Determination of Cost of Tubewell Water and Estimation of Economic Rent in Canal Irrigation

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In this paper it is primarily sought to ascertain if there is any economic rent involved in the application of canal irrigation in Pakistan. In principle if the competitive price for the public irrigation water supply in the farm sector exceeds the legal water rates charged, the surface supplies are considered to yield economic rent to the beneficiaries [20]. The competitive price for canal deliveries cannot be determined directly because they are not sold in the market but are allocated through an elaborate system of water distribution. However, it may indirectly be derived from the price of tubewell water which constitutes another significant domestic source of irrigation. If the ability of the beneficiaries to pay for cost of irrigation supply has a precedence, which is more often the case, over the recoupement of its expenses in entirety, the incremental value of additional water to farm output should serve as a guide in determining the price of canal water.

The marginal value of water on farms with only canal supplies ordinarily reveals wide variations during the crop growth cycle due mainly to the characteristic seasonal variability in irrigation water and the existence of sub-optimal cropping pattern. Consequently, no single value of the contribution of additional water in crop output can be adopted as a representative value. However, a representative marginal value of water is obtainable from those farmers that use canal water and also own a tubewell. In their case the usual constraints of fluctuations in surface deliveries and optimum cropping pattern of non-tubewell farms are not present. These farms in principle should pump water until the value from an additional acre inch of water equals its cost of pumping. Accordingly the marginal value of water in respect of such

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farms simply equals the cost of pumping [5]. The same may be assumed to hold in areas where tubewell water is available in abundance and farmers have a free choice to use it according to their requirements. Thus, the pumping cost of a given volume of tubewell water may be considered, within limits, to reflect the cost of the same volume of canal supplies. Following the same argument, the pumping cost of the tubewell water may also be assumed as a surrogate for the marginal value of canal water. The comparison between the cost of tubewell water and the government canal water rates, which account for the price of surface supplies to the beneficiaries, for given deliveries will reflect the presence of the economic rent. The existence of the economic rent in the canal irrigation of various crops will enable us to examine the repercussions of policy measures that may be designed to appropriate it for development of new irrigation projects or to allow accrual of rent to continue to the old beneficiaries.

It has been observed that farmers frequently apply tubewell water to supplement surface water supplies when available and necessary and a decrease in canal water supply has been accompanied by an increase in the use of ground water [11]. More specifically, 60 percent of sample farmers located in Central Punjab were found to purchase tubewell water upto 42 percent of their canal water supplies during kharif whereas 64 percent farmers bought upto 45 percent of their surface supplies during rabi seasons of 1965-1966 [10]. Farmers have also been found to pay in kind upto 33 percent of crops raised as payment for tubewell water supplies [15]. The measurement of the value of canal irrigation in terms of tubewell water cost to assess the accrual of economic rent is further prompted by the fact that ground water pumped by tubewells in both public and private sector accounted for one-third of the total farm level water supplies in 1977-1978 [18]. Such a substantial contribution of tubewells and the extent of integration of ground water with total irrigation supplies provide adequate justification to adopt the cost of production of tubewell water as, at least, a crude approximation of the marginal value of surface irrigation.[1]

The cost of production of tubewell water and its economic effects have been examined by Punjab Board of Economic Inquiry [3, 4], WAPDA [21], Ministry of Food and Agriculture [15] and Harza Engineering Co. [6] from survey data of private electric and diesel units scattered in various districts of Punjab. Similarly, IACA [7], IBRD [8] and Ghulam Muhammad [11] estimated the cost of water delivery from public SCARP tubwells which operated only on electricity and have a higher discharge capacity than that of private tubewells. All these studies, without exception, reported the cost of delivering diesel tubewell water substantially in excess of that of electric units of equivalent discharge capacity. The public tubewell water cost per acre foot has been found to be significantly higher than that of private tubewells running on the same motive power. The use of tubwell water both in isolation and in integration with surface supplies has shown a favourable impact on farm productivity, cropping pattern, employment of human labour, use of animal power and application of other modern inputs. None of these studies has used the cost of tubwell water as a basis to determine the cost of surface supplies

[1]It is believed that the production cost of tubewell water may have an upward bias due to scarcity of certain components of the machinery and widespread imperfections in the general market.

and thereby to identify the accrual of economic rent in canal irrigation. However, Falcon and Gotsch [5] estimated the marginal value of water by using the tubwell water cost estimates of Harza Engineering Co. [6] and determined the transfer of resources to agriculture *via* canal irrigation. Under the present era of drastically changed cost structure of tubewell water, the findings of this study based on 1969 field data are no longer relevant. Moreover, this study used data only on diesel tubewells and has not considered the cost of electric tubewells in the estimation of the marginal value of water and resources transfer to the agrarian sector[2].

The estimation of economic rent yielded by surface irrigation will first of all, reflect on the relevance of the current water rate and on the incidence of any changes that may be proposed in their level. The current level of economic rent in the existing canal irrigation system can be useful to design improved structure of water supply charges in future irrigation projects that may yield the maximum possible return and at the same time impede inequitable distribution of their benefits among beneficiaries. A knowledge about the extent of irrigation benefits over its water rates cost and their distribution among various categories of farms may indirectly be valuable to formulate appropriate policies regarding prices of both farm inputs and outputs.

The determination of the cost of private tubewell water, which is used to estimate the economic rent in canal irrigation, is in itself important in framing policy measures regarding supply of diesel/electricity at reasonable prices for optimum exploitation of groundwater, promotion of research to develop more efficient tubewell machinery, introduction of specific standards to manufacture quality equipment and to encourage both private and public investment in rural repairing facilities. Above all, the analysis of the production cost of groundwater is necessary to affect credit as well as tubewell equipment price policies to bring this important source of irrigation in easy access of a maximum number of small as well as large farmers.

THEORY OF ECONOMIC RENT

The economic rent in irrigation arises due to the existence of two distinct sources from which water supplies are obtainable at two different prices. Currently, canals and tubewells constitute two well differentiated sources of water for irrigation. Canal deliveries are suppiled by the public sector against the payment of irrigation charges whereas groundwater is obtainable from private tubewells at a price which reflects, if not precisely, their cost of production.[3] The cost of a given volume of tubewell water has frequently been observed to be considerably higher than water rates charged as the price for the same quantities of canal deliveries. Consequently, the application of canal water

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[2]The data on diesel tubewell would have probably been considered in isolation due to their dominance in the private sector at that time. Although the number of diesel tubewells is still higher than that of electric tubewells, the number of the latter type of wells has witnessed a rapid growth during the past decade. Their number is expected to increase significantly due to the continuous increase in the national supply of electricity and the recent emphasis being laid on rural electrification.

[3]Tubewell water sale price may differ from its cost of production under certain circumstance. However, in this study, we consider the price as equivalent to what it costs an owner of a tubewell to produce irrigation water for himself. Rationality postulates that normally the price of tubewell water may be equal or greater but not less than its cost of production.

