10 | 5% | 10.50 | KTCCA/ADC cost 1970. |
| Power (by contractor) | | 47.50 | 75% | 83. | IBRD estimate 1970. |
| Engine | 20 h.p. engine | | | | |
| Low speed diesel | | 4,500 | 50% | 6,750 | Author's estimate(assumes domestic production). |
| High speed diesel | | 6,000 | 100% | 12,000 | I.B.R.D. estimate 1970. |
| Electric | | 5,000 | 100% | 10,000 | Dacca market price 1970. |
| Pumps | per pump | (See Table 2 for more complete comparison) | | | |
| Centrifugal | | 750 | 50% | 1,125 | Dacca market price 1970. |
| Turbine (inc.r. angle gear) | | 7,000 | 100% | 14,000 | IBRD estimate 1970. |
| Screen | 8" diam. per foot | | | | |
| PVC | | 34.50 | 10% | 38. | (Prices based on IBRD estimates 1971. Foreign exchange |
| Fiberglass | | 125. | 80% | 250. | ( assume local production. |
| Brass | | 50. | 70% | 85. | Dacca market price 1970. |

The expectation was based on commitments or expressions of inrerest in tubewells by a variety of donors. The Government's requests to various donors were for 1,000 low-cost, 8,000 medium-cost, and 2,000 high-cost wells. In response commitments were made to finance 9,000 medium-cost and 900 high-cost wells, indicating a strong donor preference for the medium-cost well and a rejection of the low-cost well despite the fact that they were the only type proven successful in East Pakistan.

Details of the requests and donor commitments are as follows:

1. Support for 3,000 tubewells was requested in an application to the World Bank for an I.D.A. credit. Two thousand were to be drilled by contractors, 1,000 to be drilled by government agencies using labor intensive methods.

All were to be powered by high speed diesel engines, half were to have turbine pumps and fiberglass screens, and half centrifugal pumps with brass screens.

The World Bank decided to finance 3,000 wells but 2,100 were to be sunk by foreign contractors, 900 by domestic contractors, all by power drilling techniques. The wells were to have fiberglass screens and high speed diesel powered, turbine pumps. The wells were to be concentrated in five of the country's nineteen districts. The total cost of the project was $44.6 million, or Rs. 67,000 per well.

2. Under a General Electric Corporation (G.E.C.) British suppliers credit, 5,000 wells of 2-cusec capacity were to be installed by local contractors using power drilling techniques, supervised and

with materials supplied by G.E.C. The wells were to be powered by high speed diesels, with turbine pumps and fiberglass screens and costing approximately Rs. 80,000 per well.

3. A barter agreement with Yugoslavia would have provided 1,000 wells of 2-cusec capacity high speed diesel powered, and turbine pumps, and screen material undesignated. Wells were to be installed by Geotechnica, a Yugoslav firm, in the same five districts selected by the Bank, where heavy rigs can operate. The cost is difficult to determine under barter arrangements but was estimated at Rs. 75,000 per well.

4. The World Bank proposed financing an extension of the Thakurgaon Project. This project was to consist of 285 large (3 cusec) and 600 small (½ cusec) wells wells, all to be electrically powered. The large wells would use fiber glass and the small wells, PVC screens. The large wells were to be equipped with turbine pumps and the small wells with a new design floating centrifugal pump. They were all to be electrically powered, at an average installation cost of RS. 106,233 per cusec of capacity.

5. Another 1,110 wells were proposed by the Government in three tubewell fields located in the three districts where well development was being concentrated. Feasibility studies were carried out for these, recommending contractor installation, electric power and a capacity ranging from 2 to 4 cusecs; cost was in the range of Rs. 100,000 per cusec. Financing was never obtained for these.

The trend of tubewell development was clear while the Government requested all types of wells, but primarily medium cost --

for all but the high cost alternative.

Table 2 indicates the cost of the three types of wells both at actual cost and shadow priced. For each of these alternatives internal rates of return have been calculated. The benefits used in the rates of return given below are calculated on the basis of the international market price for rice. They assume a one-year lag between investment and production on irrigated land, that the output of a two-cusec centrifugal pump is only 75 percent of the output of a turbine and that low speed diesel engines have lower operating and maintenance costs and a life expectancy estimated of 15 years as opposed to the high speed engines with an estimated life of seven years. All turbine pumps are assumed to last seven years.

The internal rates of return are as follows:

| | Actual prices | Shadow prices |
|---|---|---|
| Low cost | .29 | .18 |
| Medium cost | .19 | Less than .10 |
| High cost | less than .10 | " " .10 |

On this basis, justification for low cost wells exists, medium cost is questionable, and high cost unjustified.[19/]

The rates represent the return to the economy. The return to private investors who benefit at the market price of rice which is

19/ The tubewells financed by the World Bank were Rs. 13,000 more than the medium cost wells on which these calculations were made, but by assuming more efficient use of water than in the past and a somewhat higher price of rice, they calculated the rate of return on medium cost wells at .32.

approximately double the international price, and who pays the actual market costs would be over 1.0 for a low cost, roughly .50 for a medium cost, but under .10 for the high cost well.

On the basis of these calculations, the low cost wells have the clearest justification for either public or private investment. Medium cost wells are in a questionable range, probably not attractive to private investment (despite the effective rice price and foreign exchange subsidy) and with considerably less justification than the low cost well for public investment. The high cost wells appear to have no economic justification.

(B) Employment and training.

In Bangladesh, with its labor surplus, capital short economy, the creation of new employment opportunities and the conservation of capital are high priorities. The low cost drilling techniques create far more jobs while requiring only a fraction of the capital investment necessitated by using contractors. It is important to calculate the employment potential. During sinking of a well by percussion or water jet methods, two shifts of eight unskilled laborers are employed for a four-week period, a total of 16 man-months or 1-1/3 man-years. If 20,000 wells of this type are installed, 26,000 man-years of employment for unskilled labor will be created. In addition to this, employment is created for the drillers and assistant drillers. This would amount to 8,990 man-years employment. The total for the program would be 34,000 man-years. By contrast, the power-drilled wells have a very small employment component. The 160 power rigs needed to drill 4,000

TABLE 2

Comparison of Cost of Five Tubewells of Varying Specification in Shadow Prices
[In Rupees; Shadow Prices, Rs 9.50 = $1, in ( )]

| | Low Cost | | Medium Cost | | High Cost | |
|---|---|---|---|---|---|---|
| Drilling - | Jet/Percussion | | Contractor/Power | | Contractor/Power | |
| Screen - | Brass | | Fiberglass | | Fiberglass | |
| Pump - | Centrifugal | | Turbine | | Turbine | |
| Engine - | Low speed diesel | | High speed diesel | | Electric (inc. generation/transmission cost) | |
| Move in and out | 300 | (300) | 4,500 | (4,500) | 4,500 | (4,500) |
| Drilling cost 160 feet 180 feet | 1,440 | (1,800) | 7,600 | (13,300) | 7,600 | (13,300) |
| Pumphousing 10" diam. 80 feet | | | 4,800 | (9,600) | 4,800 | (9,600) |
| Blind pipe 8" diam. 20 feet | 800 | (1,600) | - | | - | |
| Screen 80 feet 140 feet | 7,000 | (11,900) | 4,280 | (13,482) | 4,280 | (13,482) |
| Bail plug and reducer | 500 | (1,000) | 500 | (1,000) | 500 | (1,000) |
| Gravel pack 80 feet 140 feet | 2,400 | (2,400) | 1,200 | (1,200) | 1,200 | (1,200) |
| Install well hardware 160 feet 180 feet | 2,160 | (2,160) | 1,920 | (1,920) | 1,920 | (1,920) |
| Develop and Test Well | 1,500 | (1,500) | 1,500 | (1,500) | 1,500 | (1,500) |
| Pump | 750 | (1,125) | 5,500 | (11,000) | 5,500 | (11,000) |
| Engine (20 h.p.) | 4,500 | (6,750) | 6,000 | (12,000) | 125,000 | (215,000) |
| Right angle gear drive | - | | 1,500 | (3,000) | 1,500 | (3,000) |
| Pumphouse | 3,500 | (3,500) | 4,500 | (4,500) | 3,500 | (3,500) |
| Install pump and engine | 750 | (750) | 750 | (750) | 750 | (750) |
| Consultants (Eng., Ag., Mgt.) | - | | 5,000 | (10,000) | 10,000 | (20,000) |
| Contingency | 2,560 | (2,560) | 4,955 | (4,955) | 17,255 | (29,975) |
| Total | 28,160 | (37,345) | 54,505 | (92,707) | 189,805 | (329,727) |
| Internal Rate of return | .29 | .18 | .19 | | less than .10 | |

wells annually would employ two men each. This would amount to 1,605 man-years' employment for 20,000 wells. The 32,400 additional man-years of employment created by percussion drilling mean that this form of well sinking is definitely preferable from the employment perspective.

