Paper No. 137

Public Tubewells vs Private Tubewells

By

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1. General

With the advent of 20th century, the era of irrigated agriculture was ushered in by diverting large volumes of river supplies through construction of diversion structures across the rivers. The diverted waters was used for irrigation through a network of canals. All the canals were unlined and not before long, it was realised that the ground water balance had been upset. There was constant recharge to the ground water reservoir and this was resulting in gradual rise of sub-soil water table. By 1940, the water-table came within 10-15 ft in most of the irrigated areas. It was apprehended that this constant rise would pose a severe threat to the agricultural economy of the country. Further rise of water-table resulted in the appearance of waterlogging and salinity.

By 1959, the water-table had risen to within 5 ft in 1.969 million acres in Northern zone (Punjab) and 1.479 million acres in the Southern Zone (Sind) by October, 1963. For surface salinity, surveys indicated that from 1954-64, 6.43 million acres (24%) in northern zone were effected to various degrees.

2. Salinity Control and Reclamation Projects (SCARP)

In early 1960s, the Government of Pakistan embarked upon a massive programme of "Salinity" Control and Reclamation Projects (SCARPs) to combat the ever growing menace of waterlogging and salinity. It became the world's most extensive vertical tubewell drainage programme based on publically owned and

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managed tubewells. Out of 42.2 MA of gross commanded area, nearly 7.6 M.A. (18 percent) are covered by 21 SCARPs having 11,200 tubewells in FGW and 1260 Tubewells in SGW. Appendix-1 show completed tubewell Projects. This appendix also shows areas of various projects for six years (1978 to 1983) where depth to water table has been under 5.0 ft (150 cm). This table thus shows fluctuation of areas over a span of six years.

A big omission was made in these Projects while planning large capacity tubewells. The existing water courses were used to carry the combined discharge of canal and tubewell water. No provision was made in the projects to remodel the water courses to carry almost more than double the previous discharge from canal outlet. Therefore the water-courses overflowed their banks and lot of valuable pumped water was wasted. In some cases water course carried water from one source at a time and thus conjunctive use of the two sources of water was not made.

Handling of large volumes of water in unlined water courses was very difficult for the farmers. In filling reaches, breaches were not uncommon. This experience was made use of while planning tubewells in Southern zone. Maximum size of proposed and installed tubewell was not greater than 3.0 cusecs.

3. Objectives of SCARP Tubewells

The two objectives of SCARP tubewells were to control water table and increase cropping intensities. These are discussed below :

Control of Ground Water

Providing adequate drainage was a basic requirement to be met. An average water depth between 10 to 15 feet, which had generally been recommended in the project planning reports of the SCARPs, was considered to meet all the drainage requirements and water table need not be lowered below this level. However in

pareinal areas where irrigation requirement permitted water table could be maintained between 7 to 10 ft. In rice area and date gardens it could be 5 to 7 ft.

The SCARP Projects were generally planned so that the ground water reservoir was operated on a safe-yield basis, where the total tubewell pumpage did not exceed the drainable surplus recharging the aquifer. Long-term pumpage was to be limited to the aquifer reacharge only and no long-term overpumping or mining of the ground water resource was to be permitted. Occasional over pumping could be permitted however, so as to meet the irrigation requirement during a period of short canal supply. In areas with exceptionally high recharge potential, like areas adjacent to the rivers, consideration could be given to over pumping as that would increase the aquifer rechargeable storage which could be utilized, for pumping water.

In the initial stage of operation, the tubewells were to be operated for the maximum number of hours for providing drainage relief to waterlogged and salt affected areas as quickly as possible. After the water table had been stabilized at a desired level, the total pumpage was to be equivalent to the annual drainable surplus from the project, so as to control the water table at a desired level.

Increase in Cropping Intensity

Second objective was to supplement the canal irrigation supplies with tubewell water, so as to meet the crop consumptive use. The use of surface and ground water supplies of the project area was to be coordinated in order to provide adequate supply of suitable quality water at the proper time to raise future cropping intensities. The water quality criteria specified in a project Planning Report or those adopted by the Provincial Irrigation Department concerned, were to be strictly adhered to when a tubewell water was used for iririgation with or without maxing with the canal supplies. Whenever mixing of tubewell water and canal water was done, the resultant mixture was always to be periodically tested to ensure that

its quality did not exceed the specified limits.

4. Installation of SCARP Tubewells

High capacity tubewells are invariably installed with power rigs which drill holes often 22 to 26 inches in diameter and upto a depth of 400 ft. During boring the hole is kept in position by hydrostatic pressure which is constantly maintained inspite of percolation of water through the drilled formation. After drilling the hole of the required depth, the components of tubewells are lowered into it; the important ones being:

i. a bail plug
ii. strainer pieces facing water bearing formation
iii. blind pipe facing clays or low yielding medium
iv. housing pipe which surrounds the pumping set

The diameter of strainer and blind pipe is between 8 to 10 inches. The length of the strainer as a thumb rule is 50 ft. per cusec installed for medium sand. For a 3 cusec tubewell, depth of drilled holes varies from 250 to 350 ft and the lengths of strainer required vary from 150 to 180 ft. The type of strainer used in SCARP-I area is mild steel.

The outer space between the strainer and the casing pipe is filled with a suitably graded filter material called shrouding. Casing pipe is gradually pulled up after pouring the shrouding material. Shrouding is done right upto the top of the well i.e. natural surface ievel. Water brone shrouding material is best and is obtained from natural deposits in the stream beds. It should be well graded pass through ½ inch hole sieve and should be retained on 1/20th inch sieve.

