CHAPTER III

TECHNICAL ASPECTS OF MAJOR SOURCES OF IRRIGATION IN PUNJAB

3.1 INTRODUCTION

There are at present two major sources of irrigation in Punjab, viz., canals and tubewells, both shallow and deep. In the present chapter we will concentrate on the technological aspects of these sources with the following viewpoint:

In the first place, we will note the essential features of the particular irrigation source, the geo-physical pre-conditions of its feasibility and the manner of its operation in order to assess its potentially realisable efficiency in a given geological region.

A point of clarification: while referring to the efficiency of irrigation we keep in view the following features of irrigation:

(i) The quantum of water thus supplied,
(ii) The certainty of water supply, and
(iii) The control over water supply as regards its timing and quantity.

The efficiency thus reflects the quality of irrigation with respect to control over time and quantity of water supplied from a particular source and crucially influences the production decisions of the users. While assessing the role of irrigation in the production process therefore, it is not merely the quantum of available irrigation but its quality...
that assumes fundamental significance. This is so particularly in the case of the modern agricultural technology which involves the cultivation of high yielding variety of crops and is widely prevalent in Punjab.

However the typical experience with regard to the utilisation of irrigation is that the realised efficiency of irrigation has been distinctly lower than what is technically feasible. The second point of emphasis in the present chapter, therefore, would be to identify the major factors accounting for the deviation of the actual effectiveness of the operation of the source from the ideal realisable efficiency.

Finally it may be pointed out that the benefit-cost calculations on which the investment decisions regarding irrigation works are usually based, can be seriously upset when consideration is given to the impact of the resultant ecological imbalances.¹ The latter can seriously alter the picture regarding the net benefits expected from the project and may even render the entire investment irrational from a social point of view. In the appendices to the present chapter we will briefly discuss some of the major ecological problems associated with irrigation development in Punjab and their extent, giving a critical evaluation of the steps taken to contain them (see Appendix A.3.1 and A.3.2).

¹The typical ecological problems associated with irrigation are waterlogging and pollution or lowering of the level of the ground water reserves.
3.2 CANALS

A canal system is fundamentally a mechanism for conveying water from its source (mostly rivers) to the fields through a network of channels wherein the flow of water is based on the gravitational pull i.e. on the existence of a gradient between two points which determines the direction of flow. In order to realise the above two basic steps need to be taken. First, there is the need to control and regulate the river water supplies and secondly, to transmit these supplies to the point of its actual use i.e. the fields. The effectiveness with which it can achieve these will determine the efficiency of canal irrigation available to the users at the point of outlet.

3.2.1 Control of River Supplies

The canal water supplies are limited by the river flows - both as regards their quantity and seasonal pattern of fluctuations. Figure 3.1 shows the average flow in the three major rivers in Punjab throughout the year. It is clear that unless effort is made to smoothen the fluctuations in the river flow, the water supply to the farmer through the canal is likely to follow the same fluctuating pattern. In Punjab, the construction of multipurpose storage dams on the major rivers, i.e. Bhakra on Sutlej and Pong on Beas, have gone a long way towards improving the regulation of water and

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2In fact the major revolutions in the technique of canal irrigation have been concerned with the development of precisely this aspect.
MEAN 10 DAILY RIVER DISCHARGES

(a) BEAS AT MANDI PLAIN

(b) RAVI AT MADHOPUR

(c) SUTLEJ AT ROPAR

FIG. 3:1

spreading the supplies uniformly over the year.\(^3\) However the dams notwithstanding, the water supplies to the canals continue to fluctuate, although to a lesser extent,\(^4\) on account of the following reasons: closure of canals due to maintenance requirement, breaches, cuts etc., shortage of water supplies in the reservoir, specially during draught year, and finally, due to the multipurpose nature of these dams whereby the criteria of water release is often other than the irrigation needs e.g. those geared to power generation,\(^5\) flood control etc. Hence the inherent element of irregularity of water supply through the canals in spite of the substantial improvement achieved in the field of water regulation.

\(^3\)Figure 3.2(a) shows the yearly pattern of flow in the Bist Doab Canal taking off from Sutlej after the construction of Bhakra Dam. It is clear that the ability to supply water perennially in the canal has been acquired solely as a result of the dam construction which is a devise for storing the surplus water of the river during the peak period to be released gradually during the lean period. But in spite of that, the supplies in the canal fluctuate drastically within short periods. In fact the same story is repeated in the case of the other major canals (see Figure 3.2(b & c)) which shows the hydrographs for the UBDC and Sirhind Canal respectively for the year 1970-71. The situation is particularly dismal in the former case as there is as yet, no dam on river Ravi which feeds the UBDC system. The surplus water during the monsoons therefore continues to flow down to the river.

\(^4\)These fluctuations of the head of the canal (i.e. the point at which it takes off from the river) get further accentuated at the field level due to the cumulative impact of the water losses route.

\(^5\)In fact the impact of low power generation on Sundays (due to low demand by industrial/commercial sector) is felt by the farmers in Bhatinda after a time lag of 2-3 days. With the result that all the farmers having their turn on Wednesday either do not get water or it is far below normal with the situation worsening for the tail enders.
WATER CONSUMPTION DIAGRAM 1970-71

DISCHARGE IN THOUSAND CUSECS

SIRHIND CANAL (C)

UPPER BARI DOAB CANAL (B)

BIST DOAB CANAL (A)

APR May Jun July Aug Sep Oct Nov Dec Jan Feb Mar

FIG. 3.2
3.2.2 Transmission of Water

Given the water availability at the canal head, the next requirement is its smooth transmission to the field through the canal network. The maintenance of the desired channel slopes acquires critical importance for ensuring the correct velocity\(^6\) of water and controlling the losses on the way. As discussed below, both these aspects affect the efficiency of water supplied from the canals to the individual farmers.

Figure 3.3 shows the layout of a typical canal network, where the arrows show the direction of water flow. Water from the river is fed into the main canal which splits up into the Branch canals which further branch out into the distributaries and finally into the minors. No direct irrigation is generally provided from the main or branch canals. Outlets (or moga) are provided either on the distributaries or, to avoid lengthy watercourses, on the minors (e.g. at point E). The government jurisdiction for supplying water ends at the outlet. Beyond point E, the responsibility of maintaining the watercourse rests collectively with the farmers whose fields receive irrigation from the particular outlet. Outlets on the watercourses at various points, called nakkas are fixed along the watercourse for the final delivery of water to the private fields e.g. at point F.

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\(^6\)The velocity of water supply is crucial for the farmer as the water distribution is effected through the allocation of water time and not quantity. The actual quantity of water available to him during the fixed time therefore depends on its velocity.
LAYOUT OF A TYPICAL CANAL NETWORK

FIG. 3.3
beyond which (F to G) the individual cultivator digs his own field channels to evenly distribute water throughout his field. In order for the flow to be smooth and regular therefore it is important to maintain the correct gradient throughout the course from A to C. Especially, since no water regulation is provided at D or the outlet (E), the flow is entirely dependent on the designed slope. However the slope of the channel bed specially in case of unlined channels (as is the case for most of the channels in Punjab) should not be too steep or too flat. Very steep slopes result in scouring of the channel beds which reduces the command area of the canal, with the position aggravating for the tail enders. On the other hand, very flat slopes tend to encourage silt deposit and berm formation, which by reducing the channel capacity renders it incapable of carrying the designed discharge, with worse effects on the tail enders (see Uppal 1966).

