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Tubewell Irrigation in the Punjab

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TUBEWELL IRRIGATION IN PUNJAB*

The purpose of this paper is to estimate the time required to irrigate an acre of land with varying tubewell installations in the East Punjab, India. This is done by estimating the brake horsepower required by various tubewell installtion under varying conditions of soil seepage, varying size of pipes and discharge with the help of engineering equations in order to allow an estimate of the time requirement for irrigation. Once the time requirement is available then it becomes possible to estimate the variable costs associated with different tubewell installations, for which no data is available. This paper tries to fill this gap.

Tubewell irrigation is of crucial importance to Punjab agriculture. About 55% of the net area sown is irrigated and out of this about 38.6 percent is irrigated either by wells or tubewells. Though the total area commanded by tubewells alone is not known, the number of tubewells used for irrigation both government and privately owned have shown an increase of over 83 percent over the period 1969-60 to 1963-64, an annual increase of some 16 percent; whereas wells run by animal power sources (mostly persian wheels drawn by camels, buffalos and bullocks) have increased only 3.2 percent over the same period an annual increase of less than 0.65 percent. Tubewell irrigation has become more feasible due to canal seepage in the state since the water table has risen substantially, and the increased use of tubewells is being recommended as a means to lower the water table. Well and tubewell irrigation is even more important for the districts of Jullunder, Ludhiana, Patiala,

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Kapurthala and Rupar which have over 70 percent of their net area irrigated under well and tubewell irrigation, while Hoshiarpur and Gurdaspur have over 55 percent of their net area irrigated under tubewell irrigation. The southwest districts of Ferozepur, Bhatinda and Sangrur are predominantly canal irrigated with over 70 percent of their net area irrigated under canal irrigation, but even there the importance of tubewell irrigation cannot be denied.[1]

Though the importance of tubewell irrigation is realized, little data is available on the costs of tubewell irrigation. No doubt the subject is complex. Even if fixed costs can be amortized over the life of a tubewell, the variable costs that are incurred in its operation are not easy to calculate since they depend upon the time it takes to irrigate an acre with a certain quantity of water--say an acre inch. The time it takes to deliver this amount of water depends on many factors such as the discharge available at the tubewell, the slope of the field to be irrigated, the loss due to seepage in the water channels and the type of soil to be irrigated. Even if tenable assumptions could be made about the loss due to seepage, the type of soil to be irrigated and the slope of the field, the discharge available at a tubewell depends upon many factors. The discharge depends upon the depth from which water has to be lifted, the diameter of the pipe used for this prupose and upon the horsepower of the electric motor or diesel engine installed. If the discharge for different sized motors and engines is known for different sizes of pipes then it would be possible, by making certain assumptions about the other factors, to know the time it takes to deliver an acre inch and hence the variable costs of irrigation.

There is a dearth of experimental data on this subject for the Punjab. A study of different water lifting devices carried out on the campus of Punjab Agricultural University is a step in the right direction. The results showed that an electric motor with a BHP of 5, lifting water 22 feet, with a 3 inch pipe gave a discharge of approximately 0.4 cusecs, while a 5 BHP diesel engine with a 2 1/2 inch pipe, also lifting the water for 22 feet gave an approximate discharge of 0.306 cusecs. However, both the pumps had a low efficiency (.35 - .38) due to the large size of engines used.[2] These data however are not enough to describe the varying tubewell irrigation in the Punjab. This paper is an attempt to construct some data from an engineering approach with a view to finding out the discharge available for different sized motors and different sized pipes in use in the Punjab.