Length and diameter of housing pipe varies with the discharge to be pumped. It is seamless mild steel pipe with diameters from 12 to 20 inches. The lengths

may vary from 60 to 200 ft.

A bowl assembly is suspended within the housing by a stainless steel shaft which is fitted with water lubricated bushes at every 10 ft. As the lift increases the number of bowls is increased. The lift and the discharge depend upon the diameter of the impellers of the bowl. This type of pump is called the turbine pump. The verticality of the bore hole is very important for the working of this type of pump.

The pump is connected to a hollow shaft electric motor which is placed on the top of housing. The power of the motor depends upon the discharge and the lift involved. For SCARP-I the H.P. of motor varies from 30-70 H.P.

The power regs for installation of large capacity tubewells are mostly available in the public sector.

5. Size of SCARP Tubewells

The public tubewells which have been installed in various SCARPs are bigger capacity wells ranging from 2-5 cusecs. Large capacity tubewells were preferred as it was considered economical to instal and operate bigger tubewells as compared to convensional small one cusec capacity tubewells. The following table shows various capacity tubewells in three SCARPs of Punjab:

Size of Tubewell (Cusecs)	SCARP-I No.	SCARP-II No.	SCARP-III No.
1.0	4	–	–
1.5	14	–	–
2.0	404	247	199
2.5	426	53	–
3.0	658	512	407

Size of Tubewell (Cusecs)	SCARP-I No.	SCARP-II No.	SCARP-III No.
3.5	241	56	–
4.0	263	599	496
4.5	54	43	–
5.0	5	695	533
TOTAL	2069	2205	1635

6. Cost of Large Capacity Tubewells

On the basis of market prices existing in 1983, the average cost of 3.0 cusec capacity tubewell with following specifications come to Rs. 281,400/-.

i)	Depth of bore	300 ft.
ii)	Dia of casing	18 inches
iii)	Type of Pump	Turbine
iv)	Dia of "Fibreglass" Strainer	8"
v)	Size of Electric motor	40 HP, 3-Phase, A.C. 50 Hz.

This cost did not include overheads.

7. Operation and Maintenance Cost

According to the expenditure for the year 1982-83 for SCARP-I the average figure of O&M comes to Rs. 41,568/- per tubewell. Break under the major heads is as below :–

Particulars	Expenditure of Tubewell (Rs.)	Percentage
Electric charges	32,106.00	77 %
W.C. Establishment	2,677.00	6.5%
Maintenance & Repairs	6,777.00	16.5%
TOTAL:	41,568.00	100 %

This cost did not include expenditure of regular establishment which was about 27% of the direct O&M Cost. Based on 3000 hours of operation of a 3 cusec SCARP Tubewell, the calculated cost per annum came to Rs. 49,500 without depreciation and component of regular establishment. A utilization factor of 35% gave 3000 operation hours per annum.

8. Life of a SCARP Tubewell

Tubewell life about which there has been much discussion in the past is of major importance in projecting and comparing costs of pumped water. In the late 1950's some estimates suggested an average life of 40 years for a SCARP tubewell; later as more experience was gained this estimated average was reduced to 30 and then to 20 years. The present experience has set 12 years as the average life of a SCARP tubewell.

One of the major difficulties in arriving at a meaningful figure for average life is to reach consensus on criteria for deciding when the useful life of a tubewell has ended. If a tubewell fails suddently, the termination of its life is evident. If, however, the discharge and specific capacity[1] of a tubewell decline gradually, as is the case with most SCARP tubewells, at what point should its useful life be con-

1/ Discharge per foot drawdown of a tubewell.

sidered to be complete. According to the critetion fixed by the Irrigation Department, the operation and maintenance of a tubewell becomes uneconomical when the specific capacity[1] or discharge deteriorates to about 50% of the designed value. On this basis, from the available data, the average useful life of a tubewell comes to 12 years. This is also confirmed by a statistical analysis which was carried out in 1974 by the Superintending Engineer SCARP-I Circle. Therefore, for economic analysis average useful life of a tubewell has been taken to be 12 years. Another approach of regression analysis which is given in Appendix 2 has been used.

9. Evaluation of SCARPs Tubewell Performance

A monitoring programme of SCARP tubewells was initiated by WAPDA in 1966 and is being continued to date. The monitoring was mainly concerned with control of waterlogging and salinity, groundwater pumpage and behaviour of water logging and salinity, groundwater pumpage and behaviour of water table, water quality, tubewell performance, availability of water for irrigation and its effect on cropping intensity. It was found that the dual objective of control of waterlogging and increase in cropping intensity had been achieved but not to the extent envisaged in the Project. It was also found that the SCARP concept through sensible in theory and beneficial in numerous ways did not function satisfactorily for the following reasons.

a. public resources were not available to finance efficient operation and maintenance, and replacement of tubewells;

b. pricing policies were not introduced for SCARP tubewell water to promote efficient water use;

c. provision was not made for efficient distribution of the tubewell water within the chak;

d. full advantage was not taken of the potential for operational flexibility of tubewells to meet crop water requirements; and

e. centralised management of large batteries of tubewells did not function

satisfactorily for various reasons.

f. the machinery of public tubewells is sophisticated for which adequate maintenance and repair facilities are not available in the private sector.