In a society in which the absence of skilled manpower serves as a severe constraint on development, a program of tubewell development that would train 7,286 foremen and drillers is preferable to employing foreign contractors whose operations would provide training to only a few hundred Bengalis. In addition, percussion and jet drilling would provide 524,500 laborers with two to four weeks experience in drilling operations. This is not an immediately marketable skill, but it is an exposure to simple mechanical principles and skills which can be quickly and profitably applied to well operation and maintenance and other agricultural operations. In terms of training, the low cost system is clearly preferable.

Foreign contractors can make an important contribution to the general knowledge of tubewell technology particularly in the early stages of the program. They bring much greater experience and greater engineering knowledge and they can impart important training in the techniques and skills of well installation. Such training is a benefit in depth in that it increases the capacity of local well technicians rather than providing broad training in simple mechanics and well technology as do the other wells.

(C) Time sequence of drilling. The preceding calculations of returns to different types of wells assumes that wells can be installed at the same rate and are subject to the same time constraints. Most advocates of the foreign contractor drilled (medium and high cost) wells claim that their much higher cost is justified by much more rapid rates of installation, which gives the more expensive wells a higher present value. One adviser to WAPDA suggested this is an official report. "The question is whether or not local contractors can cope with the great number of wells which must be installed in East Pakistan in the next 5 to 10 years. If the capacity is not available and foreign contractors must be brought in, the cost price per unit is likely to increase considerably. However, the increase in cost price may be offset by the total return in the larger number of units which can be installed with the aid of foreign contractors."[20/]

There is considerable international capacity for well sinking which can be attracted rapidly at an appropriate price. To obtain this capacity, foreign firms would have to be guaranteed substantial profitable business before they would bring their equipment to the area. Although no such commitments have yet been made, for purposes of this analysis, it is assumed that all the equipment necessary to drill 20,000 wells in a five-year period could be imported.

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20/ Peter Mulder, ILLACO, General Consultants to EPWAPDA, Socio-economic Cost of Irrigation by Tubewells and Low Lift Pumps, Daac, 1970, mimeo., p. 6.

There is always a lead time of six months to a year or more between the time contracts can be signed and the time it takes to import drilling equipment and supplies and bring personnel to operate the equipment. Once in the country, wells can be installed by a single power drilling rig in about a week. Given the monsoon climate, however, it is possible to drill only about 5 to 6 months of the year, or 24 to 25 wells by one rig per year.

In any situation, and particularly so in the case of Bangladesh, it is necessary to assume that resources represent some constraint. Therefore, for purposes of this analysis let us assume that the generous East Pakistan Fourth Plan budget of Rs. 1,400 million, or Rs. 70,000 per well, represents the financial limit of resources for investment in tubewells and that with this guarantee foreign firms can be attracted to install wells at the rate of 4,000 per year to achieve the target of 20,000 wells in five years.

This must then be compared with the rate of development of capacity to install low-cost tubewells. Table 3 shows the maximum rate of expansion of the capacity to install percussion-drilled wells over a five year period. (The basis for these calculations is given in Appendix C.)

TABLE 3

Rate of Increase of Well Installation Capacity by Low Cost Methods

| Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Rigs operating | 85 | 212 | 530 | 1,325 | 3,312 |
| Annual capacity | 510 | 1,272 | 3,180 | 7,950 | 19,872 |
| Cumulative instal. | 510 | 1,782 | 4,962 | 12,912 | 32,784 |

It is then possible to compare the installation capacity of low-cost wells with foreign contractor drilled wells. Figure 13 shows the rate of development of foreign contractor wells, assuming the cost limit of Rs. 1,400 million. As the figure indicates, more wells can be installed in the first four years by foreign contractors, but by the end of the fifth year, capacity to install wells by low cost methods will have vastly exceeded foreign contractor capacity.

The question that must next be answered is this: Does the slower initial capacity to install percussion wells offset the cost advantage in a rate of return comparison? To determine this, it was assumed that 20,000 wells would be installed in a five year period by each technique. For this calculation mlow cost (Rs 29,000) jet and percussions drilled wells were compared with 20,000 medium cost (Rs 55,000) contractor-drilled wells. The two alternatives were compared with installation for the low cost wells at the rate indicated in Table 3 above except that in year five the installation was stopped at 20,000 rather than proceeding to the theoretic maximum of 32,784.

Compared in this manner the rates of return were as follows:

| | |
|---|---|
| Low cost jet and percussion-drilled wells | .27 |
| Medium cost contractor, power-drilled wells | .17 |

From this, one must conclude that the economic return on the low cost wells, despite lower initial rate of installation, is substantially higher. Anything that can be done to improve these wells or cut their costs, will increase the return, but the low cost

drilling method is clearly the more economic alternative.

The installation of 20,000 wells in five years by either of these methods is a theoretical maximum figure. In practice neither would probably be achievable. Nevertheless this analysis does refute the argument that the time saved by foreign contractors provides the medium and high-cost wells with a higher present value. To the contrary it suggests that the low cost wells are more economic despite an initial lag in installation capacity.

D. Organization of demand for water.

The failure of past irrigation projects in East Pakistan has resulted in large part from an absence of farmer demand for water. Until 1967, irrigation projects focussed on the supply side and neglected demand for water. With the Thana Irrigation Low Lift Pump Program, which made demand a prerequisite for supply, an important start toward solving this problem was made.

The issue of demand and the capacity to organize irrigation groups will be the critical determinant of the rate at which the number of tubewells can be expanded. If installation capacity surpassed demand, then the rate of installation must be slowed because wells sunk in excess of demand will be only partially utilized.

It is difficult to determine in advance the rate at which demand for water will expand. It is clear that once available and utilized, irrigation water becomes a highly prized commodity which villages will fight to retain.[21/]

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21/ The East Pakistan newspapers occasionally carried reports of clashes over water. One report from Mymensingh reads, "On the morning of May 9 two groups of people clashed with each other over water pumped out from an irrigation pump in an IRRI paddy field in village Hoglakandi under Hossainpur Police Station. As a result two persons of the locality, Abdul Hai and Abdul Mojeed, lost their lives, it is learnt (sic)." Dacca Morning News, May 26, 1970.

Judging from the pattern of demand at Comilla, there is an important demonstration effect governing demand. It is useful to examine the experience of Comilla for demand did much to regulate the rate of expansion. Figure 2 shows the cumulative rate of expansion. After year four, the rate of demand and installation approximately doubled. It is useful to compare Figure 1 with Figure 2. They suggest that the demonstration effect causes a lag in demand and that the installation of wells at a high rate in the early years may not be desirable. The lag in demand may well fit with the time needed to develop capacity for installation of wells by low cost techniques.

It is also quite probable that installation techniques will have some influence on both farmer utilization, operation and maintenance. Although there is no way to quantify this psychological aspect, farmers who have participated in the installation of a well, having spent four weeks working on it, will have a much greater understanding of well operations as well as a feeling of personal investment in it. As a result, they may be much more aware of its potential benefit. If the process is one of bringing in heavy equipment which they do not understand and which in one week installs the well and departs, they will not understand how the well works or feel it is anything with which they are associated. The process of participation in installation of low cost wells could provide the farmers a comperhension of the principles of a well and its operation. As a result, they will have much more capacity to use it correctly, maintain it and make minor repairs.

FIGURE 1

Comparison of Rate of Installation of Wells by Low and Medium Cost Drilling Methods