To begin with the discharge available from an installed tubewell depends upon the depth from which the water has to be lifted. Table 1 shows four zones of the Punjab with different water levels and different depths at which the water bearing strata exist. These zones have also been shown in Fig. 1 along with a fifth zone where the underground water is unsuitable for irrigation due to salinity.[3] When a bore is sunk for a tubewell, it has to go as far as the water bearing strata to get at the underground water. Thus, the depth to which the bore is sunk determines the length of the piping to be used in constructing the tubewell and hence, the fixed costs of the sinking of the wall. Once this has been done, the water then rises to the water level in the pipe and from that depth has to be lifted by the pump and power sources. It is true that the water level varies over the year, being higher during the monsoon rains and immediately after, and then slowly dropping till it reaches its lowest level in late May during the dry season. However, for purposes of analysis an average water level has been assumed and zones A and B considered together. An average water level of 10 feet for zone A and B,

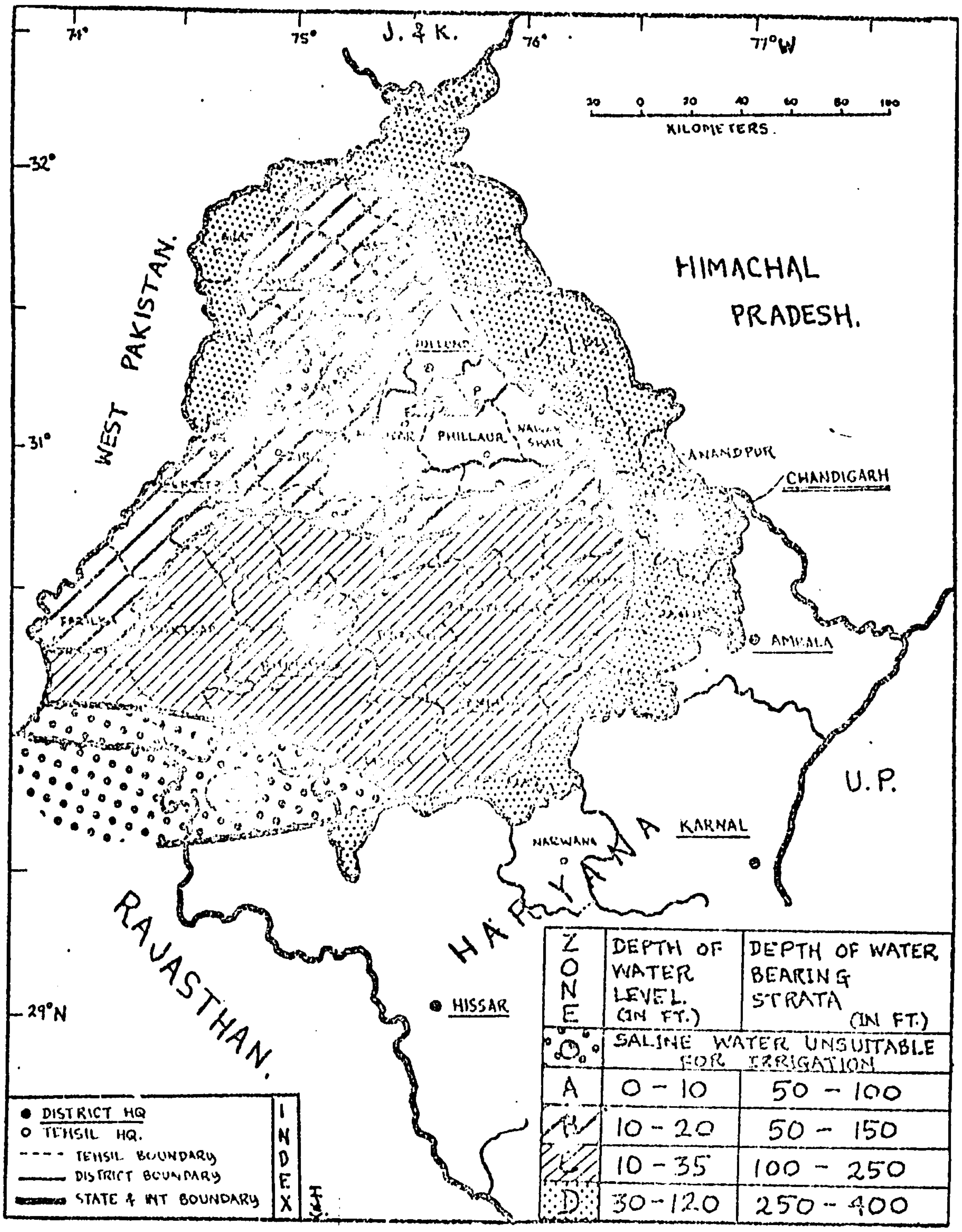

FIG.1. WATER LEVEL AND WATER BEARING STRATA IN PUNJAB.