10. Disastrous Areas

The disastrous area has been defined as the area where water table depth during summer is 0-5 ft. The extent of such areas as shown in the Sixth Five Year Plan in the three Provinces is as below:

Province	Disastrous Areas (M.Acres)	
	Summer	Winter
Punjab	0.558	1.090
Sind and Baluchistan	0.149	0.443
N.W.F.P.	0.039	0.049
TOTAL	0.746	1.582

11. Strategy in the Sixth Five Year Plan

The general strategy for controlling waterlogging and salinity during the Sixth Plan period is as below:

i. Instead of reclaiming large gross commanded areas, emphasis would be laid on the disastrous areas where water table is within 5 ft in summer.

ii. Most of the on-going projects on Fresh Ground Water (FGW) zone would be completed as originally conceived.

iii. The reclamation of FGW where cultivation of crops is possible, would be left to the private sector.

iv. Private sector would also be encouraged to reclaim the disastrous areas.

v. For (iii) and (iv) above, the private sector would be encouraged to install private tubewells by providing closely spaced electric grid, advancing loans and giving credit and subsidy facilities.

This shows that private tubewells have to play important role during Sixth Plan Period.

12. Private Tubewells

In the past private tubewells have played an important role in the exploitation of fresh ground water. This is evident from following tbale which has been taken from the Sixth Five Year Plan.

PUBLIC AND PRIVATE TUBEWELLS

	Type of Tubewells	No. of Tube-wells	Average designed capacity (cusecs)	Opera-ting Effici-ency (%)	Deli-very Losses (%)	Estd. Annual Pumpage per T.W. (A.F.)	Total Annual Pumpage (MAF)
1.	Private Tubewells	181,200	1.05	20	5	145	26.3
2.	SCARP Tubewells (FGW)	12,608	2.0	50	15	615	9.4
3.	Public Irrigation Tubewells	1,569	1.5/1.0	50	15	416/ 307	0.6
	TOTAL:	195,377	—	—	—	—	36.3

This table shows that about 72% of pumpage from ground water in F.G.W. is being

done by the private tubewells. Greater emphasis has been laid on installation of private tubewells in the Sixth Plan period. Therefore various aspects of this category of tubewells are discussed below in detail.

13. Design Features

The design of a private tubewell is based on experience and judgement. No consideration is given to aquifer constants and size and gradation of its materials. The design features of private tubewells are practically the same from the northern part of the country to its southern part.

A brick lined sump (sometimes it is unlined) usually 8-10 ft dia is excavated to get closer to the water-table. A bore is then drilled with percussion rigs which in general are manually operated. Sometimes power winches are used to operate the rigs. Normally, the dia of the bore is 8" but sometimes it is 10 inches if a filter of 8" dia is to be used. Boring is done to a depth of 110-150 ft. Filter is lowered inside this bore with length ranging from 100–128 ft. On the top of the filter blind pipe 20–30 ft long is fitted.

A vast majority of farmers (about 70%) use coir rope strainer. This consists of coir string woven over a cylinderical cage. Now P.V.C. filter is becoming more popular because of their longer life.

Private tubewells are exclusively designed for operation with centrifugal pumps. In case of electric tubewells, the pumps are generally directly coupled to the pumps. For diesel engines belts have to be used.

Both diesel and electric motor driven pumping units are being used. Out of a population of about 200,000 shallow wells in private sector electric prime movers power about 40% of installations. The farmers prefer to have electric tubewells due to high cost of diesel oil.

14. Cost of Installation

(a) Electric Tubewells

The cost of installation of a one cusec electric tubewell on the basis of cost of materials in 1983 is about Rs. 90,000/-. The cost of tubewell installation is about Rs. 38,000/- and of electric connection is Rs. 42,000/-. Details are shown in Appendix 3.

(b) Diesel Tubewell

The cost of a diesel tubewell is about Rs. 50,000/-. Details given in Appendix 4.

15. Operation and Maintenance Cost

a) Electrically Operated Tubewells

During 1984, the applicable WAPDA Tarrif for private tubewells was as below :

a)	Fixed charges	=	Rs. 19 per kW per month
b)	Charges for electric consumption	=	Rs. 0.23 per kWh
c)	Fuel Surcharge	=	Rs. 0.12 per kWh
d)	Electricity duty	=	4% of actual energy cost
e)	Meter rent	=	Rs. 5.00 per month

On the basis of 20% utilization and the power terrif given above the annual Operation and Maintenance charges of 1 cusec tubewell amount to Rs. 7850/- for 10 H.P. motor without depreciation (See Appendix 5).

b) Diesel Engine Operated Tubewell

b) **Diesel Engine Operated Tubewell**

For working out the operation and maintenance, cost of a diesel operated tubewell, the following data have been used :—

H.P. of diesel engine	=	15
Price of light diesel oil	=	15.00 per imperial gallon

The installation cost of a 1.0 cusec diesel tube well is Rs. 50,000/- and total annual operating cost comes to Rs. 26830/- without depreciation. The cost of diesel fuel used per year is Rs. 15830/- it means that operating cost of a diesel tubewell is about 4 times the cost of electric tubewell.

The details are given in Appendix 6.

16. Fractional Shallow Tubewells

Fractional tubewells are defined as facilities designed and constructed for yields of less than 1 cusec. Such units have applications for farmers cultivating less than 20-30 acres who do not have the opportunity of water selling. Such facilities have attracted considerable interest at Government level on the basis of potential cost savings, but wells designed and equipped for yields of say 0.5 cusec do not appear to have attracted much interest among the farmer/investers.