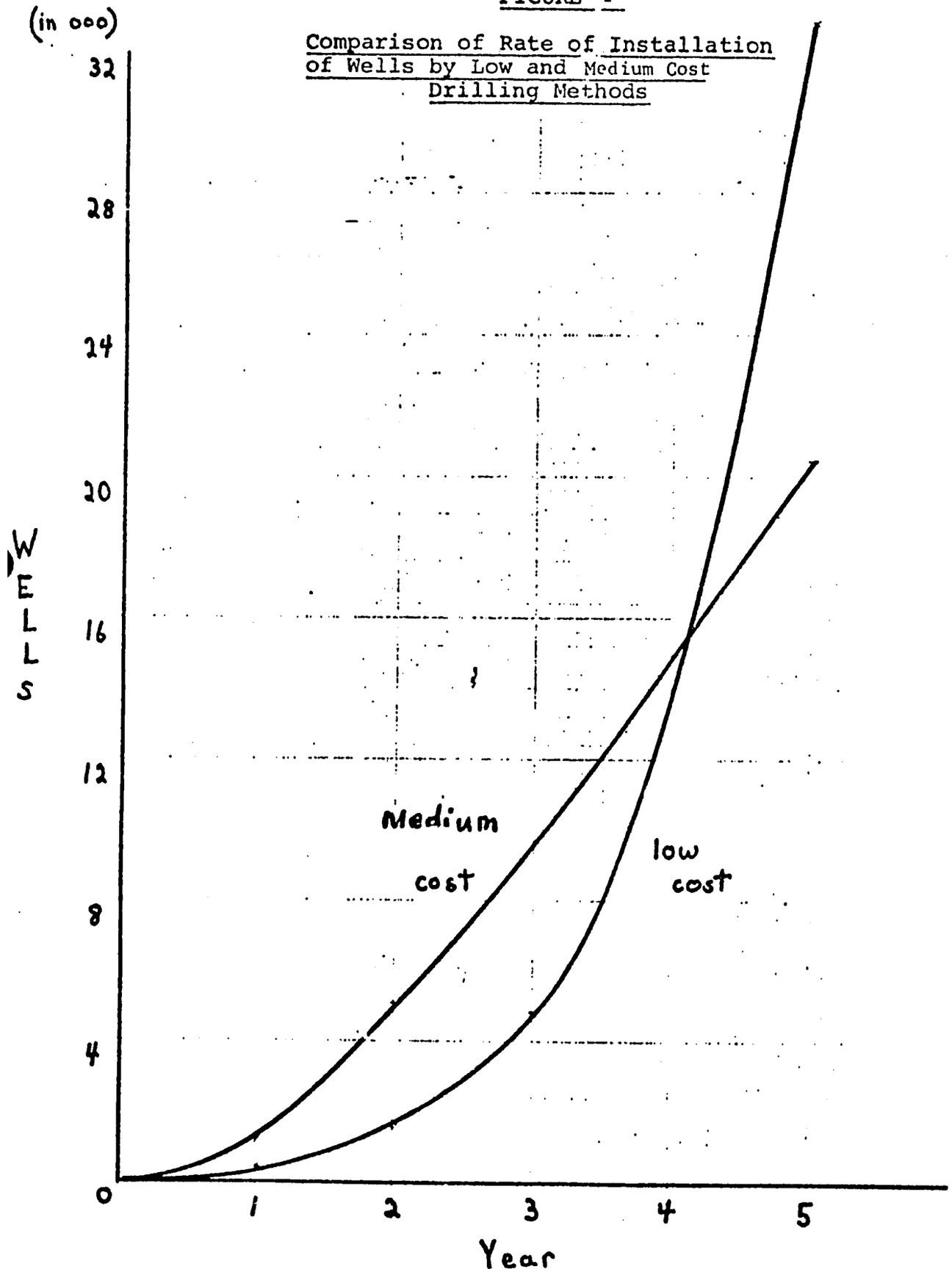
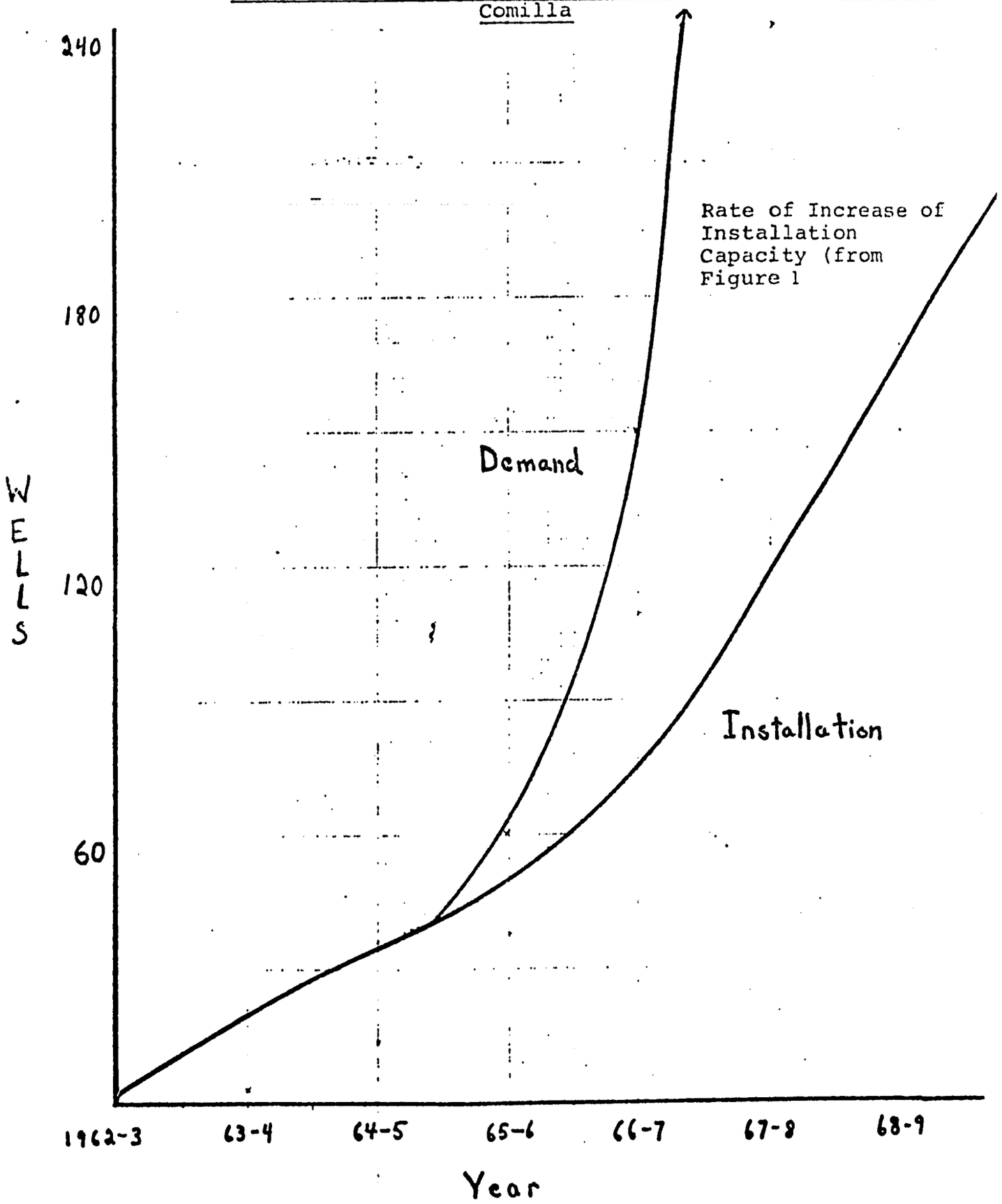


FIGURE 2.

Demand and Rate of Installation for Wells by K.T.C.C.A., Comilla



E. Location and distribution of benefits.

Both the World Bank and the Yugoslavs (presumably GEC too, although details of the agreement are not known), have limited their drilling sites to portions of six of the nineteen Districts of Bengladesh. These have been selected partly because of the known groundwater supply in the area and partly because it is only in these areas that the heavy 10-15 ton power rigs mounted on trucks can be moved from one drilling site to another easily. In other areas, mobility of heavy truck-borne power rigs is limited by the absence of roads and bridges and specially adapted rigs must be obtained. However, the jet and percussion drilling rigs are relatively light weight, easily taken apart and reassembled. As a result they can be transported from one site to another by almost any means, tractor-drawn wagon, boat, animal cart, or men's shoulders. this means they can be moved almost any place and can operate and be moved in all seasons. This mobility makes the low-cost drilling equipment much more versatile and much cheaper to move into the many areas of Bengladesh where it is difficult to transport heavy equipment. This means that the wells and resulting benefits can be more broadly distributed across the country if low cost drilling methods are used.

The locational benefits of the installation process vary according to the type of installation technique employed. The low-cost wells provide a broader distribution of employment, training and financial benefits most of which are retained in the rural areas. They also create the potential for rural small repair and manufacturing industry.

Alternatively, the benefits from medium and high cost, power-drilled wells go to city based contractors or foreign contractors, and the installation itself provides almost no benefit to the location in which it takes place.

F. Linkage effects.

Development of small rural industry will be an important benefit from a tubewell development program. With some encouragement from the Government, the number of private domestic contractors installing wells will inevitably increase. These will develop either from those trained by the public sector program or directly in response to private dem and. In addition to these, the important question is what local small industries would be developed by alternative techniques. This has to be considered in terms of actual well components.

Rigs. Power rigs must be imported in final form. The components of percussion and jet drilling rigs; tripods, hand winches, pulleys and the sludger or bit can all be fabricated in Bangladesh. Their fabrication and maintenance would provide the basis for one or more small firms.

