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DRAINAGE OF IRRIGATED LANDS OF PAKISTAN A CRITICAL REVIEW

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INTRODUCTORY SYNOPSIS

Irrigation Engineering developed in this country during the last 180 years was mainly based upon certain assumptions, actual construction, checking the results and then developing an improved design. There are many instances supporting this statement. After Independance many drainage and water improvement schemes were undertaken. In the last fifty years there has been several contributions discussing the outcome of these projects. This note is another of the kind discussing some aspects of drainage, groundwater, tubewells construction and water saving devices.

During the last 35 - 40 years the country has been favoured to receive every third or fourth year proposals and guidances to undertake some aspects of the problem mentioned above. The suggestion centered round the installation of tubewells to drain irrigated lands, reduce soil salinity and make available urgently needed water resources. In this paper certain aspects of their design, problems of their operation and maintenance, their cost and present proposals about their disposal are discussed. These tubewells were designed by Foreign Experts and installed according to Scientific Technique, with an assumed useful life of 50 to 100 years, yielding usable water. Punjab Province which has the largest number of these tubewells had by 1985-86 spent Rs. 3669.0 million mainly obtained as foreign loans. The operation and maintenance cost of these wells have continued to rise and due to high operation cost these are now being dispensed with under the project of Tubewell Transition. According to the trail at a site, it is estimated that transition of all fresh water tubewells of Punjab will cost Rs. 11143 million (Rs. 1114.3 crors). The initial construction cost will also be lost as practically no recovery is possible. In this note suggestions are putforth to save this national loss. The method suggested will save the tubewells, increase their output, improve the quality of pumped water and the responsibility of Operation and Maintenance will become that of the water users.

Another aspect discussed in this paper is the disastrous effect of withdrawal of water of high salinity and its spreading on agricultural lands of the Punjab.

Another point relates to the construction of Scavenger type tubewells, about their costly design and withdrawal of highly deep located saline groundwater which may ruin the irrigated lands. The alternative suggested if adopted will save Rs. 160 millions from construction of 400 proposed scavenger wells. Another point which has started to be propagated is the possible stoppage of construction of tubewells by farmer in areas of declining groundwater. Punjab is fortunate to possess its 60 percent underground formation unsaturated. She has also surface water potential of 10 to 15 maf which runs off during annual precipitation. A part of this water can recharge and fill an empty formation and become a source of additional supplies.

In this paper two more aspects of assumed increased water resources are discussed. Some details of water saving by lining of distributaries and minors is given together with the expected saving of water and cost of construction of lining. The last item includes some information about drainage by tiles, design of its filter and some suggestions about alternative cheaper method of land drainage.

It is expected that the Engineering profession will carefully consider these suggestions and start adopting these alternatives which are important for this loan ridden country.

BRIEF SUMMARY OF INFERENCES

1. In 1950, Pakistan requested the World Organizations to help solve problems of waterlogging and salinity. The response was very quick. Experts of F.A.O., Colombo Plan and U.S. Agency for International Development started understanding various aspects of the problem.

In 1959, WAPDA came into being and with the advise of its Consultants and American Aid started the first SCARP.

2. In 1961, President Ayub was asked to get help from President Kennedy for the solution of the problem. President Kennedy sent Dr. Revelle with a team of experts. Dr. Revelle recommendations were received in 1964.

In 1967 World Bank entrusted Peter Leiftinik to prepare a comprehensive Report of Water and Power Resources of Pakistan. Leiftinik also acquired the help of Irrigation Agriculture Consulting Association (IACA) and Chas T.Main.

In 1970, Indus Basin Review Mission of World Bank arrived to evaluate Leiftinik report. In 1973, Pakistan Planning Division started an accelerated programme to control the problem.

In 1975, WAPDA with guidance of Harza and other Consultants started a comprehensive study and their report named Revised Action Plan was available in 1979.

In 1990, Water Sector Investment Planning Report become available for completion of the works in progress in all the four Provinces and undertaking new projects during 1990 to 2000. This is a brief mention of the guiding reports rarely received in such large number at such quick accession.

3. The advise received fundamentally centered round the use of Tubewells, some action on which had already started in this country in 1915 and practical demonstration of their design and working was available in case of 1500 Tubewells of U.P. constructed by Sir William Stamp in 1932-30 and 1800 proposed Tubewells of Rasul Project Planned by Mr. Haigh in 1944.

4. The first SCARP Project started in 1960 was fundamentally based upon Tubewells with this difference that the pumping machinery and Tubewell components had to be imported. Even the construction was done by an American Firm. It was claimed that these Tubewells will last for 50 to 100 years. On operation, the mild steel strainer started to misbehave. All help of scientists could not improve the working of these wells. Rather than

to revert to the experienced design of this country, mild steel was replaced by Fibre Glass and such large stocks were imported which could last for all future scarps. This new material had its own many problems. Another serious problem with SCARP Tubewells is the pumping of deep located saline water. In case of SCARP I, about 40% tubewell gave water of 1000 ppm. Out of 8070 tubewells for withdrawing usable water about 30 percent yields water with salts more than 1500 ppm.

5. By 1985-86 Punjab had 8070 tubewells pumping usable water and 1134 Tubewells pumping saline groundwater. The cost of their construction was Rs. 3668.0 million. The operation and maintenance cost has risen so high that it has now been decided to completely finish the existence of these Tubewells and instead provide farmers to have their own Tubewells. This project is called transition of SCARP Tubewells and transition of 213 Tubewells of Khangah Dogran has cost Rs. 380 million. On this scale the estimated expenditure for transition for all fresh water Tubewells of Punjab is Rs. 11143.0 millions.

6. In this paper alternative suggestions are putforth to save this national wealth and to take measures to keep the Tubewells in operation, increase their yield, and improve the water quality and entrust their operating responsibility to water users.

7. Some brief information is given about farmers Tubewells which were considered inefficient and expected to be eliminated at the start of SCARP Tubewells but just the reverse has happened.

Farmers Tubewells have saved the Agricultural economy of the Punjab by yielding about 22 to 25 maf. Water of usable quality and without pumping the operating cost from Public funds. The Public Tubewells are designed to yield 7.0 maf at a very heavy cost.

The serious disadvantage is the deterioration of the quality of water due to up-coming and saline water intrusion into fresh groundwater zone.

8 With all this experience of Tubewells, Scavenger type Tubewells have started to be installed at a very high costs. Such design has been adopted which pumps water as saline as sea water on to the land surface. No body has experimented with a design costing 1/5th the cost of well being installed and with much less chance of pumping highly saline groundwater. The practice of pumping deep located highly saline water is in progress in Punjab also. Here about 70 m-tons of salts pumped with water are being spread on land surface.

9 In zones of certain canals, the groundwater is declining. Punjab has 60 percent area in which the underground has water deeper them 10 ft. Punjab also has about 10 to 15 maft of surface water which runs off during monsoon. It is time that we should start development a recharge technique to conserve surface water in underground formations for our needs.

10 It is being stressed to save loss of water as canal seepage. Lining of Distributaries and Minors is being practiced. In this note order of seepage loss through distributaries has been worked out which is hardly 0.2 cusec per mile. In the Water Sector Investment Planning Report, the loss order from distributaries has been raised from 7 to 15 percent without giving any supporting data. It is another example of raising the estimated loss without the support of investigations.

In case of water-course the loss has been raised to 25 percent and is stated to be of the same order as in Fields : For water course losses there were some observations but no such experimental results are reported for Farms and distributaries.

11 Volume of water saved from lining of distributaries is too small and cost of lining already practiced exorbitantly high.

12 The propagation of lining of distributaries in areas possessing saline groundwater is being propagated without the basic data about the position of existence of saline groundwater.

13 The last item mentioned in the note relates to the construction of tile drains in Faisalabad area called as drainage-IV. Its cost of construction, disposal of drained water, lack of additional water for drainage of soil salinity are mentioned. An alternative method much cheaper and effective is proposed for test at site.

14 Another very essential item for tile drains is the selection of suitable grade of Drain envelope for which advise of several experts was sought for using a suitable grading at site. The grades and size distributions used for envelopment are quite different from those used in this country. Even the experimental methods used for tests are different from those in use in this country.

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HISTORY OF DRAINAGE REPORTS FOR PAKISTAN

The first drainage measure for the irrigated area Located in Pakistan, was undertaken in 1904 along the Lower Chenab Canal just a few years after its construction. The problem of rising groundwater and land deterioration by salinity however continued inspite of several counter-measures. After Independence, in about 1950 Pakistan requested UNESCO, Food and Agricultural Organization and other Countries for help to overcome the problems of waterlogged and salinized lands. The response was very quick. Milo B. William a Drainage expert visited Pakistan when it was called West Pakistan. He acquainted himself with the problem and then managed to send a few experts which included Selby a tubewell expert, Olafson a Drainage Engineer, Bowser a Soil Expert and a few others. On their advise between 1952 to 1954, a few Tubewells were got installed at Churkana and Jaranwala. Study of discharge, groundwater quality and the extent of drainage data was started. Bowser worked on soils and classified soils of the Punjab into soil series. In 1953 United States sent Maierhofer who was a Drainage Engineer of Bureau of Reclamation and Frank M. Eston of U.S. Salinity Laboratory. Under Colombo Plan Canada started an aerial and ground soil survey of Pakistan irrigated area in 1954. In the same year the United States Agency for International Development helped to set up a Groundwater Development Organization in cooperation with U.S. Geological Survey and Punjab Irrigation Department. This Organization in 1958 prepared the first Salinity Control and Reclamation Project for about 1.2 million acres of Central Rechna Doab. By 1959 WAPDA was established and then the inflow of several experts and Consultant Organizations came over to undertake the Drainage and Reclamation projects in Pakistan. Tipton and Kalambach, became Consultants for Northern area of Indus Plains i.e. the Punjab and NWFP. Hunting Technical Services in Association with Sir M. MacDonald and partners took over Consultancy Services for Sindh and Balochistan. Harza Engineering International became General Consultants to WAPDA.

The report prepared by Mr. Laroque of Groundwater Development Organization was reviewed by Tipton and Kalambach and was taken up for implementation as the first Salinity Control and Reclamation Project (SCARP NO. 1).

In 1961, President Ayub Planned a visit to America. He was provided with a few Drainage schemes of Pakistan, based upon tubewells and field drains. He was to request President Kennedy of United States to help in their implementation. President Kennedy

appointed a team of experts headed by Dr. Revelle . These experts studied the problems of soil and water of Pakistan and their report was issued in 1964. Tipton and Kalambach continued to prepare SCARP Projects for rest of the Punjab Irrigated area. They prepared SCARP-2, 3, 4, 5 and 6. This firm also remained associated with several other Projects of Indus Basin.

In 1962, Hunting Technical Services started investigations in Sindh and by May 1966 submitted a plan for this area. Harza remained associated with all project under study by WAPDA.

Actually with the creation of WAPDA, the working system of Irrigation and Power Department was completely changed. Several consulting Firms and experts found a vast field for their working. The funds for implementing the schemes were provided by World Bank, American Aid and other loan giving agencies. Perhaps this is the only country of the world which has been provided every third or fourth year with a comprehensive report for the utilization of its water and soil resources. After the receipt of Reveale Report in 1964, the World Bank in 1967 appointed a team of expert headed by Peter Leiftinik to prepare a comprehensive report on Water and Power Resources of Pakistan.

At the same time another Consulting Organization in the name of Irrigation and Agricultural Consulting Association (IACA) was engaged to prepare their exhaustive report. For study of power resources Ches. T. Main another Consulting firm was engaged.

Three years later in 1970, World Bank sent an Indus Basin Review Mission to evaluate the implementation of the recommendation of Lei ftinik Report.

Guided by these fresh reports, the Planning Division of Pakistan in 1973, prepared an Accelerated Programme for control of waterlogging and salinity.

About two years later in 1975, WAPDA in association with Harza with funds of United Nations started another comprehensive study in the name of Revised Action Programme for Irrigated Agriculture. The results of this study were made available in 1978 by the Master Planning and Review Division of WAPDA. In 1990, Federal Planning Cell of Pakistan issued an exhaustive report of four volumes on Water Sector Investment Planning Study prepared by World Bank with assistance of Sir M. MacDonald and Partners Ltd., Harza Engineering Co. International, National Engineering Services of Pakistan and Associated Consulting Engineers (ACE) Lahore. The proposals are under implementation for each province and their cost estimate in Punjab is upto Rs. 100 Billion.

Pakistan is fortunate to receive such extensive guidance from the World Famous Experts and their implementation by the resources of the world. Actually the guidance contained in 1990-2000 report are based upon the outcome of experience gained after

implementation of drainage projects completed in this country during the last thirty years. So far there is no critical examination of actions and their out come. A healthy scientific discussion of the completed works and those presently under implementation can create a healthy effect and in certain cases may become a food for thought. The Author became associated with Irrigation problems in 1934 and has remained associated with implementation todate. May be his 58 years of active association would be of some value to the profession and the country.

1 - Drainage Started by Tubewells

With the evaluation of Central-fiugal pumps by 1880 and perfection of strainer by 1912, tubewells were started to be installed to pump groundwater and use it for Irrigation. The Punjab Irrigation Engineers were very cautious in the use of this technique and installed this system at a few sites. The first attractive scheme was prepared by Sir William Stamp who got installed 1500 tubewells in United Province (U.P.) of India in 1930-32. The Punjab Engineers constructed 16 tubewells in Amritsar area in 1920, and twenty two tubewells in the Karol area near Shalamar Gardens in 1938-40. A Rasul Tubewell scheme was got sanctioned in 1944 under which 1800 tubewells were to be installed along Major Canals of Rechna and Chaj Doabs.

The installation of these tubewells was in progress at the time Independence. It was thus possible to complete 1526 tubewells by 1951. These were to be energised by Power obtained from Rasul Hydel which was made available in 1954. On the arrival of FAO experts, 25 tubewells were got installed in the Chuharkana area during 1952-54. In this period a soil Reclamation Board was created by the Punjab Government which helped to get another 41 tubewells installed in Jaranwala area, 12 tubewells in Chichoki Mallian and 21 tubewells in Pindi Bhattian. Some of these tubewells in Jaranwala and Chichokimallian area were provided with turbine pump to withdraw higher discharges of 3 to 4 cusecs.

2 - Design of Rasul Tubewells

The Rasul Tubewells had a slotted brass strainer made out of brass sheets. Its usual length was 100 to 120 feet. At top a blind pipe, 30 to 40 feet in length and five feet long bail plug at bottom was provided. Both the pipe and strainer had 7.5 inches bore and formed into a pipe by welding the joints. The strainer and pipe were also provided with a suitable grade of shrouding while lining with 12 to 14 inches casing pipe, 30 to 40 feet in length and five feet long bail plug at bottom was provided. Both the pipe and strainer had 7.5 inches bore and formed into a pipe by welding the joints. The strainer and pipe were also provided with a suitable grade of shrouding while lining with 12 to 14 inches casing pipe. These were pumped through a centrifugal pump operated by an electric motor of 15 to 17 H.P. Each

Tubewell pumped 1.5 to 2 cusecs of water which was disposed into the canal. The siting of Tubewells was at the toe of the canal bank. This design was very cheap. All components were manufactured locally. These were installed on the land belonging to the Irrigation Deptt:. This design had all advantages of very low cost as all the components were manufactured locally. The working of Tubewells could be checked while driving along the inspection bank. There was no problem about the quality of pumped water which was discharged into the canal. At Independence some persons strongly objected about the location of Tubewells so close to the canals. It was stressed that these were pumping water out of the canals. Without deeper consideration about the siting of tubewells, it was decided to shift their location 500 feet away from the canal. This was a very hasty action. It spoiled all the merits of original design of the scheme. Additional land had to be purchased both for inspection roads, tubewell sites and operators quarters. The transport of pumped water back into the canal through 500 feet long pipes was another serious problems.