The fractional shallow tubewell is essentially a scaled down version of certain elements of the typical 1.0—1.5 cusec private well. The basic design and construction technology remains the same for both well types. While significant capital and replacement cost savings could be made by installing fractional wells on small farms, these are not as large as might be expected because only the drilling, tubular components and pump size can be scaled down, while such elements as the power connection, sump and pump house remain about the same for both well capacities.

The elements which could be scaled down for fractional wells and their suggested sizes are summarised below :—

a) Bore diameter—this could be reduced to 5—6 in. diameter as against 8—10 in. diameter for standard shallow wells;

b) Bore depth—the well depth could be reduced by 20% of the depth of a standard well;

c) Tubular components—the casing and screen could be of 3—4 in. diameter compared to the 5—6 in. diameter of standard well.

d) Pump unit—reduction in the pump discharge capacity would also imply a smaller motor; 5 HP electric motors or 7.5 HP diesel engines would often be adequate for 0.5 cusec discharges. Smaller diameters of suction and delivery pipe work could be used (2 in. and 3 in. diameter respectively). A direct on-line starter relay could be installed.

Significant capital and replacement cost savings could be made by installing fractional tubewells on small farms. In the case of electric motor powered pumps, there would be also a significant energy cost saving due to the lower fixed charge on the lower installed capacity of prime mover. Appendix 7 gives cost estimates for an 0.5 cusec shallow tubewell equipped with either an electric motor or deisel engine pump. The well is assumed to be 110 ft deep and a 10 ft deep sump and a pump-house is provided.

Type of 0.5 cusec Tubewell	Capital Cost
Electric motor Tubewell	Rs. 54150.00
Diesel Engine Tubewell	Rs. 36650.00

17. Potential for Fractional Tubewells

Every farmer would like to have his independent source of water supply so that he could irrigate his fields according to his convenience in normal as well as water stress periods. This is more true in case of small farmer who has to eke

out his livlihood out of the limited land sources. He never ventures to install a small tubewell (fractional) because of his inadequate financial resources. He obtains water from other tubewells either on cash payment or on crop sharing basis. However, if facilities are made available to him to own a small tubewell, he wuld welcome it.

For fractional tubewells electric motors of 5 to 7 HP would be required. Motors of such capacity are not being manufactured on commercial basis as there is no demand for them. However, there is enough manufacturing potential in the country and small capacity motors can be produced locally tomatch the demand.

It would not be possible to provide electric connection to all the fractional tubewells. Therefore a good proportion may have to depend up the diesel engine operated tubewells. Diesel engines of 7.5 to 10 H.P. rating would be required fro such tubewells. Some noted firms like PECO, Ittefaq are manufacturing high speed diesel engines of 7.5 H.P. to 10 H.P. About three years ago 10–12 H.P. diesel engines were imported from China. These are very popular among the farming community. Therefore, PECO has started manufacturing them under a licence from the Chinese makers.

18. Comparison of O&M Costs

Comparison of cost of operation of 3 cusecs, 1 cusec and 0.5 cusec tubewell has been set up in the following table without depreciation. This shows that the cost of pumped water becomes expensive as the size of the tubewell becomes smaller. Besides operational cash of a diesel tubewell is more than that of electric tubewell.

Cost	3 Cusecs	1 Cusec		0.5 Cusec	
	Electrical	Electric	Diesel	Electric	Diesel
Per A/ft.	97/-	150/-	237/-	173/-	279/-

19. Advantages of Small Capacity Tubewells

a) No Shrouding Required

Tubewell is constructed without shrouding. It is estimated that about sixty to seventy percent quick decline in yield of a big capacity shrouded tubewell is due to the improper use of shrouding material. The Indus formation is highly stratified so that thick layers of one grade do not exist. the stratified deposit consists of very fine sand (particles size 0.15 to 0.2 mm), fine sand (particles between 0.2 to 0.25 mm), medium fine sand (particles between 0.25 to 0.35 mm), usually attempt is made to install a long piece of strainer as putting in a small pieces is not practicable. A long strainer thus very often faces all grades of sands. The shrouding commonly used has a diameter of 3 to 4 mm, with uniformity coefficient equal 2.5 to 3. Pouring of this materials through 200 to 300 hundred feet of water column results in segregation of various grades of the shrouding material. During pumping particles of fine sand enter the pores of shrouding thus reducing its permeability. This is a serious cause of quick fall in discharge of high capacity tubewells. Since no shrouding is used for small capacity tubewells, the above mentioned defect does not occur.

b) Draw-down is Smaller

A high capacity tubewell of 3 to 5 cusecs operates with a depression increasing to 30 to 50 feet resulting in low suction pressure. Due to low suction pressure, Carbon Dioxide is released from the water and changes bicarbonates into insoluble carbonates which deposit around the shrouding. With greater draw-down, lower suction pressure results in quicker conversion of bicarbonates to carbonates, thus incrustation of shrouding material begins. For small capacity tubewells drawn-down limited to 8 to 12 feet. Their suction pressure is lower than that of high capacity tubewells. Thus a farmer's tubewell is not faced with the problem of incrustation. If multiple strainers are added to a low capacity tubewell, the depression head further decreases although the discharge increases. This type of tubewell has a still

lower chance of carbonates incrustation.

c) Groundwater Quality is better

Deeper groundwaters are usually inferior. A shallow groundwater constantly receives fresh water recharge from the irrigation supplies and other surface sources. A deep tubewell can pump inferior water causing deterioration of the pumped water. For this reason it is being apprehended that after some years the groundwater will become so saline that its export will become necessary.