Pipe and strainer. If 20,000 wells are to be drilled in the five-year period and the average well is 170 feet, the demand for blind pipe and strainer is clear. Using 40 feet of blind pipe and 120 feet of screen for a 170 foot well, the demand for pipe would amount to 2.4 million feet of screen and 800,000 feet of blind pipe. In financial terms this would mean an expenditure of Rs. 120 million ($27 million) on screen and Rs. 40 million ($9 million) on blind pipe. Blind pipe is not difficult to manufacture, and with the demand generated by a

investment. It is important that this demand be met despite the fact that the government must put much higher priority on other forms of tubewell development. If a few private contractors can become sufficiently proficient that they can drill wells for a cost between the Rs. 20,000 to Rs. 30,000, this potential market which is probably limited to the 10 percent large landholders (a total of 1.3 million individuals) should be met.

If the Bangladesh Government can finance and install 20,000 wells in a five-year period which is problematic, it would take thirty years to install the number of wells West Pakistan installed in the sixties. If this rate is to be accelerated, it will be necessary for Bangladesh to find a third alternative, beyond private investment and Government investment. The best hope for this would appear to be local government or local cooperative federations.

In the 1960's the competence of local government increased through its administrative responsibilities for the Rural Works Program and the Thana Irrigation Program. Simultaneously the model for an effective system of farmers' cooperatives was developed at Comilla, and is scheduled for expansion nationwide. If these plans are carried out, each local Council or Cooperative Federation could obtain a number of drilling rigs, and assume responsibility for tubewell sinking in their area. Subsidies from the Government would be necessary in the early stages, but over time, with cooperative financing and the pooled resources of beneficiary irrigation group members, local demand could be met by a program increasingly administered and financed at the local

level. It is clear, however, that such a program would depend very much upon the existence of a proven, low cost well design. Neither local institutions nor private farmers would find a medium high-cost well an economic proposition. Furthermore, local agencies could not easily acquire the competence to install wells with rotary drilling rigs and complex equipment.

On balance the arguments for the low cost wells over medium and high cost, appear impressive. With low cost wells, economic return is higher, the employment and training effects are greater, the components of the wells hold greater potential for the creation of domestic industry and they will provide a broader distribution of the benefits of well irrigation. This evidence, plus the fact that the low cost wells were the only ones proven in actual operation in East Pakistan suggests that the low cost wells with percussion, or jet drilling, brass strainers, centrufugal pumps and low speed diesel engine represented the logical tubewell technology for the country. The fact that the Government requested assistance primarily for medium and high cost wells and the aid donors almost exclusively preferred the medium cost wells suggests that standards, other than those examined, are paramount in the decisions of Governments and aid givers as the appropriate technologies for developing countries.

## IV. Factors Affecting the Choice of Technology

Economic factors can play an important role in the choice of technology. Price distortions, which can enter the system through inconsistencies in the tax and duty structures influence choices as

they did in East Pakistan where the market cost of imported high speed diesels was less than that of the locally produced low speed engines despite the fact that the latter cost only 75% as much to produce. Similarly the contractors or government agencies implementing tubewell programs will have a rational preference for scarce capital goods (machinery) over abundant human labor when selecting technology, if the local currency is overvalued, as was the Pakistan rupee. In that situation imported equipment, such as pumps, or power drilling rigs, could be obtained for as little as half their true cost to the economy. The result is a large subsidy to capital goods which any economizer, public or private, is happy to accept.

If wage rates exceed the opportunity cost of labor, as they did in East Pakistan in 1970 labor intensive methods become less attractive. When the problems of management of labor crews are added, contractors will generally adopt capital intensive methods despite the fact that this is highly inconsistent with existing factor endowments.

Although economic factors can bias the choice of technology, project analysis techniques such as shadow prices can factor these out. The preceding rate of return analysis demonstrated that despite economic distortions the low cost technology yielded a better economic return. Therefore it is necessary to look further for an explanation of the choice of technology.

The availability of external aid to finance new investment also affects the choice of technology, for the preference of the aid giver then becomes an important element in the decision-making process. The

administrator in a developing nation may accept a technology that he considers second best if foreign financing is available only for that choice. Furthermore, the official may tailor his program to the technology he considers most likely to attract foreign aid.

On the donor side, many considerations other than the needs of the recipient country may affect the type of aid or credits made available. The form of aid frequently depends more on the requirements of the donor countries economy than on those of the recipient. Clearly national commercial interests affected the forms of assistance available under the G.E.C., British suppliers credit and the Yugoslavian barter agreement.

An international agency like the World Bank, however, is not directly tied to such parochial interests; nor are the developing countries seriously constrained from arguing their own interests. Yet both concurred in a tubewell technology that was less than optimal in Bangladesh.

In this case, the organizational requirements of the developing countries and the aid donor agencies appear to have superseded development policy objectives. Under these circumstances, organization theory provides more insights into the choice of technology than does economic theory and proves useful in explaining the choice of tubewell technology.

Work in this field has stressed the concept of "bounded" or limited rationality in decision-making. According to the theory, the limits of man's capacity as solver of complex problems constrains

the decision-making processes of individuals and organizations by forcing them to simplify problems in a variety of ways which result in replacement of the goal of maximizing with that of finding a course of action that is satisfactory.[22/] Elaboration of the factors that limit the exercise of full rationality helps to explain the choice of tubewell technology.

1. Satisfactory, rather than optimum, solutions.

Since an optimum solution is rarely identifiable or ascertainable, a satisfactory one is accepted. In this case, established procedures, protection of bureaucratic domains and routines, and the need to avoid risk all were obstacles blocking the economically rational solution. For the Government officials, aid was available only for medium-cost wells, and this technology supported their institutional requirements and perhaps their personal preferences as well. For IBRD officials, medium technology was familiar and considered reliable. Since the Bank was able to show an anticipated .32 internal rate of return for their medium-cost wells, a less than optimum solution was satisfactory.[23/] For both the Bank and the Government, a tubewell project on which they could cooperate was a satisfactory basis for action and an optimum solution was not necessary.

2. Avoidance of uncertainty and reliance on established programs of activity. Minimization of risk characterizes organizations

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22/ Herbert, Simon, Models of Man, (New York, 1957), pp. 198-9.

23/ It is relevant to note that the Bank's report on "East Pakistan Tubewells Project," the basic document that top decision-makers received from the project appraisal mission, contained no discussion of alternatives to the type of technology recommended.

and individuals within them. This tendency is a deterrent to innovation and provides an inertia that tends to stress repetition of procedures that are familiar and tested. For the western engineer, machine power drilling, fiberglass screens, high speed engines and turbine pumps represented a familiar and reliable technology unlike the low cost technology. Foreign drillers who could be held contractually responsible for performance appeared safer (despite serious mistakes at Thakurgaon) than a decentralized program involving a large number of low-cost rigs. As a result, familiarity and an assumption of risk avoidance was preferable to optimality.

For Government officials, technology with the appearance of modernity is less prone to criticism than simple technologies. Furthermore, they could reduce personal risk by claiming they had accepted less than optimal technology under pressure of aid officials in order to obtain aid.