The working of Rasul Tubewells however, dried all the barrow pits and the waterlogged depressions having intensive weeds growth. Previously it was not possible to drain these lands by any other means. The farmers immediately started utilization of the previously 1000 to 3000 feet wide abandoned lands. In many cases where the canal had a few feet of soil under its bed, the groundwater started declining. The Operational Incharge Engineer could seldom visit these tubewells located 500 feet away. At that time no body could plan the distribution of this water to farmers as was done later on in case of SCARP Tubewells which were sited close to the distributary canals. The planner of the scheme Mr. Haigh also tried to introduce wooden strainer and pipe made out of plantation of irrigation department to further lower the cost. The uncertain conditions during Independence was a reason against the proper construction of tubewells with wooden strainer. Misuse of Government Plantation also started. These were a few causes which stood in the full benefit of Rasul Project Tubewells. At that time the cost of a Rasul Tubewell was about Rs. 16,000/00. Every component was manufactured locally. The construction was also carried out by local labour.

3. Design of SCARP tubewells

In 1961, the construction of SCARP Tubewells was started. Each tubewell was to be located near an outlet, the pumped water was to be used mixed with canal supplies. The capacity of each tubewells was fixed to increase the available water required to raise the agricultural intensity to 150 percent. The capacity of majority of tubewell was between 2.5 to 3.5 cusecs. This much volume of water was planned to be pumped by a Turbine Pump which had to be imported as those days these were not being manufactured in Pakistan. For an average yield of 3.0 cusecs the depth of each tubewell was invariably more than 200

feet. The Consultants considered the use of brass strainer too costly. They decided to import seamless mild steel pipes of 10 inches bore. Slots to a maximum width of 1/16 inch and about 8 percent open area were drilled locally. A turbine pump had to be located in 14 inches diameter housing. Initially the housing was connected to the strainer pipe through an overlap joint and later on a reducer mild steel joint was adopted.

At that time Pakistan was not equipped with tubewells boring machines. An American firm of Harold Smith was thus engaged to install these tubewells. These design changes raised the cost of each tubewell to Rs. 78,000/- without electrical provision. While installing tubewells of SCARP-I, complete information about the quality of deep water had not been collected. When these tubewells started operation, a large number of tubewells were found to yield unfit water even after mixing with canal water. On the protests of the farmers, many tubewells yielding highly unfit water had to be closed. The groundwater quality of tubewells of this SCARP between 1962-63 just after completion and in 1980-81 is indicated below in Table - 1:-

TABLE - 1 - WATER QUALITY OF TUBEWELLS OBSERVES AT TWO PERIODS

No. of T/wells checked ppm	Year	Usable upto 1500 ppm		Marginal Water 1500 to 3000 ppm		Hazardeous Water more than 3000	
		%age	No. of T/Well	%age	No. of T/Well	%age	No. of T/Well
1112	1962-63	40.3	448	40.6	451	19.7	219
"	1980-81	29.3	326	50.0	556	20.7	230

Water quality of some tubewells of the SCARP which was inferior continued to deteriorate with time as indicated in this Table. There were two causes of deterioration. One was the upcoming of deep saline groundwater and the second was the solute transport so that water from saline zone moved towards the fresh groundwater zone, While recording the number of tubewells pumping saline groundwater, the tubewells of SCARP-I yielding hazardeous water are not included in that group. These tubewells are causing deterioration of the groundwater formation which had taken imperceptibly long time to build up zone of usable water by pushing away the saline groundwater.

It is necessary that some steps are taken to stop the spread of salinization to areas of fresh groundwater. Another great mistake was the use of mild steel strainers. SCARP-I tubewells started operation in 1963. First reports on the performance of these tubewells was issued for the period of October 1964 to September, 1965.

It was stated that out of more than 2000 tubewells 1712 were progressively deteriorating, 53 had seriously deteriorated and 47 were also heading towards deterioration. There were some tubewells which pumped sand and then suddenly got sunk into the formation. Two or three tubewells thus got damaged every month. Thirty nine tubewells had already been rebored. The discharge by that time had declined by 363.7 cusecs out of designed capacity of 5877.3 cusecs.

This was the performance of tubewells, constructed by Marold Smith who asserted that the tubewells installed by him will last 50 to 100 years. Consultants who advised use of mild steel strainer proposed that as soon as SCARP Tubewell will start operation, no inefficient tubewell of farmers will remain in action.

Then very extensive investigations for the causes of so quick deterioration of these tubewells were started. Vast useful information about the presence of Chemicals in water and formation and the type of salts in existence were determined.

A few rehabilitation measures were tried but without much success. The Consultants rather than to revert to the use of tried brass strainer and groundwater withdrawal through the design of Rasul Tubewells decided to us strainer and pipe made of fibre glass bonded with epoxy. Large stocks of this stuff costlier than brass strainer were imported. The stock were sufficient for all future SCARPS.

4 - Cost of SCARP Tubewells

After the completion of SCARP-I, three additional SCARPS No. II, III and IV were quickly undertaken between 1963 to 1969. These four SCARPs were provided with 6844 tubewells pumping 6.106 ma. ft. of so called fresh water which according to WAPDA classification was water with 1500 ppm to be used directly on lands and between 1500 to 3000 ppm to be used by mixing with canal supplies. Water of Tubewells yielding more than 3000 ppm were not to be used.

By 1985, about 8070 tubewells pumping water within the range of usable water had been yielding about 7.05 maf (9729 cusecs) of water. In this very period 986 tubewells were installed to withdraw highly saline groundwater not used directly on lands. In Table-2 number of tubewells of a few important SCARPs upto 1985 are recorded. The cost of SCARP Tubewells has continued to increase. In 1961-63, a SCARP Tubewell was installed at Rs. 78,000/-. In 1983, World Bank in their Sub-sector Reports worked out the cost of tubewells of this capacity equal to Rs. 305,000/-. Provision of electrical energy, increased the cost to Rs. 605,200/-. It is interesting to note the rising cost of tubewells during different SCARPs. Some data about the number of tubewells installed in different years is indicated in Table-3 :-

TABLE-2 PUMPAGE OF SCARP TUBEWELLS INSTALLED IN PUNJAB (1985-86)

Project	Year of Construc-tion.	Tubewells for		Total Pumpage in MAF Per Annum	
		S.G.W.	F.G.W.	F.G.W.	S.G.W.
SCARP-1	1960-63	-	2969	1.604	-
SCARP-II	1961-83	-	2805	2.418	-
- do -	- do -	821	-	-	0.278
SCARP-IV	1969-78	-	935	0.758	-
	1975-77	51	20	0.039	-
Shorkot Kamalia	1975-77	-	101	0.069	-
Allahabad	1975-79	-	623	0.438	-
Minchanabad	1976-80	23	203	0.125	-
Shahkot	1975-79	-	258	7.05 (9729 Cusecs)	0.3278 (452.3 Cusecs)

TABLE-3 - ESTIMATED COST OF EACH SCARP AND EACH TUBEWELLCONSTRUCTED DURING DIFFERENT YEARS.

Scarp No.	Year of Construction	No.of T/Wells installed	Estimated cost in Rs. Million	Cost per T/Wells in Rs. Million
I	1960-63	2069	239.2	0.1156
II	1961-83	2205	242.64	0.1100
III	1969-81	1635	465.6	0.2848
IV	1969-73	935	311.0	0.3326
Allahabad	1975-79	623	292.0	0.4687

This only indicate to some extent the rising cost of tubewells as this estimated cost is for the project. The increase in cost is approaching Rs. 0.602 as worked out by World Bank in 1983. The total estimated cost of the Punjab completed SCARP in 1985-86 was Rs. 3779.138 million and actual expenditure was Rs. 3668.1 million. The total water out put (see Table-2) was 7.05 maft or Rs. 520.3 per ac. ft.

5 - Cost of Farmer Tubewells

In 1960, a farmer could install a tubewells yielding one cusec at about Rs. 10,000.00. AT that time slow speed diesel engine at a cost of Rs. 3,000.00 was available. Its present cost is about Rs. 15,000.00. Now high speed diesel pumping sets have been developed. These cost nearly the same as slow speed diesel engine. The present day cost of a farmer tubewells lies between Rs. 30 to 40 thousands. At present it is estimated that about 240000 tubewells exist in Punjab. Construction of an electric operated tubewells is costly than diesel operated due to 30,000 subsidy for transmission of electric energy. Due to the problems of getting electric connection in time and frequent load shedding, some farmers prefer operation by diesel pumping set, so that about 70 percent of farmer's tubewells are diesel operated. The farmers operate their tubewells during shortage of supplies. Surveys have shown that the average yield of farmer's tubewells is one cusec and they operate for about 20 percent of annual time. There are varying estimates of total pumpage by farmer tubewells. A minimum estimate is about 22 million acre feet and maximum is 32 million acre feet. It is thus assumed that about 25 maf of water is being withdrawn by the farmer's tubewells. Withdrawal of this much water would have cost the Government Rs. 13007.1 million being the rate of constructing of the existing SCARPS.

6 - A few very important Advantages of Farmer's Tubewells

Average depth of a farmer's tubewells is 100 feet. In case of damage to a tubewells or fall in its yield, a farmer invariably pulls out the strainer, repairs the damage and reinstall it a few feet away from its original position. In case of Rasul tubewells with depth upto 200 feet, any damaged strainer or pipe or with excessive decline in yield, the full tubewells components used to be pulled out and after necessary repair installed near its original position. Components or a tubewells were seldom allowed to remain in the formation. It is very unfortunate that it has never been possible to pull out a strainer and pipe of fibre glass. With any defect in this type of tubewell all the money spent on it is lost.

7 - An estimate of Salts being spread on lands as pumped out by SCARP and other tubewells

In Table-1 data of tubewells pumping groundwater of salinity range of 1500, 1500 to 3000 and above 3000 ppm out of 1112 tubewells of SCARP-1 during 1980-81 was recorded.

Actual tubewells of SCARP-1 are 2070. These tubewells are of different capacity. The number of tubewells with varying capacity are as under :-

TABLE-4A - Number and Capacity of Tubewells

No. of Tubewells	25	415	449	527	338	261	41	11
Capacity in Cusecs of Each	1.5	2	2.5	3.2	3.5	4	4.5	5
Total Pumping Capacity, Cusecs	37.5	830	1122.5	1581	1183	913.5	184.5	55

Thus the actual number of tubewells of SCARP-1 pumping water of different salinity are :-

TABLE-4B - ACTUAL NO. OF TUBEWELLS OF DIFFERENT SALINITY

No. of T/wells Tested	Number of Tubewells of Salinity Range		
	1500 ppm	1500 to 3000 ppm	above 3000 ppm
1112	326	556	230
Actual No. out of 2070	607	1035	428

The average discharge of each tubewells as noted in Table-4-A is about 3.5 cusecs or 7 A. ft. per day. If these tubewells operate for 182 days in a year the total salts being pumped out by tubewells of varying salinity are as under :-

Case-1 - Tubewells, 607, Average salinity 1000 ppm.

Salt in m. tons are 607x1000x7x182x0.00136 = 1.053 m. tons.

Case-2 - Tubewells, 1035, Average Salinity 2000 ppm

Salts in M. Tons are 1035x2000x7x182x0.00136 = 3.585 m. tons.

Case-3 - Tubewells, 428, Range of salinity 3000 ppm.

Salts in m. Tons are 428x3000x7x182x0.00136 = 2.224 m. Tons.

Based upon these assumption the total salts being pumped out by 2070 tubewells of SCARP-I tubewells amount to 6.862 m. tons per year.

8 - Salts - pumped by SCARP Tubewells of Usable Groundwater of the Punjab

Recently an attempt was made to estimate the salts being pumped out by Fresh Water and Saline Water tubewells operating in Punjab. The data contained in a few reports of SCARP Monitoring organization of WAPDA for SCARP-I, III, VI and Setiana, constituting 4450 tubewells was studied. The number of tubewells yielding groundwater with a range of 600 ppm, 1500 ppm and above 2000 ppm was determined. It may be noted that the salinity range was found less than that given in Table 4B. Assuming the average capacity of each tubewell equal to 3.0 cusecs and the number of working days equal to 183 in a year, an estimate of salts being pumped out was determined as given in Table-5.

TABLE - 5

AN ESTIMATE OF SALTS PUMPED BY 4450 SCARP TUBEWELLS OF FRESH WATER

Scarp	Total Tubewells	Tubewell With Average Salinity Of 600 PPM	Tubewell Average Salinity Of 1500 PPM	Tubewell Average Salinity Of 2000 PPM
I	2070	695	891	493
III	1638	1101	365	165
IV	671	475	105	91
Satiana	71	20	6	45
Total	4450	2291	1367	794
Estimate of Total Salts in M.Tons	-	2.053	3.062	2.371

This is a very conservative estimate. The previous estimate vide Table-4B for SCARP-I was much higher. This estimate shows yearly salts being pumped by 8070 fresh water SCARP Tubewell equal to 13.6 m.Tons per year.

9- Salts - Pumped by Tubewells from saline Groundwater

Tubewells installed to pump saline groundwater are given in Table-6. These are 2548 tubewells. The groundwater being pumped is of average salinity of 10,000 ppm. the capacity of each well is 2.5 cusecs or 5 a.ft. per day. If these wells operate for 250 days in a year, then the salts pumped out amount to :-

2500 x 10000 x 5 x 250 x 0.00136 = 42.5 m. tons

Besides these two sources of SCARP tubewells there are salts being pumped by farmers tubewells and by river water diversion into canals. The estimate of salts pumped by these two sources is worked out.

The number of farmer's tubewells is estimated to be 242000. We assumed that 220000 tubewells are located within the canal culturable area. Between 1971 to 1974, very detailed study was carried out by Irrigation Research Institute on certain number of tubewells selected at random in several districts of the Punjab. The tubewells studied included both operated by Electric Energy and Diesel Power. The water quality of each well, its discharge and depth of bore was determined and is recorded in Table 7. A fairly large number of tubewell which had a depth of 100 feet, pumped a discharge of 1-0 cusec or less. Eighty percent tubewell pumped water containing salts of 640 ppm. Fifteen percent, tubewells yielded water of 1000 ppm and nearly equal number yielded water upto 1300 ppm. This was the case for water of Bahawalpur, Faisalabad, Sahiwal and Multan.

Assuming water of 600 ppm out of 220000 tubewells each yielding one cusec or 2 acre feet per-day and operating for 73 days in a year, the quantity of Salt being pumped out was found equal to 25.85 m.tons as per details of calculation :-

22000 x 600 x 2 x 73 x 0.00136 = 25.85 M.Tons.

The salts estimated by 56 maf of canal diversion possessing salt upto 150 ppm and water available for say 330 days are :

56 x 1380 x 150 x 330 x 2 x 0.00136 = 10.4 m.tons

The total salts being spread on Agricultural Lands every year from different sources are thus from :-

1.	SCARP Tubewells	13.6 m.tons
2.	Salts out of Saline Water being pumped	42.5 m.tons
3.	Salts being added from Water of farmer's Tubewells	25.95 m.tons
4.	Salts from Irrigation Water	10.4 m.tons

The area under irrigation in Punjab is 20.0 m.acres so that each acre is receiving 4.62 tons of salts per year. Some alternative measures need to be utilized to reduce the spread of these salts.