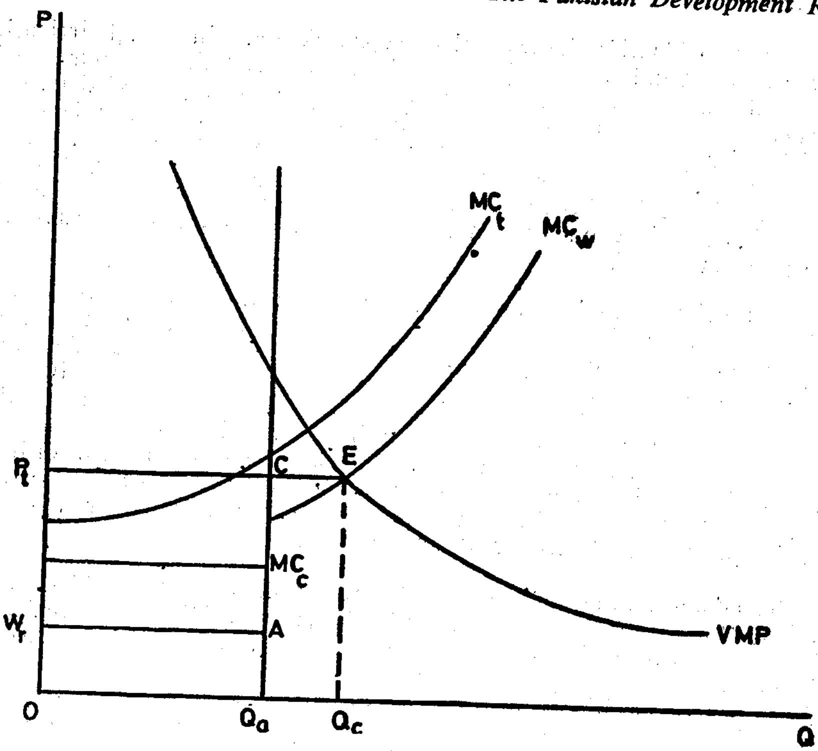

Figure 1
Occurrence of Economic Rent in Canal Irrigation

vis-a-vis tubewell water results in the occurrence of economic rent to the beneficiaries. The phenomenon of differential costs which leads to the generation of economic rent on canal irrigation may be explained with the help of the diagram depicted above. In the diagram OQ_a represents the quantity of surface irrigation available from the canal system for a given crop.[4] Q_aQ_c denotes the volume of tubewell water used in its irrigation. The demand of irrigation water is theoretically determined by the value of the marginal physical product (VMP) of a crop. What this means is that a farmer will be willing to pay for a unit of irrigation water, as will be the case in respect of tubewell water, any price less than or equal to the value of the marginal physical output of the additional unit of water. Thus, VMP curve indicates different quantities of irrigation water demanded by a farmer at different prices to irrigate a crop. MC_c represents a hypothetical marginal cost curve of canal water. This curve is hypothetical because the data on cost of operation of the public irrigation water supply has not been collected due to the following of a particular approach which did not require such data. MC_t curve reflects the marginal cost curve of producing tubewell water. Finally, MC_w depicts the combined marginal cost curve of water derived by a horizontal summation of marginal cost curves of canal water and tubewell water. The intersection of VMP and MC_w curves at E indicates the equilibrium price paid and the aggregated quantities of both

[4]The available volume of canal water frequently falls short of the actual allocation in the canal system due to inefficiencies in the canal water distribution and excessive water course losses. As the size of farm diminishes and as the distance from the watercourse outlet increases, water losses are accentuated.

canal and tubewell water consumed in raising a crop. Thus, the equilibrium price is the market price of canal water. The farmer receives OQ_a quantities of canal water and uses Q_aQ_c quantities of water from his own tubewell. The argument may be extended to non-tubewell farms that purchase the same volume of Q_aQ_c of water from private tubewells on the same equilibrium price as faced by the owners of tubewells. On the application of OQ_a quantities of surface water to a crop, the farmer pays equal to the area (CQ_aAW_r) as the cost of canal water but receives an income from it equal to the area (OQ_aCP_t). Thus, the canal irrigation devolves on the farmers an economic rent equal to the area (W_rACP_t) on the cultivation of a given crop.

CANAL IRRIGATION AND WATER RATES

The current allocation of canal water is based on the Sind-Punjab Draft Agreement of 1945 in which priority to withdraw water from the rivers was given to old inundation canals [22]. However, the volume of water diverted into each branch of the main canal varies in accordance with the command area to be sown under a common cropping pattern and cropping intensity. The irrigation department maintains the canal network upto the farm water course outlets on the distributaries. The main water courses are designed by the irrigation department but they are dug and maintained collectively by the beneficiaries. The discharge in these water courses varies normally from 1 to 3 cusecs, with rare exceptions, depending upon the area to be fed. Each farmer shares water for his acreage from the common water course at the same length of time per acre. Under the existing regulations of water distribution, farmers are not allowed to make adjustments of water supply from a water course according to their needs without obtaining prior authorization from the irrigation department. If an arrangement is authorized, they cannot make another adjustment without again seeking the permission from the same department [8, 22]. It takes a long time to change a previous arrangement of farm delivery due to a lengthy procedure and conflicting interest of farmers. The violation of water allocation rules is subject to penalty imposed by the department of irrigation. As such the farmers must receive irrigation water supply as and when it is available.

Water rates are charged for irrigated crops. They are differentiated but in no systematic relationship with variations in quantities of water allocated among crops in the canal system. The rates per acre of various crops in practice are practically uniform throughout Pakistan. Earlier, in the southern zone of Sind the irrigation charges were combined with land revenue. However, since kharif 1959 they have been isolated from land revenue and charged separately as has been prevalent in the northern irrigated zone [9]. The irrigation water rates are unresponsive to distance from the source of supply, volume of water actually delivered, the value of land to be irrigated, appreciation in its value with irrigation or the cost of delivery upto the head of the cultivators watercourses. They are higher for raising subsistence than cash crops and this trend persisted in all the previous upward revisions as may be observed in Table 1.

In general, water rates are not fixed on any scientific basis. The Taxation Enquiry Committee reports that the total cost of a canal and its working expenses, and the capacity of the beneficiaries to pay the charge are considered tacitly to set the limits for the assessment of irrigation water rate [19]. The

Table 1

Canal Irrigation Water Charges in Rupees Per Acre

Crops	1937-1938	1959	1965	1969 onwards
Wheat	4.25	6.00	7.20	10.40
Rice	6.50	10.00	11.20	16.86
Sugarcane	11.00	20.00	24.00	35.60
Cotton	5.25	10.00	12.00	16.00
Oilseeds	4.25	7.25	8.80	7.64
Fodder	2.50	3.50	4.80	8.00
Average	5.75	9.46	11.30	15.75

Source: The data in columns 2-4 has been derived from [9]. The figures in column 5 have been obtained from the Punjab Irrigation Department, Lahore.

debt repayment of financial obligations of the canal system has been important but not the overriding consideration in the fixation of water rates. The assessment of water rates has usually been influenced by a mix of objectives like mobilization of savings, efficiency, growth of farm income, food production and stabilization of growers' income. However, the water rates policy did not assign definite weights to these objectives. Nevertheless, the importance of the farm welfare objectives far outweighs those that emphasize to recoupe the entire expenses of the irrigation system. Therefore, water rates are fixed deliberately low [12].