25 feet for zone C and 75 feet for zone D is assumed. No allowance has been made for draw down.

It is the average water level that determines the depth from which the water has to be lifted and hence the discharge available. Assuming a total suction and delivery head of 15 feet for zones A and B, of 30 feet for zone C and of 80 feet for zone D, one gets the length of pipe which offers friction to the water to be lifted. This friction varies in addition to the length of pipe used, with the diameter of pipe used, with the diameter of pipe used and the discharge available. Using the formula:[4]

$$h = \frac{4.66 n^2 \ell Q^2}{d^{5.33}}$$

where:

h = loss of head due to friction (in feet)

ℓ = length of pipe offering resistance (in feet)

d = diameter of pipe used (in feet)

Q = discharge in cusecs

n = Mannings coefficient (The design value of u used here is 0.016)*

and taking the values of ℓ (15 feet, 30 feet, and 80 feet), and assuming various discharges (Q = 0.4, 0.8, 1.2 and 1.6 cusecs) and various diameters of pipe d (2 1/2 inches = 0.21 feet, 3 inches - 0.25 feet, 4 inches = 0.33 feet, and 6 inches = 0.5 feet), the loss of head due to friction was calculated and the total head (H = 1 + h) obtained for different values of d and Q for each of the three zones. Further using the formula:[5]

$$HP = \frac{62.4 \times Q \times H}{550 \times E}$$

where:

HP = The brake horsepower required to drive the pump

62.4 = Weight (in pounds) of 1 cubic feet of water

Q = The discharge in cusecs

H = Total Head (in feet)

550 = Foort lbs/second

E = Efficiency of the pump

and assuming an overall efficiency of 0.6 (60 percent) for all pumps being used, it is possible to estimate the BHP of the engines required to drive the pumps. These have been shown, along with loss of head due to friction and total head for different discharges, for different diameters of pipe for the different zones in Table 2. The BHP required has been calculated to the next half horsepower unit required.

Now if electric motors and diesel engines were abailable in continuous units (i.e., one-half horsepower units) it would be possible to work out the variable costs of irrigating an acre inch. Since it takes approximately one cusec discharge to deliver one acre inch in one hour, and since on electric motor consumes approximately 0.88 kwh/BHP* and a diesel engine consumes approximately 0.2 liters/BHP/hr. of diesel it becomes possible to calculate the variable costs of the delivery of an acre inch of irrigation. Thus, for example, an electric motor installed in zone A and B with a 5.5 BHP engine and a 3 inch pipe, lifting water an average of 10 feet would discharge approximately 0.8 cusecs, and assuming a seepage loss of 50 percent, this would mean 2.5 hours running time and a variable cost of 2.2 kwh. These can be added to any maintenance costs and with known fixed costs, the total costs per hour can be calculated. Similarly the costs of other combination of BHP and size of pipe can be worked out.

*It takes 0.746 kwh/BHP to run an electric motor, and adding another 15 percent to run the pump, the unit would consume 0.88 kwh/BHP.

In the Punjab, motors and engines are not available in continuouc BHP units so that the farmer is forced to install the next highest BHP unit available. Diesel engines are available in 5, 7.5, 15, 20, and 25 BHP units, while electric motors are available in half BHP units in the 0.5 to 5.0 BHP range, in two and a half BHP units in the 5.0 to 20 BHP range. The availability of more continuous units in electric motors along with a lower cost per hour accounts for their popularity in areas where electricity is available. However, electricity has reached only a very few rural areas and diesel engines are more commonly used for tubewell irrigation in the farm. There is also a scarcity of engines, because manufactures expecting rural electrification have been tardy in expanding their capacity.