At this stage it may also be pointed out that a critical factor affecting the flow from E to F is the height of the outlet (point E). In fact the maintenance of relative levels from E to F and to G is particularly critical because of the reduced volume of water in the watercourse and consequently, the reduced momentum and increased dependence on the gradient for the flow to take place at all. The height of outlet at E should be such that the water flows into the watercourse with sufficient pressure to reach the 'tail-end' (X). However it should be low enough so that water is let out from it in the distributory even during reduced flow - an
eventuality which is fairly common. The mislocation of the outlet is often a cause for considerable discrimination in the water distribution among users - even when the integrated canal system may be otherwise working ideally. Further, in order that the water to reach the point C, it is important that the nakka (point A) should be at a level lower than E but higher than the field. Similarly, FO (in the field channel) should be lower than EF (the water course) but higher than the field. In practice this requires the maintenance of very fine relative level differentials. This is hard to attain in practice, more so, as the periodic clearing of the watercourse of the weeds and silt is done manually in a rather clumsy manner. This leads to an uneven bed surface and improper gradient, resulting in sluggish flow and high losses, as will be discussed below.

### 2.3 Water Losses

Given the water supply at the canal head and its distribution through the channel network, the actual flow of water reaching the fields gets reduced by the losses on the way which occur primarily through seepage, evaporation or directly through canal cuts, breaches, overflow etc. Apart from the geological and climatological factors, such as the soil make-up of the region, the average temperature etc., these sources of water losses are critically influenced by the nature of flow of water as regards its quantum and
velocity. Two most crucial aspects of the construction and operation of the canal system which influence the flow of water and hence the losses, are the lining (or its absence) of channels and the problem of sedimentation. Below we briefly point out the role of each in determining the quality of flow (or, the efficiency of irrigation through canals ultimately available to the cultivators).

(a) **Lining of Channels:** The lining of channels, has always been considered an optional requirement for a canal network, particularly due to the fact that lined canal costs about 2 to 2½ times an unlined one. However, the net advantages from lining far outweigh the apparent saving in initial cost. Through its impact on the flow of water and control of the adverse externalities commonly associated with canal irrigation, lining of channels leads to a distinct improvement in the efficiency of irrigation thus supplied.

For example, lining leads to a significant reduction of the losses due to seepage which is the primary source of water loss in unlined channels. Secondly, the reduction of

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7It is not surprising therefore, that losses are maximum in the water course where typically, one finds a significantly reduced volume of water moving at slow speed, further aggravated by uneven slope of the watercourse.

8Such as those of waterlogging due to heavy seepage from unlined channels, danger of breaches of canal banks etc.

9An idea of the saving in the transit losses by lining can be had from Table 3.1, which shows the losses for lined and unlined channels. On the average the losses for lined channels are found to be less than a quarter of those
seepage limits the rise in water table of the surrounding areas which, if uncontrolled, brings up the alkali salts to the surface, rendering the land unfit for cultivation. 10 Thirdly, lining permits higher velocities of flow 11 thereby improving the regularity of water supply and affecting a greater economy in the cost of construction of canals. 12

In the unlined ones. The water loss by evaporation is generally negligible compared to that due to percolation. On the average it is 1/4 of 1% of the flow, particularly in the main system, i.e. excluding the watercourses. On the other hand, according to the International Commission of Irrigation and Drainage, the accepted figures for the total transit losses in alluvial areas, such as those of Punjab, are as follows:

Losses from

(1) Main canal and branches = 17% of head discharge
(2) Watercourses = 25% of head discharge

Total losses in transit = 45% of head discharge

In addition to this 16.5% of the head discharge is lost in the actual field—leaving only 33.5% of the supply let into the canals, to be used by the crops (see Singh:1978, p. 35).

10 In some districts of Punjab in areas along unlined canals, an estimated 2% of the irrigated land was going-out of cultivation every year due to this (see Concrete Association of India:1960, p. 3).

11 This is largely due to reduced resistance by the smoother surface and negligible danger of erosion on account of lining, and also reduced weed growth — which in case of unlined channels can seriously obstruct the flow. Thus while (for the soil conditions similar to those in Punjab) the maximum permissible velocity is 2.5 ft/sec. for unlined channels for the lined canal it is almost double i.e. 6 ft/sec. as for example in the case of Nagal Hydel Channel.

12 For example it prevents silt deposition leading to a considerable reduction in the recurring cost of maintenance, as well as interruption of water supply; secondly, increased velocities in the lined canals make it possible to either double the capacity of the canal, with the same area of cross-section, or alternatively, reduce the cross-section for the same discharge. Either way, this effects considerable saving in the excavation of canals or acquisition of land or right of way etc.
Fourthly, due to the reduced danger of erosion either steeper slopes are permissible with lining resulting in shorter alignments, or very flat slopes can be used to bring certain high altitude areas under command. Fifthly, lining of channels greatly reduces the probability of the breaches and cuts of embankments. This danger is ever present in the case of unlined channels and may lead to damage to the adjoining areas for both life and property, in addition to the consequent water loss and interruption of supply. Finally, periodic removal of weeds and water plants from the sides and bed of the canal in the case of unlined canals becomes unnecessary after lining, which reduces the cost and improves regularity of water supply.

The deplorable state of maintenance of the canal network in Punjab where most of the distributaries and watercourses are unlined further reinforces the case for lining.  

(b) Sedimentation: This can best be described as follows, "If the sediment load is more than the stream can carry, the material deposits. If it is less than the transporting power of the stream, scour takes place. There exists a sensitive equilibrium between the two, which the stream tries to maintain. Mostly, it is the excessive sediment load which causes

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13 The total length of main canals, branches, distributaries and minors as of 1961 in Punjab is 14,482 kms., out of which a length of 506 kms. of main canal, namely Bhakhra Main Line, Farozapur Feeder and Sirhind Feeder, were constructed as lined in the first instance. Out of a total length of distributaries and minors of 12,275 kms., only 1,305 kms. have been lined upto March 1979. Another 634 kms. have been lined during 1979-80 (Irrigation Department Note: 1981).
trouble and is required to be tackled" (Uppal:1966, p. 6). Its impact on the hydel and canal works is particularly hazardous as it causes reduction of channel capacity, silting up of canals and reservoirs, damage to power units on hydels channels etc. The danger of canal breaches is a cause of great insecurity in canal irrigated areas and finally, repeated sediment clearance requires heavy expenditure. In spite of the fact that some of the earliest sediment control works were installed on the canal systems in Punjab, the problem continues to persist to date, specially on the UBDC system.

14. The problem is mainly encountered in the rivers arising in regions of younger sedimentary rocks where the rocks in the mountains disintegrate into granular material due to weathering action - mechanical or chemical - and these are carried away by the rivers. Strong winds, deforestation of the catchment areas, unrestricted grazing, cultivation undertaken along steepest declivities etc. All aggravate the problem, which has been encountered in all the northern and eastern rivers of India (Uppal:1966, p. 3).

15. For instance Michael notes that, "Some of the earliest work in the direction of sediment control were attempted in India, in the State of Punjab. It is also believed that a larger number of sediment control devices are located in Punjab, than anywhere else in the world. Practically, every canal system is provided with an elaborate arrangement of sediment exclusion" (Michael:1966, p. 215).

16. The Upper Bari Doab Canal in Punjab has been chronically afflicted with this malady ever since its inception. Uppal points out that "Between 1869 and 1872 ... a permanent shattered weir was constructed across the entire river and a new gated intake was provided for the canal. Then it was discovered that this intake silted up with the coarse material brought down by the Ravi, problem that was soon found to be common to all the river station headworks". Further, "In 1951 again it silted up by 6 to 8 ft. and consequently the banks had to be raised by 8 to 10 ft. Ultimately, a heavy breach occurred, flooding the whole countryside" (Uppal:1966, p. 9).
Ironically enough in the part of the canal system taking off from Bhakra, it is precisely the clear water in the canal that is causing problems of a different nature, with fairly similar consequences. As a result of the all-free clear water in the channels, the sunlight penetrates right to the bottom of the canal and encourages excessive weed growth along its bed and sides, causing considerable impediment to the smooth flow of water in the absence of prompt clearance.