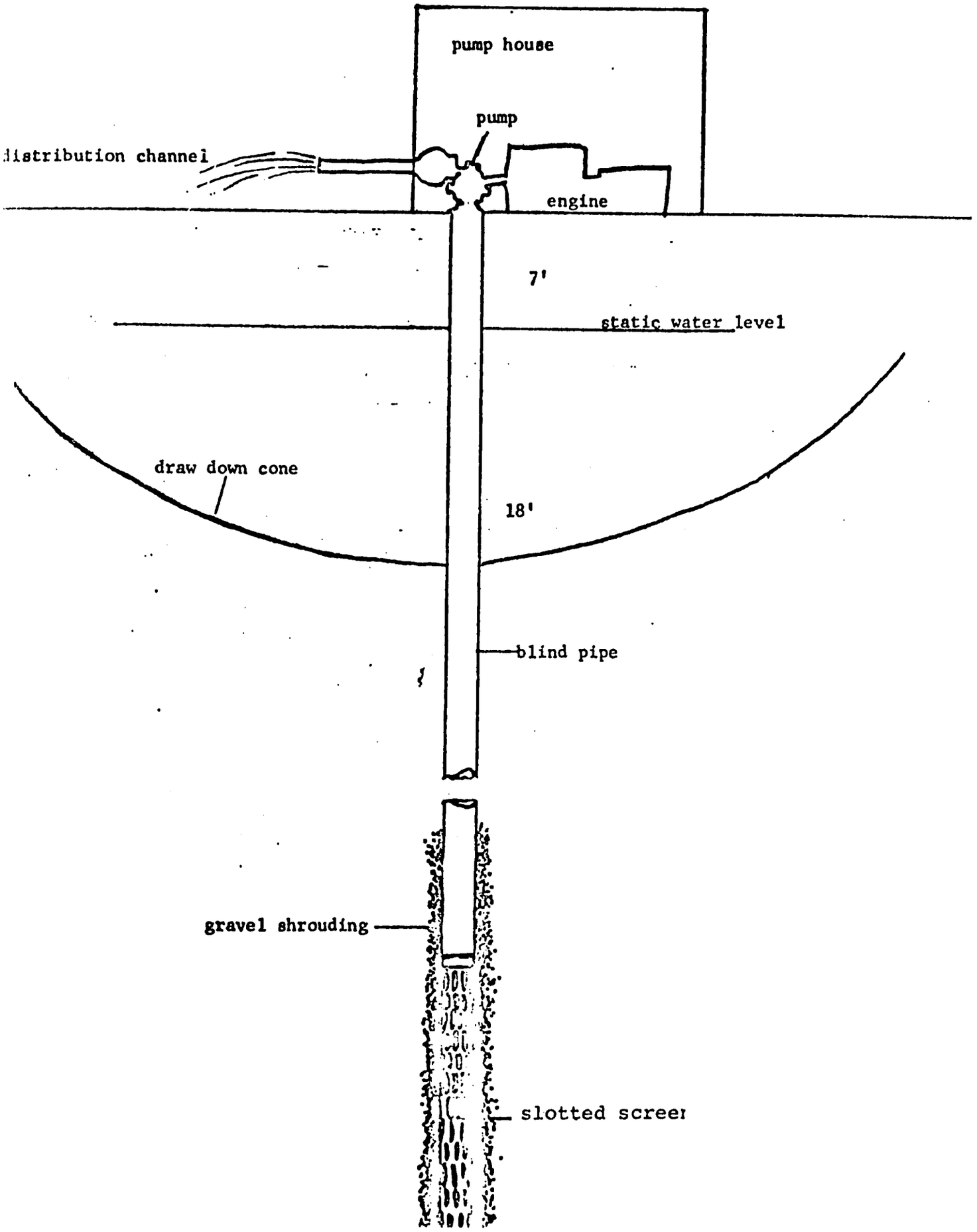
3. Organizations are bound by their operating procedures and established routines. An agency like the Water and Power Development Authority which is staffed with the engineers trained in modern construction methods, and is supported by large groups of foreign consultants, and a flow of foreign aid makes decisions on the basis of feasibility studies, and has a large capitalized construction division, is almost incapable of employing low cost technology. Its staff, equipment, procedures, and its mentality are all oriented towards high cost, high quality construction. Although the other Bangladesh sponsor of tubewell programs, the Agriculture Development Corporation was less tied to "high" technology, the head of their

water development division had just come form WAPDA and organizationally there were strong preferences for a modern technology. For both Bank and the Government, existing organizational routines and physical procedures limit the options available to them in the short run.

4. Control is an objective of most organizations. It is closely related to risk minimization and was an important factor both for Government agencies and the Bank. For Government agencies, attracting foreign aid, and implementing large programs gives them and their sta ff power, prestige and sometimes an opportunity for profit. For the Bank, control was equally important to ensure proper implementation to protect against misuse of funds, and to ensure maximum return on the project. These objectives were, in the Bank's eyes, best accomplished in a program they could supervise closely and control. For Government and Bank alike, a low-cost program with up to 3,000 rigs operating at scattered locations throughout the country required a decentralized administrative system and a resultant loss of control. To avoid this, they were all willing to accept somewhat less than optimal economic returns and social benefits.

Ultimately, it was the organizational requirements of the implementing agencies, including the aid donors, that determined the choice of tubewell technology for Bangladesh. In the actual decision-making, such factors as - risk avoidance, appearance of modernity, established procedures and familiar techniques, and control - outweighed development policy objectives, and it is in these factors that an understanding of decisions as to choice of technology must be sought.

BASIC TUBEWELL DESIGN - BANGLADESH



## Appendix A

### Detailed Specification of Tubewell Components

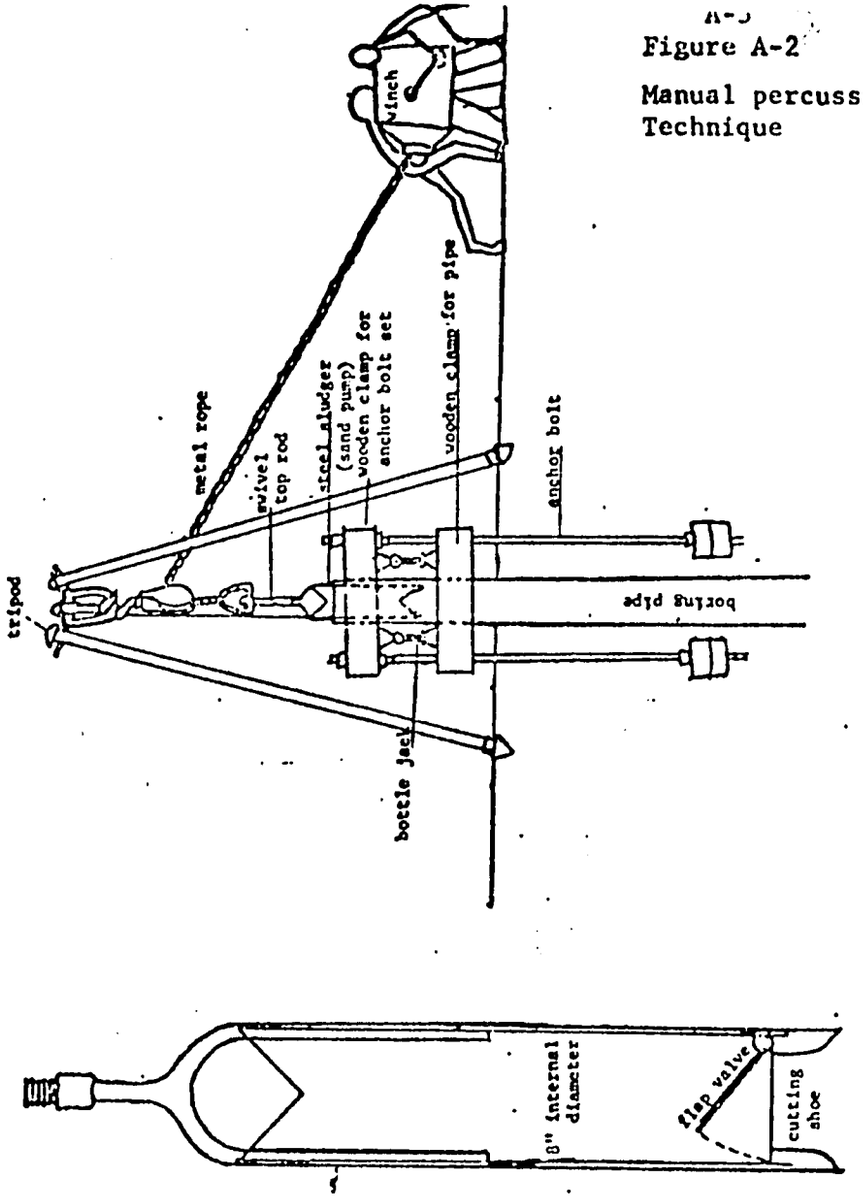
In section II (B) the major alternatives affecting the cost of tubewells; (1) Drilling technique, (2) Power source and type of engine, (3) Type of pump, (4) Screen material utilized, and (5) Drilling agent were listed with brief comments as to their most important cost and performance characteristics. This appendix amplifies and elaborates on these comments. Figure 1 illustrates the basic design of tubewells.

(1) Drilling techniques. The two power drilling techniques, rotary and reverse rotary drilling are essentially similar. Both are capital intensive, utilizing large heavy rigs that are either mounted on a truck body or some other similar type of mobile unit. The result is a rig that is heavy and difficult to move in many parts of deltaic Bangladesh. The initial cost of the rig is Rs. 560,000, entirely in foreign exchange. The advantage of the rig is that it drills a well in one day and produces a hole of excellent verticality and uniformity. However, drilling operations can be carried out only in the dry season, November through April.

The alternative low-cost drilling techniques, percussion and jet drilling, are labor intensive and relatively low cost. The percussion rig consists of a tripod, winch, bit and steel cable, costs Rs. 38,500 and is easily fabricated in Bangladesh. The rig is light and mobile and drilling can be done year round although it is slower in the monsoon season. The disadvantage of percussion drilling is that it takes 4 to 6 weeks to drill one well. The technique is illustrated in figure 2.

Figure A-2

Manual percussion Drilling Technique




**Explanation of Manual Percussion Drilling**

The metal rope imparts a circular movement to the sludger as it is worked up and down.

The method of forcing the casing or boring pipe downward illustrated in the drawing is called the Anchor Bolt Method. The upper clamp is secured tightly to the two anchor bolts, whose lower ends have been buried 7 - 10' under ground. (The square at the bottom of each anchor bolt is a cross-sectional drawing of a rail piece 6" x 4" x 6'.) The bottom wooden clamp is secured to the pipe itself. It is held in place on the anchor bolts but can move up or down along them.