TABLE - 6

SHOWING NUMBER OF TUBEWELLS PUMPING SALINE GROUNDWATER (SGW) DIRECTLY INTO CANALS OR THROUGH OPEN DRAINS IN PUNJAB PROVINCE

SR. No.	No. of SCARPS		No. of T/Wells Installed	Disposal of Saline Water into Canal	Saline water into Drain Length in Mile
1.	SCARP-II		821	–	465
2.	SCARP-III		61	Canal	–
3.	SCARP-V	(a) Satiana	50	Canal	–
		(b) Khairwala	48	–	174
		(c) Paharang Drain	84	–	57
		(d) Drainage-Iv	148	–	92
4.	Along	(i) R.O.B. Link	85	Canal	–
		(ii) T.P.Link	64	Canal	–
		(iii) T.S.M.B. Link	76	Canal	19

5.	SCARP-VI Panjnad Abbasia	391	Canal	--
6.	SCARP-VIII (i) Machinabad	23	Canal	--
	(ii) Fordwah, Sadiqia Phase-I	30	--	111
7.	C.B.D.C Pandoki Unit	101	--	85
	Sub - Total	1982		
8.	On going to be completed	566	--	--
	Grand Total	2548	--	747
9	Khairpur Area of Sindh	380	Canal	

10 PRESENT CONDITIONS OF SCARP TUBEWELLS

A brief reference to the working of tubewells of SCARP-I, about two years after their construction, has already been mentioned. After the serious problems of deterioration of tubewells having Mild Steel Strainers, the Consultants shifted over to strainers of fibre Glass. The use of this materials also did not help to overcome the declining yield of tubewells. In 1978, both the SCARP Monitoring Organization and the World Bank estimated the rate of fall in yield of tubewells having strainers of mild steel and fibre-glass . A part of this information is reproduced in table - 8 :-

TABLE - 8

RATE OF REDUCTION IN YIELD OF SCARP TUBEWELLS

Scarp Project	Years of Construction	Type of Strainer	Initial Yield. Cusecs	% Reduction Upto 1975-76.	% Reduction Per Year
I	1962-63	Mild Steel	6343	47.9	3.7
II (Lalian)	"	"	676	30.7	2.4
III (Alipur)	1960-72	Fibre-glass	--	32	8.0
IV	"	"	--	47	12.0

TABLE - 7 DISCHARGE, WATER QUALITY AND BORE DEPTH OF FARMER'S TUBEWELLS

Sr. No.	District	No. of Tubewells Tested	Average Dis. Pumped in Cusecs Percentage of T/Wells with			Water Quality PPm/) EC) % of T/Well				Depth of Bore in Ft.		
			Dis. 0.5	Dis. 1 to 1.5	Dis. 2	320 (500)	640 (1000)	980 (1599)	1280 (2000)	100 % of Tubewells	150	200
1 -	Gujranwala	48 (28 Elc, 18 Die)	69	17	14	21	79	--	--	86	14	--
2 -	Sialkot	56	44	38	18	47	53	--	--	22	18	60
3 -	Jhang	60 (42 Elc, 18 Die)	48	52	--	33	53	14	--	60	40	--
4 -	Faisalabad	52 (24 Elc, 30 Die)	47	43	10	23	46	6	25	43	51	6
5 -	Multan	60 (30 Elc, 30 Die)	50	48	2	15	55	15	15	27	70	3
6 -	Sahiwal	60 (40 Elc, 20 Die)	63	32	--	--	63	24	13	32	38	30
7 -	Rahimyar Khan	42 (21 Elc, 21 Die)	43	57	--	43	31	14	12	17	66	17
8 -	Bahawalpur	40 (21 Elc, 19 Die)	63	37	--	10	28	28	34	10	37	53
9 -	Kasur	56	--	--	23	52	16	9	--	--	--	--
10 -	Rawalpindi	22 T/well 20 Open wells with strainer	100 (0.2 to 0.4)	--	--	50	50	--	--	--	--	
11 -	Campbellpur	20 T/well 80 Open well	100 (0.3)*	--	--	28	62	10	--	--	--	

* Yield in Cusecs.

At the same period Superintending Engineer, SCARP-I also estimated the useful life of tubewells. His analysis gave the useful economic life of tubewells equal to 12 years. This analysis was carried out about 14 years ago. On this rate of decline, the output of tubewells would have completely ended but these are still yielding water. CMO WAPDA has been analysing the yield data of SCARP tubewells. Their findings has not yet been published. It however appears that each tubewell is still yielding sufficient water. It seems that in the beginning with high output the rate of decline was high and it has continued to get reduced with time.

11. SOME CAUSES FOR THE UNSATISFACTORY PERFORMANCE OF SCARP TUBEWELLS

SCARP-I tubewells started operation in 1962-63. Some problems about yield of water started appearing. The operating agencies did not realise that tubewells performance is like the working of a machine which needs off and on some minor repairs. An important component of a tubewells is the turbine pump which is contained in deep groundwater in a housing. There are no performance rules to examine its components after a certain period of operation. Usually the pump is extracted only when some trouble has advanced too far.

The second important component of a tubewell is the strainer which receives water flowing through the water bearing formation which is made up of a mixture of different ingredients some of which are reactive with water containing certain types of salts. Reactive materials commonly contained in the formation are carbonates of Calcium and Magnesium which change to soluble bicarbonates by water containing Carbon Dioxide. Bicorbonate release carbon dioxide at low pressure due to suction of the tubewell and changes into solidified Calcium and Magnesium Carbonates. It is also known that fungus is often found in standing water. It is due to some bacterial action. The presence of different types of bacteria such as sulphate reducing or iron reactive has been established to exist in the Indus formation. Colloidal clays produced from clayee deposit have electrical charge. These are a few well know parameters which can change the character of the underground formation near the zone of an operating tubewell. Thus it is very necessary that there need to be some operating rules, to counter act these obvious causes of deterioration of yield of a tubewell. During the last 32 years no procedures have been adopted to counter the above stated causes of decline in yield of a tubewells. We know that for each barrage certain procedures are framed for its operation. Still every year after the flood season each barrage is examined and any defect found is rectified. Tubewell is such a device which is considered to be so perfect that after its construction for years one expects no deterioration and damage. It is not disappointing to note that in 32 years since the start of SCARP tubewells no manual for operation and maintenance and procedures for upkeep of a tubewells have so far been issued. Every incharge of a SCARP scheme adopted his own techniques to set right the

problems which appeared at each tubewell. If operator of each SCARP had ever met within these years to discuss the problems of SCARP Tubewells, the conditions would have been different. If the SCARP Tubewells have not performed well, the main cause can be the absence of application of various timely measures.

12 TAKE STEPS TO SAVE HUGE NATIONAL WEALTH INVESTED ON TUBEWELLS

In Punjab by 1985-86, about 8070 tubewells had been constructed to pump usable water and 1105 tubewells to pump saline groundwater for drainage. By this time an expenditure of Rs. 3668.00 million had been incurred. the cost of operation and maintenance is also a problem. It has continued to increase every year. In Table - 9 cost of O&M for tubewells compared with Punjab Irrigation Canals is given :

TABLE - 9 ANNUAL OPERATION AND MAINTENANCE COSTS IN MILLION RUPEES

YEARS	CANAL	TUBEWELLS	TOTAL
1971-72	113.7	50.9	164.6
1972-73	129.8	78.6	208.4
1973-74	135.9	93.3	229.2
1974-75	196.0	116.4	312.4
1975-76	210.0	161.1	371.1
1976-77	228.3	162.5	390.8
1977-78	257.8	159.2	417.0
1978-79	249.0	231.7	480.7
1979-80	229.1	346.3	645.4
1980-81	312.1	425.3	737.4
1981-82	461.9	469.6	931.5
1982-83	494.3	513.2	1007.5
1983-84	563.6	632.2	1195.8
1984-85	661.4	722.6	1384.0

This Table shows the increasing cost of operation of Tubewells. Its rate of increase per year is much more than that of canals. By 1990-91 it was reported to have increased to about Rs. 1300 million. The rising cost for O&M of tubewells has compelled the country to take counter measures. World Bank studies had suggested an alternative. This constitute to stop all SCARP Tubewells and in their place water users are suggested to install their own tubewells by obtaining loans. The Government will provide electrical energy. This scheme is named SCARP Transitions. This programme was tried on 213 tubewells of Khangah Dogran. In about five years, farmers have been provided with an alternative arrangements. The Government has incurred an expenditure of Rs. 360 million so that the elimination of each SCARP Tubewells has cost Rs. 1.8 million. It appears that perhaps no recovery was possible from the disposal of pumping sets, the pump house, its electric fitting and operator quarters.

No components of tubewells can be pulled out. This technique is now to be extended to the remaining fresh water tubewells of the Punjab. If the cost of replacement remain at Rs. 1.8 million per tubewell then 7858 remaining fresh water tubewells will need an expenditure of Rs. 11143.0 million. The readers can work out the time of replacement. In the Water Sector Investment Plan in progress for 1990 to 2000, a provision for Rs. 1796.0 million has been included, Rs. 296.0 million are for on going projects and Rs. 1500.0 million for the new programme of Transition.

The Irrigation Engineer has advised the Government that they cannot undertake any tubewell projects and will help in the transition of existing SCARP Tubewells. They have not considered the wastage of Rs. 3668.0 million spent on their construction and Rs. 11143.0 million required for their replacement.

13 SUGGESTIONS TO SAVE SCARP TUBEWELLS FROM TRANSITION

SCARP tubewells are located at the water-course serving a Chuk. The usual capacity of such tubewell was 3 cusecs and electrical provision was made to pump this much discharge. The present condition is that the discharge of each well has declined. Certain tubewells are pumping water of marginal quality. The design of SCARP Tubewell constitute about 60/70 feet of housing and the strainer length was more than 130 feet. The water is withdrawn by a Turbine pump which exists within the housing. The depth of groundwater is within 10 feet in many cases and the deeper water is upto 15 feet.

It is proposed to replace the turbine pump by a centrifugal pump. The top foundation of turbine pump and electric motor may be removed. A pit may be dug about 10 feet deep or less if the groundwater is high. The top about ten feet of housing may be removed and foundation prepared to install a centrifugal pump with a suction pipe and a foot value lowered into the housing. The water pumped may as before be discharged into the water-course. In this arrangement there can be two defects. One will pertain to discharge which may be very low. The second defect will be about water quality. In order to increase the discharge it is proposed to install a farmer type Tubewell about 25/30 feet away. Its total depth will be limited to 60 to 80 feet It will be pumped by lowering a pipe with a foot. valve into this well. Both these wells will be pumped by the same centrifugal pump. The capacity of such a well will be equal to 1.5 to 2 cusecs. If the yield is low and the deeper water was of inferior quality, then another shallow depth tubewells, similar to the first one may be installed. If groundwater is within a depth of ten feet then the arrangements of connecting pipes as shown in Figure 1 will be found suitable. If the groundwater is deep and connecting pipes are also to be laid deep then the arrangement as shown in Figure 2 can be adopted. As regards the problems of water quality, the old strainer of SCARP Tubewell shall have to be plugged at shallow depth. For this condition, the additional tubewells will also be shallow. This arrangement of tubewell will pump upto 2 cusecs using about 15 to 17 H.P. of energy. As the provision of power supply was to pump 3 cusecs, possibility of a second tubewell to use available energy exists.

It will be necessary to create some sort of an organization of residents of the chak to be entrusted to operate the Tubewells and bear the maintenance cost. These proposals are worth consideration. A few tubewells may be selected and the proposed suggestion implemented and their feasibility determined. It is stressed that we may not destroy the original SCARP Tubewells. So far we have not tried all methods of rehabilitation. May be one is found if efforts are made. The cost of this arrangement will be much less than that incurred on Khangah Dogran.

14 SCAVENGER OR COMPOUND TUBEWELLS

In 1978 Hunting Technical Services suggested a system of two tubewells called a compound well to pump usable water over lying saline groundwater. One tubewell was to be located within the depth of formation possessing usable water. The second tubewell was to be located close by which had blind pipe in the zone of usable water and a strainer in the zone of saline groundwater. Both the strainers were to be pumped separately at the same time, so that the one located in the zone of saline water did not allow it to be sucked by tubewell pumping usable groundwater. This idea has now started to be utilized in Sindh. It is planned to install about 400 such tubewells in the area to be served by LBOD. In the water sector Investment Planning Study Vol-III working data of three such wells is given. This is

reproduced in Table-11. For further clarification a Figure 3 is prepared to explain the depth and location of the two positions of the strainers. The depth of tubewells of saline water system and the length of screens is not given in this volume. As the discharge being pumped out was of the some order from both types of tubewells, we have assumed the length of tubewells of saline ground water equal to that yielding usable water. The total depth of tubewell of saline water system has thus been worked out as recorded in Table-II and explained in figure 3. In this report the variation of ground water quality along depth at each site is not given. The quality of usable water is about 600 ppm and that of saline water being pumped is 16000 to 24000 ppm. The quality of ground water seldom increases to such high order below the fresh water. There is always a Transitions zone of several feet in which the order to salinity slowly increases with depth. These wells could be designed to suck the saline groundwater just below the freshwater. This could easily be attained by keeping the length of saline groundwater strainer only a few feet. The quality of pumped water also would not have been of such high order. Another very useful advantage of this type of well system is the possibility of inflow of usable water into the zone of Saline water and creation of zone of usable water. Thus the disposal of highly saline groundwater would have also been solved. Another serious problem pertains to system of pumpage. The ground water exists within a depth of suction by a centrifugal pump. The range of discharge also lies within the pumpage limits of a centrifugal Pump. The cost of typical one cusec discharge scavenger well is given in Table 12. Thus, one tubewell is to cost about Rs. 5 Lakhs. The pumping set alone is to Cost Rs. 2.5 Lakhs. Use of a centrifugal pump will limit the cost to ten or fifteen thousands. A complete scurenger tubewell operated by centrifugal pump as shown in Fig 4 a & b will cost less than Rs. one Lakhs. In case of 400 tubewells of this type the country will save Rs. 160 million. What is the function of so many research organizations if these are unable to test alternative design which will be within the resources of the country.

TABLE - II
CONSTRUCTIONAL DETAILS OF THREE SCAVENGER TUBEWELLS

SR. NO.	FRESH WATER SYSTEM	NO. OF TUBEWELLS		
		PSW IA m(ft)	PSW2 m(ft)	PSW3 m(ft)
1	Transmission Zone	4.5(14.8)	7.5(24.6)	4.5(14.8)
2	Thickness of Fresh Groundwater lens.	33(108.2)	22(72.2)	46(151.0)
3	Depth of well	37 (121.4)	33(108.2)	42(137.8)
4	Length of Screen	22(72.2)	19(62.3)	25(82)
5	Position of Pump	15(49.5)	14(46)	17(55.8)
6	Discharge pumped L.S. (Cusec)	21(0.75)	19(0.67)	33(1.17)
	SALINE WATER SYSTEM			
8	Probable depth	59(193.6)	52(170.5)	66.9(219.51)
9	Probable length of Screen	22(72.2)	19(62.3)	25(82)
10	Pumping set	34(111.5)	38(98.4)	39(127.9)
11	Discharge pumped L.S. (Cusec)	21(0.75)	18(0.643)	22(0.786)
12	Water Quality EC (ppm)	26000 (16900)	36000 (23660)	24000 (15600)

NOTE :- The length of screen and depth in case of Tubewell pumping saline groundwater has been estimated on basis of its discharge.
L.S. is litre per second

TABLE 12

TYPICAL 1 Ft^3/Sec (28 I/s) SCAVENGER WELL COSTING

Item	Description	Units	Qty	Rate Rs.	Amount Rs.
1.	Drilling at 24 in dia in the range 0.50 m	Lin.m	34	425	14,450
2.	Supply and install 18 in dia GRP casing	Lin.m	13	2,247	29,211
3.	Supply and install 18 in dia GRP slotted screen	Lin.m	3	2,575	7,725
4	Supply and install 10 in dia GRP slotted screen	Lin.m	17	1,361	23,137
5	Supply and place gravel	lin.m	34	180	6,120
6	Development and testing	No	1	8,000	8,000
7	Supply and install pump	No	1	243,000	243,000
8	Wellhouse and associated works	No	1	19,500	19,500
9	Disposal channel and associated structures	No	1	40,000	40,000
10.	Miscellaneous works	No	1	15,000	15,000
				Sub-Total :	406,143
	Add for Preliminaries at		5 %		20,307
	for Engr's requirements at		5 %		20,307
	for Day works at		2 %		8,123
	for spares of item 7 at		15 %		36,450
				Total :	491,330

Source : Scavenger Well Studies and Pilot Projects, 1989.