A shallow tubewell has a greater chance to draw surface percolation. There are cases when the shallow groundwater has continued to improve in quality. It intercepts surface fresh water recharge and the groundwater quality tends to improve rather than deteriorate.

d) Lessir Mechanical Troubles

The bowls of a turbine pump are operated by a long shaft which is supported by bushes or bearings every ten feet. A damage to any of the bearings can cause trouble. All components of a turbine pump are invisible except the motor. Pumping set cannot be taken out easily for examination. Therefore, it remains in the well for years and is taken out when a serious trouble starts. Damaged bearing,s eccentric rotation of the bowls damage the tubewell. A centrifugal pump in comparison has only one or two bearings, and its components are visible. Any eccentricity or defect in allignment of the bushes can be noted and rectified.

d) Better Resistance to Bacterial Action

Although coir rope strainer has been used extensively yet very little research has been conducted for its improvement. According to common experience a coir string strainer lasts on the average for about four to seven years. The usual failure

is due to damage or decay of the string. No experiments to strengthen the string and protect it from damage have been carried out.

Bacteria is one of causes for encrustation of tubewell. Strainer with coir string can easily be treated with chemicals such as copper sulphate etc., to prevent growth of bacteria.

f) **Easier Extraction**

Each tubewell is provided with a bail plug. The idea is to pull out the components of a tubewell when requird. There are greater chances for safe extraction of strainer of a shallow tubewell from 100 to 150 ft. depth and its reuse. This is not possible in case of a deep tubewell. There has been practically no success with extraction of SCARP tubewells particularly those having strainer and blind pipe of Fibreglass. The latter may be in perfactly good order but it cannot be pulled out an reused.

g) Lesser Power Consumption

The H.P. of a motor depends upon the discharge and the lift involved in pumping water. For a high capacity tubewell with the decrease in discharge and the increase in depression the power input remains nearly the same. Thus a SCARP tubewells showing quick deterioration consumes extra power uselessly. According to general experience small capacity tubewell with coir string strainer does not show such excessive decrease in discharge or increase in depression head during its life time. There is thus less wastage of energy as compared to a turbine fitted high capacity SCARP tubewells.

h) **Farmer's Preference**

Every farmer, who can afford likes to have an independent source of water so

that he can supplement his water needs according to his crop water requirement. He can easily afford to install a small capacity tubewell.

20. Interference between two Tubewells

When a tubewell is operated and it draws water from the ground water storages it develops a cone of depression around it. The shape and size of cone of depression is a function of aquifer characteristics. Under stabilised conditions, the draw down and radius of influence of a one cusec tubewell are generally in the range of 4 to 6 ft per cusec and 800 to 1000 respectively.

This information is very valuable for the farmers, because sometimes they locate tubewells very close to each other and then lose certain amount of discharge due to mutual interference of tubewells. The following tables can serve as guide for 1.0 cusec and 1/2 cusec tubewells.

(a) **1 Cusec Tubewell**

i.	Spacing in ft	250	500	750	900
ii.	Estimated discharge when both wells operate	0.86	0.93	0.98	1.00
iii.	Percentage reduction	14	7	2	–

(b) **1/2 Cusec Tubewell**

i.	Spacing in fts.	250	500	650	900
ii.	Estimated discharge when both wells operate	0.41	0.44	0.455	0.47
iii.	Percentage reduction	13	6.4	3	–

From the above example it is clear that for :

i) One cusec tubewell, the distance between the two tubewells should not be less than 750 ft.

ii) Half cusec tubewell, the two tubewells should not be located closer than 650 ft.

21. Life of a Private Tubewell

The life of a private Tubewell is estimated to be 5 to 7 years with Coir Rope Stainer. However this life is shorter for electricaly operated tubewell and longer for the diesel operated tubewell. The reason for this difference is that there is control on the spead of diesel engine. When a diesel engine is started its revolvetion per minute are almost half of the revolvtion at which it is normally operated. The speed of the engine is gradually increased. The result of this gradual speed is that there is no sudden suction effect on Coir rope stainer. With the electric motor, the pump attains the maximum speed of 1400 revalutions per minute in less than a minute. Therefore there is sudden suction affect on the stainer of electrically operated tube-well.

So long as the Coir Rope is strong enough to withstand the sudden suction affect, the stainer is working normally and there is no reduction in the discharge. However, when the Coire rope loses its strength particularly if the coconut fibre has been mixed with some inferior fibre such as of reed, the coir rope cannot with stand the sudden suction affect and starts disintegrating. The life of the stainer with electrically operated motor can be increased if a gate volve is fitted on the delivery side, when the motor is started the volve should be closed and after the motor has attained its maximum speed, it should be gradually opened. In this way, the damaging effect of sudden suction can be mitigated.

The P.V.C. Stainer is giving much better life and in some cases it is satisfactorily operating for 10 to 12 years. Therefore, the P.V.C. stainer, although somewhat costly is becoming very popular with the farmers.

22. Skimming Wells

In areas like SCARPS where a limited thickness of fresh groundwater is underlain by predominently saline water exploitation of the ground water resource is often constrained by ground quality problems. Generally the fresh water floats over saline water but in some cases, the interface is reflected by a gradual change from fresh water to saline water. If the fresh/saline interface is deep enough below tubewell screen, an equilibrium is reached when pumping is done so that the saline mound does not intercept flow into the tubewell and fresh water continues to be pumped. On the other hand if the interface is shallow the saline mound will intercept into the tubewell and then mixed water would be pumped up.