DATA AND METHODOLOGY

The data were obtained from a suvery of tubewell equipment selling firms located in metropolitan Lahore. In all, 25 firms were contacted foi data on prices of the entire array of components required to install tubewells with 1, 1.5 and 2 cusecs discharge capacity, during a ten-days period from 4 to 14 August 1977. Five out of these firms also provided information on drilling operations of tubewells. The data on drilling operations were augmented with information from four additional firms that specialized in tubewell boring. The running expenses and operational hours were estimated from the anlaysis of 139 diesel and 120 electric private tubewells selected from a nation wide tubewell survey carried out by the University of Engineering and Technology, Lahore, in 1974. The diesel tubewells were categorized as 24 with 1, 66 with 1.5 and 49 with 2 cusecs capacity whereas the electric tubewells were distributed in the order of 36 with 1, 49 with 1.5 and 35 with 2 cusces discharge.

The operational expenses of private diesel and electric tubewells were estimated in the form of fixed cost and variable cost. The fixed cost was constituted by interest on installation outlay and depreciation of tubewell machinery as well as masonry work. Interest cost was determined at a market rate of 12 percent. Depreciation of tubewell equipment and masonry work was however, calculated at the rates of 10 and 3 percent respectively.

The variable expenses comprise costs of diesel, power, lubricants, spare parts repair, maintenance, and pay of the operator. The running expenses which pertained to 1974 were adjusted upwards with relevant price indices to account for any price inflation for the intervening period upto 1976. More specifically, the cost of diesel was adjusted with the index on fuel and lubricants, power consumption bill with the index of electricity and the remaining expenses with the general wholesale price index.

The production cost of tubewell water per hour was derived by deflating the total operational expenses on annual hours of operation. The cost per acre foot or per acre inch of water was estimated, on the other hand, by dividing the total expenses with volume of water delivered in these hours. Finally, the economic rent involved in canal irrigation of individual crops was determined as below:

$$ERI = \left[\frac{TC}{AI}\right]\left[WD\right] - WR$$

Where,

ERI = Economic rent in canal irrigation of an acre of a given crop

TC = Total cost of operation per annum of a given tubewell

AI = Total volume of water delivered in acre inches by the tubewell during its operation period in a year.[5]

WD = Water delta in acre inches required to mature an acre of the crop

WR = Water rates per acre for the crop.

FIXED, VARIABLE AND TOTAL COST OF OPERATION

The capital investment and operational cost of a private diesel and electric tubewell are depicted in Table 2. The total installation outlay varied with the quality of tubewell material, depth of boring and discharge capacity. A tubewell with a higher discharge level necessitates the installation of a relatively large centrifugal pump, bigger diesel engine/electric motor and longer pipes with wider diameters. This is precisely why there is a conspicuous difference in installation costs of tubewells with variable discharge capacity. However, the difference between the initial investment of 1 and 1.5 cusecs tubewells in markedly higher than the difference in the costs associated with units of 1.5 and 2 cusecs discharge capacity. The reason is that in high water table areas 1 and 1.5 cusecs tubewells are fitted with more or less the same equipment except that a centrifugal pump with enlarged impeller is used in the latter type of well. This small modification does not entail any significant difference in cost. Still another reason for the relatively smaller difference in the total investment cost of 1 and 1.5 cusecs wells is that, within a certain range, the cost of the smaller of the same two parts is higher due to difference in labour input needed to achieve precise finish.

[5]Total volume of water delivered in acre inches can be measured as:

$$\frac{(60)\,(60)\ (\text{Discharge level})\ (\text{Annual operational hours})\ (144)\ \ (12)}{(4840)\ \ (9)\ \ (144)}$$

Table 2

Total, Fixed and Current Costs in Rupees of a Private Tubewell

Cost	Diesel Tubewell			Electric Tubewell		
	1 cusec	1.5 cusecs	2 cusecs	1 cusec	1.5 cusecs	2 cusecs
Installation cost						
(*i*) Tubewell equipment	19,488	23,328	31,017	9,090	12,083	17,684
(*ii*) Masonry work	6,000	6,000	6,500	3,500	3,500	3,500
(*iii*) Non-capital expenditure	2,671	2,791	3,301	2,694	2,814	3,308
Total:	28,159	32,119	40,818	15,284	18,397	24,492
Fixed cost						
(*i*) Interest on installation cost @12%	3,379	2,854	4,989	1,834	2,208	2,939
(*ii*) Depreciation on tubewll equipment @ 10%	1,948	2,333	3,102	909	1,208	1,768
(*iii*) Depreciation on masonry work@3%	180	180	195	105	105	105
Total:	5,507	6,367	8,195	2,848	3,521	4,812
Variable Cost	13,882	11,386	16,084	8,496	10,092	10,433
Total operational cost	19,389	17,753	24,279	11,344	13,613	15,245
Sample tubewells	24	66	49	36	49	35

—*Continued*

Table 2—*Contd.*

Cost	Diesel Tubewell			Electric Tubewell		
	1 cusec	1.5 cusecs	2 cusecs	1 cusec	1.5 cusecs	2 cusecs
Total operation hours	2,956	2,179	2,728	2,390	2,335	3,200
Fixed cost per hour	1.86	2.92	3.00	1.19	1.51	1.50
Variable cost per hour	4.70	5.23	5.90	3.55	4.32	3.26
Total cost per hour	6.56	8.15	8.90	4.74	5.83	4.76
Pumpage in acre feet	244	270	451	198	290	529
Fixed cost per acre foot	22.57	23.58	18.17	14.38	12.14	9.10
Variable cost per acre foot	56.89	42.17	35.66	42.91	34.80	19.72
Total cost per acre foot	79.46	65.75	53.83	57.29	46.94	28.82

Source: Appendix A.

Fixed cost, as would be expected, rose with the increase in tubewell discharge. Although per hour fixed costs of a diesel tubewell ascended with an increase in discharge level, the difference in costs associated with 1.5 and 2 cusecs tubewells is negligible due primarily to different intensity of operation. Similarly in electric wells the fixed cost per hour has significantly been affected by the intensity of operation especially in case of those with higher discharge capacity. The variable cost per hour varied directly with the level of discharge of diesel tubewells. The positive association between the variable cost and discharge capacity is attributed primarily to the difference in the consumption of diesel, which accounts for the bulk of the running expenses, and employment of operators. Bigger tubewells run by operators were normally installed by large landowners. The variable cost of an electric well, on the other kind, increased only when discharge level rose from 1 to 1.5 cusecs and declined on its increase to 2 cusecs. The cost of power consumption was more important than any other fact in determining such a pattern of variable cost. In certain instances, the cost of spares contributed significantly to the variable cost of either form of well.