15 PROBLEMS OF DECLINING GROUNDWATER

In certain canal commads of the Punjab, net pumpage is more than usable recharge. This information for the year 1985-86 is given in Table 13 :-

TABLE - 13 GROUNDWATER RECHARGE, PUMPAGE AND DEVELOPMENT POTENTIAL

SR. NO.	CANAL COMMAND	USABLE C.C.A M.A.	USABLE RECHARGE AF/AC	NET PUMPAGE AF/AC	DEVELOPMENT POTENTIAL AF/AC
1.	Raya Br	0.242	1.45	1.77	-0.32
2.	M.R.Link	0.017	1.34	2.52	-1.19
3.	Jhang	1.036	1.41	1.84	-0.43
4.	Lower Jhelum	1.117	1.05	1.84	-0.78
5.	Mailsi	0.779	1.08	1.92	-0.84
6.	Sidhnai	0.850	1.13	1.86	-0.53
7.	Rangpur	0.322	0.70	1.59	-0.88

In these canals over exploitation is taking place. There are suggestions to restrict further exploitation. These canal commands have considerable area in which the groundwater is deeper than ten feet. The extent of these areas is recorded in Table - 14 :-

TABLE 14
AREAS OF CANAL WITH GROUNDWATER DEEPER THAN 10 FEET

SR. NO.	CANAL	AREA WITH G.W. BETWEEN 0 TO 5' ma.	%	AREAS WITH G.W between 5 to 10' ma.	%	TOTAL AREA within 0 to 10 ft ma.	%
1-	Raya Br.	0.008	1.8	1.115	26.6	1.123	28.4
2-	M.R.Link	0.003	1.8	0.029	17.4	0.032	19.2

3-	Jhang	0.026	1.5	0.734	43.4	0.760	4.49
4-	L.Jhelum	0.198	11.1	0.491	35.9	0.689	47.0
5-	Mailsi	--	--	0.077	7.1	0.077	7.1
6-	Sidhnai	--	--	0.021	2.4	0.021	2.4
7-	Rangpur	--	--	0.144	34.6	0.144	34.6

Punjab Province has large irrigated areas with groundwater deeper than ten feet. Such areas for Sindh are also given in Table - 15. In June, 42 percent area of Punjab, constituting 10.2 m.acres out of 24.62 m.acres gross had groundwater upto 10 feet. After summer monsoon in October, it increases to 11.83 m.acres becoming 48 percent of total. In case of Bari Doab in the area served by Pakpattan, Mailsi, Sindhnai and L.B.D.C, having total CCA equal to 4.604 m.acres as given in Table - 16, area with groundwater deeper than 20 feet constitutes 3.289 m.acres being 71 percent of total. Punjab thus possesses about 58 percent area with groundwater deeper than ten feet. The condition in Sindh as depicted in Table - 15 is quite different. Here only 20 percent area has groundwater deeper than ten feet. Another advantage for Punjab, is the comparatively high rain fall estimated to be 4 to 6 ma.ft. Both during kharif and rabi large volume of water runs off below Punjnad. Releases below Punjnad and Kotri are given in Table-17. On the average about 15 maf. in Kharif and more than 1.0 m.aft in Rabi flows through Punjnad. Thus Punjab has large resources of water available and has also areas in which this water can be stored and utilized.

16. RECHARGE TECHNIQUE NEEDS PERFECTION

For Pakistan recharge technique is as important as the withdrawal of water by tubewells. The Indus formation is most suitable for recharging wells. It has a thin top soil about 5 to 20 feet thick. It is then followed by sand deposits. The sand of the plains is finer than coarse sand of particles smaller than 0.5 mm, but it is an alluvial deposit transported by water so that each deposit has high uniformity between 1.25 to 2.5. The pores of sand constitute about 40 percent and a saturated sample can drain upto 25 percent. Thus surface water can saturate the formation. The Indus formation particularly in the Punjab is made up of about 70 percent sand. The remaining 30 percent is not all clay deposit. It also contains particles made up of low yielding silt.

A large volume of water supplies in rivers during winter is out of recharge from the valley storage. This water had seeped into the formation during high flow summer periods and drains out during low supplies of rivers. Thus if it is arranged to recharge the sandy formation during Monsoon when large volume of surface water is available, we can utilize

groundwater during the dry months. So far, we have not utilized any of the recharge method. Aquifer of Lahore is one example where groundwater is declining and has reached 80 to 90 feet below surface. Lahore Branch which is fed from Bambanwala Ravi Bedian (BRB) Link passes from the middle of present Lahore. This canal has a few feet of thick soil crust under its bed so that its seepage rate is insignificant. This size of distributaries generally seep at the rate of 0.2 cusec per mile. Its 20 miles length at this rate hardly seeps about 4 cusecs. It will be worth while to install drainage wells as show in in Fig-5(a).

Near the bed of the canal a choir string strainer about 30 to 40 feet long may be installed and seepage through this strainer will feed the recharge well. Such recharge well can be located every 500 feet apart. The expected recharge from each well may lie between 2 to 3 cusecs. Beyond Ravi Syphon, a length of about 30 miles receives high rainfall run off through Deg and its tributaries. This water can be carried through BRB Link to Lahore Branch and some flow can be discharged to Ravi even through Marala Ravi Link (see Fig-5(b). In an area around the two Links located in the flood plains of Deg, 40,000 acres attain groundwater between 0 to 5 feet. This water together with rainfall run off can be brought to Lahore. It is worthwhile to study the availability of water which can be used to recharge the Lahore aquifer. As referred in Table 15, Punjab has 15 m. acres with groundwater deeper than ten feet. The area served by four canals in Bari Doab vide Table 16, has 3.3 m. acres with groundwater deeper than 20 feet.

There are thus many sites in Punjab where groundwater can be recharged. Such sites are also available along Ravi and Sutlej rivers in which water can be conserved by recharge. There are a few other methods for recharge. Any one may be found suitable for each site.

16(a)- Recharge rain water in Cholistan

The source of water for drinking in Cholistan is out of rain water which is conserved in depressions. This water is used both by residents and animals. The water collected just after rain-fall is of low salts contents which are washed from surface rainfall run off. Cholistan has high evaporation of the order of about 80 inches per year. Water thus continues to evaporate resulting in increase of salt accumulation. The groundwater in the area is generally saline and 70 to 100 feet deep. At a few sites, there exists pockets of fresh water probably as remants of seepage of Hakara River which has dried out. There is a great possibility of conserving rain water in the underground formation. The rain water after removing the sediment may be recharged into the formation.

After a few recharge trials the fresh water may get accumulated under ground and will become a source of low salinity. The conserved water could be pumped out when ever needed. It will be worthwhile to conduct such an experiment at any suitable site in Cholistan.

Table 15 - Areas of high groundwater in Punjab and Sindh. (million acres)

Province	Gross area	Area with Groundwater between 0 to 5 feet duirng				Area with Groundwater between 5 to 10 feet during			
		October		June/April		October		June/April	
		Area	%age	Area	%age	Area	%age	Area	%age
Punjab	24.62	4.2	17	2.5	10	7.63	31	7.7	32
Sindh	14.46	7.52	52	3.0	19	3.62	25	8.82	61

Table 16 - Percentage area of canals with groundwater deeper than 20 feet

S. No.	Name of Canal	CCA m. ac.	Area with Groundwater deeper than 20 ft.	%age of this area
1.	Pakpattan	1.049	0.922	82.01
2.	Mailsi	0.996	0.662	61.20
3.	Sidhnai	0.869	0.669	77.00
4.	L.B.D.C.	1.690	1.036	52.00
	Total	4.604	3.289	71.4

Table 17 - Releases below Panjnad and Kotri, units are maf.

Years	Panjnad			Kotri		
	Kharif	Rabi	Total	Kharif	Rabi	Total
1970-75	15.0	0.4	15.4	34.3	0.7	35.0
1975-80	25.0	1.7	26.7	47.0	2.8	49.8
1980-85	16.2	2.8	19.0	25.0	1.5	26.5

17. WATER LOSSES FROM IRRIGATION CANAL SYSTEM

Seepage through irrigation canals has been a subject of investigation by several Engineers. An early report often quoted is of Major Dyas who in April, 1863 indicated the results of his studies to Mr. Craften. He observed a loss of 500 cusecs out of the canal passing 3,000 cusecs. These results are indicated in Table-18.

In 1874, Higham carried out another estimate. He reported a loss of 272 cusecs through the channel discharging 2176 cusecs. It amounted to a loss of 12.5 percent or 9.78 cusecs per million square feet of wetted surface.

In 1883, Kennedy conducted detailed tests. His results are given in Table-19. The subject continued to be investigated by many persons and organizations. In Volume-IV of Water Investment Planning Study, issued in December, 1990, in Annexure-'A' six Tables are included giving the results of loss estimated by several workers. A Table No. 5.21 is putforth to briefly indicates the estimates of many workers. The percentage loss through main lines/branches, distributaries/minors, water-courses and Field is given as determined by different workers, starting from Kennedy upto the recent workers like HAZARA, IACA and LIP. These estimates had been in use upto 1978.

In 1973, Scientists of Colorado State University (USU) came to work at Mona Reclamation Experimental Project of WAPDA. They reported losses upto 75 percent (W.S.I. Planning Punjab Province, page 2.15 item 2.7.2) on some individual water courses. Average water course losses varying from 30 to 50 percent were determined. WAPDA also conducted a few tests at other sites and since then the loss through water-courses has been taken as 25 percent.

This estimate has been accepted in the Water Sector Investment Plan and in Section 5.7 of Water course improvement, it is stated "that water course losses although variable have been estimated to average approximately, 25 percent of water delivered at the water course head in the Punjab and a corresponding 25 percent loss is estimated to occur in the farm field application". The data recorded in Table-5.21 was accepted upto 1978. It has now been increased to the above stated limits.

All water-course lining projects under 'On Farm Water Management' are being constructed on the basis of 25 percent loss through water-courses and fields.

TABLE - 18
SEEPAGE ESTIMATED BY DYAS FROM VARIOUS BRANCHES OF U.B.D. CANAL

	Canal System	Length in miles	Loss per mile, (cubic ft. per second)	Total loss cubic ft. per second
(1)	Main Line	28.5	5.5	156.75
(2)	Main Branch Upper	24	1.5	36.00
(3)	Kasur Branch Upper	7	3.5	22.75
(4)	Main Branch Lower	209	0.6	125.40
(5)	Lahore Branch	60	0.6	36.00
(6)	Kasur Branch	85	.0	85.00
(7)	Sobraon Branch	63	0.6	37.80
		Total		499.70

TABLE - 19
ABSORPTION LOSSES ESTIMATED BY KENNEDY

Canals and fields	Average vertical sink-age in feet per hour.	Average vertical sink-age in inches per diem	Loss by absorption in cusecs per million sq. feet of surface
Virgin Lands, flooded	0.028	8.1	8.0
Cultivated lands	0.035	10.1	9.75
Water courses	0.034	18.0	9.4
Rajbahas	0.012	3.5	3.3
Branch Canal	0.079	2.28	2.2
Main Canal	0.035	10.1	9.75

18 - WATER LOSSES THROUGH DISTRIBUTARIES AND MINORS

WAPDA, HARZA and IACA endeavoured to develop a method to determine seepage loss of each canal command on the basis of soil texture under the bed of a canal. They used soil category, water delivery category and loss category and on these basis estimated the loss through various parameters of a canal such as main line, branches, distributaries and minors. The loss of water from water-courses and Farms was also determined. They also worked out the recharge from these two parameters separately. This information was put forth in Groundwater Development and Potential of Canal Command, a Supporting publication of Water Investment Plan issued in July, 1981. This very information is included in Groundwater Development Potential of Canal Command Area, issued by Water Resources Planning Division of WAPDA in November, 1988. Such information on monthly basis for each canal command is contained in Volume-IV of Water Sector Investment Planning Study. WAPDA's report of July, 1981 is based upon data of the year 1978 while that contained in Volume-IV has based it for the year 1985-86. Utilizing the data of 1978, Table-20 has been prepared, showing 24 canal commands of the Punjab. The culturable area of each command its annual water diversion and both losses and seepage from Canal System constituting main canals, branches distributaries and minors is given.

The data for water delivered at the head of water courses and the recharge through these and Farms is not included in this Table. The seepage worked out for the canal system was to be divided into that through main canals/branches and distributaries/minors. The order of loss given in Table - 5.21 was utilized which was 27 percent and it was to be divided into 20 percent for canal/branches and 7 percent for distributaries/minors. In the Water Investment Planning Study the loss through distributaries/minors has been raised to 15 percent. No supporting tests are quoted. It is only stated while discussing lining of Shorkot Kamalia Saline Project (Vol-II Section A-3). It is putforth that conveyance losses of distributaries/minors are assumed to be 15 percent of the discharge at heads of which 88 percent adds to groundwater. This assumption was similar to that of 25 percent seepage through water courses and the same order through fields. We thus utilized the proportion given in Table - 5.21, which is more authentic and supported by actual measurement. These data are recorded in Table-20. The seepage loss in cusec per mile is also determined. The length of each parameters of canal system is given in Table-21. This analysis gave a seepage order per mile from distributaries and minors equal to 0.15 to 0.2 cusec.