Bottle jacks are placed between the two bolts. When they are unscrewed, pressure is exerted between the two clamps. As the upper one is stationary, the lower bolt is forced downward, carrying the casing pipe with it. As each new length of casing pipe is lowered into the well, it is screwed to the top of the one beneath it.

When the digging is completed, blind pipe and strainer are lowered through the casing pipe and shrouded with gravel. To remove the casing pipe, the action of the clamps is reversed, so that the lower one is held tightly to the anchor bolts and the upper to the pipe itself, and the bottle jacks then worked between them.

The jet drilling rig is similar to the percussion except that in addition an engine and pump are needed. These are usually to be installed in the completed well so, in fact, represent no increase in cost. The actual drilling is accomplished by pumping water into the well through a casing pipe and the scouring force cuts the earth beneath the pipe allowing it to drop slowly to the desired depth. Jet drilling is the cheapest drilling technique; it is quicker than percussion drilling, but cannot be done in the months of maximum rain, June through September. It also produces the least uniform well, but has so far proven satisfactory under Bangladesh conditions.

Table A-1 compares the various drilling techniques.

(2) Power source and type of engine

Reliability in provision of irrigation water is essential. The failure of water supply in the middle of an irrigated growing season means the loss of investment in all the inputs. Minimizing maintenance requirements associated with the supply of a given quantity of water is a high priority objective.

The engine is the most delicate component of the well. It is very important to find the most reliable engine and the one that can be repaired most rapidly in the event of a breakdown. In the 1960's, the 25,000 low-life pumps utilized in East Pakistan were powered by imported high speed diesel engines. This choice was justified, first because of their theoretically greater reliability and lighter weight which makes them more mobile. Second, it was reinforced by the fact that the exchange rate, duty, and tax structure made the

TABLE A-1

Comparison of Tubewell Drilling Techniques

| | Cost of Rig | Foreign Exchange | Drilling Cost Per Foot | Drilling Time 300 Feet | Drilling Season | Mobility of Rig | Uniformity of Well |
|---|---|---|---|---|---|---|---|
| Power drilling | Rs.560,000 | 100% | Rs. 47.50 | 1 day | Nov. to April | 10-15 tons moves only over road or dry field unless specially adapted for other conditions | Excellent |
| Manual percussion drilling | Rs. 38,500 | 50% | Rs. 10 | 4-6 weeks | Year Round | 1,000 lbs. can be moved anywhere | Good |
| Jet drilling | Rs. 70,000 | 65% | Rs. 7 | 1-2 weeks | Oct. to May | 1,500 lbs. can be moved anywhere | Fair |

high speed engine cheaper than the slow speed, despite the fact that the latter is much less expensive to produce.[1/] Third, high speed engines were made available under British and German suppliers' credits which made them attractive to officials not particularly concerned with debt obligations. The experience of the 1960's with high speed engines was not entirely satisfactory. The engines are complex machines, manufactured to precise specifications, and have proven susceptible to breakdowns when operated and maintained by the minimally trained operators available in villages. Neglect of standard operating procedures, poor or no maintenance, and the use of kerosene rather than high speed diesel fuel, increased the frequency of breakdowns and reduced the time between overhauls. Repairs and overhaul could only be carried out at costly, well-equipped service centers with imported spare parts. The maintenance shops established for the low lift pump program had mechanics with limited training who frequently could not service and overhaul the high speed engines adequately. The result is that the anticipated lifetime of the engines may be reduced from the expected 10-15 years to as little as five years.

Low speed diesel engines have not been used in public irrigation programs in the past. Yet, if exchange rates and duty structures are rationalized, low speed engines would be cheaper. They operate on low cost fuel, compare favorably with high speed engines in tolerance to carelessness in operation and maintenance, and major repairs including overhaul can be done at lower cost with less equipment in small workshops close to the operating site. In West Pakistan, where slow speed diesel

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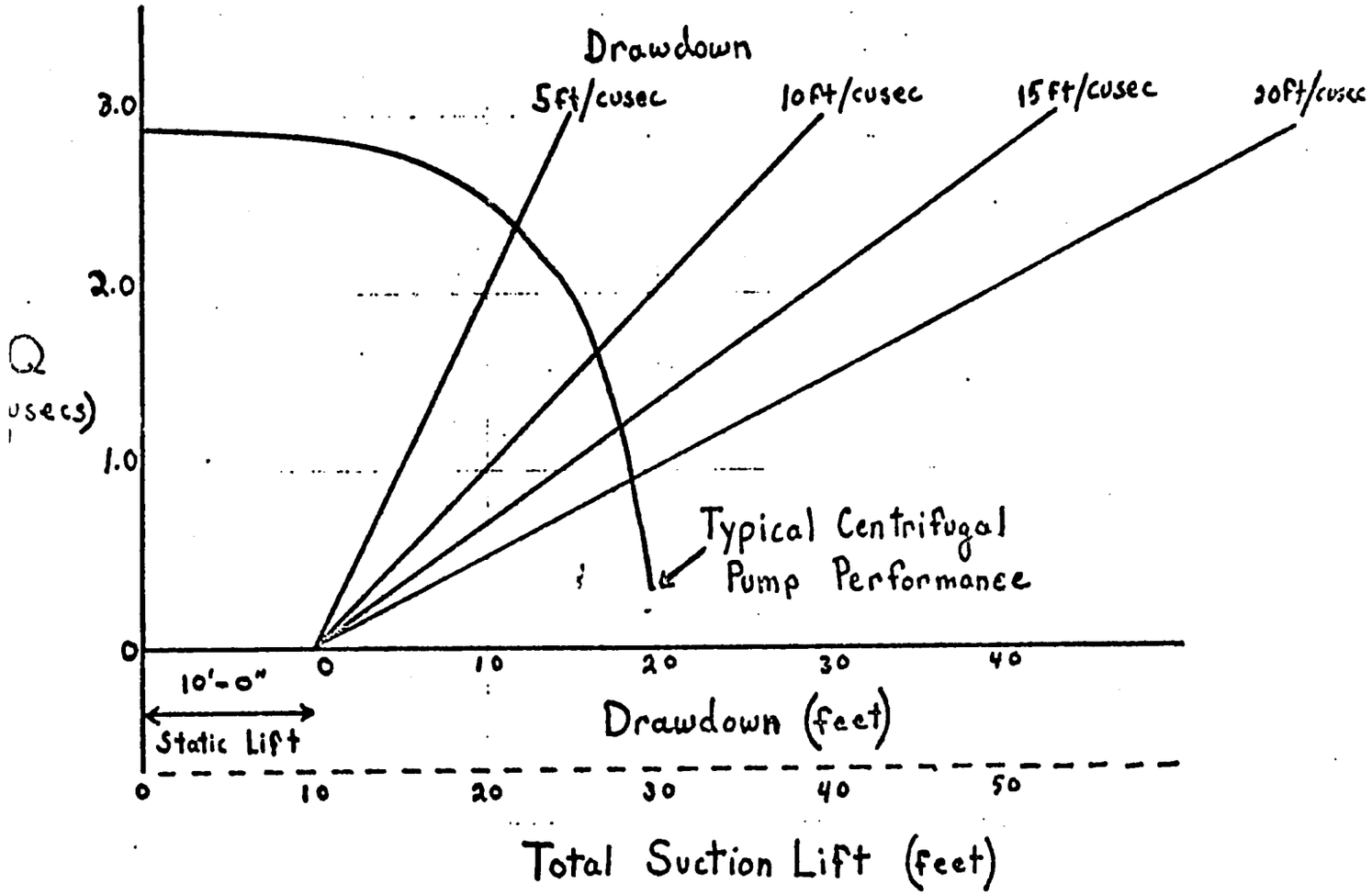
1/ This was the case because high speed engines were purchased or supplied on credit at the official exchange rate Rs. 4.75 = $1 and imported free of duties and taxes while materials for domestic production of engines were purchased at the bonus voucher rate of approximately Rs. 9.50 = $1 and sales tax was levied on the final product.

FIGURE A-3

Typical Centrifugal Pump Performance Under Differing Levels of Suction Lift




Source: Stephen V. Allison, Special Projects Department, I.B.R.D.

engines have been extensively used and are preferred to high speed diesels for tubewell operation, they have an average life of 15-20 years.

Slow speed engines and spare parts maintenance, and repair, could easily become an important rural small industry in Bangladesh as it has in West Pakistan. 2/

(3) Type of pump.- There are two types of pumps generally used for tubewells.- The centrifugal, vacuum pump, produced in East Pakistan cost Rs. 750 in 1970. The limitation on the centrifugal pump is that if the drawdown cone drops below about 18 feet, it begins to lose efficiency, and it stops pumping entirely below 25 to 27 feet. The turbine pump is submerged in the well and can operate at lower levels of water.