(c) **Unlined Channels, Weed Growth and Sedimentation - Its Impact on Available Discharge:** Since most of the watercourses in Punjab are unlined they require periodic clearance of weeds and silt. This is done in a rather crude and clumsy fashion. This upsets the required slopes, creates depressions at places, leading to sluggish flow which aggravates losses particularly due to the reduced volume of flow. Since the canal water is not distributed directly on a volumetric basis but on the basis of time allotment, this reduced discharge results in a lower quantum of water available during the scheduled times, leading to a lower efficiency of canal irrigation for all users.

Secondly, the problem gets particularly aggravated for the smaller landholders since the percentage loss of water

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17This is done in proportion to the land owned. The farmers are then allowed to claim whatever discharge there is in the watercourse for the stipulated period. Sluggish and uneven flow, therefore adversely affects the quantum of flow delivered during the period.
due to retarded flow per unit area to be irrigated increases as the landholding declines. Implicit in this is also the relative advantage of getting lumpsum water at one point rather than distributed in smaller units at different points, though technically the water is supposed to be distributed equally on a per acre basis. This system of water distribution therefore works with a systematic discrimination against the small scale cultivator.

3.2.4 Concluding Remarks

To sum up therefore, we have seen that water supply through canals remains, first, somewhat irregular due to the inability of weirs, barrages and dams to completely overcome the fluctuations of river flows which form the source of water for the canal works. Secondly, on account of problems arising from their maintenance and operation, the flow is greatly reduced, together with high losses and its irregularity is further aggravated. Finally, since the distribution of water remains a fairly remote-controlled process, the farmer is left with little control and flexibility over the supply of water. Hence the inefficiency of irrigation services provided by canals.

3.3 TUBEWELLS

A tubewell is essentially a technique for pumping out water from the ground water reservoir. Basically it comprises of a pump, a vertical tube, through which the water flows out and a source of motive force for the pump in the form of either an electric motor or a diesel engine.
The ultimate discharge of water available from a tubewell (which is a critical component of the efficiency of irrigation thus provided) depends on the following: first, whether the geo-physical feasibility of tubewell installation has been adequately examined; secondly, whether the tubewell has been designed and installed as per technical requirements; and finally, on the conditions of maintenance and operation of the tubewell. In the following sections, we briefly try to point out the technical requirements at each of the above stages and implications of their violation in practice, all of which go on to influence the final discharge - its quantum, regularity and reliability.

3.3.1 Feasibility

Since the function of a tubewell is to pump out the underground water, its feasibility is limited in the first instance by the availability of exploitable ground water sources with respect to its (a) quantity, (b) quality and (c) pressure.

(a) The availability of water for continuous withdrawal from the ground water reservoir depends on the fact that it is replenishable, the extent of which is however limited. Hence the imperative of restricting the total withdrawal to

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18 The basic hydro-geological parameters relevant for an understanding of the feasibility of tubewell installation are outlined in Appendix A.3.3.
the available surplus. This is calculated as the net of total draft from, and recharge of, ground water. While agriculture is the biggest source of draft of water, the major sources of recharge are rainfall, canal seepage and recycled irrigation. Hence, ironically enough, it is precisely the areas with high rainfall, heavy irrigation and extensive canal mileage, that are likely to have a high probability of finding feasible sites for tubewell installation. On the other hand, we have limited viability of tubewells precisely in the most needy areas.

(b) The water must also be of a quality suitable for irrigation, i.e. free from bacteria, chemicals, dissolved solids etc. Therefore tubewells are unable to serve as a suitable irrigation source in the low rainfall, sandy tracts of South West Punjab due to the high salinity of ground water in the area. In fact this salinity of ground water tends to develop precisely in the low rainfall sandy tracts since the salts which are washed down are not sufficiently diluted. However, it is also these areas, with low rainfall

19 Particularly if the dangers of over-exploitation of ground water are to be avoided.

20 The presence of bacteria or chemicals in the water which is either toxic to plants or reacts with the soil leading to encrustation, hardening etc., is undesirable. While the former contaminates the crop produce, the latter serves to restrict soil aeration necessary for plants. A high percentage of total dissolved solids restricts plant osmotic activity and absorption of soil nutrients (see Michael:1978).
and highly permeable soils that need irrigation most. Here again one finds a limitation on providing tubewell irrigation in water-deficient areas.

The broad conditions on feasibility of tubewells which confine their use as a mode of irrigation to specific regions are particularly important considerations for planning the irrigational development of an area. A disregard for the same can entail considerable wasteful expenditure involving the construction of tubewells with an output far below that originally designed for.

(c) Lastly, the pressure of the ground water also influences its exploitability. When water bearing stratum is pierced by drilling or boring it rises to the water table level due to hydrostatic pressure. It is then pumped out from this level. A large quantum of water at low pressure, therefore, can be more difficult to tap than a smaller volume at higher pressure which rises closer to the ground surface, requiring therefore simpler pumping mechanism.

3.3.2 Design and Installation

Given the overall feasibility of tubewell installation in a region, the output of a particular tubewell\textsuperscript{21} (in

\textsuperscript{21}Basically, a tubewell consists of a pipe or a tube fixed in a deep bore of a smaller diameter, passing through many geological strata, some water bearing and some non-water bearing. Depending on the type of tubewell the tube consists of a perforated pipe put against the water bearing stratum to allow water to enter, while preventing the soil particles from doing so, or a complete pipe with a cavity at the bottom. The tubes are fitted with mechanical pumps for raising the water from the well to the ground level, driven by electric motors or diesel engines.)
terms of the quantum of discharge available with regularity and reliability) depends on the proper technological management of the following aspects of tubewell construction:

(a) Site selection and spacing of tubewells.
(b) Design of the major components.
(c) Installation of a tubewell.
(d) Selection of pumps and their functional aspects.
(e) The use of electric motors and diesel pumps.

(a) Detailed investigation of the ground water conditions in the area under consideration prior to the sinking of tubewells is a necessary prerequisite for their successful operation. Carelessness on this score has led to the forced abandonment of a high proportion of tubewells installed under some of the earliest deep tubewell schemes of the PSTC.

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22 The most reliable method to ascertain the character of formations beneath the earth's surface is to drill through them, obtain samples while drilling and record a log of the bore holes - known as well logging. This test drilling is done to satisfy two objectives: (i) to explore the ground water resources of a region and (ii) to obtain information on the geological and ground water conditions of a well site prior to installing a regular tubewell. Further, pumping tests need to be conducted which provide information on the hydrogeological properties of the well site such as the type of aquifier, its areal extent and thickness, water table gradients and recharge boundaries.

23 Table A.3.5.1 shows the total number of tubewells drilled and abandoned so far. A comparison of Columns 7 and 8, reveals that the proportion of tubewells abandoned vary from one third to one half of the total number drilled under the different schemes.
The second critical consideration of site selection is the requirement of maintaining a minimum distance between the wells. If the wells are spaced too close together, their respective areas of influence may interfere with each other. This results in a lower drawdown, reduced discharge and increased pumping costs. In the case of deep and shallow tubewells backed by institutional finance, the adherence of the stipulated norms regarding spacing of wells has been neglected.

24 This in turn depends on the discharge of the pumps, duration of pumping, transmissivity of the aquifer and the slope of water table.