TABLE - 5.21
COMPARATIVE STATEMENT OF CONVEYANCE LOSSES IN THE INDUS BASIN IRRIGATION SYSTEM

Authority		Canal(s) System	Main Canals and Branches	Disty.	Water Course	Farm	Total
			(Losses as percent of Head Diversion)				
Kennedy		Upper Bari Doab Canal (Rabi)	20.0	6.5	21.0	13.0	60.5
Benton		UBDC	17.5	6.5	21.5	10.5	56.0
Higham		UBDC (Main Line)	12.1-14.0				
Blench			20.0	7.0	20.0	--	--
Khangar	i.	Lower Chenab Canal	15.6	6.0	11.0	--	--
	ii.	Lower Jhelum Canal	14.0	6.0	11.0	--	--
Khana's Handbook			15 - 20	6.7	17.5 - 21.0	8.5 - 25.0	--
Irrigation Research Institute	i.	Dipalpur Canal (8 Water courses)	--	--	8 - 14	--	--
	ii.	LCC (2 Water courses of Upper Gugera Branch)	--	--	5 - 10	--	--
	iii.	LCC (2 Water courses of Jhang Branch)	--	--	10 - 15	--	--
IACA	i.	North Zone	30.0	--	7.0	19.0	56.0
	ii.	South Zone	20.0	--	7.5	20.5	53.0
HARZA	i.	North Zone	29.0	--	7.0	8.0	44.0
	ii.	South Zone	25.0	--	8.0	8.0	41.0
LIP		South Zone	20.0	--	7.5	20.0	53.0

TABLE - 20

SEEPAGE LOSSES (CUSECS PER MILE) FROM MAIN CANALS PLUS BRANCHES (C + Br) AND FROM DISTRIBUTARIES PLUS MINORS (DY + MR.), AND OTHER LOSSES FOR VARIOUS CANAL COMMANDS (PUNJAB)
(BASED ON HAZARA, IACA, WAPDA REVISED METHODS)

Sr. No.	Canal Command	Diversion	Canal System Losses	Canal System Recharge (Seepage)	Evaporation and other		Seepage Loss (C + Br) @ 20/27 Ratio		Seepage Loss (Dy. + Mr) @ 7/27 Ratio		Length (C + Br)	Length (Dy + Mr)	Seepage Loss (C + Br)	Seepage Loss (Dy + Mr)
		(M A F)	(M A F)	(M A F)	(M A F)	%age	(M A F)	(Cusecs)	(M A F)	(Cusecs)	(Miles)	(Miles)	Cusecs/Mile	Cusecs/Mile
(1)	(2)	(3)	(4)	(5)	(6)		(7)		(8)		(9)	(10)	(11)	(12)
1.	Upper Depalpur	0.771	0.139	0.110	0.028	20.10	0.0822	113.52	0.0290	39.70	106.50	375.50	1.066	0.106
2.	Ravi Syphon	1.420	0.261	0.209	0.052	19.90	0.155	213.80	0.054	74.80	214.50	591.00	0.996	0.127
3.	Raya Branch	0.435	0.063	0.050	0.013	20.60	--	--	--	--	--	3903.00	--	--
4.	Upper Chenab	1.912	0.407	0.326	0.081	19.90	0.241	333.50	0.085	117.00	72.60	1130.00	4.59	0.103
5.	M.R. Link	0.644	0.087	0.070	0.017	19.50	--	--	--	--	--	189.90	--	--
6.	Sadiqia East	2.971	0.492	0.394	0.098	20.00	0.292	403.30	0.102	141.10	131.60	771.40	3.064	0.183
7.	Fordwah	0.775	0.227	0.184	0.043	19.00	0.136	188.00	0.048	65.90	95.70	410.50	1.97	0.160
8.	Pakpattan	3.730	0.843	0.674	0.169	20.00	0.499	689.00	0.175	241.30	264.60	878.60	2.61	0.275
9.	Lower Depalpur	1.540	0.341	0.273	0.068	19.90	0.202	279.00	0.071	97.70	49.00	730.00	5.70	0.134
10.	L.B.D.C.	4.962	1.140	0.912	0.228	20.00	0.076	933.00	0.320	491.00	146.00	1375.90	6.40	0.32
11.	Jhang	3.427	0.583	0.466	0.117	20.00	0.345	477.00	0.121	166.80	200.00	900.50	2.40	0.32
12.	Gugera	3.954	1.54	0.923	0.231	20.00	0.683	944.20	0.240	330.00	315.60	1567.60	3.00	0.211

TABLE - 20 (Contd...)

SEEPAGE LOSSES (CUSECS PER MILE) FROM MAIN CANALS PLUS BRANCHES (C + Br) AND FROM DISTRIBUTARIES PLUS MINORS (DY + MR.), AND OTHER LOSSES FOR VARIOUS CANAL COMMANDS (PUNJAB) (BASED ON HAZARA, IACA, WAPDA REVISED METHODS)

Sr. No.	Canal Command	Diversion	Canal System Losses	Canal System Recharge (Seepage)	Evaporation and other		Seepage Loss (C + Br) @ 20/27 Ratio		Seepage Loss (Dy. + Mr) @ 7/27 Ratio		Length (C + Br)	Length (Dy + Mr)	Seepage Loss (C + Br)	Seepage Loss (Dy + Mr)
		(M A F)	(M A F)	(M A F)	(M A F)	%age	(M A F)	(Cusecs)	(M A F)	(Cusecs)	(Miles)	(Miles)	Cusecs/Mile	Cusecs/Mile
(1)	(2)	(3)	(4)	(5)	(6)		(7)		(8)		(9)	(10)	(11)	(12)
13.	Upper Jhelum	1.495	0.237	0.190	0.047	20.00	0.141	194.40	0.050	68.00	128.40	601.40	1.510	0.113
14.	Lower Jhelum	3.215	0.860	0.688	0.172	20.00	0.510	704.00	0.178	246.00	277.50	1288.90	2.54	0.190
15.	Bahawal Link	1.565	0.347	0.278	0.069	20.00	0.210	284.40	0.720	99.50	107.00	569.00	2.66	0.175
16.	Mailsi	2.665	0.690	0.552	0.138	20.00	0.410	564.70	0.143	197.60	61.80	921.40	9.14	0.214
17.	Sidhnai	2.154	0.504	0.403	0.101	20.00	0.300	412.30	0.105	144.20	134.20	874.80	3.10	0.165
18.	Haveli	0.500	0.129	0.103	0.026	20.00	--	--	--	--	--	133.30	--	--
19.	Rangpur	0.433	0.149	0.116	0.033	22.00	0.086	118.70	0.03	41.50	157.60	365.70	0.753	0.114
20.	Panjnad	4.565	1.406	1.125	0.281	20.00	0.833	1151.00	0.292	402.80	175.40	1463.90	6.52	0.275
21.	Abbasia	0.574	0.133	0.106	0.027	20.30	0.079	108.40	0.275	38.00	25.70	112.70	4.22	0.335
22.	Thal Canal	4.028	1.120	0.897	0.223	20.00	0.664	917.60	0.233	321.10	124.30	1995.80	7.38	0.161
23.	Muzaffargarh	2.650	0.907	0.726	0.181	20.00	0.538	742.70	0.188	260.00	131.40	921.60	5.65	0.282
24.	Dera Ghazi Khan	2.762	0.557	0.446	0.111	20.00	0.330	456.00	0.116	160.00	265.10	853.30	1.72	0.187

TABLE - 21

LENGTH OF CANAL COMMAND SYSTEM

COM-SYM No.	Canal Command	G.C.A. (1000 Acres)	CCA (1000 Acres)	Length (Canal Miles)						Canal System Length Cagetory Assigned.
				Link	Main	Branch/ Sub-branch	Distri-butary	Minor	Total	
	PUNJAB									
1.	Depalpur Upper	386	360	--	52.9	53.6	234.7	140.0	481.2	D
2.	Ravi Syphon/CBDC	709	649	--	--	213.8	370.8	220.0	804.6	C
3.	Raya (BRBD Int.)	484	424	54.9	--	--	179.8	210.5	445.2	D
4.	U. Chenab	1079	1017	--	42.8	29.8	733.6	397.4	1203.6	B
5.	M-R Link (Int)	175	158	60.5	--	--	140.2	49.7	250.4	D
6.	Sadiqia East	1172	969	--	49.0	82.6	443.4	328.0	903.0	C
7.	Fordwah	581	426	--	9.2	86.5	319.6	90.9	506.2	C
8.	Pakpattan 1/	1177	1049	--	183.1	81.5	492.6	386.0	1143.2	B
9.	L. Dipalpur	656	615	--	6.4	42.6	343.6	386.4	779.0	C
10.	L.B.D.C.	1789	1670	--	29.9	16.2	630.9	745.0	1522.0	A
11.	Jhang	1463	1168	--	99.5	100.9	572.5	328.0	1100.9	B
12.	Gugera	2235	1866	--	56.4	259.2	1043.6	524.0	1883.2	A
13.	U. Jhelum	613	544	--	88.0	40.4	338.9	262.5	729.8	C
14.	L.Jhelum	1616	1500	--	39.4	238.1	824.4	464.5	1566.4	A
15.	Bahawal Lower	733	605	--	17.9	89.1	384.3	184.7	676.0	C
16.	Mailsi 2/	1098	996	62.0 3/	33.0	28.8	578.1	343.3	1045.2	B
17.	Sidhnai	965	869	--	31.5	102.7	571.2	301.6	1007.0	B
18.	Haveli	201	179	--	4.9	--	70.6	62.7	138.2	D
19.	Rangpur	358	344	--	138.2	19.4	259.0	106.7	523.3	C
20.	Panjnad	1532	1348	--	57.2	119.2	817.5	646.4	1640.3	A
21.	Abbasia	174	154	--	25.7	--	108.7	34.0	168.4	D
22.	Thal	2219	1641	--	31.5	92.8	1055.8	940.0	2120.1	A
23.	Muzaffargarh	928	809	--	74.2	57.2	515.6	406.0	1053.0	B
24.	D.G. Khan	957	909	--	69.0	196.1	647.3	206.0	1118.4	B
	Total (Punjab)	23300	20269	177.4	1239.7	1950.5	11676.7	7764.3	22808.6	

19 - VOLUME OF WATER SAVED BY LINING OF DISTRIBUTARIES AND MINORS

The canals in Punjab are either perennial or non-perennial. The length of perennial distributaries of the Punjab is 9621.9 canal miles and those of minors is 6436.8 canal miles. The seepage used at the rate of 0.2 cusec per mile gave 1.822 ma. ft. No lining can be hundred percent impervious. The amount of seepage will reduce according to the type and condition of lined canal.

20 - COST OF LINING OF DISTRIBUTARIES TO SAVE SEEPAGE

Lining of Distributaries is proposed to save the above estimated seepage loss. So far no cheap and durable means of lining has been adopted. Recently about 210 miles of distributaries have been lined. Its thickness was 3 or 4 inches made of cement concete of mix ratio of 1:2:4. The majority of distributaries lined carried discharge less than 30 cusecs and had water depth of 2 to 4 feet. The purposes for use of such grade of concrete for this much thickness is not clear. In Pakistan and Indian Punjab canals passing very high discharges have been lined with 4 inches thick concrete with mix ratio of 1:3:6. Even the type of concrete lining in Stage-I and partly in Stage-II of Chesma Right Bank Canal was of the same type. Here the depth of channel was about 15 feet.

The cost for this type of lining is given in Paper No. 524 of Pakistan Engineering Congress Volume-64 of March, 1990. The expenditure incurred to line 210 miles of distributaries was Rs. 357.1 million so that lining of each miles cost Rs. 1.631 million. The present rate may be slightly higher say upto Rs. 1.8 million per mile. Thus to line 9621.9 miles of distributaries and 6434.8 miles of minor the cost may be 1.8 x (9621.9+6436.8) = 2,89,566.00 or say Rs. 29000 million. Assuming 100 percent impervious lining, the water saved will be 1.822 ma. ft. so that each cusec saved costs Rs. 11.08 million.

21 LINING OF DISTRIBUTARIES POSSESSING SALINE GROUNDWATER

In the water Investment Planning study it is emphaticelly streassed to line the distributaries and water courses overlying saline groundwater. No instance is giving about any site possessing saline groundwater immediately below the bed of canal or within shallow depths. So far there are no records of location of saline groundwater at shallow depths except, that determined during groundwater investigation of 1954 to 1960. The maps showing location of saline groundwater are generally prepared without mentioning the depth of saline groundwater. One instance showing the location of saline groundwater

contained in Water Investment Planning is reproduced as Fig. 3.3. This Figure shows extensive existence of saline groundwater areas occuring at depths deeper than 350 feet. Based upon 1954-60 investigations no map is available showing the groundwater quality with depth of 50,100 or 150 feet. The extent of existence of groundwater of 1000,2000 and more than 2000 ppm quality within shallow depths during 1959 is given in Table 23.

This was the condition when canal diversion was 84 maf, there were no SCARPS, farmer tubewells were a few hundred and cropping intensity was about 90 percent. Within the last 33 years the conditions of surface application and groundwater withdrawal has completely changed.Since completion of Tarbela the canal diversion in Punjab has risen to about 56 maf, 7 maf of groundwater has been pumped by SCARP tubewell and about 25 maf by farmers tubewells. These increased water sources has changed the condition of shallow groundwater, maps for which have not yet been produced. It is well known that at the start of Rakh Branch of Lower Chenab Canal, Saline groundwater existed at about 94 ft in the area now called Faisalabad. The present condition is that groundwater now exists within 5 to 10 feet and water depth up to 80 feet has salinity of 1500 ppm.

The fresh water build up exist under Rakh Branch to a depth of 150 feet as shown in Fig. 6. It also exist under other distributaries of the area. Another such instance is of Sargodha, the increased population of which is using fresh water build up from seepage of Northern Branch.

Since 1975, when the canal diversion increased to about 56 maf, 28 maf is the order of seepage into the underground formation. It is also estimated that out of Monsoon rains at least 4 maf seeps underground. Thus 20 m. acres of culturable area receives at least 32 maf. of freshwater recharge, so that, every year 1.6 feet of water per foot area, percolates underground. The seeping freshwater does not mix with saline groundwater which under pressure of freshwater is pushed away. This has been the process in action for the last hundred years. The Saline groundwater has been pushed towards deeper waters and the formation at shallow depths possess usable water.

There do exist some small saline groundwater pockets, the location of which needs determination. The build up of fresh groundwater within 100 feet depth is demonstrated by a study of farmer's tubewells. Between 1971 to 1975, water quality of farmer's tubewells of the Punjab was checked at randam. These results are depicted in Table-7. Thus groundwater within a depth of one hundred feet, is very fresh. These instances are given to confirm that groundwater within a depth of 50 to 100 feet is generally usable. Seepage water is not wasted. It continues to build a fresh water reservoir. Even a shallow depth of 20 to 50 feet is a source of water for future use. Hand pump type multiple strainer wells pumping usable water from 20 to 30 feet depth can also be a source for crops.

This is another argument against the lining of distributaries located over deep saline groundwater.

TABLE-23 AREAS OF FOUR DOABS OF THE PUNJAB HAVING SHALLOW GROUNDWATER OF DIFFERENT QUALITIES

Zone Doabs	Total Area m. ac.	Area in M.A. with T.D.S. in PPM. Upto 1000	1000 to 2000	above 2000
Thal	6.381	6.164	0.107	0.110
Chaj	2.824	2.542	0.176	0.105
Rechna	7.500	6.622	0.603	0.275
Bari	7.800	7.103	0.366	0.330
Bahawalpur	3.785	3.115	0.153	0.517
Total :	28.290	25.546	1.405	1.337
% of Total		90.3	5.0	4.73

22 - PROBLEMS OF LINED CANALS

The lining of canals is carried out to ;

(i) save loss of water;

(ii) reduce chances for rise of groundwater to cause water-logging and

(iii) to minimize maintenance expenditure.

There are several other minor advantages. In the area of Pakistan, Haveli was the first canal lined in 1937-38. It was followed by lining of Thal Canal Main Line Upper and Lower and Mohajar Branch between 1944-51, Bambanwala Ravi Bedian Link in 1951, Balloki Sulemanki Link during 1954-56, and Sidhani Mailsi Bahawal Link during 1965. Lining of Chashma Right Bank Canal was undertaken in 1984 in two Stages and lining of Stage-2 has just been completed. A few short lengths of canals in SCARP-VI has also been lined recently. For the lining of Haveli Canal, a system of double layer of tiles with sand witching of 1/2 inch thick cement sand morter was used. This design had continued to be used in Haveli, Sidhnai, Mailsi, Bahawal, a part of Chashma Right Bank Canal (CRBC) and in SCARP-VI. A modification of this design by replacement of the bottom layer of tiles by 1 in 6 cement sand, 1 1/2 inch thick, was used in Thal Main Line Lower from RD.68 to tail and in Bambanwala Ravi Bedian Link. The lining of cement concrete of mix ratio of 1:3:6 generally

4 inches thick was used in Thal Main Line Upper, in Mohajar Branch and partly in Lining of SCARP-VI and CRBC. Only recently in case of CRBC Stage-II and in lining of distributaries, 1:2:4 cement concrete, 3 to 4 inches thick has been used. In Sidhnai Mailsi Bahawal Canal a layer of 1/8 inch bitumen was sprayed on 1/2 inch thick 1 in 3 cement sand plaster. This design was also used in small lined channels of head race canals. In Thal Main Line Lower from RD. 5 to 68 four inches thick lining of 1 in 6 cement sand was used. All these structural designs are illustrated in Figure F_7. A few functional changes were also introduced. In case of Balloki Sulemanki, in between the layer of soil and lining a stablized layer of 1 in 30 cement sand, 3 inches thick was used. Its purposes was the drainage of water accumulating behind the lining. For its drainage, bore-holes of 9 inches diameter filled with sand and located 50 feet apart were provided as explained in Figure 7.