Since the next highest available BHP units have to be installed, the problem then is to calculate the discharge available for these discrete units. For purposes of further analysis it has been assumed that units of BHP of 5 and 7.5 will be used in zones A and B, units of 5, 7.5, and 10 BHP will be used in zone C and units of 7.5, 10, and 15 BHP will be used in zone D. Again assuming an overall efficiency of 0.6 for all pumps the discharge has been worked out for the most widely used diesel engines for different sizes of pipes. Table 3 gives the discharges calculated on the basis of different total heads (H) taken from the values of H in Table 2. (The values of H assumed are the averages of values above the step line for each size of pipe and BHP used.)

Not all combinations of pipes and BHP are used. However, it should be kept in mind that the usual diameters of pipe used with an engine of 5 BHP are 2 1/2 inches and 3 inches, with 7.5 BHP diameters of 3 inch and 4 inches, with 10 BHP pipes of diameters of 4 inches and 6 inches and with a 15 BHP engine a pipe of diameter 6 inches. These are the most probable cominations in the Punjab.

Since it takes 1.008 cusecs discharge one hour to deliver an acre inch of water, the time to irrigate an acre can be calculated if one knows the depth (in inches) to be applied in each irrigation. For most crops in the Punjab, a standard irrigation can be defined as one that requires three inches of water. (The pre-sowing irrigations given to rice require nine acre inches of water, but there are only a few such exceptions to the three acre inch rule.) Allowances can be made for loss of water due to seepage for different soils. In general, the sandy soils of the south-west account for a higher loss than the loamy and clay soils of the Central and Sub-Montane zones of the Punjab, where the loss is about 30 percent.[6] Assuming a loss of 20 percent for clay soils, 30 percent for loam soils and about 50 percent for sandy soils,[7] the time required to deliver a standard irrigation has been calculated for three different levels of loss due to seepage in Table 4. It is now possible to calculate the variable costs for tubewell irrigation (in the various zones) for various tubewell installations, by multiplying the time coefficients by the variable costs of each tubewell combination in terms of fuel, oil, and repair costs per hour of operation.

FOOTNOTES

1. All data from The Statistical Abstract of the Punjab, 1965.

2. Scheme on Minor Irrigation, Part II, Project 2, Study of Different Water Lifting Devices, College of Agricultural Engineering, Annual Report 1965-66, Punjab Agricultural University, Ludhiana, pp. 28, 37, and 39.

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TABLE 1

ZONES OF WATER LEVEL AND WATER BEARING STRATA IN PUNJAB

ZONE	DEPTH OF WATER LEVEL (in ft.)	AVE.	DEPTH OF WATER BEARING STRATA (in ft.)	AVE.	TEHSILS APPROXIMATELY IN ZONE
0	-	Saline Water, Not Fit For Irrigation			west Taran Taran and Patti and east Kapurthala
A	0 - 10	5 ft.	50 - 100	75 ft.	Jullunder, Phagwara Nakodar, Phillaur Nawansher
B	10 - 20	15 ft.	50 - 150	100 ft.	Batala, Amritsar, Kapurthala, Zira, Ferozepur, north of Fazilka, Moga, Jagraon, Ludhiana, Samrala
C	10 - 35	25 ft.	100 - 250	175 ft.	South of Fazilka Moga, Jagraon, Ludhiana and Samrala Muktsar, Faridkot, Bhatinda, Barnala, Malerkota, Mansa, Sangrur, Nabha, Sirhind
D	30 - 120	75 ft.	250 - 400	325 ft.	Patiala, Rajpura, Kharar, Rupar, Garhshankar, Una Hoshiarpur, Dasua, Gurdaspur, Pathankot