The water quality in SCARP areas has been well monitored and the trends of water quality are known with acceptable accuracy. In most cases it has been observed that water quality at shallow depths is fit for agriculture and it deteriorates with depth of groundwater. It is therefore desirable that in SCARP areas shallow private tubewells should be installed to pump out water fit for agriculture and installation of deep tubewells as has been done at present should be avoided. Such tubewells which pump out shallow water are called skimming wells. The farmers are already aware of this technique and have successfully installed skimming wells close to the canals to pump fresh water in areas where ground water is very saline and unfit for agriculture.

A practical approach for a skimming tubewell is to design a well for pumping fresh water so that upward distortion of the flow line from the underlying salt water zone does not intercept the screened section. The most critical area is below the immediate vicinity of the well where draw down is maximum and upconing of saline water is liable to occur. This implies that a skimming well should minimise draw down to acceptable limits and its screened length penetration should leave a buffer zone of fresh groundwater aquifer above the sline zone to absorb any upward deflectin of flow of saline water. As a thumb rule, the skimming well would normally

be successful if the screen penetration does not exceed two thirds of the fresh water aquifer thickness.

In order to reduce the draw down, it has been suggested that a group of two or three shallow wells can be linked to one suction point. This is theroatically correct but in practice this design has to be proven. The success of such skimming well may be greater in higher permiable aquifers where the cone of depression is very flat an the interference effects of closely spaced tubewells is not greater. It would be desirable to instal such multiple strainer tubewells in saline areas at a few sites on experimental basis.

23. Solar Powered Pumps

Introduction

Solar power technology has recently been developed for pumping water for small scale irrigation, water supply and livestock watering. However, the discharge and head of the units developed so far is very limited. It compares favourably with the discharge of a Persian wheel. The solar energy replaces the pair of bullocks used for lifting water from an open well. The usual discharge of a well worked by Persian wheel is about 0.15 cusecs or 4 litteres/Sec for a lift of 10 to 15 ft.

Available Literature

The available literature on this technology was collected from M/s. KSB Pumps Company Limited, Lahore and Pakistan Agricultural Research Council, Islamabad. A Solar pumping unit model SEI-15 produced by the Solar Electric International, Washington DC USA was supplied to the Pakistan Gricultural Council, Islamabad in September 1979 for demonstration, testing and evaluation purposes. The descriptions and specifications of this pumping unit are as below :—

(a) **Pumping Unit**

The pumping unit consists of a array of photo-voltaic cells connected to a submersible motor directly coupled to a centrifugal pump designed to operate over a lift range of 2-5m to give a discharge of about 3500 gallons per hour or -.15 cusecs.

(b) **Photovoltaic Array**

The key component of photovoltaic cell is the array of cells which convert sunlight directly to direct current electricity. The cells produce 240 peak watts at about 120 volts.

(c) **Maximum Power Tracker (M.P.T.)**

It automatically selects the optimum operational points of the array to maximize water output.

(d) **Pump Set**

It consists of 1/3 H.P. permanent magnet type, D.C. motor 3000 RPM at maximum operating speed, sealed in submersible casing with high efficiency centrifugal pump.

Results of Study

The study on the Solar pump was carried out by the Research Council for eight months 9/79 to 5/80. The main conclusions drawn from the study are as below :—

1. The Solar unit can be installed for pumping water from open wells, streams, canals, ponds etc., where the lift is from 2 to 5 meters.

2. This unit can provide irrigation to about 2 hecters (5 acres).

3. The maintenance and running cost of the unit is practically nil.

4. The efficiency of the unit is affected by heat i.e. it is reduced.

5. The effective period of operation of the unit is from 8.00 AM to 4.00 PM.

6. Watertightness of the unit needs improvement.

7. The pin connecting the pump with motor is week and breaks down frequently.

8. The lift range has been about 3.5 meters and never reached the figure of 5 meters.

Suggestions

1. The present cost of the unit is Rs. 50,000. This is very high and beyond the reach of small farmers.

2. The discharge of the pump should be about 7 liters/Sec or 0.25 cusecs and the lift range should be 5 to 8 meters. Thus the unit would be very useful for small farmers of 8-10 acres.

3. Research on solar pumps is in progress and it is possible that capital cost is reduced so that smaller farmers can avail of this technique.

SCARPWISE 0–15 CMS. (5.0 FT) DEPTH TO WATER TABLE (APRIL/JUNE)

000 Hectares (0.405 hect = 1.0 acres)

SCARPS	Area G.A.	First year of DTW observation	1978	1979	1980	1981	1982	1983
1	2	3	4	5	6	7	8	9
		A. COMPLETED TUBEWELL PROJECTS						
PUNJAB								
I	492.5	66.7 (1961)	6.1	15.8	5.7	19.8	44.1	26.0
II (F.Z)	667.3	73.2 (1964)	59.1	99.1	43.7	45.7	108.9	100.0
II (S.Z)	279.2	58.3 (1980)			58.3	51.8	75.3	100.0
III (F.Z)	460.5	189.7 (1969)	88.2	128.3	105.6	119.0	59.1	67.0
III (S.Z)	57.5	38.0 (1976)	36.8	36.4	29.9	29.1	34.4	38.0
IV (F.Z)	225.8	0.4 (1969)	0.0	0.4	1.6	0.4	0.4	0.4
Satiana PP	47.8	6.9 (1976)	5.3	10.5	2.8	12.5	39.7	4.0
Shorkot-Kamalia P.P	68.4	6.5 (1976)	6.5	2.0	2.4	2.8	2.0	1.0
Allahabad P.P	87.4	40.1 (1979)		40.1	16.6	17.8	20.6	21.0