This design caused the canal seepage to be constantly added to the formation during the operation of the canal causing quick rise of groundwater. Unfortunately no designer ever considered this defect in design so that lining with back filter and bore-holes have continued to be constructed in CRBC Stage-I and partly in stage II. All the lining of small portions of SCARP-VI has been constructed in the same design. The defect of this design were pointed out to Design Office. A recent change in design of lining of Stage-II has been introduced on the advise of experts of U.S. Bureau of Reclamation. The lining is constructed with 4.0 inches thick cement concrete of 1:2:4 mix with panels of 10 feet wide but without provision of soil stabilization called domalies under the edges of the panels.

23 - SAFETY OF LINING OF A CANAL

The safety of lining of a canal is a problem. The alignment of canal at certain sites had to be in deep digging. At these sites the groundwater continues to rise so that its level rises close to full supply level. In the canal provided with drainage holes, groundwater rose rather quickly. Another serious defect which has helped to build high groundwater is the construction of unlined links very close to lined canals. Balloki Sulemanki Link No.1 is a lined canal and B.S. Link No.2 flows along it at a distance of 350 feet. This intervening zone has build up high groundwater. Similar is the condition for Haveli Canal along which flows Trimmu Sidhnai Link. Its full supply is two feet higher than Haveli and the groundwater in between the two canals is as high as the full supply level of Haveli. The existence of high groundwater has caused extensive damage to lined canals. In case of Thal Main Line Upper, the canal from RD. 60 to 106 is in deep cutting so that between RD. 30 to 80, it is highly damaged. Mohajar Branch is another lined canal which although not in deep cutting but here the groundwater rose to the full supply level within ten years of its operation. Thus the highly damaged lined canal are :-

1). Thal Main Line Upper between RD. 30 to 80.

2). Full lined length of Mohajar Branch.

3). Balloki Sulemanki Link No.1 from RD. 73 to 106.

4). Haveli Canal with extensive lifting of lined bed.

The obvious causes of damage are the high soil water pressure which damaged the lining generally at the time of closure. It is unfortunate that when the damage to lining started generally after about ten-fifteen years of its construction or after the completion of links along the old lined canals, the irrigation Engineers never planned any counter-measures to solve the problem. When the Haveli Canal was constructed in 1937-38, upto 1943, four papers were submitted to the Engineering Congress describing the problems of lining and suggestions for its stability.

After independence, the damages to lined canal of Thal Main Line Upper and Mohajar Branch started but in these 45 years problems of lined canals have never been brought before the engineering forum to plan solution. Evidently it is highly deplorable. The counter-measures in use for Thal Main Line Upper since many years does not appear to be an effective solution.

Links were started to be constructed, the creation of high groundwater was obvious and its pressure was to damage the lining. Since their construction during these 28 years never this serious problem of damages to lining has ever been brought to light.

The lining of CRBC Stage-II started to indicate damages to lining although drainage filter and bore hole 100 feet apart were provided. The doners of the project, the Asian World Bank arranged for advise of two experts of U.S. Bureau of Reclamation. Their suggested design has been used in CRBC Stage-II without considering its usefulness. This design eliminated the domalies at the joint of the panels. Water seeping through the joint, will wet the soil which will be sucked out by flowing water, causing hallows and cavity in the soil.

A deep hole of 2.5 ft square is provided in the slab 15x32 feet in dimention. No expansion joints are provided. Will this design stand the back pressure, is yet to be seen.

Another design has been adopted in the case of lining of small distributaries with small water depth. Exceptionally strong 1:2:4 cement concrete, 3 to 4 inches thick is being used. Generally this ratio is not used even in big canals. The size of panels is 6 feet and the endges of the two panels are placed on soil. In place of domalies of bricks or concrete, a polyethene 0.2 mm thick film, one foot wide is used. Is this film strong enough to resist the penetrating forces of weeds at the position of the free board. The country is thus still faced with serious problems of old damaged lined canals and the new ones being constructed also need review at this stage.

24 - DRAINAGE-IV BY TILE SYSTEM

In Rechna Doab, a drainage scheme by tiles has been constructed in the district of Faisalabad. This area has three surface drains called Paharang, Samundri-I and Samundri-II. The total CCA of these drains and that now provided with tiles is as under :-

TABLE-24 - AREAS SELECTED FOR TILE DRAINS

Drains	Area, Acres	Area selected for Tiles Drains in Acres
Paharung	113080	20,000
Samundri-I	33490	20,000
Samundri-II	149370	35,000
TOTAL	295940	75,000

According to the report of WAPDA of May, 1982 in October 1981 seventy seven percent of the area had groundwater within 0 to 5 feet. The extent of areas with different depths of watertable in October, 1981 was as under :-

TABLE-25 - AREAS WITH VARIOUS DEPTHS OF GROUNDWATER

Units	0 to 5 ft.		5 to 10 ft.		Deeper than 10 ft.	
	Acres	%	acres	%age	acres	%age
Paharang	84100	61	45100	33	8800	2
Samundri-I	38800	90	4200	20	--	--
Samundri-II	149600	86	24400	14	--	--
TOTAL :	272500	77	24400	21	8800	2

In June the high groundwater of October usually declines by 2 to 3 feet. Extensive areas around Faisalabad District before the construction of Lower Chenab Canal in about 1886 had the deepest groundwater at about 94 to 100 feet. No other sites within the present irrigated area of Indus Plains had a deep groundwater in the area. The quality of groundwater was highly saline. As soon as irrigation system started the groundwater started to rise at a steady rate of about 2.0 feet per year. This rate of rise started to decreases when it reached a depth of 15 to 20 feet below surface. From this depth onward yearly rise continued to decrease. At five feet depth it became steady rising by 2 to 3 feet, during Monsoon and declining back to its original position by June.

24-A - TYPE OF SOILS AND GROUNDWATER SALINITY OF THE AREA

Area	Farida	Buchiana	Churkana (moderately fine)
Paharang	7	59	31
Samundri-I	7	75	15
Samundri-II	7	66	24
TOTAL	7	70	20

This area had the deepest highly saline groundwater which had been washed from the formation along the high water levels of rivers. This area continued to get accumulated this saline groundwater. The seepage from Farida, Buchiana series also continued to wash the top formation located above the deep highly saline water. This formation say upto 50 feet has water with salinity of 1000 to 5000 ppm. There exists a few small pockets which have groundwater of 3 to 5 thousand ppm. The under ground formation of the area is as pervious as in the rest of the Indus Plains and the top soil was also of a lighter nature but due to existence of saline water no high capacity SCARP tubewells could be installed. Even the farmer tubewells are also a few in number. It was thus decided to drain the area by a system of tile drains.

25 - PROBLEMS OF DRAINAGE BY TILES

Drainage by tiles has its own problem. The cost of construction of this method is very high. It was estimated to cost Rs. 22,000/per acre. Thus the drainage of 75,000 acres by this method may cost Rs. 1650 millions.

Another problem is the disposal of drained water. There are no outfall sites. The drained water is collected in 95 - drainage wells and is regularly pumped out. The quality of this water for the first few years will not be usable except by mixing with canal water. Electric pumps has to be provided to pump out the inflow out of the sumps.

The most serious problem is the availability of additional water for drainage of the excess salts. The present warabandi system makes water available after every one week. The tile drainage system is so designed as to keep the groundwater at a depth of 4 feet.

The high evaporation may cause accumulation of salts at soil surface. There may be problems particularly during winter when water supply is limited and some distributaries have to operate in rotation. Thus more surface water will be needed to wash the surface salts.

26 - A TRIAL OF DRAINAGE BY TUBEWELL IS SUGGESTED

As the groundwater within a depth of 25 to 40 feet is not too saline and the formation is as water yielding as in the rest of the Indus Plains, it is suggested to conduct a few trials with very shallow multiple strainer tubewells of the type as shown in Figure-9. Such a tubewell will drain 4 to 5 thousands acres of the area. The cost of such a tubewell is less than one lakh. This type of tubewells could drain 75,000 acres with 150 tubewells costing Rs. 150 million, against the tile drain system costing Rs. 1650 million.

The energy used for pumpage may be slightly more than used during pumping water out of 95 drainage sumps. Another advantge is that these tubewells can be operated even with diesel energy which cannot be used in case of pumping of sumps. The possibility of improvements of quality of shallow water also exists for such type of tubewells.

It is suggested that such a trial may be carried out by constructing a few tubewells in this very area where tile drains have not yet been provided.

27 - SOME PROBLEMS EXPECTED WITH FUNCTIONING OF TILE DRAINS

The tile drains have been provided with 91 man-holes at the rate of one per 100 acres. There will be a problems of their maintenance in this country.

Another problem relates to the provision of 4 to 6 inches of drainage filter around the tile.

Presently it is laid by mechanical machines which digs the formation, lays the plastic tiles and envelope it at the same time. The envelope is the most important component of tile

drainage, on which depends the future working of this technique. For the last nearly three years experts of Neitherlands have continued to test, design and conduct research on the drain envelope. With the active cooperation of International Waterlogging and Salinity Research Institute and supported by United Nations Development Programme (UNDP) and Neitherlands Research Assistance Projects, a workshop on 23rd August, 1990 was organized in which several experts on the subject like Nod Van Havermech, Dr. Willy Diericks, Lindsay D. Jones and Dr. William P. Voltman Team Leader of NRAP putforth their experience and even started research investigations on testing of various materials in a laboratory. Presently a few publications on the subjects issued with the assistance of IWASRI are mentioned in the Bibliogrophy. The ultimate size of the envelope is mentioned in the Design Memorandum Sub-surface Drainage for Fourth Drainage Project of Faisalabad issued by U.S. Bureau of Reclamation, Advisers to WAPDA. It is reproduced as Table-27.

TABLE - 27
GRAVEL ENVELOPE GRADATION ADOPTED
PERCENTAGE
BY WEIGHT PASSING GIVEN SCREEN SIZE

Screen Size	Minimum	Maximum
1 to 1.5 inch	100	--
0.75 inch	75	100
Mesh 4	20	60
8	10	35
30	0	15
50	0	5
200	0	3

In Figure-F_{10}, the gradation of soil to be protected and that of envelope is shown. The sizes worth notice are 0.75 to 1.5 inches as coarsest and 0.074 (200 mesh) as finest. This envelope has a mean diameter (D_{50}) equal to 7 mm and uniformity equal to 5.5.

In Pakistan thousands of tubewells have been installed protected by gravel envelope. The characteristics of their grading had been 5 times mean diameter of sand to be protected, which gave mean diameter of envelope material equal to 2 to 3 mm. The coarsest grade was passing 4 mesh sieve and finest upto 100 mesh. Another important

factor is uniformity which was always kept nearly of the same order both for envelope and sand. It was kept between 1.5 to 2.5. What will be the behaviour of the envelope used at site will become apparant after a few years.

28 - LABORATORY INVESTIGATIONS CONDUCTED ON ENVELOPE

Laboratory experiments have been conducted in C.M.O. Laboratories on the advise of Consultants mentioned in this note. The technique of tests adopted is shown in Figures-11 and 12. In this country such experiments were started, in 1934 while considering the design of tubewells.

The experiments conducted were according to the horizontal natural condition of flow. This new technique has not been adopted before as it was against the natural condition of flow. A particle of a formation can flow through envelope when it is lifted up against the forces of gravity and cohesion. The behaviour of envelope designed on the basis of these experiments will become apparent after a few years of operation of the Project.

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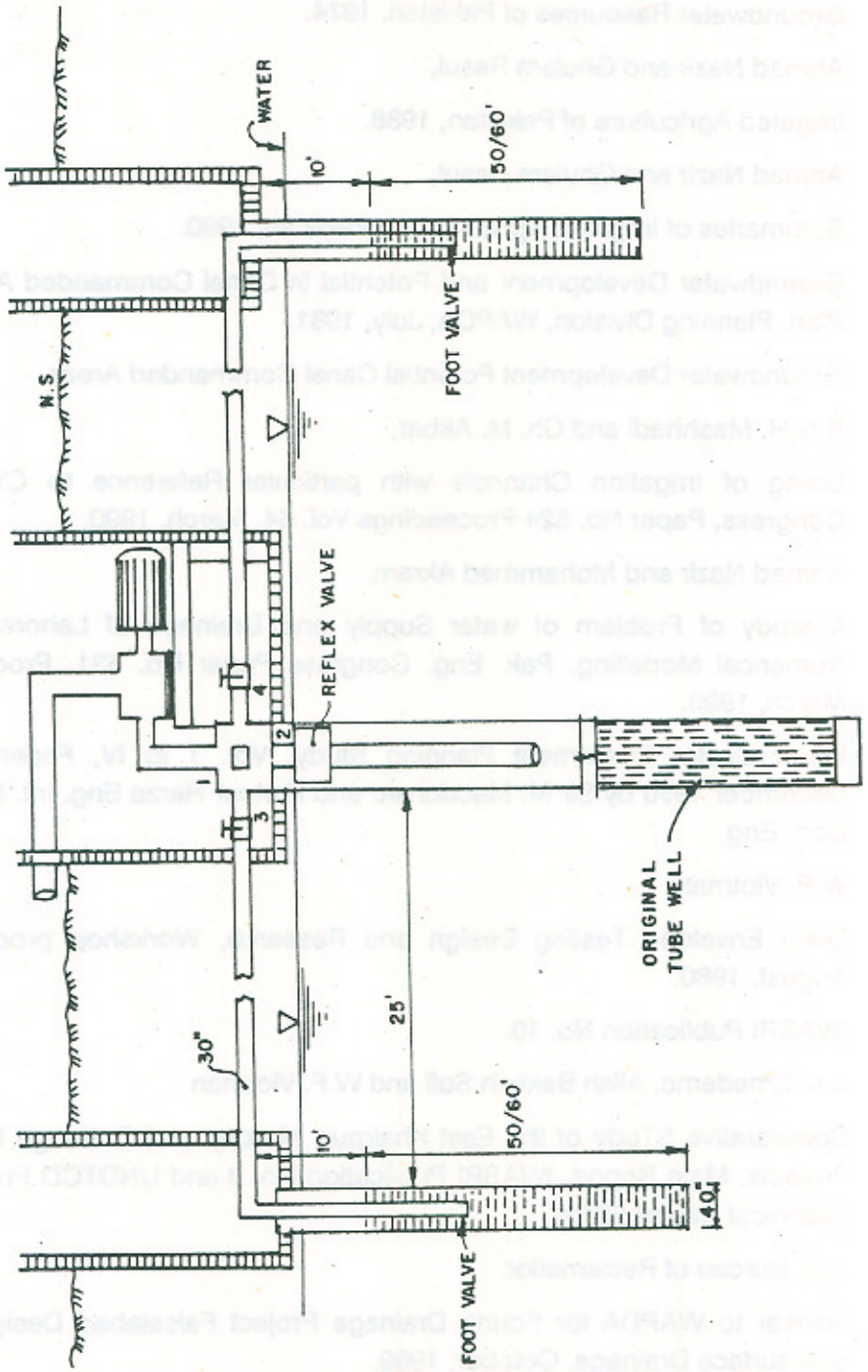
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FIGURE – I