The average variable cost per hour as derived from the combined expenses of all discharge level diesel tubewells came to Rs. 5.26. It compares with Rs. 2.94 reported by the Ministry of Food and Agriculture during 1972 [15] and with Rs. 3.79 estimated by the Board of Economic Inquiry in 1965 [3]. The per hour average variable cost derived, with the same principle, for electric tubewells, on the other hand, was observed as Rs. 3.66 compared to Rs. 1.86 and Rs. 1.62 found by the above agencies. The average total cost per hour estimated on the same line as variable cost amounted to Rs. 7.54 for diesel and Rs. 5.07 for electric tubewells. During 1975, the Board of Economic Inquiry in its second study [4] reported the total cost per hour as Rs. 8.31 for diesel and Rs. 3.73 for electric units.

All the three forms of costs, fixed, variable and total cost, per acre foot were observed as negatively related to the level of tubewell discharge. By comparison, diesel wells exhibited significantly higher cost per acre foot than electric wells of equal discharge capacities. Specifically, the total pumping cost per acre foot of water of 1 cusec diesel tubewell came to Rs. 79.46 compared to Rs. 57.29 of an electric tubewell with a corresponding discharge. The total pumping cost dropped by 32 percent in diesel and by 50 percent in electric tubewells, respectively, on the increase of discharge level to 2 cusecs due principally to the economy of scale. The variable cost based on the aggregated pumpage of all discharge level diesel and electric tubewells was determined as Rs. 42.85 and Rs. 28.54 per acre foot respectively. However, the common average total cost per acre foot of water was observed as Rs. 63.65 for diesel and Rs. 39.53 for electric units.

The pumping cost of tubewell water supply has increased considerably over the years. Previously, WAPDA [20] estimated the cost of an acre foot of water as Rs. 14.49 and Rs. 20.93 for private electric and diesel tubewells. Similarly, Harza Engineering Co. [6] reported Rs. 28 as the per acre foot cost of a private diesel and Rs. 19 of an electric unit. Later, IACA [7] and Ghulam Muhammad [11], working independently, determined the same cost of Rs. 24 per acre foot of groundwater pumped by diesel and Rs. 16 by electric tubewells at private farms. The Ministry of Food and Agriculture [15] recorded

Rs. 26.69 and Rs. 17.96 as the costs to pump an acre foot of water from private diesel and electric tubewells. More recently, however, the Punjab Board of Economic Inquiry ascertained the cost of delivering an acre foot of water from diesel tubewells as Rs. 99.72 and from electric tubewels as Rs. 44.82 [4].

The relationship between various costs associated with diesel and electric tubewells may also be expressed in the form of differential ratios to ascertain the pattern of change in their costs over the years as has been depicted in Table 3. The total cost of installation of a diesel tubewell exceeded that of an electric tubewell by 28 percent in 1965 and by 74 percent in 1977. However, the operational cost alone rose from 47 percent to 61 percent for the same set of tubewells in the same period of time. It shows that over the years the cost of capital investment of a diesel tubewell has exhibited a relatively higher increase than that of an electric tubewell. The trend of relatively higher increase in capital investment than in running expenses of a diesel compared to an electric set has persisted in all the recent studies.

Table 3

Differential Ratios of Relative Costs of Private Diesel and Electric Tubewells[a]

Agency/Study		Total Cost Ratios	Total Operational Cost PAF of Water Ratios
Harza Engineering Co.	1965	1.28	1.47
Board of Economic Inquiry Punjab	1965	1.44	1.78
IACA	1966	N.A.	1.50
Ghulam Muhammad	1967	1.29	1.50
WAPDA (Mona Project)	—	1.47	1.35
Ministry of Food and Agriculture	1972	1.25	1.49
Board of Economic Inquiry Punjab	1975	1.73	2.23
Present Study		1.74	1.61

Source: Data on costs of installation and operation of tubewells were obtained from the publications referred in the table.
[a]Differential ratios are determined by dividing costs of diesel tubewell by corresponding costs of electric tubewells.

As a way of recapitulation, all the three forms of operational costs—fixed, variable and total costs—estimated in terms of per hour and per acre foot were significantly higher for diesel than for electric tubewells. During the period around 1965, fixed cost and variable cost accounted for approximately an equal share in the total operational expenses of either type of tubewell. However the recurring expenses since 1970 have outpaced the fixed cost component. A relatively higher increase in capital investment and price of diesel has caused a higher increase in running cost of diesel than electric tubewell over the years. Although the installation and operational costs have revealed a considerable increase over the year, the rise in expenses may be viewed in relation to the increases in farm price. Since both the tubewell expenses and farm product prices have witnessed increases simultaneously, although not in precisely the same proportion, tubewells operation does not appear to have been adversely affected. Although some concern has been expressed about diesel prices and its availability, supplies of fuel and lubricants have never fallen to the distressing level.

The problem of field performance of tubewells is largely unknown to the farmers. Although the performance of tubewells is expected to decline with the afflux of time, the efficiency has been recorded much below the rated level even at very early stages of their operation [2]. The main reasons of rapid decline in the efficiency of tubewells over time are the poor quality of material, unsatisfactory precision of finish and imperfections of installation. Diverse brands of tubewells components are being marketed by a variety of firms who hardly adhere to any standard specifications. It was observed in the market survey that no single firm sells a complete set of tubewell components but every firm claims the ability to assemble the entire unit. Obviously, it is done by picking up parts from other firms in the business. Such a collection of components made by diverse firms allows a possibility of imperfections. This is where instantaneous state intervention is called for the introduction of scientifically determined rigid specifications in the manufacturing of tubewell equipment. An increase in both efficiency and operational hours drives the cost per acre foot of water down. It is believed that the efficiency can improve considerably but only if rigid standards for the manufacturing of tubewell equipment are introduced and the compliance is closely watched. The quality equipment will increases the operational hours by reduction in running faults.

COST OF CROPS STANDARD IRRIGATION WATER REQUIREMENTS AND ACCRUAL OF ECONOMIC RENT

The optimum water requirements of different crops reveal wide variations depending upon the gestation period and plant growth pattern. The diversity of optimum water delta is reflected as would be expected, in the cost of tubewell irrigation. Ordinarily, the cost of water to mature an acre of a crop varies directly with its required level of irrigation water. The cost of diesel tubewell water to fulfil the standard irrigation requirements varied from a maximum of Rs. 361 for sugarcane to a minimum of Rs. 45 for oilseeds. However, the average cost of diesel tubewell water per cropped acre of the major crops considered in analysis amounted to Rs. 180. The cost of electric tubewell water to supply the same water delta, on the other hand, ranged from Rs. 224 for sugarcane to Rs. 33 for oilseeds and averaged to Rs. 112 per acre.