The cost of the turbine is Rs. 6,250 more than the centrifugal pump 3/ at the official exchange rate, and at a shadow rate (Rs. 9.50 = $1), the gap between the imported turbine pump and the locally produced (but with imported components) centrifugal would increase to almost Rs. 11,000. The off-setting fact is that under pumping conditions, when water levels in the well begin to drop, the centrifugal pump may lose efficiency and output drop to 1.5 or 1.25 cusecs while the turbine pump still delivers the rated two cusecs.

Given these differentials in cost and performance between pumps, it is necessary to examine the drawdown during pumping to determine the limits of the centrifugal's performance. Figure A-3 indicates the performance of a typical 2-cusec rated centrifugal pump.

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2/ Edwin H. Smith, Jr., The Diesel Engine Industry of Daska, Sialkot District, Reprint Paper No. 20, Planning and Development Department Lahore, 1969.

3/ Pump costs are estimates made by the World Bank in 1970.

If drawdown drops below about seven to eight feet per cusec, the centrifugal pump becomes quite ineffective. For both Comilla and Thakurgaon, where ground water levels are good, drawdown is about seven feet per cusec; if drawdown exceeds this, the centrifugal will pump 25 percent less water than the turbine pump, with the related reduction in benefits.

(4) Screen material utilized.

The three screen materials seriously considered for East Pakistan tubewells in 1969-70 were brass, which had been proven successful in operation, fiberglass which everyone was quite sure could be successful, and PVC which was low cost if manufactured locally, but needed testing under local conditions.

Brass is moderately priced and durable in installation but subject to corrosion, resulting in the shortest anticipated lifespan. Its greatest advantage is that for some time it has been fabricated in Bangladesh from scrap or sheet brass with only simple equipment. As a result, if widely used, there would be potential for local small industry to fabricate brass screens. Its Dacca market cost in 1970 was Rs. 50.00.

The basic cost of fiberglass is similar to brass. The price c.i.f. Chittagong is U. S. $11.25 (Rs. 53.50 or Rs. 107 shadow priced). Duty of 100% and internal transportation were additional. With duty the actual delivered cost of fiberglass screen was Rs. 108.50.[4/] While duty is normally excluded from calculations of real cost, for East Pakistan in 1970, where all duties went into Central Government revenues, of which only 20% were spent

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4/ Agricultural Development Corporation, Project Loan Application, p. 95.

in East Pakistan, it can be legitimately argued that 80% of the duty paid in fiberglass screen should be included in the real cost. Calculated in this manner, with foreign exchange shadow priced the cost becomes Rs. 151, three times the cost of brass screen. There was discussion of establishing a domestic plant to produce fiberglass. If this were done, it would lower the price, but it would probably only be done if a decision were made to use fiberglass screen exclusively, insuring adequate demand to justify a factory. In this case it would be a single large firm operating with imported equipment and technology in a single location and would not have the potential for establishing local small industry.

Many experts felt PVC might ultimately prove the best screen material. PVC could be produced at approximately $6.00 per foot in Bangladesh, either using imported resins, or utilizing domestic natural gas to produce it.[5/] However, PVC has not yet been tried in irrigation tubewells, although it has been used extensively in smaller wells installed for drinking water supplies by the Department of Public Health Engineering. PVC can be damaged by heat or rough handling, both of which may occur in Bangladesh. As a result, it will be necessary to experiment with PVC on a small scale before adopting it for widespread use.

Table A-2 compares the three screen materials, with a simple ordinal rates of return that take account of cost and anticipated life. This shows that PVC is the most attractive screen material if it proves itself under Bangladesh conditions, and if it can be produced locally. As of 1970, however, brass had the best economic return.

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[5]The potential for local production is discussed in detail in Camp Dresser and McKee, Analysis of Local Procurement Development Potentials - DPHE, November 1965, pp. 3-40.

TABLE A-2

Comparison of Tubewell Screen Materials
(prices in rupees)

| | Cost Per Foot w/o Duty | Foreign Exchange Component | Shadow Price | Anticipated life (yrs.) | Comparative Rate of Return[1/] | Rate at Shadow Price |
|---|---|---|---|---|---|---|
| Fiberglass | 53.50 | 100% | 107.00 | 20 | .38 | .23 |
| Brass | 50.00 | 70% | 85.00 | 10 | .35 | .29 |
| PVC | 34.50 | 10% | 38.00 | 15 | .44 | .43 |

Sources of cost data listed in Table 1.

[1/] These rates of return should be treated as ordinal numbers for comparison of screen materials only. For ease of calculation, a round number was used to approximate all other costs, and only screen costs and the resulting anticipated well life were varied.

(5) Drilling agent. There is little information about various drilling agents other than the cost figures contained in the text.

## Appendix B

### Rate of Return on Tubewells

The estimate of benefits from irrigation is conservative. First, it is difficult to estimate benefits from supplemental irrigation of aus and amon rice crops, although they may be substantial, and these are not included. Second, rice is one of the most expensive crops to grow on irrigated land because of its high rate of water consumption. It can be assumed that as irrigation becomes more widespread and rice production increases toward levels of self-sufficiency, cropping patterns will change and higher value crops will be grown in the irrigated season. This will result in considerably higher returns on fixed units of land and water. Third, presumably within the next few years, all farmers planting winter rice will be using new high-yielding varieties. However, because of difficulties in finding a variety that is entirely appropriate to the conditions of the season, the irrigated crops are now planted partially in new varieties and partially in traditional varieties, and these benefit calculations are based on present practices.

#### Benefits

In calculating benefits the experience in Comilla Thana will be utilized since this is the only area from which detailed information as to production under irrigation is available. Table B-1 indicates the cropping patterns observed under irrigated agriculture in Comilla.

## TABLE B - 1

### Cropping Patterns in Areas Under Tubewell Irrigation

| Category of Crop | Percent of Land Under Crop |
|---|---|
| Improved variety rice | 84.8 |
| Local variety rice | 4.2 |
| Non-rice crop | 11.0 |

Source: M. Solaiman, "Winter Crop Survey in Comilla Kotwali Thana 1969-70," Comilla, Pakistan Academy for Rural Development, p. 5.

From the calculation of areas under different crops, it is necessary to calculate the net benefit per acre for each of the above crops. To do this the established price for which the Government sells rice in ration shops throughout the country, which is very close to or a little below the average wholesale price, Rs. 30.80 per maund, (82 2 pounds) will be taken as the standard value of rice. Table B-2 contains the calculation of benefits from irrigated land.

Assuming that one 2-cusec tubewell will irrigate 45 acres, which is the average for a 2-cusec water source, it is then possible to calculate the net annual benefit accruing from a 2-cusec tubewell, assuming the cropping pattern that exists in Comilla. Table B-3 summarizes these calculations.

## TABLE B - 2

### Calculation of Net Benefit per Acre of Tubewell Irrigated Crops*

#### Improved Varieties of Rice

Costs per acre

Input cost (labor, power, fertilizer, seeds, insecticides, except irrigation) . . . . . Rs. 343.00

Overhead costs (interest on land and credit, land and sales tax) . . . . . Rs. 110.43

Total cost per acre . . . . . Rs. 453.43

Benefits per acre

| | Yield (mds.) | Price per md. | Return per acre |
|---|---|---|---|
| Grain | 41.3 | 30.80 | 1272.04 |
| Straw | 19.4 | 3.00 | 58.20 |
| | | | 1330.24 |

Net benefits per acre: Rs. 879.81

#### Local Varieties of Rice

Costs per acre

Input costs . . . . . Rs. 236.53

Overhead costs . . . . . Rs. 84.38

Total cost per acre . . . . . Rs. 320.91

Benefits per acre

| | Yield (mds.) | Price per md. | Return per acre |
|---|---|---|---|
| Grain | 21.8 | 30.80 | 671.44 |
| Straw | 13.7 | 3.00 | 41.10 |
| | | | 712.54 |

Net benefits per acre: Rs. 391.63

TABLE B - 2 cont.

Other Crops

| | Net benefit per acre |
|---|---|
| Watermelon | 650.55*[1] |
| Potatoes | 886.52*[2] |

Average net benefit per acre . . . Rs. 768.53

*[1] Anwarul Hoque, ibid, pp.53, 65.

*[2] Statistical Digest, Comilla, P. A. R. D., 196[illegible], p. 56, Table 25.

* Source: Anwarul Hoque, Cost and Returns, Comilla, Pakistan Academy for Rural Development, 1968.