25 Experience and tests have shown that wells should not be at a distance of less than 70 mts. for deep tubewells. However the Agricultural Refinance and Development Corporation (ARDC), the major financing body for deep tubewells in Punjab, has stipulated a spacing requirement based not only on area of influence but also on minimum command area to avoid over-capitalisation of the well e.g. it is 15 mts. in the hard rock areas of Maharashtra, 180 mts. in the alluvial tracts of Haryana, and probably in the same range for Punjab. However for shallow tubewells, Rohwer reported that no particular advantage could be gained by spacing the well farther than 16 to 24 meters apart (see, Michael:1978, p. 116).

26 For instance, at the various meetings of the Punjab State Ground Water Board (PSGMB), Dr. M.S. Randhawa, Vice-Chancellor of the Punjab Agricultural University (Ludhiana), has repeatedly drawn attention to the possible dangers faced by the owners of shallow tubewells in the areas surrounding the 500 augmentation deep tubewells along the Sirhind canal between Daura and Ropar, due to tapping of the common aquifers. In Punjab, the various aquifers are interlinked - except in the sub-mountainous Kandi tract. Therefore the static water level for deep and shallow tubewells is the same and hence the impact of one on the discharge of the other. This in fact has been confirmed by the preliminary findings of the ground water cell (G.W.C.) of the Agricultural Department, which show that, "at certain places the government deep tubewells and the private shallow
(b) The essential features of a design of tubewell include the specification of well diameter, well depth, well screen and gravel pack. Below we briefly try to point out the relation of the above parameters with the cost and quality of discharge of a tubewell.

The yield of a well is proportional to the diameter of its intake portion (i.e. where the water enters the well from the aquifier) but not directly. The percentage increase in yield with increasing diameter reduces progressively. Hence the need to select the optimum diameter for most economical use of resources. Similarly, higher well depth permits greater yield and more drawdown which extends generally to the bottom of the aquifier. However the length of the intake portion of the well screen is a compromise to be struck between higher yield and greater efficiency - the latter is possible with a shorter screen length.

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tubewells are tapping the same aquifier and hence the shallow tubewells near the canal are likely to be adversely affected by the deep tubewells". Further it notes that, "no detailed ground water investigations were carried out by PSTC before submission of the project for installation of augmentation tubewells along Sirhind canal". (G.W.C. Comments:1974). That alone provides sufficient justification for Dr. Randhawa's timely warning - which may as well have fallen on deaf ears - since more than six years have elapsed without any substantial progress in this matter. Adverse experience on this score has already been faced by the farmers of Karnal district in Haryana. Although the problem may not have emerged on a similar scale in this case, this may be due to the fact that the said deep tubewells have been grossly underutilised - operating at less than 1/3rd of their capacity.
A well screen is a strainer which separates the ground water from the granular material in whose pores it is contained. The quantity of water that can be tapped from a well depends primarily on matching the characteristics of the water bearing formations to the elements of the well screen. 27

Improper design of the screen can lead to the inflow of fine sand, silt and muddy water at the outlet which is unsuitable for irrigation purposes, damages the pump, causes choking, and silting in the conveyance channels. 28

The use of over-fine screens against course sand or gravel formation, on the other hand will restrict the inflow of water, resulting in higher drawdown and reduced discharge.

Gravel pack is a thin layer of coarse material (specially gravel) formed around the screen portion of a well. When designed properly, the gravel pack provides sand-free water, thus increasing efficiency of the well and the pumping unit. It also prevents the caving-in of the formation material,

27 The well screen elements refer to the length of the screen, its diameter, total open area and size and arrangements of the slot openings. These should be designed to meet the basic requirement of any well screen i.e. resistance to corrosion, enough structural strength to prevent collapse, and suitability to prevent excessive movement of sand into the well while, at the same time, offering minimum resistance to the flow of water into the well.

28 A problem, as we shall see later, after encountered in the state specially in case of deep tubewells.
thus reducing the danger of clogging of the well screen. The important consideration in the gravel pack design is that first, it should be uniform in size and secondly, the mean grain size of the pack material should bear a specific relation to the mean grain size of the formation. The thickness of the gravel envelope by itself does nothing to increase the yield, the controlling factor being the ratio of the grain size of the pack material to that of the formation material. This size of the gravel pack then forms the basis for designing the slot opening of the screens. Upsetting the relative ratios can have adverse effects on the discharge.29

(c) Installation of Tubewell: The major problems created at the installation stage arise primarily due to eccentric drilling of the bore, mismatching of the well screen against the water bearing stratum and poor development of the wall. Though barely noticed at the drilling stage itself, unregulated drilling effects the pump-performance leading to reduced discharge and causing its premature breakdown. Secondly, mismatching of the well screen due to poor knowledge of the strata or careless design and installation can lead to reduced discharge, muddy water, silt deposit in the tube and can damage the pump etc. Finally, the tubewells have to be

29Carelessness on this score was cited as one of the major reasons of not only lesser than designed discharge but also the presence of mud, sand etc. in the water by certain officers of the PSTC, when interviewed personally.
"developed" to increase their specific capacity, prevent sanding and to obtain maximum economic life of the well. The problem at this stage typically arises due to delay in development after drilling a tubewell. This increases the chances of formation of mud cakes all around the annular space of the bore hole leading to the obstruction of water flow into the tube. Besides, if drilling is done by a Rotary Rig, as in the case of Punjab, which involves the use of Bentonite, a delay in developing can mean considerably greater expenditure due to the likelihood of the Bentonite caking up. In fact improper development often leads to cavity formation as a result of which the gravel pack collapses. This causes reduced discharge and mixing of mud and sand in the water.

(d) **Selection of Pumps and Their Functional Problems:** Given the site selection and installation of tubewells, their performance with respect to the cost and quality of discharge depends critically on the correct selection and operation of

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30 Development means stabilisation of the walls of a well adjacent to the screen by a process which removes fine particles from the formation immediately surrounding the well screen, leaving coarser particles to contact and surround the screen. The main objectives of this operation are (1) to correct any damage to the water bearing formation, (2) to increase the porosity and permeability of the water bearing formation in the well vicinity and (3) to stabilise the sand formation around the well, so that it will yield sand free water. Development is necessary for most gravel packed wells, as in the case of Punjab. Improper development can therefore seriously impair the proper functioning of the well.
the pumps used. The three major types of pumps for tubewells currently in use in Punjab are: Centrifugal for shallow tubewells, and Vertical Turbine and Submersible ones for deep tubewells. The basic characteristics as well as the problems typically encountered in their use have been discussed in Appendix A.3.4, where we have tried to argue that the typical causes for the malfunctioning of the various pumps which ultimately affect the yield can be located not so much in the structure of the pump itself as in the actual manner of its utilisation.

The most economical criteria of pump selection has been found to be the one which can draw water up to the maximum safe yield of the aquifer. This is on the assumption that one uses as much water as required in an area, selling the spare capacity of the tubewell. Although pumps are usually selected according to this criteria, in practice they have turned out to be very economical in case of both shallow and deep tubewells due to the under-utilisation of their capacity thus created. Secondly, the pump rating selected finally is the one which gives the highest discharge from the given head per unit of power consumed - i.e. giving the highest overall efficiency. Deviation of the actual discharge from the above, results in wastage of energy and increase in cost of water. Existing evidence in the wide variations of the realised discharge from that designed for, both in the case of shallow (see Chapter V) and deep tubewells (see Appendix A.3.5) in Punjab, point to the low level of operational efficiency of the pumps.
We find, therefore, that although the pumps are capable of giving trouble-free service at lower (than actual) costs, in practice they have been typically found to operate under financially uneconomical and technically inefficient conditions. This, we shall argue, occurs predominantly due to the social mismanagement of their use.