The amount of the economic rent earned in canal irrigation of a crop varies directly with its water delta because water rates, which constitute a basis for its estimation, do not appear to exhibit any precise correspondence with the rate of water use. For instance, water rates charged for rice using 64 acre inches of water are Rs. 16.86 whereas they amount to Rs. 16.00 for cotton that consumes only 25 acre inches of water in about the same span of crop season. Conversely, water rates for cotton and maize are different for use of the same 25 acre inches of water. A relatively lower rate of water charges in maize compared to other crops consuming the same amount of water is because its substantial acreage is raised for fodder which is harvested earlier than its grain crop. In this way maize fodder consumes less canal water than maize grain crop. As such the economic rent as represented by the difference between the tubewell water cost for surface supplies and the relevent water rates depends almost entirely on specific water delta of field crops as may be observed in Table 4. Consequently, its accrual in surgarcane and rice crops, indicating peak water requirements, is much in excess of that involved in any other crop.

More specifically, the amount of the economic rent fluctuated from a maximum of Rs. 325 per acre of sugarcane to a minimum of Rs. 45 for oilseeds consequent to diesel tubewell water cost. The average amount of the economic rent in canal *vis-a-vis* tubewell irrigation water was observed as Rs. 163. As would be expected, the amount of economic rent in each crop reduces by a significant margin when the pumping cost of electric tubewells is assumed to reflect the commercial value of surface irrigation.[6] The economic rent was recorded as varying from Rs. 198 in rice to Rs. 25 in oilseeds with an average of Rs. 94 per acre of major crops. These figures indicate a reduction in economic rent of 40 percent compared to those associated with diesel tubewell water cost.

Table 4

Cost of Tubewell Water for and Economic Rent in Canal Irrigation per Acre of Major Crops

Crop	Standard Water Delta (Acre Inches)	Canal Water Rates	Diesel Well		Electric Well	
			Cost	Economic Rent	Cost	Economic Rent
		..................Rs.				
Wheat-Maxi-Pak	18	10.40	95	85	59	49
Rice-Irri	64	16.86	339	322	211	194
Sugarcane	68	35.60	361	325	224	188
Cotton	25	16.00	133	117	82	66
Maize	25	9.60	133	123	82	72
Potatoes	40	20.00	212	192	132	112
Onion	30	20.00	159	139	99	79
Tabacco	25	16.86	133	116	82	65
Oilseeds	10	7.64	53	45	33	25

Source: Data on water delta in column 2 were obtained from the Ministry of Food and Agriculture, Planning Division, Islamabad and that on canal water rates were obtained from the Punjab Irrigation Department, Lahore. The remaining columns were computed from survey data.

The difference in the irrigation economic rent of individual crops and rotations is attributed mainly to the unresponsiveness of water rates to variations in canal water allocation. Although water rates have periodically been raised, no revision attempted to relate them with differences in water allocations or with variations in farm prices and income. Water rates as a

[6]The simultaneous existence of electric and diesel tubewells leads to the generation of economic rent to the beneficiaries of the electric set, whose access is restricted by institutional constraints, in the same manner as surface irrigation yields rent in the presence of tubewell water.

proportion of farm income have declined with the passage of time. For instance they decreased from 30 percent of net farm income in 1933-1934 to 5.8 percent in 1975-1976[7] [9, 17].

During 1964-1967, the Soil Survey Organization assumed Rs. 5 per acre foot in kharif and Rs. 10 in rabi seasons as the canal irrigation cost derived from only running and replacement expenditure [1]. These rates, which are exclusive of interest and depreciation cost of capital outlay of the canal network, increase considerably when they are worked out inclusive of these items. For example, the adjustment for the general rise in prices from 1966 to 1976 raises the above estimated cost per acre foot of canal water to Rs. 13.35 in kharif and to Rs. 28.70 in rabi. The level of canal irrigation cost per acre foot during rabi works out about the same as variable cost of water from electric tubewells found in the current study. This adjustment affords us the opportunity to have a rough comparison of the tubewell water and canal water costs.

EFFECTS OF REMOVAL OF ECONOMIC RENT

This section analyses the effects on farm sector of the removal of the economic rent accruing to canal irrigation of field crops. Theoretically, the removal of the economic rent which is the surplus over the opportunity cost of canal irrigation water is not expected to cause any change in its application by the farmers.

It may be observed from the previous diagram that as the level of irrigation charges shifts from W_r towards P_1, society captures an increasing proportion of the rent without any effect on the demand for canal irrigation.

Farming in Pakistan has profoundly been affected by climatic variations and inherent physical endowments especially irrigation water supply. Consequently, specific crops thrive in specific regions in particular rotations. Thus, the assessment of the canal irrigation economic rent in particular crops rotations may also be interesting. For this purpose, four crop rotations prevalent in most of the rice and wheat belts of Punjab have been considered. The average economic rent per acre for rice zone crop combination as indicated in Table 5 was in excess of that for wheat zone because the crops raised in the former region are irrigation intensive. In rice zone, average economic rent per cropped acre estimated with diesel tubewell water cost turned out to be above Rs. 200 in one and substantially less than this in the second rotation. However, it was above Rs. 150 in one and less than this in the other rotation followed over a wide area of the wheat zone. By comparison the irrigation economic rent per acre as estimated from electric tubewell water cost was over Rs. 100 in the rice area and less than Rs. 100 in wheat area for the same crop rotations.

However, the speed of the removal of the economic rent by increasing water rates involves more complex issues of equity, growth and efficiency of water use. In fact, any variation in water rates may be viewed from the point of view of the total environment of canal irrigation, expenses of cultivation and whether agriculture may or may not be required to contribute more to the state

[7]Net farm income during 1975-1976 was determined from estimates derived by the Planning Division for major crops raised under both irrigated and dry conditions.

Table 5

Economic Rent in Canal Irrigation Per Acre Under Important Crop Rotations
(Rupees)

Crop Rotations	Diesel Well	Electric Well
Rice Zone		
Rice-Wheat-Fallow-Maize-Sugarcane	214	126
Rice-Wheat-Potatoes-Onion-Maize	172	101
Wheat Zone		
Wheat-Cotton-Sugarcane-Maize	163	94
Wheat-Oilseeds-Cotton-Maize (Fodder) - Sugarcane	139	80

Source: Derived from Table 4.

revenue. Surface irrigation is both indispensable and all but insufficient. Its inadequancy contributes to the vulnerability of farm products to fall in productivity. Its amelioration with addition of tubewell water adds to cost of production. But the inherent inadequacy of canal water and purchase of tubewell water in increasing proportions reduce net income. Any increase in water rates that exacerbates the reasonable relationship between irrigation charges and net income is expected to impinge upon the welfare of the farm sector despite the occurrence of substantial economic rent in canal irrigation.