TUBE WELL WITH CENTRIFUCAL PUMP AND
ONE OR TWO SHALLOW WELLS

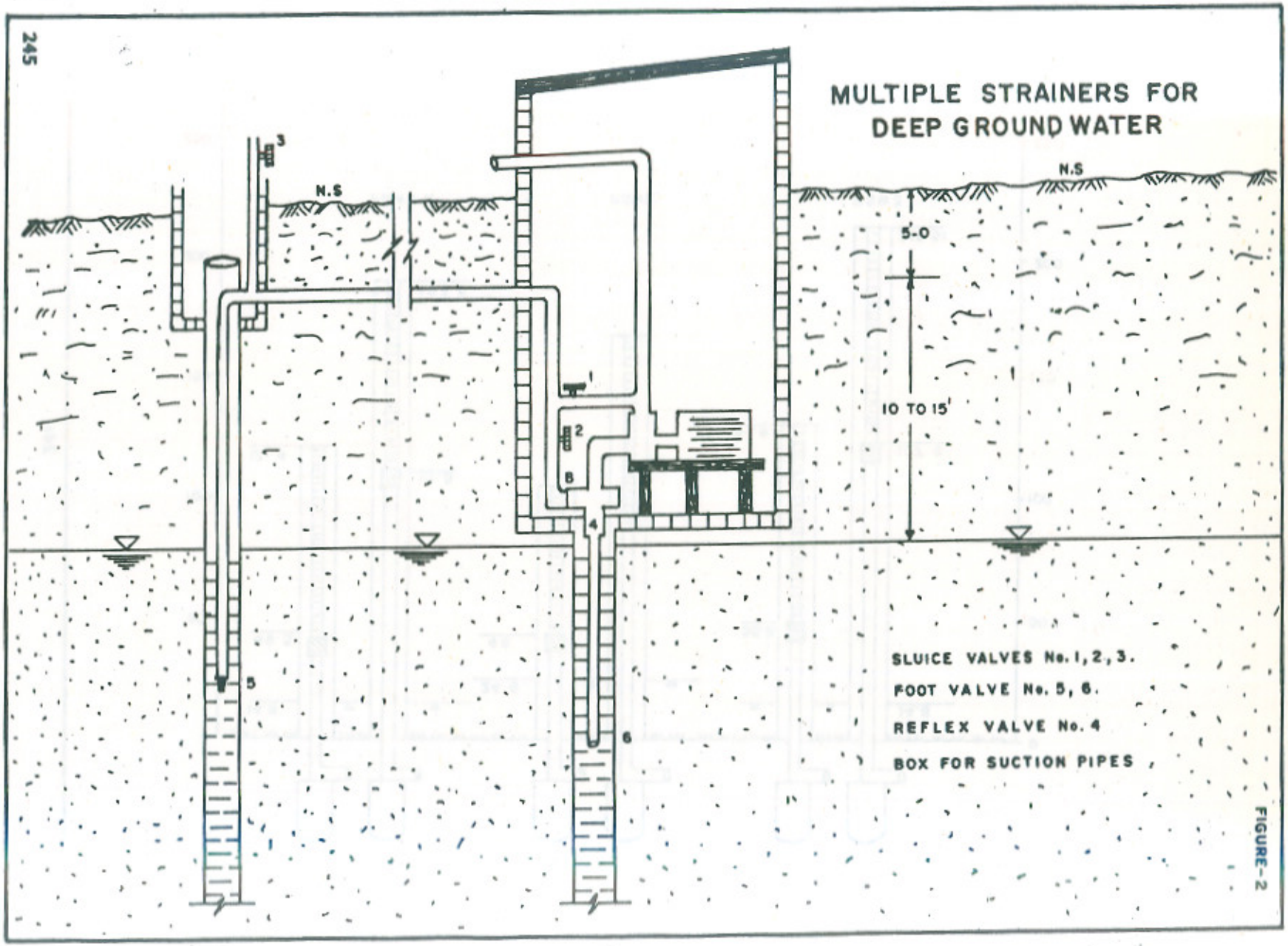
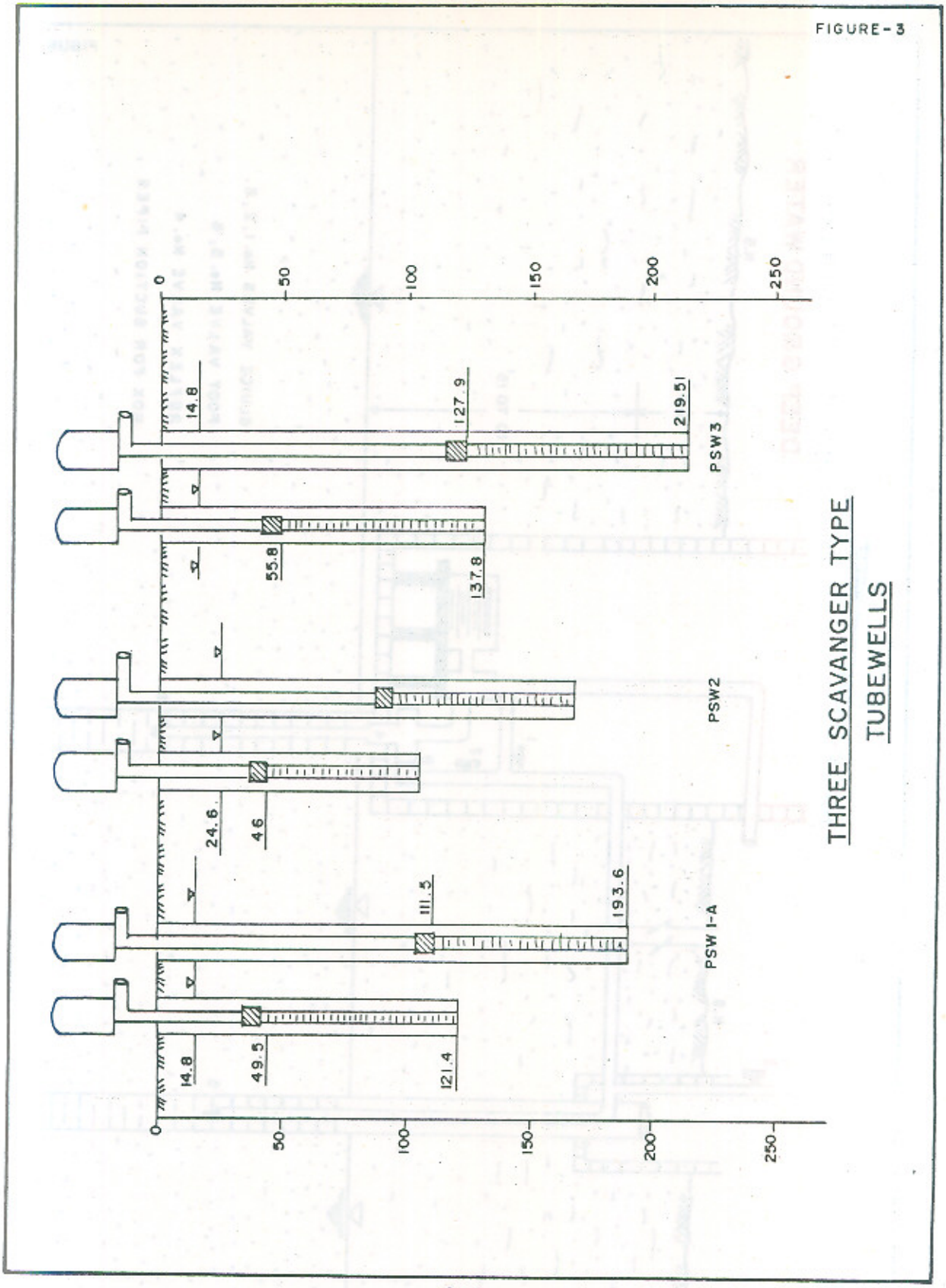

MULTIPLE STRAINERS FOR
DEEP GROUND WATER
N.S
N.S
5-0
10 TO 15'
1
2
3
4
5
6
SLUICE VALVES No. 1, 2, 3.
FOOT VALVE No. 5, 6.
REFLEX VALVE No. 4
BOX FOR SUCTION PIPES

FIGURE-2

FIGURE-3



THREE SCAVANGER TYPE TUBEWELLS

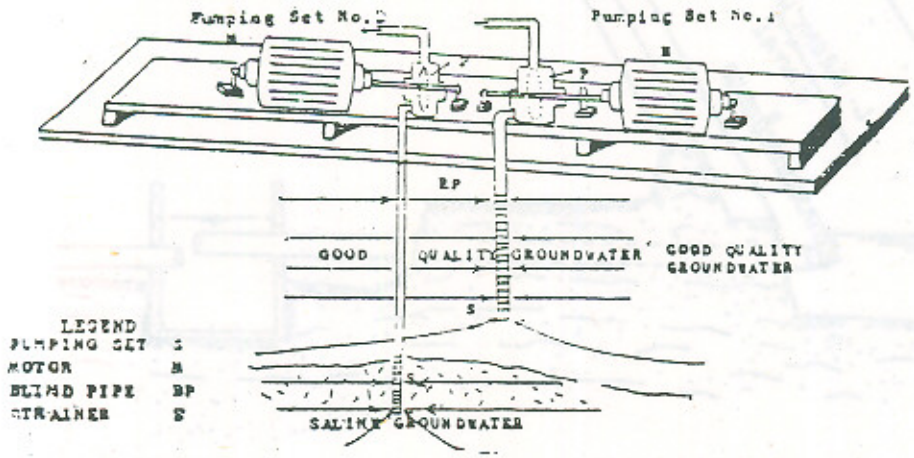


Fig. 4-A -Compound tubewells with separate pump and motor, one pumping freshwater and the second saline groundwater.

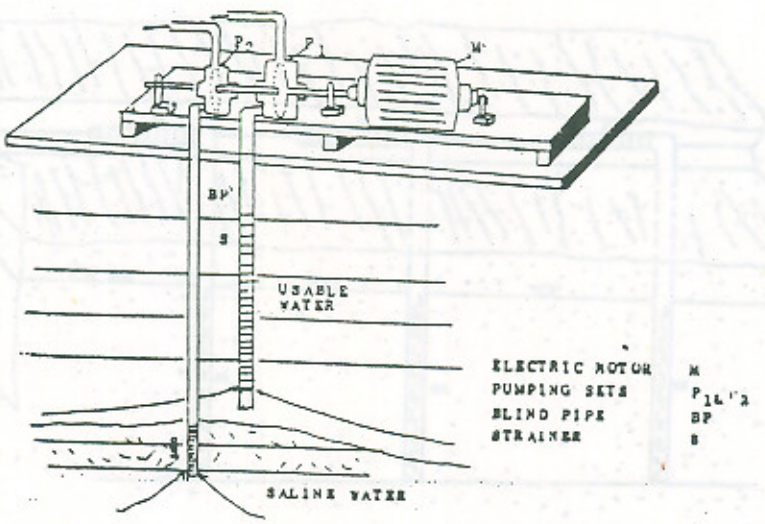


Fig. 4-B—Two tubewells, one pumping freshwater and the other saline water operated by the same motor.