(e) Use of Electric Motors and Diesel Engines: The final component of the tubewells is the source of motive power for the pumps provided through an electric motor or a diesel engine. Their operational problems further aggravate the irregularity of the discharge by interrupting the supply apart from adding to the cost of irrigation.

Given the relative rates for diesel and electricity, it has been found\(^1\) that the costs both operational and maintenance, are higher for diesel engines than for electric motors. In terms of its actual use also the diesel engine is found to be more problematic than the latter.\(^2\) Therefore,

\(^1\)See Chapter V for a detailed discussion of the relative cost of irrigation from tubewells, using electricity and diesel oil.

\(^2\)For instance, there exists a relative difficulty of starting; once it starts, it fires intermittently and stops as the engine lacks power and gets over heated; besides, it is more prone to accidents due to inhalation of poisonous exhaust of the engine, and risk of trash material or clothes of the operator getting entangled in the running engine etc. The single major problem in the case of electric motors arises owing to their burning up, partly due to bad handling and absence of starters, and partly due to voltage fluctuations in the electricity supply. However, these problems are less frequent than in the case of diesel engines (see Singh: 1978).
on account of both the cost aspect and operational features, the diesel tubewells (mostly shallow) stand at a relative disadvantage. For reasons discussed later, it has been observed that it is typically the small cultivators who depend entirely on diesel tubewells and thus stand discriminated against.

3.3.3 Concluding Remarks

In the foregoing sections we have briefly tried to draw attention to those technological aspects associated with tubewell installation which have a bearing on the cost and efficiency of irrigation supplied through them. An attempt has also been made to point out the implications of the deviation of the actual practices from the technological requirements of providing irrigation through tubewells. The sources of these deviations which adversely affect the efficiency and cost of irrigation, it is argued, can be located in certain socio-economic conditions and not only in technologically derived limitations.

3.4 CHAPTER CONCLUSION

In the two major sections above we have tried to point out the following with respect to canals and tubewells:

(i) The essential technological features of the source of irrigation and its mode of operation.

(ii) The technological requirements for its ideal operation, giving a potentially realisable efficiency of irrigation.
(iii) Sources of deviation from these technological requirements and their consequences for the efficiency and cost of irrigation.

We have in the course of our discussion indicated that reasons for realised efficiency falling below that which is technically attainable have a basis in the socio-economic conditions influencing creation and utilisation of the irrigation potential. The role of social factors in determining the realised efficiency of irrigation is further highlighted in our discussion of the utilisational aspects of canals and shallow tubewells in the following chapters.

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33 This point can best be illustrated by considering the example of deep tubewells, wherein the contrast between the realised and technically feasible efficiency is most marked. It has been estimated that a deep tubewell is capable of giving sustained discharge as designed for a period of 15-20 years if installed and maintained with due regard to its technical requirements. An additional significant advantage particular to this mode of irrigation is the fact that the supply of water through them is independent of the yearly fluctuations in the amount of precipitation. This is on account of their tapping the deeper aquifers, which are inert to the short term variation in the surface precipitation, quite unlike in the case of shallow tubewells and canals. While the former taps the water table aquifer, whose level closely follows the annual cycle of rainfall, the latter is directly dependent on both, the rainfall (and its drainage into the river), as well as the melting snow, in case of rivers taking off from the snow clad Himalayas, as in the case of Punjab rivers. Canals are therefore most vulnerable to the climatic fluctuations, followed by shallow tubewells. However it is precisely the deep tubewells in Punjab that have in actual practice, proved to be the most inefficient source of irrigation and are thereby also highly underutilised. The reasons for such paradoxical observation lie in the technical malfunctioning, characteristic of a majority of these tubewells (all under public ownership), which affects the cost, as well as efficiency of irrigation faced by the farmer. In Appendix A.3.5 we discuss in detail, the social basis of some of the major technical problems faced in the use of this mode
of irrigation. There, we try to point out some of the implications of the mode of creation of irrigation potential and its utilisation for the technological problems encountered. These problems adversely affect the irrigation efficiency - reducing potentially the most efficient source, to the lowest position on the efficiency scale.
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<th>2,000</th>
<th>5,000</th>
<th>7,000</th>
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<td>(14.16)</td>
<td>(28.32)</td>
<td>(56.14)</td>
<td>(141.60)</td>
<td>(198.20)</td>
<td>(283.20)</td>
<td>(339.84)</td>
<td>(424.80)</td>
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<td>7.40</td>
<td>7.70</td>
<td>7.90</td>
<td>8.50</td>
<td>8.70</td>
<td>8.90</td>
<td>9.00</td>
<td>9.12</td>
</tr>
<tr>
<td></td>
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<td>2.41</td>
<td>2.59</td>
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<td>2.71</td>
<td>2.74</td>
</tr>
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<td>2. Lined ft³/s</td>
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<td>0.61</td>
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</table>

Source: From The Lining of Channels, Concrete Association of India, Bombay, 1960.
APPENDIX A.3.1

ECOLOGICAL CONSEQUENCES OF CANAL IRRIGATION

1. The sudden introduction of artificial irrigation in an area necessarily implies the disturbance of the natural equilibrium between the surface and ground water. Therefore, if due attention is not paid to restoring the balance, serious problems can arise. The development of canal irrigation works without adequate development of drainage facilities has, in Punjab, led to the emergence of waterlogging, resulting in soil salinity and alkalinity. As a result, large tracts of land formerly productive, were rendered unfit for cultivation.

2. An area is identified as waterlogged if the water table depth is within 5 feet from the natural surface. Depending on the soil permeability and the initial water table depth, waterlogging can arise when a canal system begins to operate, particularly if the irrigation from it is perennial. In addition, it can be caused by deep percolation from over-irrigated areas or floods; by obstruction of natural drainage by deep masonry structures, railway lines, embankments etc.

3. This rise in water level results in the saturation of the crop root zone, constricting the air circulation, hence depleting the oxygen supply to the plant which leads

\footnote{For example the black cotton soil is highly prone to waterlogging due to its low permeability.}
to wilting of the plants and also their greater vulnerability to disease. Further, the relatively low temperature of most soil hampers seed germination. Finally, serious damage is caused by the water rising to the surface through capillary action, carrying harmful salts from the soil and the ground water. These get encrusted on the soil surface as the water evaporates leading to a decline in the soil fertility.

This problem of salt accumulation on the surface is referred to a 'alkalinity' and 'salinity'. The two are however different. While the latter comprises of soluble salts which can easily be flushed down with excessive water, suitably drained away, the former requires lengthy and complex process of reclamation - possibly including gypsum treatment along with alkaline resistant crop rotation.

4. Waterlogging and salinity have been serious problems of canal irrigated tracts right from the beginning (see Michael:1966, p. 412). At present the problem is largely confined to the districts of Amritsar, Gurdaspur, Sangrur, Ferozpur and Patiala, together accounting for 80.2% of the total area thus affected. These are also the districts falling under the command of UBDC and Sirhind Canal Systems - the two earliest to be constructed by the British around the middle of the 19th century. Thus the problem was partly inherited and partly aggravated after independence with the increase in the capacity of these canal systems.
5. The official policy dealing with the drainage problem has taken a two pronged approach. On the one hand an attempt has been made to open up the natural drainage by digging drains, flood protection embankments etc., and on the other, soil conservation and water management schemes have been launched.

6. However, the progress under the latter set of schemes is rather diurnal. Evidence from some evaluation reports relating to these schemes indicates that whatever little benefit did result, it was monopolised by the larger farmers. Secondly, it was found that careless implementation of some of these schemes led to the paradoxical result of aggravating the problem (see ESO:1971).