An excessive increase in water rates to remove the economic rent rapidly is likely to have an adverse effect on the value of land especially that which is located at the tail end of a water course. The farms at a distance from outlets have lower market value due to greater losses in surface irrigation. A significant increase in water rates is expected to be accompanied by a sharp decline in the rental as well as sale value of such lands. Under the present system of water distribution, the introduction of only a gradual increase in water rates to reduce the economic rent appears to be expedient. This is because slow increase in water rates is more effective to compell farmers to adjust their irrigation techniques that may need capital investment to avoid wasteful utilization of canal water which has also been reported to occur simultaneously with its scarcity. Moreover, a slow increase in water rates is apt to risk less political opposition.

Water rates are payable by every category of farmers and any change in them has a widespread reaction. Therefore, the course to attenuation of the economic rent needs to be treaded with full awareness of the capacity of the beneficiaries to pay enhanced irrigation charges.

A reduction in or removal of the economic rent involved in canal irrigation is not theoretically expected to affect prices of farm products. But on an increase of water rates in pursuance to curtail economic rent, farmers will be expected to shift to the cultivation of relatively high market value crops to meet high irrigation charges. Similarly, its attenuation is expected to result in the adoption of efficient land and water management practices. If an increase in water rates of canal irrigation is expected to induce the adoption of high market value crops, it is also then expected indirectly to increase the demand for tubewell water because such crops are irrigation intensive. The additional demand for irrigation will inevitably have to be met from tubewells in the face of fixed supply of canal water. The net result will be an increase in the price of tubewell water at least in the short-run. What this means is that although an increase in water rates is expected to result in improvement in water utilization and selection of crops, it is also expected to add to the cultivation expenses through indirect increase in tubewell water. Therefore, increase in water rates must take into account such indirect effects that may affect the net income of the farm entrepreneure.

The current water rates policy on indiscreminatory assessment of irrigation charges without any regard of the situation of land fails to give adequate weight to the efficiency of canal irrigation which is adversely affected on the increase of distance from water outlets. Accordingly, the occurrence of the economic rent cannot be expected to be uniform on the entire land in a water course zone. Since the soakage and evaporation losses increase with distance from the canal outlet, the amount of the irrigation water reduces successively on remote farms and thereby the size of the economic rent compared to those located close to the outlet. Therefore, the increase in water rates should ideally be differentiated with respect to distance of land from the outlet. But a uniform increase in water rates is a necessary evil. It is because the prevalent system of water allocation does not lend itself for the estimation of losses in water supply with distance from its source. Any change in the practice of water rates assessment is expected to lead to enormous confusion and, therefore, only a uniform increase in the charges of irrigation conducted from old canals appears feasible. At the same time there does not seem to be any possibility of compensating the farms away from the outlet for the conveyance losses of water supply. As in irrigation charges, any change in the allocation of water among farms at various distance from its course of delivery is expected to create serious conflicts in the farming country. As a matter of fact, certain amount of inequality in the water distribution among farms at a variable distance from the canal outlet is inevitable under the present design of the irrigation system. However, the allocation of water supply from new canals may be varied in accordance with the location of the farms from the outlet. The farms at a distance from the source of delivery may be compensated for loss of water in two-ways: Firstly, the time of water flow may be adjusted to allocate equal volume of water on all farms catered by a water course. In other words, the farms further away from the outlet may be authorized a relatively greater length of time for water flow. Secondly, the water rates may be differentiated with respective to distance. To ensure optimum utilization of irrigation water, the assessment of water rates in new canal areas may be determined by a relationship between the marginal value product of water and its marginal cost of production. The marginal cost of water supply should be derived on the basis of the operation and maintenance expenses of the canal. It should not include the interest on capital expenditure but the beneficiaries may be required to pay its cost over a specified period as is done in respect of irrigation projects in many countries of the world [9].

LIMITATIONS

The adjustment of field data on running expenses of tubewells may have introduced certain upward bias in their pumping cost. Due to the non-availability of indices for the most recent year, the adjustment of the running expenses could not be made beyond December 1976. Thus, the adjusted data for running expenses for 1976 is combined with market price data for 1977.

The other limitation pertains to water rates policy which does not furnish any precise information of weights that may be assigned to various objectives that govern the fixation of water rates. It is agreed that water rates are fixed deliberately low. To the extent water rates are underestimated, the economic rent is overestimated.

The accrual of the economic rent has been based on the volume of water allocated to crops in the irrigation system and not on its amount that is actually received by them. This is because there is no data available on actual quantities applied or any method to estimate the discrepancy in the original allocation and actual availability of water for each crop. The accrual of the economic rent is, therefore, overestimated to the extent of reduction in original allocation of water due to its percolation, evaporation and mismanagement.

CONCLUSIONS

The study sought to estimate the economic rent appropriated in canal irrigation. The economic rent has been ascertained as a residual of the value of surface irrigation at its market price derived *via* the value of tubewell water cost minus water rates.

Prior to the estimation of the economic rent the study examined the cost of production of water from a private diesel and electric tubewell. The total cost per hour was directly and per acre foot inversely related with the discharge capacity of both types of tubewells. The total puming cost per acre foot of water declined from Rs. 79 to Rs. 54 in diesel and from Rs. 57 to Rs. 29 in electric tubewells on the increase of discharge rate from 1 to 2 cusecs. However, the pumping cost of tubewells of all discharge levels was found to be Rs. 63.65 in diesel and Rs. 39.53 in electric set.

The economic rent in sugarcane and rice, heavy water delta crops, accrued at the rate of over Rs. 300 per acre and a little less than Rs. 200 when diesel and electric pumping cost was assumed to reflect the value of canal irrigation. The minimum level of the economic rent was observed to be Rs. 45 and Rs. 25 in oilseeds with respect to diesel and electric water cost. However, the average amount of the economic rent per cropped acre of major crops was estimated as Rs. 163 and Rs. 112 when the value of surface supplies was expressed in terms of diesel and electric tubewell water cost respectively.

The economic rent appropriated in rice zone crop combinations was considerably in excess of that for wheat zone rotations. The average economic rent per cropped acre estimated from the cost of diesel tubewell was above Rs. 200 in one and substantially less than this in the other rotation of the rice zone. In wheat zone, on the other hand, the economic rent hovered around Rs. 150 per acre of the two rotations followed over a wide area. The per acre economic rent of irrigation as estimated from electric tubewell delivery cost was over Rs. 150 and less than Rs. 100 for the same crop rotations in the above zones respectively. The occurrence of large economic rent in canal irrigation is primarily due to the water rates which do not vary in any consistent manner with the increase in water application.

It is concluded that canal irrigation involves substantial economic rent. Its removal appears theoretically to leave the application of irrigation water unchanged. However, its rapid removal with a large increase in water rates is expected to lower the value of especially those lands which are unfavourably located with respect to the site of water outlets. Moreover, a high increase in irrigation charges is not socially and politically feasible in the event of secularly rising prices of all agricultural inputs. To obviate a decline in the value of lands at unfavourable locations and precipitation of political opposition, a gradual increase in water rates may be introduced. While the removal of the economic rent at some modest rate appears justified in the face of excessive increase in running expenses of the existing irrigation facilities and in capital investment of new projects, a definite quantitative estimation of the increase in water rates cannot be suggested due to the characteristic complicacies on the diverse issues involved in setting irrigation charges. In this regard Falcon and Gotsch argued that, "We believe that an increase in water rates is both economically feasible and sensible. However, to say more specifically what should be done and to propose rate system towards which the irrigation department should move is extremely difficult" [5].