SCARPS	Area G.A.	First year of DTW observation	1978	1979	1980	1981	1982	1983
1	2	3	4	5	6	7	8	9
Minchinabad P.p	31.6	0.0 (1979)		0.0	0.0	0.0	0.0	0.0
Shahpur	45.3	7.7 (1980)			7.7	8.9	4.9	4.0
N.W.F.P.								
Peshawar	41.9	15.8 (1976)	11.3	11.7	11.3	13.8	10.9	15.4
Mardan-I	50.2	5.7 (1980)			5.7	15.4	10.9	15.0
Bannu-I	36.4	1.2 (1980)			1.2	2.0	4.5	4.0
SIND								
Khairpur	178.5	53.0 (1960)	34.0	32.8	27.9	54.2	100.4	68.8
North Rohri	320.9	3.6 (1976)	2.0	2.4	0.8	2.8	10.1	10.1
Shikarpur PP	7.1	0.16 (1977)	0.20	0.28	0.20	0.40	0.28	0.16
Larkana P.P	3.16	0.45 (1977)	0.53	0.12	0.20	0.20	0.40	0.27
Sukkur P.P	1.6	0.0 (1977)	0.0	0.0	0.0	0.0	0.0	0.0
Kandkot P.P	3.6	0.0 (1980)			0.0	0.01	0.16	0.03
Sukkur R.B	61.1	4.9 (1980)			4.9	7.3	6.5	6.1

APPENDIX – 2

INSTALLATION

Cost of

1-Cusec Electric Tubewell (Private)

(150 ft deet)

A. TUBEWELL INSTALLATION:

1.	Bore drilling 140 ft 8" dia @ Rs. 40/- per foot		5600.00
2.	Construction sump 10 ft dia and 10 ft deep with masonary lining and concrete floor	L.S.	6000.00
3.	Supply and installation of M.S. casing 6" dia 40 ft @ Es. 50/- per foot		2000.00
4.	Supply and installation of Coir Rope Wound Strainer 6" dia 110 ft @ Rs. 45/- per ft		4950.00
5.	Well cleaning		500.00
6.	Electric pumping set on common bed plate with control switches		9000.00
7.	Fitting charges for the pumping set	L.S.	1000.00
8.	Miscellaneous hardware, bends, valves and bail plug.		1000.00
9.	Transportation		500.00
10.	Delivery pipe discharge box and pumphouse link water course		5500.00
11.	Electricity installation wiring inside pumphouse		500.00
12.	Priming arrangement		500.00
		Total Rs.	37450.00

B. ELECTRIC CONNECTION

1.	0.5 Km 11 kV line upto Transformer (Gopher) @ 54600/- per km	27300.00
2.	Transformer with fittings	20000.00
3.	L.T. Connection with energy meter	3000.00
		87750.00
	Add contingencies L.S.	1700.00
		89450.00

APPENDIX - 3

ASSESSMENT OF LIFE OF SCARP TUBEWELLS

It has been assessed that the operation and maintenance of tubewell becomes uneconomical when the specific capacity or pumpage deteriorate to about 50% of the designed value. In the absence of detailed information about particular tubewells/site is not possible to determine the average productive life of a public tubewell. In order to resolve the issue, the group data about the reduction in specific capacity and pumpage based at projects level has been analysed and regressed against time under linear relationship assumption of :–

$$Y = a + bx$$

where, Y = Value of discharge or specific capacity at time X after inception

a = Discharge or specific capacity at base year (Intercept of Y-axis).

b = Slope of the line.

x = Time after inceptions (in years)

The missing information in the data was computed through interpolation.

(A) PUMPAGE

Regression Analyses done on the available data of the SCARP Tubewells pumpage in SCARPs I, II & III show a general decline with time. Taking the inception year of a SCARP Project as 100%, discharge, the slope of regression line is negotives. Table 1 shows the values of parameter 'a' & 'b' against particular SCARP for pumpage.

TABLE - 1

Name of SCARP	Value of 'a'	Value of 'b'
I	94.45	– 3.05
II	97.8	– 3.56
III	98.82	– 5.07
Total =	291.07	– 11.68
Mean =	97.02	– 3.89

The resultant equation for percentage pumpage (Y) after time x in years therefore is :–

$$Y = 97.02 - 3.89\ x$$

Accordingly the average pumpage of group of SCARP tubewells after 12 years works out to be 50.34 percent of the designed value of the pumpage. In other words the pumpage of group of tubewells shall reduce to 50 percent capacity in 12.09 years.

(B) SPECIFIC CAPACITY

The results of similar analysis done on the reduction of specific capacity are given in Table 2 below :–

TABLE - 2

Name of SCARP	Value of 'a'	Value of 'b'
I	97.63	– 3.78

Name of SCARP	Value of 'a'	Value of 'b'
II	95.82	– 4.23
III	102.90	– 2.91
IV	97.71	– 5.44
North Rohri	98.90	– 5.10
Total =	492.96	– 21.51
Mean =	98.59	– 4.30

The resultant equation for percentage of specific capacity Y after time X in year after inception is : –

$$Y = 98.59 - 4.30\ x.$$

Accordingly the average specific capacity of SCARP tubewells after 12 years shall be 46.99 percent of the designed value. In other words the specific capacity of group of tubewells shall reduce to 50 percent in 11.30 years.

From the above it can be concluded that the average productive life of public tubewells system is about 12 years.