7. Construction of drains etc. has been a more effective step to counter waterlogging. In response to the aggravation of this problem towards the late 50s, a master plan for flood control and drainage schemes was prepared in 1959. However, analysis of the progress under this plan indicates a significant gap between the actual and the proposed goals. The major reason for this has been primarily the inadequate financial allocation for the project (see Irrigation Department, Note:1979). Secondly, most of the progress has dealt with reconditioning of the earlier drains, rather than the construction of new ones. Thirdly, it may be noted that the construction of link drains was left to the collective initiative of the beneficiaries who failed to respond. This
incomplete construction of the drainage systems often caused waterlogging, as water would flow into a drain, but not have an outlet. Finally, the level of some of the drains was higher than the surrounding areas, thereby causing waterlogging. Factors such as these led to a considerably reduction in the efficiency of the drainage system.

8. Whatever the drainage system created, its maintenance was found to be very poor on account of inadequate financial allocation for the same as also due to the inaccurate assessment of the finances required. This was in spite of repeated stricutures in the official circles against improper maintenance of drains (see G.O.I., Report:1975). It may be noted that the need for maintaining the drains is particularly acute due to the uneven and variable flow of water through them resulting in excessive growth of weeds and silt deposit.

9. Finally, it has been found that the construction and operation of the drainage system is subject to extensive political and non-technical forms of interference. For instance all the cultivators tend to resist the passage of drains through their fields and whose will ultimately prevails depends on the ability of the respective groups to put political pressure on the Irrigation Department. Such entanglements plus the legal problems of acquiring land etc. delay the actual digging of drains. At the level of operation also, the already sluggish performance is further aggravated by the
actions of some cultivators who tend to construct temporary bunds across the drains in an attempt to store water for use during the lean period. These bunds are however, seldom removed and tend to obstruct the water flow through the drains during the heavy rush. Similarly, cuts are often made on the drain embankment for extracting water for irrigation during scarcity. If not blocked (which is the typical case) these cuts defeat the very purpose of controlled drainage. Hence the need for collective control of the operation and maintenance of the drainage system, if it is required to work efficiently.
APPENDIX A.3.2

ECOLOGICAL CONSEQUENCES OF TUBEWELL DEVELOPMENT

1. As with any other natural resource, an unjudicious tapping of the ground water reserves over a period of time is bound to lead to undesirable consequences which may block not only its further exploitation but also endanger the existing assets. Hence the imperative of restricting the annual draft of ground water to the level of safe annual yield. This may be defined as the average annual draft of artificial extraction of water by wells up to the level which does not lead to an excessive lowering of the water table and/or quality deterioration of the ground water.

2. Before proceeding further it may be mentioned that lowering of the water table is not necessarily an undesirable happening, as it may act (and in fact has done so in case of some districts in Punjab) as an antidote to the waterlogging menace which renders the soil useless for any meaningful cultivation. Besides, a low water table would increase the possibility of better utilisation of precipitation by increased infiltration, minimising losses due to evapo-transpiration etc. The safe yield of the basin can thus be increased by permitting depletion of water table up to lower levels, subject to equilibrium being obtained through increased
recharge through natural and induced channels.¹

3. Below the optimum level the decline of water table has the following implications: First, the interests of the existing shallow tubewell owners are adversely affected in so far as deepening of wells and lowering of pumping sets becomes necessary in order to maintain the former discharge. This requires additional investment the costs of which fall proportionately heavier on the smaller cultivators, although it is the larger landholders who reap the major benefit of the increased draft. Besides, in case of the former, investment in a tubewell typically represents an overcapitalisation of investment on account of his disabilities due to land size and fragmentation. Secondly, by affecting the ground water level in surrounding areas, it aggravates the position of the small cultivator using precipitation wells by further reducing its already low efficiency. Very often as pointed by Dhawan (1977), it makes impossible the use of relatively cheaper methods of lift irrigation which cannot operate below a certain depth. This would force the affected cultivator either to go in for heavy investment in a tubewell or depend on the better off farmers for purchase of water. Either way it implies a deterioration of his economic position. Thirdly, the ground water reserves fail to provide the

¹Ideally speaking, for the geological conditions pertaining in Punjab, the water table depth should remain within 5 to 10 meters below ground level (BGL).
buffering during draught years when the water table decline is likely to be aggravated owing to the additional factor of lower than normal precipitation, which as mentioned earlier, is one of the major sources of recharge of the aquifier. Even the short term seasonal lowering of water table during the peak water demand periods (e.g. summer months) would be aggravated.

Finally, the sustained yields of an aquifier if not checked periodically, could lead to the withdrawal of inferior quality of water specially in case of coastal aquifiers where excessive draft could lead to the intrusion of the saline water from the sea. The same could happen near saline tracts - as in the case of S.W. Punjab. In some areas where layers of saline and sweet water are interspersed, improper construction of tubewells and heavy pumping from them are likely to lead to similar consequences.

4. The sudden and sharp development of tubewell installation in Punjab after 1970-71, was bound to have its repercussion on the existing depths of water table in the different districts. The conclusions of the various studies based on the existing evidence all point to a distinct declining tendency of the water level from about 1964 till the mid-70s, in the central belt of Punjab. Table A.3.2.1

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2 That is, those carried out by Central Ground Water Board, Punjab Agricultural Department, Punjab State Tube-well Corporation, Irrigation and Power Research Institute (Amritsar) etc.
presents data of the water table depths of some of the blocks for years 1966 and 1976 (columns 1 and 2) along with the respective rates of change of the level. This is important, since even if the final levels may well be within the 5-10 meters, the rates of decline may be such as to cause alarm. If these are ignored, excessive damage could be caused in years to come. In fact, water balance studies—another method of estimating the availability of exploitable water reserve of the basin for Punjab for the years 1977 and 1979 (G.W.C., Note: 1978) point to a net overdraft from the districts of Ludhiana, Jullunder, Kapurthala with very small margins for Patiala district. All such studies point to the emerging problem of overdraft due to continued unregulated tapping of the reservoirs.

5. This brings us to the whole question of systematic regulation and control of the ground water exploitation specially in light of the evidence presented above. So far however, there is virtually a total absence of any direct control over the installation of shallow tubewells. The entire investment is carried out by private individuals for which no special licence or permission by the government is required. Some form of limited control is effected indirectly through the allocation of electricity connections (in the case of electrical tubewells) and in the case of tubewells financed through institutional sources. However, in the former case, the control is more the by product of attempts
to ration out the limited power resources. The latter measures are not very significant because institutional finance has supported only a small fraction of the tubewell growth (see Chapter VI).

In recent years an attempt to introduce some kind of control over this development has been made through an effort to introduce ground water legislation. The problem had been identified for the first time at the conference of the agricultural production commissioners held in Delhi in May 1969. However, till the end of 1980, no concrete progress had been made in this direction. Therefore, while precious time is being lost due to administrative failures, the probability of serious damage to the tubewell users in the state is continuously on the increase. If the tubewell growth continues at the rate prevailing in the last decade it may effect the performance of all the tubewells old and new, thus undermining one of the pillars of green revolution.
### TABLE A.3.2.1

**Fluctuations of Water Table Depth in Some Blocks of Punjab Between 1966 and 1976**

<table>
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<tr>
<th>Sl. No.</th>
<th>Name of the block/district</th>
<th>Initial level (1966)</th>
<th>Final level (1976)</th>
<th>Change (1)</th>
<th>Percentage change</th>
<th>Percentage change (col.3/col.1)</th>
<th>Year (col.4/10)</th>
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<tr>
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**District Patiala**

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**District Bhatinda**

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<td>Maur</td>
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**District Faridkot**

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<td>Moga-II</td>
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<td>Bhagha Purana</td>
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<td>Nihal Singh Wala</td>
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</table>

**District Ferozpur**

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<td>Guru Har Sahai</td>
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<td>2.60</td>
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<td>Fazilka</td>
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<td>Ferozpur</td>
<td>1.95</td>
<td>3.30</td>
<td>1.35</td>
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</table>

APPENDIX A.3.3

HYDROGEOLOGICAL PARAMETERS

The geological formations of the upper layer of the earth's surface, the lithograph, relevant for the ground water exploitation, can be divided into the following three basic categories based on the degree of hardness of cementation of the formation:

(i) Consolidated sediments e.g. limestone quartzite etc.
(ii) Unconsolidated sediments e.g. sand, clay, etc.
(iii) Semi-consolidated sediments and stones, shale etc.