SOURCE: Office of the Agricultural Engineer (Tubewells) Punjab, Ludhiana

TABLE 2

LOSS OF HEAD, TOTAL HEAD AND HORSEPOWER REQUIREMENTS

ZONE	Length of Pipe (1)	Discharge Assumed (Q)	LOSS OF HEAD (h)				TOTAL HEAD (H = h+1)				BHP REQUIRED (To the next ½ unit)			
			For d Values of											
			.21	.25	.33	.5	.21	.25	.33	.5	.21	.25	.33	.5
A and B	15 ft	0.4	10.4	4.6	1.1	0.13	25.4	19.6	16.1	15.3	2.0	1.5	1.5	1.5
		0.8	41.5	18.5	4.3	0.52	56.5	33.5	19.3	15.5	9.0	5.5	3.0	2.5
		1.2	93.0	41.5	9.5	1.15	108.0	56.5	24.5	16.2	25.0	13.0	5.5	4.0
		1.6	165.5	73.5	16.9	2.08	179.5	88.5	32.0	17.1	55	27	10	5.5
C	30 ft	0.4	20.7	9.2	2.1	0.26	50.7	39.2	32.1	30.3	4.5	3.0	2.5	2.5
		0.8	82.6	36.6	8.5	1.03	112.6	66.6	38.5	31.0	23.5	9.5	6.0	5.0
		1.2	185	83	19	2.34	215	113	49.0	32.3	49	25.5	12	7.5
		1.6	332	147	33.8	4.15	362	117	66.8	34.2	110	55	20.5	11
D	80 ft	0.4	55	25	5.7	0.7	135	105	85.7	80.7	10	7.5	6.5	6.5
		0.8	218	93.5	22.5	2.75	298	173.5	102.5	82.8	45	26.5	15.5	12.5
		1.2	490	222	50.5	6.2	570	302	130.5	86.2	130	70	30	20
		1.6	885	398	90	11	965	478	170	91	295	150	52	28

TABLE 3

DISCHARGE AVAILABLE (IN CUSECS)

ZONES	5 BHP				7.5 BHP				10 BHP				15 BHP			
	2½"	3"	4"	6"	2½"	3"	4"	6"	2½"	3"	4"	6"	2½"	3"	4"	6"
A & B	1.04	1.08	1.49	2.26	1.56	2.02	2.24	3.36	-	-	-	-	-	-	-	-
C	0.52	0.68	0.76	0.86	0.79	1.0	1.12	1.28	1.04	1.35	1.50	1.70	-	-	-	-
D	-	-	-	-	0.29	0.38	0.42	0.49	0.39	0.51	0.58	0.65	0.59	0.75	0.85	0.98

TABLE 4

TIME REQUIRED TO DELIVER A STANDARD IRRIGATION (3 ACRE INCHES) - (IN HOURS)

ZONE	LOSS DUE TO SEEPAGE (ASSUMED)	5 BHP				7.5 BHP				10 BHP				15 BHP			
		2½"	3"	4"	6"	2½"	3'	4"	6'	2½'	3'	4'	6'	2½'	3'	4"	6"
A & B	20%	3.7	3.5	2.5	1.7	2.4	1.9	1.7	1.1	-	-	-	-	-	-	-	-
	30%	4.2	4.0	2.9	1.9	2.8	2.1	1.9	1.3	-	-	-	-	-	-	-	-
	50%	5.8	5.6	4.1	2.7	3.9	3.0	2.7	1.8	-	-	-	-	-	-	-	-
C	20%	7.3	5.6	5.0	4.4	4.8	3.8	3.4	3.0	3.7	2.8	2.5	2.2	-	-	-	-
	30%	8.3	6.4	5.7	5.0	5.5	4.3	3.9	3.4	4.2	3.2	2.9	2.5	-	-	-	-
	50%	11.7	8.9	8.0	7.0	7.7	6.0	5.5	4.8	5.8	4.5	4.0	3.6	-	-	-	-
D	20%	-	-	-	-	13.1	10.0	9.0	7.7	9.7	7.5	6.5	5.8	6.5	5.0	4.5	3.9
	30%	-	-	-	-	15.0	11.3	10.3	8.8	11.1	8.5	7.5	6.7	7.4	5.7	5.1	3.1
	50%	-	-	-	-	20.8	16.0	14.4	12.3	15.5	11.9	10.4	9.3	10.3	8.0	7.1	6.2