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TABLE B - 3

Calculation of Benefits Accruing From One Tubewell

| Crop | % of total area | Net benefit per acre (in Rs.) | No. acres per 45-acre pump group | Net annual benefit per tubewell |
|---|---|---|---|---|
| Improved variety rice | 84.8 | 879.81 | 38.1 | 33,520.76 |
| Traditional variety rice | 4.2 | 391.63 | 1.9 | 744.10 |
| Other crops | 11.0 | 768.53 | 5.0 | 3,842.65 |

Net annual farmer's benefit Rs. 38,107.51
(excluding irrigation costs)

On this basis the farmer's annual benefit from a tubewell would be about Rs. 38,000. This calculation is important because it suggests the profitability of a tubewell to the water users, which is sufficiently high to repay the investment cost of a low-cost well in one year or even a medium cost well in two years!

However, the real value of additional rice is not that price at which the farmer can sell in the local market, but the international market price at which the nation must purchase rice to make up its annual food deficit. Or stated differently, the amount of foreign exchange saved by the domestic production of each additional ton of rice. For this calculation the current export price for Burmese rice, $103 per ton, is used.[1/]

Calculated at this price, the benefit from one tubewell is reduced to Rs. 17,483.34 per well, and it is this benefit calculation that will be used in the internal rate of return calculation. (Unless a turbine pump is used, with a 25% increase in output and the benefit rises to Rs. 21,854.17.)

Comparison of wells of alternative specifications. The calculations are a comparison of the internal rates of return on low, medium and high cost tubewells. The costs of these well alternatives at market and shadow prices are contained in Table 2 in the text. The time streams of benefits and cost and the resulting rate of return are shown in Table B-4.

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1/ F.A.O. Monthly Bulletin of Agricultural Economics and Statistics, No. 9, Vol. 19, (Rome, 1970) p. 46.

Rate of return for alternative time sequences of installation.

The previous calculation compares three well alternatives open to Bangladesh in a static situation. The following calculations attempt to compare two more realistic alternatives and include a time dimension. For purposes of this calculation, it is assumed that the low cost percussion or jet-drilled wells have brass screens with a ten-year life, and a combination of centrifugal and turbine pumps. The medium cost contractor, power-drilled well is assumed to have a fiberglass screen with a twenty-year life, and turbine pumps. The installation of power-drilled wells is to take place at the rate of 4,000 per year and the percussion-drilled well, according to the schedule in Table 3 (in the text). The results of these calculations are shown in Table B-5.

TABLE B-4

Comparison of Rate of Return on Five Alternative Tubewells of Varying Specifications

| Year | Low Cost Benefits | Low Cost Costs | Medium Cost Benefits | Medium Cost Costs | High Cost Benefits | High Cost Costs |
|---|---|---|---|---|---|---|
| 1 | 0 | 28,160 | 0 | 54,505 | 0 | 189,805 |
| 2 | 17,483.17 | 6,500 1/ | 21,854.17 | 8,000 2/ | 21,854.17 | 8,000 2/ |
| 3 | " | " | " | " | " | " |
| 4 | " | " | " | " | " | " |
| 5 | " | " | " | " | " | " |
| 6 | " | " | " | " | " | " |
| 7 | " | " | " | " | " | " |
| 8 | " | " | " | 21,000 3/ | " | 21,000 3/ |
| 9 | " | " | " | 8,000 | " | 8,000 |
| 10 | " | " | " | " | " | " |
| 11 | " | " | " | " | " | " |
| 12 | | | " | " | " | " |
| 13 | | | " | " | " | " |
| 14 | | | " | " | " | " |
| 15 | | | " | " | " | " |
| 16 | | | " | 21,000 3/ | " | 21,000 3/ |
| 17 | | | " | 8,000 | " | 8,000 |
| 18 | | | " | " | " | " |
| 19 | | | " | " | " | " |
| 20 | | | " | " | " | " |
| 21 | | | " | " | " | " |
| 22 | | | | | | |
| Internal Rate of Return | | .29 | | .19 | | less than .10 |
| Shadow Costs | | 37,345 | | 92,707 | | 329,727 |
| Shadow Rate of Return | | .18 | | less than .10 | | less than .10 |

1/ Annual operation and maintenance cost, low speed diesel engine (estimated life 15 years)
2/ Annual operation and maintenance cost, high speed diesel engine (estimated life 7 years)
3/ Replacement costs of pump and engine plus operating cost
(Operating and maintenance costs from A.D.C., Tubewell Loan Application, p. 113)

TABLE B-5

Comparison of Rate of Return on 20,000 Wells, Low Cost and Medium Cost Wells
(in Rupees millions)

Low Cost Well, Rs. 29,000

| Year | Operating Wells | Benefits | Operation & Maintenance | Capital & Replacement Cost | Total Cost |
|---|---|---|---|---|---|
| 1 | 510 | 0 | 0 | 14.8 | 14.8 |
| 2 | 1,780 | 8.9 | 4.1 | 36.8 | 40.9 |
| 3 | 4,960 | 31.1 | 14.2 | 92.2 | 106.4 |
| 4 | 12,910 | 86.7 | 39.7 | 230.5 | 270.2 |
| 5 | 20,000 | 225.1 | 103.3 | 205.6 | 308.9 |
| 6 | | 349.7 | 160.0 | | 160.0 |
| 7 | | " | " | | 160.0 |
| 8 | | " | " | | 160.0 |
| 9 | | " | " | | 160.0 |
| 10 | | " | " | | 160.0 |
| 11 | | " | " | | 160.0 |
| 12 | 19,490 | 340.8 | 155.9 | | 155.9 |
| 13 | 18,220 | 318.5 | 145.8 | | 145.8 |
| 14 | 15,040 | 262.9 | 120.3 | | 120.3 |
| 15 | 7,090 | 124.0 | 57.7 | | 57.7 |

Internal Rate of Return .27

TABLE B-5 (continued)

Medium Cost Wells, Rs. 55,000

| Year | Operating Wells | Benefits | Operation & Maintenance | Capital & Replacement Cost | Total Cost |
|---|---|---|---|---|---|
| 1 | 4,000 | 0 | 0 | 220. | 220. |
| 2 | 8,000 | 69.9 | 32.0 | 220. | 252. |
| 3 | 12,000 | 139.9 | 64.0 | 220. | 284. |
| 4 | 16,000 | 209.8 | 96.0 | 220. | 316. |
| 5 | 20,000 | 279.7 | 128.0 | 220. | 348. |
| 6 | | 349.7 | 160.0 | | 160. |
| 7 | | " | " | | 160. |
| 8 | | " | " | | 160. |
| 9 | | " | " | 60. | 220. |
| 10 | | " | " | 60. | 220. |
| 11 | | " | " | 60. | 220. |
| 12 | | " | " | 60. | 220. |
| 13 | | " | " | 60 | 220. |
| 14 | | " | " | | 160. |
| 15 | | " | " | | 160. |
| 16 | | " | " | 60. | 220. |
| 17 | | " | " | 60. | 220. |
| 18 | | " | " | 60. | 220. |
| 19 | | " | " | 60. | 220. |
| 20 | | " | " | 60. | 220. |
| 21 | | " | " | | 160. |
| 22 | 16,000 | 279.7 | 128.0 | | 128. |
| 23 | 12,000 | 209.8 | 96.0 | | 96. |
| 24 | 8,000 | 139.9 | 64.0 | | 64. |
| 25 | 4,000 | 69.9 | 32.0 | | 32. |

Internal Rate of Return .17

## Appendix C

### Calculation of Low Cost well Installation Capacity

The Comilla KTCCA low cost wells are installed by two-man teams of a Driller and assistant Driller who hire and direct a group of 10 to 20 local, unskilled laborers. One Foreman supervises the work of five rigs. It is conservatively estimated that one rig using either low cost method can drill about six wells per year.

Drilling rigs are simple and can be fabricated more rapidly than men trained to operate them, so the constraint is the time needed to train crews. In Comilla, six months of apprenticeship on a drilling rig was the time needed to train assistant drillers. After an additional half year's work, an assistant driller is promoted to a driller and is given charge of a rig. Foremen are selected from among the drillers on the basis of aptitude, knowledge, and organizational ability.

As of the end of 1970 there were 87 drilling crews which had been trained at Comilla. There were enough foremen and drillers to begin operating 85 rigs immediately. In addition to this, there are at least 14 local contractors with capacity to drill percussion wells. However, private contractor capacity will not be included in these calculations.

Since drilling can be done with efficiency in only nine months of the year, it is possible to train only three men on each rig each year. (In other words, one 2-man team in six months and half the training of a 2-man team in the remaining three months.) If you begin from the existing 85 rigs and calculate that each one trains three men per year, it is possible to have 3,312 rigs with an annual installation capacity of approximately 19,000 wells in operation in five years.