Initially deposits are loose and unconsolidated and are called alluvium or unconsolidated sediments, comprising mainly of sand, pebbles, clay etc., where the solid particles are distinguished solely by their size. Later, physical, chemical and thermal actions convert these into consolidated and semi-consolidated strata with considerably reduced permeabilities. It is therefore only the formation of unconsolidated sediments that presents an opportunity to extract water depending on the characteristics of the acquifers.1 The geological formation of the Punjab region comprises of such unconsolidated sediments.

1In the Indo-gangetic plains, unconsolidated formations are found up to a depth of 34,000 ft. So far only a depth of 2200 ft. has been drilled for tubewells.
An aquifer is a stratum of sediments which is saturated with water. Depending on the case of water flow it is known as

(i) Acquiclude - which has very poor permeability and porosity (only 5%).

(ii) Acquifuse - formations which can store water but are incapable of transmitting it.

(iii) Acquitard - those that have high porosity but have obstruction to free flow of water.

(iv) Acquifier - has the highest permeability besides being porous.

The suitability of an aquifier for tapping water depends on the following two properties:

(1) **Porosity:** This is defined as the total void or intergranular spaces called pores, as a percentage of the total volume of the aquifier. Although theoretically the porosity indicates the total quantity of water stored in the aquifier on account of the water retained by the molecular attraction and surface tension etc., the amount actually drained by the aquifier is called the specific yield. Its values range from 1.2% for hard rocks (as also for clay) to 25-30% in case of gravel found in the central districts of Punjab.

(2) **Transmissivity:** This is defined as the rate of flow of water at the prevailing water temperatures, in gallons/day, through a vertical strip of the aquifier one foot wide and extending the full saturated thickness of the aquifier, under a hydraulic gradient of 100%. In other words, it is an
index of the permeability of the formation. High porosity by itself does not guarantee suitability for ground water extraction. For instance, clay has a porosity nearly double that of sand but very poor permeability rendering clay useless for direct water extraction. Ground water occurs in alluvial formations under both confined and water table conditions due to the wide degree of variations in the permeability of materials. The water table depth is generally subject to a wide range of seasonal fluctuations depending on the annual recharge and draft due to natural causes and ground water development unlike the pizometric surface where such variations are of a small nature. The ground water is not stationary and continually moves towards the point of discharge, however at a very slow rate (i.e. 10 ft./yr.). The transmission of pressure differentials is, however, much quicker.

\[\begin{array}{|c|c|c|}
\hline
& \text{Porosity (\%)} & \text{Sp. yld. (\%)} \\
\hline
\text{Clay} & 45 & 1-2 \\
\text{Sand} & 20 & 20 \\
\hline
\end{array}\]

\[\text{Confined Aquifer: The aquifer in which the ground water is under pressure to rise above the zone of saturation is defined as the confined aquifer.}\]

\[\text{Water Table: The upper surface of the zone of saturation is called the water table. The distance from the ground surface to the water table is called the water table depth, while the geological formation (aquifier) in which the ground water occurs under water table conditions is termed as the water table aquifier.}\]

\[\text{Pizometric Surface: The imaginary surface formed by joining equipressure points in wells, is called pizometric surface.}\]
It is for this reason that excessive lowering of water table in the vicinity of saline water should be avoided. Carelessness on this score can lead to the intrusion of saline water into the fresh water, rendering it unsuitable for irrigation (see Appendix A.3.2).
OPERATIONAL CHARACTERISTICS OF PUMPS

(i) Centrifugal Pumps: Amongst the modern pumps, the centrifugal pumps are most widely used in tubewells. Its biggest limitation is that it cannot lift water from a depth exceeding 6 meters and thus is unfit to be used in deep tubewells. They are simple in construction, easy to operate, low in initial cost and produce a constant steady discharge if installed and maintained properly. During installation, particular care has to be taken to provide a rigid foundation to absorb all the vibrations. In practice however, the pump has been found to face the following problems. Either it fails to deliver water or not enough is delivered; the pump works intermittently, requires excessive power etc. The reasons for the same are invariably the following: (1) the discharge head is too high; (2) the suction lift is higher than the maximum operable; (3) insufficient submergence of the suction inlet; (4) the head is situated lower than anticipated hence too much water is pumped out requiring excessive power or (5) misalignment of the pump and the prime mover etc. Its functional problems arise more from the mode of utilisation than from inherent technical defect of the pump.

(ii) Vertical Turbine Pumps: These are specially adapted to tubewells where the water level is below the practicable limits of the centrifugal pump and where the pump is adjusted
to the seasonal fluctuations in the water level. Therefore if the seasonal fluctuations are sufficiently large - this would require lowering and raising the pump level during the course of the year. The critical consideration during the installation of this pump is that the pump must be in correct alignment with the well and the power unit so that no part of the pump assembly touches the well casing. The foundations should also be rigid and firm. For the alignment to be maintained, great care needs to be taken while handling all its parts, particularly the shaft and the tubes. These are machined to close tolerances for accurate alignment and must not be spoilt by mistreatment. When properly installed and maintained, turbine pumps can be expected to give trouble free service. In practice however, the following problems have been encountered: (1) The pump may fail to start on account of faulty electrical connections. (2) Excessive bearing friction may arise due to misalignment of the pump or insufficient lubrication. (3) The shaft may be broken or disengaged. (4) If it does start it may either not deliver water or deliver insufficient quantity. ¹ (5) Water may enter the shaft tubes and mix with oil due to loose connections. (6) There is often premature wearing out of the components.

¹This is largely due to insufficient submergence of the pump bowls; plugged impeller due to sand and mud on account of poor well development; clogged strainer; too high a pumping head, etc.
again due to misalignment of the pump bearings, crooked boring of the well, bent shafts, vibrations due to misalignment or improper installation which may also result in excessive power withdrawal.

(iii) **Submersible Pumps**: A vertical turbine pump closely coupled to a small diameter submersible electric motor is termed a submersible pump. The pump element and the motor operate entirely submerged. Such an installation eliminates the long vertical shaft in the column/pipe. On the whole efficiency is increased by the direct coupling of the motor and its effective cooling by submergence in water. The primary advantage of the submersible pump is that it can be used in a very deep well where a long shaft would not be practical. These pumps are also less effected by deviations in vertical alignment of the wells. When correctly installed and operated under suitable working conditions, this pump requires little maintenance. After about 6000 hours of operation (or 2 years of service life) it may be necessary to withdraw the pump from the bore hole and overhaul it. However in this case also, its actual functioning in providing a steady discharge is impaired on account of the following: (1) Heavy load on the pump due to which it may fail to start; (2) If the pump is operating against a head greater than intended; the pump suction is blocked by foreign matters or reflux value above pump is jammed. (3) When voltage and frequency is considerably lower than required. (4) When there is mechanical friction in pump and motor or the pump is worn out due to sand or
mechanical friction, etc. Operational features such as these, can either reduce or at times, even eliminate the discharge altogether.
1. In the following sections we point out certain features of the mode of creation and utilization of deep tubewells which have adverse effects on the quality of irrigation.