APPENDIX - 4

INSTALLATION

Cost of

1-Cusec Diesel Tubewell Private)

			(150 ft.)
1.	Bore drilling 140 ft. @ 40/- per foot.		5600.00
2.	Construction of sump 10 ft. x 10 ft. with masonary lining and concrete floor.	L.S	5400.00
3.	Supply and installation of M.S. Casing 6" dia: 40 ft. @ 50/-		2000.00
4.	Supply and installation of coir rope wound strainer 6" dia 110 ft. @ 45/- per foot.		4950.00
5.	Well Cleaning	L.S	500.00
6.	Diesel pumping set with 5" x 6" C.F. pump, belt drive and pulleys		20000.00
7.	Fitting charges for the pumping out	L.S	3000.00
8.	Miscellaneous hardware, bends and value		1000.00
9.	Transportation		2000.00
10.	Delivery pipe discharge box and pumphouse and link water course		6000.00
	Total Rs. =		50450.00
	Say Rs. =		50000.00

APPENDIX - 5

OPERATION COST
of
1-Cusec Electric Tubewell (Private)

DATA

1.	Horse Power/kw of motor	=	10/7.5
2.	Working hour/year	=	1750
3.	Electric Tarrif		
	(a) Fixed charges @ Rs. 19/- per kw per month		
	(b) Energy charges @ Rs. 0.23 per kwh		
	(c) Fuel Surcharge @ Rs. 12/- per kwh		
	(d) Duty @ 4% cost of energy		
	(e) Meter Rent Rs. 10/- per month		
4.	Cost of Pumping	Rs.	9000/-
5.	Cost of Bore	Rs.	16365/-
6.	Life of Pumping Set	15	years
7.	Life of Bore	7	years

CALCULATIONS

1.	Energy Cost		
	— Fixed charges 7.5 x 12 x 19/-	=	1710/-
	— Energy charges 1750 x 0.23 x 7.5	=	3018/-
	— Fuel Surcharge 1750 x 0.12 x 7.5	=	1575/-
	— Duty 3018 x 0.04	=	121/-
	— Meter Rent 10 x 12	=	120/-
2.	Lubricants/greases L.S.	=	100/-
3.	Repair Cost Rs. 100 per month 100 x 12	=	1200/-
4.	Total O&M Cost		7844
		Say =	7850/-

APPENDIX - 6

OPERATING COST OF
1-Cusec Diesel Tubewell

DATA

H.P. of Engine		15
Working hours		1750
Cost of Fuel	Rs.	14/- per 1mp. gallon
Efficiency of Engine		80%
Sp weight of fuel		7.8 ths/Gallon
Specific consumption		0.42 ths/BHP/HR
Life of P/Set		15 years
Life of Bore		7 years
Cost of P/Set		2000/-
Cost of Bore		16365/-

CALCULATIONS

1.	Fuel Consumption/year $\frac{0.42 \times 1750 \times 0.8}{7.8}$	1130 gallon	
	Cost @ 14/-; 1130 x 14	15830/-	
2.	Lubricants and greases L.S.	2000/-	
3.	Repair charges @ Rs. 150/- per month	1800/-	
4.	Pay of operator @ 600/-	7200/-	
	Operation Cost without depreciation	26830/-	
	Hourly Cost without depreciation	26830/-	15/-

COST PER ACRE FOOT

No. of Acre feet per annum	$\frac{1 \times 1750}{12}$	=	146
Cost per acre foot without depreciation	$\frac{26830}{146}$	=	184

APPENDIX - 7

INSTALLATION COST OF

0.5 Cusec Electric/Diesel Tubewell

Sr. No.	Particular	Qty.	Cost/ Unit	Amount	Electric Pumping Set	Diesel Pumping Set
1.	Bore drilling 6" dia	110 ft	25	2750/-	2750/-	2750/-
2.	Construction of sump 10 ft dia x 10 ft deep	1 ft	5000/-	5000/-	5000/-	5000/-
3.	Supply & installation of M.S casing pipe 4" dia	35 ft	40	1400/-	1400/-	1400/-
4.	Supply & Installation of coir wrapped strainer	75 ft	20	1500/-	1500/-	1500/-
5.	Well developing	L.S			500/-	500/-
6.a)	Pumping set with suction limb and reflex value				5000/-	—
b)	Belt drive attachment in case of Diesel set					15000/-
7.	Fitting charges including foundation	L.S			500/-	2000/-
8.	Miscellaneous hard-ware bends, wiring, flanges and bolts and nuts	L.S			500/-	500/-
9.	Transportation	L.S			1000/-	2000/-
10.	Power connection less Rs. 15000/- subsidy	L.S			30000/-	—
11.	Delivery pipe and discharge sump and pump house	L.S			6000/-	6000/-
				Total	54150/-	36650/-

CONCLUSIONS

1. The public tubewells are of bigger capacity and it is difficult for the farmers to manage their discharge.
2. For installation of large capacity tubewells adequate facilities are not available in the private sector.
3. Fibre glass strainers and turbine pumps make the public tubewell very costly.
4. Public sector management of a large battery of big capacity tubewells has not functioned satisfactorily.
5. It is the policy and stratigy of Pakistan Government to encourage farmers to install small capacity private tubewells.
6. Private sector has gone in a big may for installation of small capacity tubewells.
7. Installation cost of an electric tubewell is greater than a diesel tubewell but operational cost of the former is much less than the latter.
8. Skimmy tubewells can play a great part in disastrious areas by pumping good quality water for agriculture.
9. Solar pumps have a good future for fractional tubewells for smaller farmers if their capital cost comes within their reach.