The most appropriate approach to remove the economic rent, however, is perhaps to revise water rates to maintain them in a reasonable relationship with net income of each crop. The critical caveate, of course, is the realistic estimation of the net income of various crops. At the same time, however, the interruptions in water flow must be minimized so that the crop revenue is not depressed by shortage of surface supplies. To make the increase in water rates mor acceptable, enlarged part of the increased revenue must be spent to improve the efficiency of the canal system.

Appendix A-1

Cost of Installation of a Tubewell with a Discharge of 1 Cusec

Item	Number	Length Dimensions	Price per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
1. Centrifugal Pump						
(*a*) Pump	1	5″ × 5	1177.00	1177.00	1177.00	—
(*b*) Accessories						
(*i*) Bends	2	5″ each	82.00	164.00	164.00	—
(*ii*) Flanges	4	5″ each	31.00	124.00	123.00	—
(*iii*) Reflux Value	1	5″	236.00	236.00	236.00	—
2. Diesel Engine						
(*a*) Engine	1	16 HP	825/HP	13200.00	—	—
(*b*) Accessories	—					
(*i*) Belt		40′	6.25/FT	250.00	—	If shaft is used then two pieces of less than 100 FT.
(*ii*) Belt nuts	16	—	2.00	32.00	—	—
(*iii*) Pulley	1	33″	8.50 each	281.00	—	Three pulleys when shaft is used, (22″-30-48″) or (22″-28″-48″) for 16-20 HP Engine.
(*iv*) Cooling pipe	1	50′	—	165.00	—	

—Continued

Item	Number	Length of Dimensions	Price Per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
(*v*) Nuts and Belts	58 with engine	—	—	288.00	288.00	—
(*vi*) Silencer pipe	1	14′	—	130.00	—	—
(*vii*) Rubber sheets	5 to 6	—	—	30.00	—	—
(*viii*) Oil set	—	—	—	46.00	—	—
3. Electric Motor						
(*a*) Motor (1400 RPM)	1	15 HP	2644	—	3044	PECO and Siemen brands are nearly two times more expensive than common brands.
(*b*) Accessories						
(*i*) Starter (MEM)	1	For (10-18 HP)	140	—	140.00	Imported Material is more expensive.
(*ii*) Switch (60 AMP)	1	,,	533	—	533.00	—
(*iii*) Electric Wiring	—	—	—	—	2000.00	—
4. Plain Pipe (M.S.)	—	(30′,6″,1/8″)	30.00/Ft.	990.00	900.00	—
5. Strainer Pipe (Coir)	—	(90′,6″,1/8″)	22.00/Ft.	1980.00		
6. Delivery Pipe (M.S.)	—	(7′,6″,1/8″)	30.00/Ft.	210.00	210.00	—
7. Bail Plug	—	5″	—	275.00	275.00	—

—*Continued*

Appendix A-1—*Contd.*

Item	Number	Length Dimensions	Price per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
8. Boring Charger	—	(130′, 8″)	10.50/Ft.	1350.00	1350.00	With Farmers own labour.
9. Engine House (Concrete)	—	(10′×10′×10′)	—	2500.00	—	Low estimate.
10. Masonry Work of Well	—	(10′, 6′ Radins)	—	3500.00	3500.00	Low estimate.
11. Engine Fitting	—	—	—	593.00	—	—
12. Motor Coupling	—	—		—	616.00	—
13. Transportation of Boring Equipment	— —	—	—	600.00	600.00	—
14. Testing Water Samples	2	—	32.00	64.00	64.00	—
15. Testing Sand Samples	2	—	32.00	64.00	64.00	—
	Total Cost of Installation			28,159.00	15,284.00	—
	Non-Capital Expenditure			2,671.00	2,694.00	—
	Cost of Tubewell Machinery and Brick Work:					
	(*i*) Capital Equipment			19,488.00	9,090.00	—
	(*ii*) Masonry Work			6,000.00	3,050.00	—

Note: If Brass filter then its cost @ Rs. 85 per foot for (90′, 6″, 1/8″)=Rs. 7,605.

Appendix A

Cost of Installation of a Tubewell with a Discharge of 1.5 *Cusecs*

Item	Number	Length of Dimensions	Price Per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
1. Centrifugal Pump						
(*a*) Pump	1	(6″ × 6″)	1401.00	1401.00	1401.00	—
(*b*) Accessories						
(*i*) Bends	2	6″ each	92.00	184.00	184.00	—
(*ii*) Flanges	4	,,	37.00	148.00	148.00	—
(*iii*) Reflux Valve	1	,,	263.00	263.00	263.0	—
2. Diesel Engine						
(*a*) Engine	1	20 HP	825/HP	16500.00	—	—
(*b*) Accessories						
(*i*) Belt	1	50′	6.25/HP	250.00	—	—
(*ii*) Belt nuts	16	—	2.00	32.00	—	—
(*iii*) Pulley	1	33″	8.50 each	281.00	—	—
(*iv*) Cooling pipe	1	50′	—	165.00	—	—
(*v*) Nuts and Belt	58 with Engine, 52 or 25 with motor	—	—	288.00	288.00	—
(*vi*) Silencer pipe	1	14	—	130.00	—	—
(*vii*) Rubber sheets	5-6	—	—	30.00	—	—
(*viii*) Oil set	—	—	—	46.00	—	—

—*Continued*

Appendix A-2—*Contd.*

Item	Number	Length of Dimensions	Price Per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
3. Electric Motor						
(*a*) Motor (1400 RPM)	1	1400 RPM/20 HP	3452.00	—	3452.00	—
(*b*) Accessories						
(*i*) Switch (60 AMP)	1	20 HP	160.00	—	160.00	—
(*ii*) Starter (MEM)	1	,,	577.00	—		577.00
(*iii*) Electric Wiring	—	—	—	—		2000.00
4. Plain Pipe (M.S.)	—	(30′,6″,1/8″)	30.00/Ft.	900.00	900.00	—
5. Strainer Pipe (Coir)	—	(100′6″,1/8″)	22.00/Ft.	2,200.00	2,200.00	—
6. Delivery Pipe (M.S.)	—	(7′,6″,1/8″)	30.00	210.00	210.00	—
7. Bail Plug	—	6″	—	300.00	300.00	—
8. Boring Charges	—	140′,8″	10.50/Ft.	1,470.00	1,470.00	—
9. Engine House (Concrete)	—	(10′×10′×10′)	—	2,500.00	—	—
10. Masonry Work of Well	—	—	—	2,500.00	3,500.00	—
11. Engine Fitting	—	—	—	593.00	—	—
12. Motor Coupling	—	—	—	—	616.00	—
13. Transportation of Boring Equipment	—	—	—	600.00	600.00	—
14. Testing Water Samples	—	—	—	64.00	64.00	—