2. Creation of irrigation potential: The responsibility for the design, installation, maintenance and operation of deep tubewells lies with the Punjab State Tubewell Corporation (P.S.T.C.) Ltd., Chandigarh. However, the various tubewell schemes undertaken by them are financed through bank loans and government subsidy. The bank loan is conditional on the government acting as the guarantor for PSTC. This implies, that in case of default or financial losses the burden of debt repayment would fall on the government. Further, in case the sanctioned amount is less than demanded, the deficit is made up by raising loans on the market in the form of share capital. However, 95% of these are bought by the government. The mounting losses suffered by the PSTC as discussed below are therefore in effect mostly borne by the government.

At the level of the actual execution of the schemes, a very high rate of failure of tubewells is noticed with tubewells being abandoned at various stages of construction.
(see Table A.3.5.1). The actual rate of abandoning is 10% while that allowed for is only 2% (see PSTC:1976). The major reasons cited for this was the failure to carry out preliminary surveys, non-availability of competent personnel, careless assessment of feasibility of a particular site etc. The tubewells which did work often failed to give the desired discharge. This was largely due to faulty design of the strainer and gravel pack, mismatching of well screen, poor construction and workmanship (see PSTC:1976).

3. Utilisation of tubewells: In Punjab, as elsewhere (e.g. in U.P.), the performance of public deep tubewells has been characterised by a high degree of underutilisation resulting in high losses - a fact repeatedly brought to light within the PSTC and outside. For example, an evaluation study conducted in 1977 shows that only 50% of the capacity of the deep tubewells was utilised during the years 1970-71 to 1974-75 (ESO:1977).

The major reasons for the low level of utilisation have been primarily the malfunctioning of tubewells and the

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1 See also, the PSTC file on tubewells under Emergency Agricultural Production Programme (EAPP) for a discussion of the reasons for high rate of failure of tubewells (PSTC, EAPP:1978).

high cost of water supplied through them. The major manifestation of malfunctioning is the poor discharge available from most of the tubewells. Although all of them are designed for a discharge of 1.5 cusecs, only 0.75 cusecs is available on the average (see PSTC:1976, 1980). The reasons for this dismal performance can again be located at the level of design and installation of tubewells. Secondly, the erratic electricity supply discourages utilisation, not only by limiting the quantum of irrigation but also its reliability. Poor reliability of the source during critical periods forces the farmer to look for alternative sources. Finally, the maintenance and operation of the tubewells is very inadequate leading to poor irrigation service to the users. The rate of breakdown of tubewells is very high and the repairs are undertaken only after considerably delay (see PSTC:1976, 1979).

The second major factor contributing to the low utilisation is the high water rates charged. The water is charged not on a volumetric basis but on the basis of the number of electricity units consumed to pump out a unit of water. This implies the following: first the number of electricity units consumed per unit volume of water depends on the horse-power of the pump used which is a function of the hydrogeological parameters of the sub-soil strata and as such, is bound to be different for different tubewells. Hence the systematic non-uniformity in the cost of water
Secondly, the actual discharge has been found to be far below that designed for, and to that extent, cost per unit volume of water in fact received by the user rises further, thereby aggravating the already weak demand.

4. Consequences of poor utilisation: As a result of the flaws in the mode of creation and utilisation of deep tubewells, the P.S.T.C. has been suffering from mounting losses. Table A.3.5.2 shows the yearwise losses on account of irrigation by tubewells from 1974-75 onwards. The rate to be charged per unit of electricity was decided on the assumption of their operation for a stipulated period on a no-profit no-loss basis. However, the cost of operation of the tubewells has since been pushed up by inflation while the returns have been depressed due to poor utilisation resulting in a net loss. Besides, even during the non-operation period the Corporation has to bear the minimum overhead charges on the upkeep and maintenance of tubewells which further aggravates the losses. As a result, the government has been forced to subsidise the corporation since 1978, with the subsidy increasing every year. Hence the poor returns from the investment of public resources in the entire program of public tubewells in Punjab. This is particularly ironic given the availability of ideal objective conditions for the successful use of this technique of irrigation in this region.

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3 For example, in areas like the Kandi tract which has deep aquifers requiring heavy pumping, the cost of irrigating an acre of wheat can range from Rs.60 to Rs.300. This is very high, specially when compared to the corresponding cost in case of canals i.e. Rs.16.

4 The government gave a subsidy of Rs.41 lakhs in 1979-80 and Rs.69 lakhs in 1980-81.
## TABLE A.3.5.1

Statement Showing the Position of Tubewells up to 31.3.1980

<table>
<thead>
<tr>
<th>Name of scheme</th>
<th>Number of tubewells sanctioned</th>
<th>Tubewells in operation</th>
<th>Abandoned during Drilling Development</th>
<th>Abandoned during Operation</th>
<th>Total abandoned</th>
<th>Total drilled</th>
<th>Number of tubewells operating successfully</th>
</tr>
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<tbody>
<tr>
<td>1. Kharar, Sialba Majri and Ropar Block</td>
<td>56</td>
<td>39</td>
<td>10</td>
<td>13</td>
<td>22</td>
<td>45</td>
<td>86</td>
</tr>
<tr>
<td>2. Derra Bassi Block (Phase I)</td>
<td>30</td>
<td>19</td>
<td>6</td>
<td>5</td>
<td>12</td>
<td>23</td>
<td>43</td>
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<tr>
<td>3. Derra Bassi Block (Phase II)</td>
<td>35</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>4. Saroya Block</td>
<td>35</td>
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<td>2</td>
<td>7</td>
<td>7</td>
<td>16</td>
<td>40</td>
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<tr>
<td>5. Balachaur Block</td>
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<td>2</td>
<td>1</td>
<td>3</td>
<td>16</td>
<td>45</td>
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<tr>
<td>6. Rajpura Block</td>
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<td>2</td>
<td>3</td>
<td>8</td>
<td>25</td>
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Source: Office of Maintenance and Repair, PSTC, Chandigarh
### TABLE A.3.5.2

Loss in Respect of Direct Tubewells

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<tr>
<th>I. Cost of Tubewells in Operation (Rs. lakhs)</th>
<th>Year</th>
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<tr>
<td>(a) Interest Charges</td>
<td>9.4</td>
<td>17.4</td>
<td>21.4</td>
<td>40.2</td>
<td>44.5</td>
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<tr>
<td>(b) Establishment Charges</td>
<td>4.5</td>
<td>3.8</td>
<td>7.0</td>
<td>8.2</td>
<td>11.0</td>
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<tr>
<td>(c) Contingent Expenditure</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.7</td>
<td>0.8</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>14.2</strong></td>
<td><strong>21.5</strong></td>
<td><strong>28.7</strong></td>
<td><strong>49.1</strong></td>
<td><strong>56.3</strong></td>
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II. Revenue Earned

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<td><strong>2.4</strong></td>
<td><strong>3.4</strong></td>
<td><strong>8.4</strong></td>
<td><strong>4.9</strong></td>
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III. Net Loss

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<td><strong>11.8</strong></td>
<td><strong>18.1</strong></td>
<td><strong>20.3</strong></td>
<td><strong>44.2</strong></td>
<td><strong>51.1</strong></td>
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Source: Financial Section, Punjab State Tubewell Corporation, Chandigarh.