—*Continued*

Appendix A-2—*Contd.*

Item	Number	Length of Dimensions	Price per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric	Remarks
15. Testing Sand Samples				64.00	64.00	—
Total Cost of Installation				32,119.00	18,397.00	—
Non-Capital Expenditure				2,791.00	2,814.00	—
Cost of Tubewell Machinery and Brick Work:						—
(*i*) Capital Equipment				23,328.00	12,083.00	—
(*ii*) Masonry work				6,000.00	3,500.00	—

Note : If Brass Filter then its cost @ Rs. 85 per foot for (100′, 6″, 1/8″=)Rs. 8,500

Appendix A-3

Cost of Installation of a Tubewell with a Discharge of 2 Cusecs

Item	Number	Length of Dimensions	Price Per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
1. Centrifugal Pump						
(*a*) Pump	1	7″ × 6″	1,637.00	1,637.00	1,637.00	
(*b*) Accessories						
(*i*) Bends	2	7″, 6″	108.00	216.00	216.00	
(*ii*) Flanges	4	7″, 3-6″	46.00	184.00	184.00	
(*iii*) Reflux Valve	1	7″	290.00	290.00	290.00	
2. Diesel Engine						
(*a*) Engine	1	24 HP	825.00	198.00	—	
(*b*) Accessories						
(*i*) Belt	1 to 2	40′	6.25	250.00	—	If crank shaft is used then two pieces of less than 100 Ft.
(*ii*) Belt nuts	16	—	2.00	32.00	—	—
(*iii*) Pulley	1	36″	8.25	306.00	306.00	If crank shaft then three pulleys (22′-30″-48″) are needed.
3. Electric Motor						
(*a*) Motor (1400 RPM)	1	25 HP	—	—	4,283.00	—
(*b*) Accessories						
(*i*) Switch (200 AMP)	1	For 20-25 HP	—	—	186.00	—

—Continued

Appendix A-3—*Contd.*

Item	Number	Length of Dimensions	Price Per Unit	Total Cost of Diesel Tubewell	Total Cost of Electric Tubewell	Remarks
(*ii*) Starter (MEM)	1	For 20-25HP	—	For 20-25HP	657.00	—
(*iii*) Electric Wiring	—	—	—	—	2,000.00	
4. Plain Pipe (M.S.)	—	45′, 8″, 1/8″)	45.00	2,025.00	2,025.00	—
5. Strainer Pipe (coir)	—	(120′, 8″, 3/18″)	40.00	4,800.00	4,800.00	—
6. Delivery Pipe (M.S.)	—	(10′, 8″, 1/8″)	45.00	450.00	450.00	—
7. Bail Plug	—	8″	—	350.00	350.00	—
8. Boring Charges	—	(180′, 10″)	11.00	1,980.00	1,980.00	—
9. Engine House (Concrete)	—	10′ × 10′ × 10′	—	3,000.00	—	—
10. Masonry Work of Well	—	10′, 7′ redius)	—	3,500.00	3,500.00	—
11. Engine Fitting	—			593.00	—	—
12. Motor Coupling	—		—	—	600.00	—
13. Transportation of Boring Equipment	—	—	—	600.00	600.00	—
14. Testing Water Samples	2		32.00	64.00	64.00	—
15. Testing Sand Samples	2		32.00	64.00	64.00	—
Total Cost of Installation				40,818.00	24,492.00	—
Non-capital expenditure				3,401.00	3,308.00	—
Cost of Tubewell Machinery and Brick Work:						
(*i*) Capital Equipment		—	—	31,017.00	17,684.00	—
(*ii*) Masonry work		—	—	6,500.00	3,500.00	—

Note : If Brass Filter then its cost @ Rs. 135 per foot for (120′, 8″, 1/8″) = Rs. 16,200.

Appendix B

Operational Characteristics of Different Size Private Tubewells in Punjab

		DIESEL WELL					
		Sample Tubewells	Annual Operation Days	Average Daily Operation Hours	Annual Operation Hours	Operational Cost	Adjusted Operational Cost
1.0 Cusec	Lahore Division	8	245.0	13.0	3.185	7,069	8,827
	Sargodha Division	6	224.7	10.5	2,359	11,825	14,804
	Multan Division	10	256.5	12.5	3,206	14,427	18,067
	Overall Division	24	244.3	12.1	2,956	11,091	13,882
1.5 Cusecs	Lahore Division	26	260.0	8.7	2,262	9,230	10,090
	Sargodha Division	19	266.0	8.4	1,899	7,976	10,246
	Multan Division	21	212.0	11.9	2,533	12,525	15,583
	Overal Division	66	227.0	9.6	2,179	10,173	11,386
2.0 Cusecs	Lahore Division	19	232.0	13.1	3,039	12,088	15,155
	Sargodha Division	8	198.0	10.1	2,010	13,689	17,125
	Multan Division	22	243.6	11.0	2,680	13,371	16,747
	Overall Division	49	231.2	11.8	2,728	12,838	16,085

—*Continued*

Appendix B—*Contd.*

		ELECTRIC WELL					
		Sample Tubewell	Annual Operation Days	Average Daily Operation Hours	Annual Operation Hours	Operational Cost	Adjusted Operational Cost
1.0 Cusec	Lahore Division	22	214.3	9.1	1,950	5,222	6,482
	Sargodha Division	—	—	—	—	—	—
	Multan Division	14	296.7	10.7	3,175	8,373	10,384
	Overall Division	36	246.4	9.7	2,390	6,847	8,496
1.5 Cusecs	Lahore Division	11	270.0	9.8	2,659	6,168	7,676
	Sargodha Division	12	240.8	9.0	2,179	9,097	10,391
	Multan Division	26	230.9	10.5	2,322	8,219	10,298
	Overall Division	49	242.0	9.6	2,335	8,116	10,092
2.0 Cusecs	Lahore Division	6	283.4	11.8	3,340	8,758	10,891
	Sargodha Division	6	256.6	14.3	3,669	9,463	11,756
	Multan Division	23	293.9	10.3	3,027	8,304	10,238
	Overall Division	55	285.7	11.2	3,200	8,389	10,433

Source: Appendices 4 to 9.

Figures in columns 7 to 13 represent operational cost for the final quarter of 1974 during which the field survey was conducted. These figures have been adjusted to account for the rise in prices of different components of variable cost, with reference to relevant price indices for December 1974 and December 1976 for which the indices are available to combined them with capital cost of tubewell machinery as certained with a market survey during the latter month. Diesel, electricity and the rest costs of operations were adjusted with fuel and lubricants, electricity and general wholesale price indices respectively (Statistical Bulletins, Nov. Dec., 1975 and Sept. and Dec., 1976, pp. 85 and 90 respectively).

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