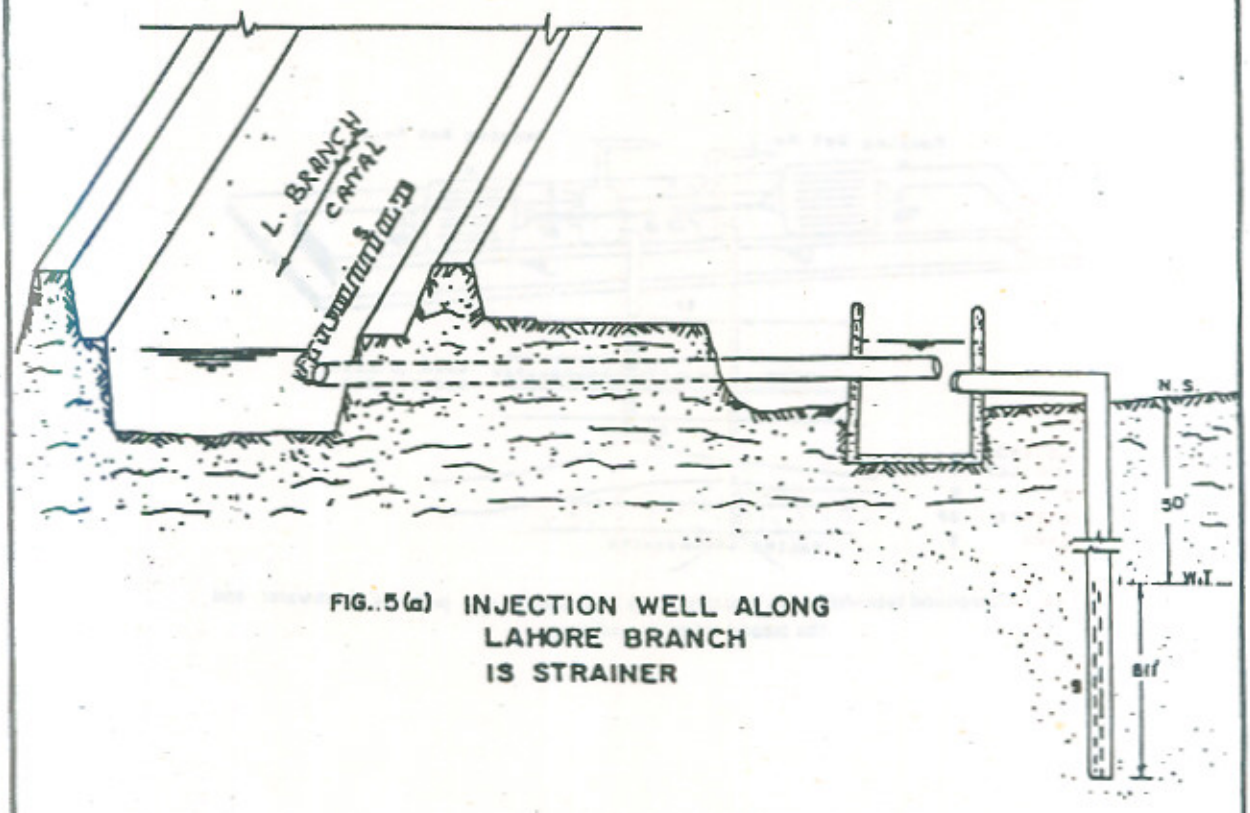


FIG. 5 (a) INJECTION WELL ALONG LAHORE BRANCH IS STRAINER

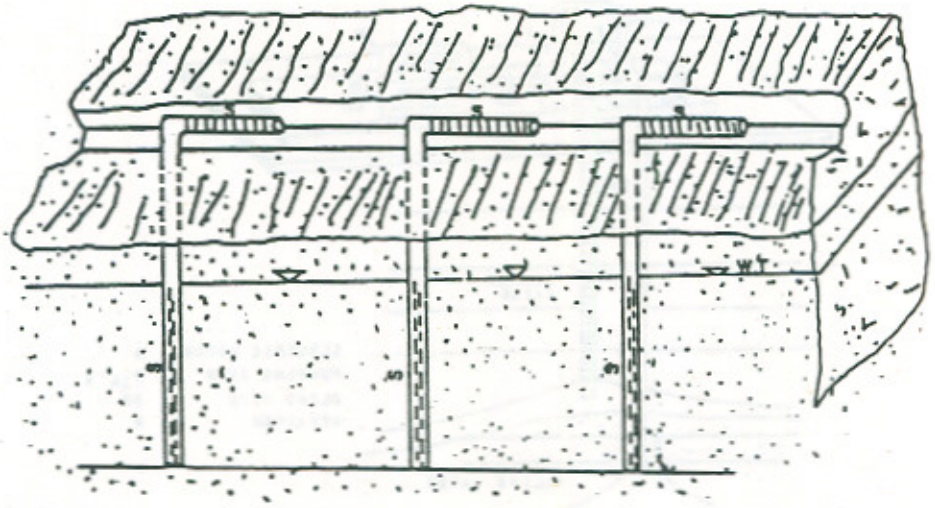
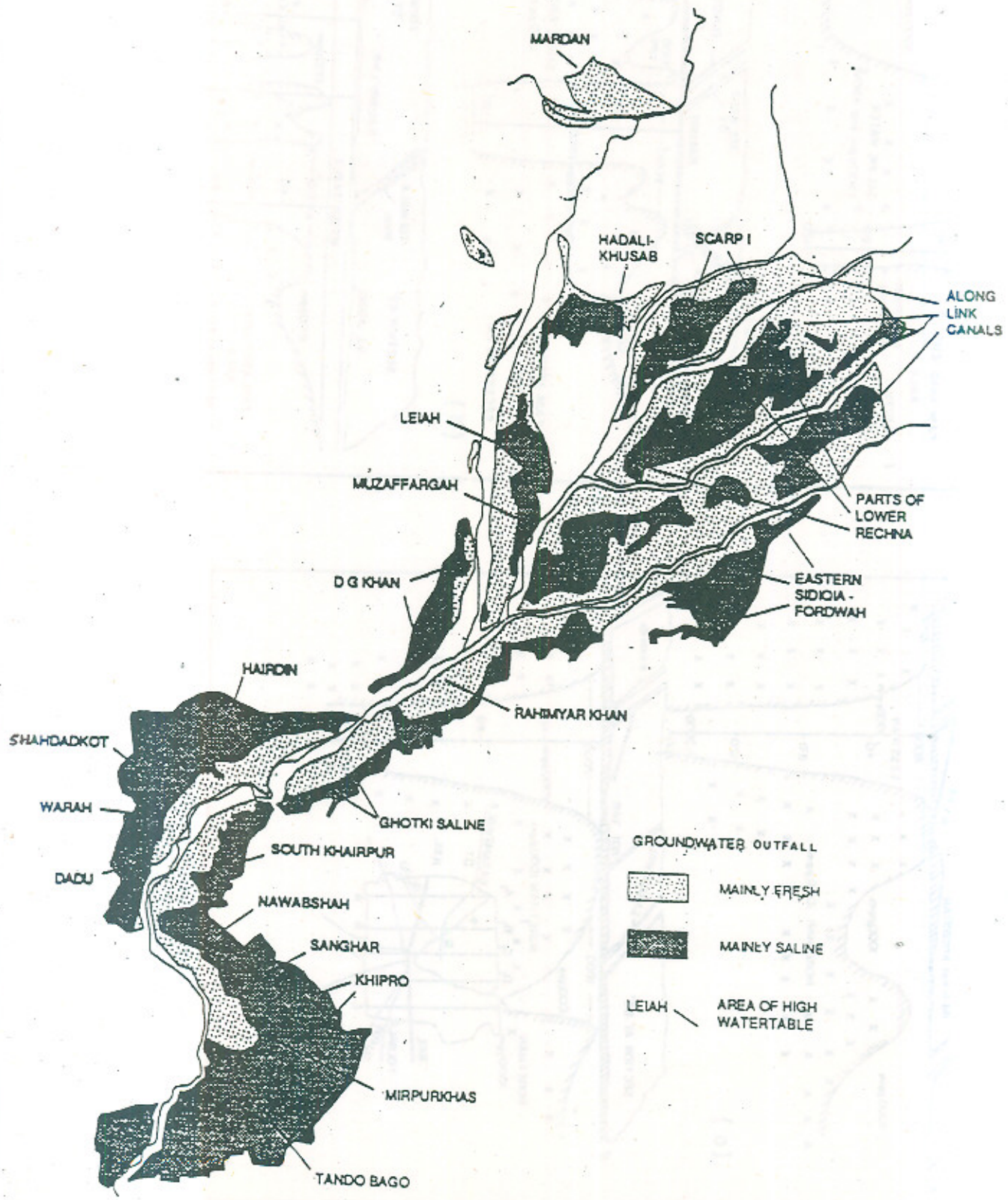
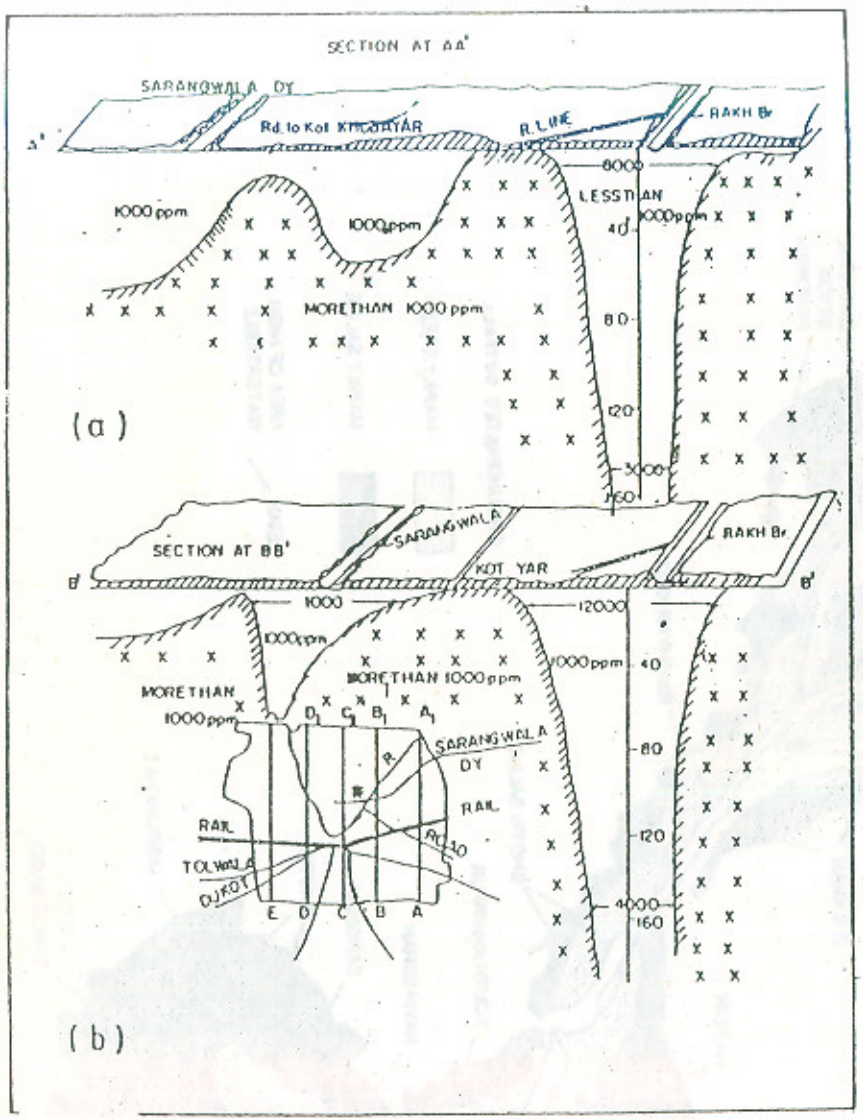


FIG. 5 (b) RECHARGE WELLS IN A CREEK OF RAVI RIVER

FIG. 3.3

Saline Groundwater Areas and Principal Areas of High Watertable





b) GROUND WATER QUALITY ALONG X-SECTION FAISLABAD AREA

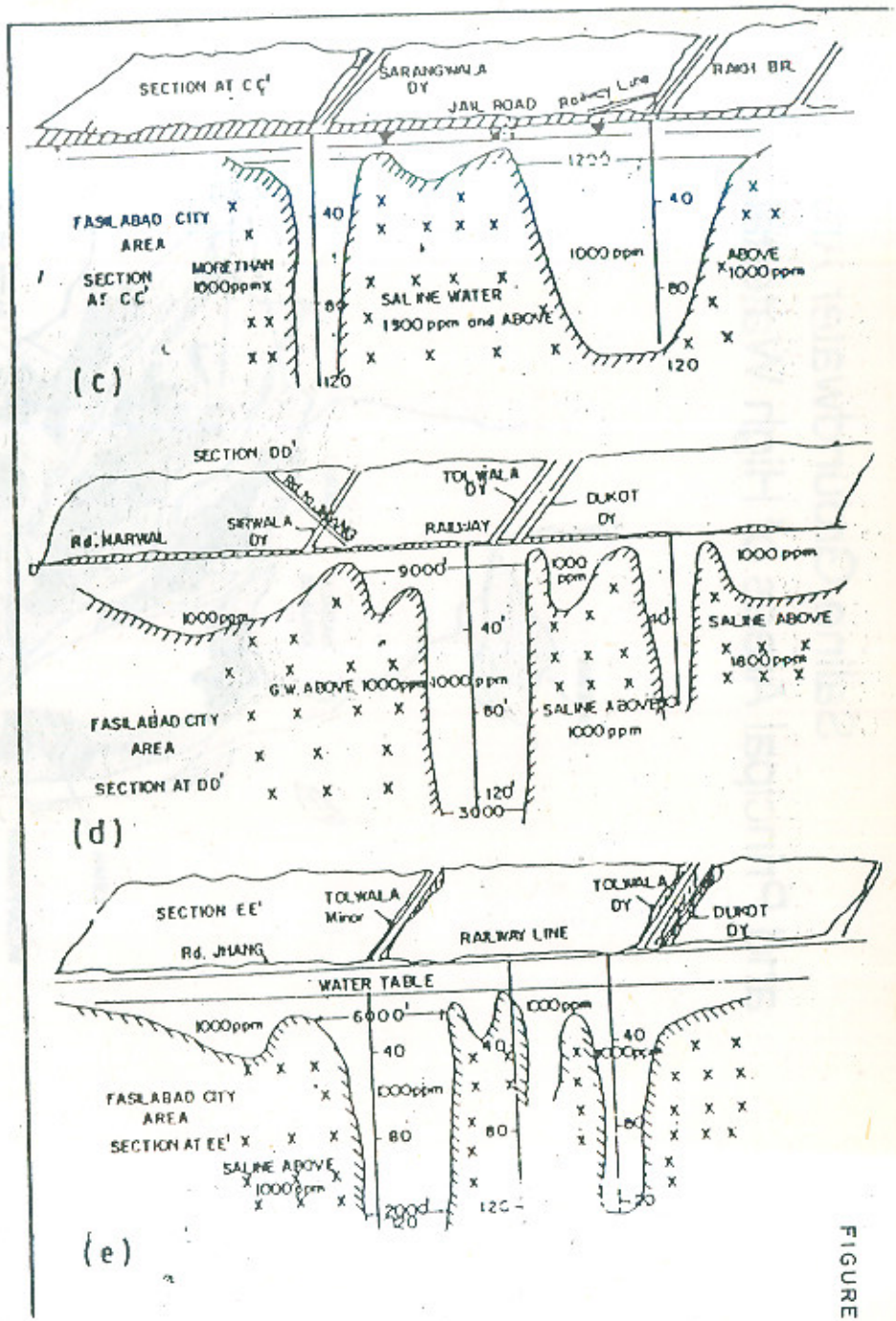


FIGURE-6

FIGURE-7

DESIGN OF LINED CANALS

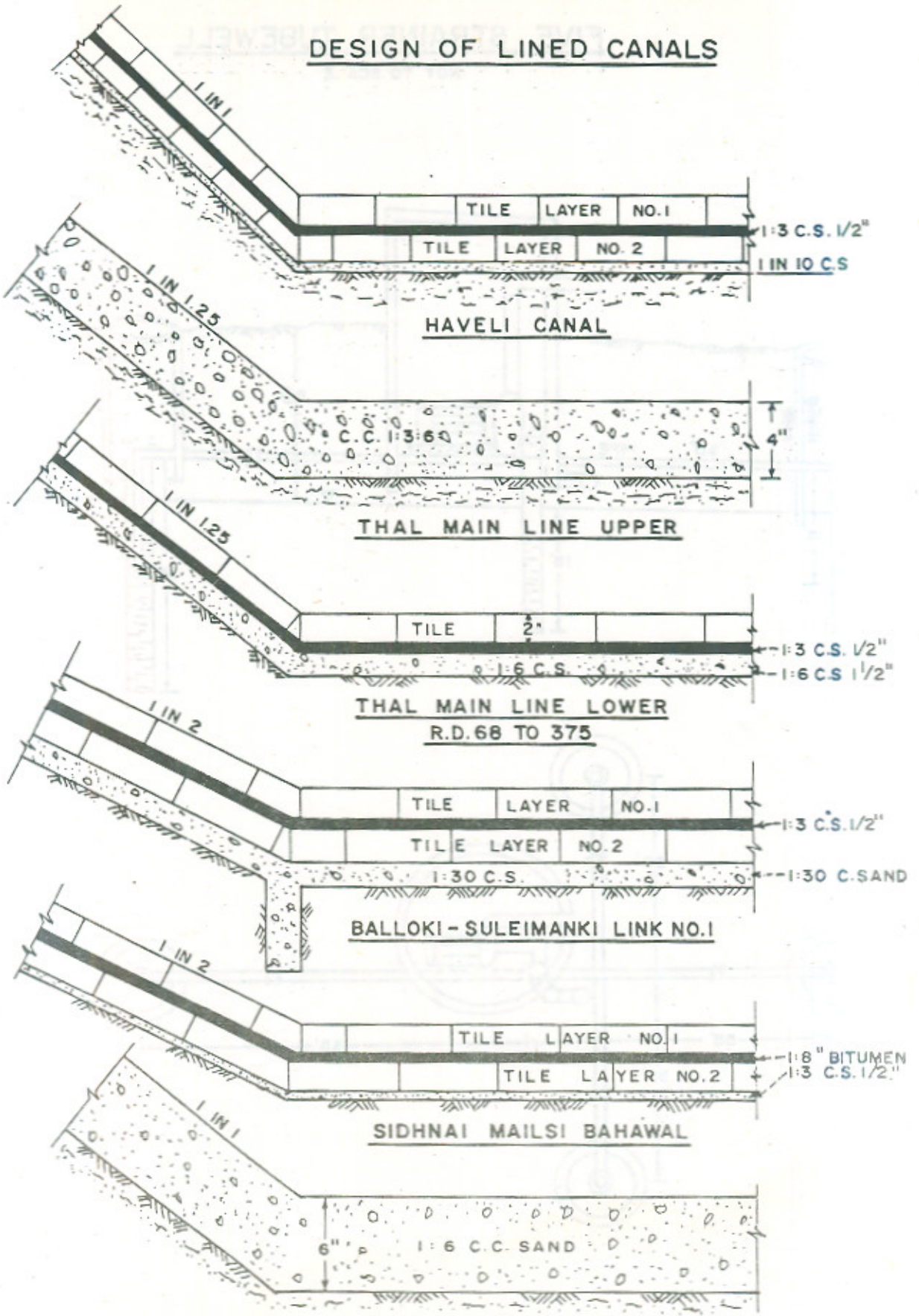
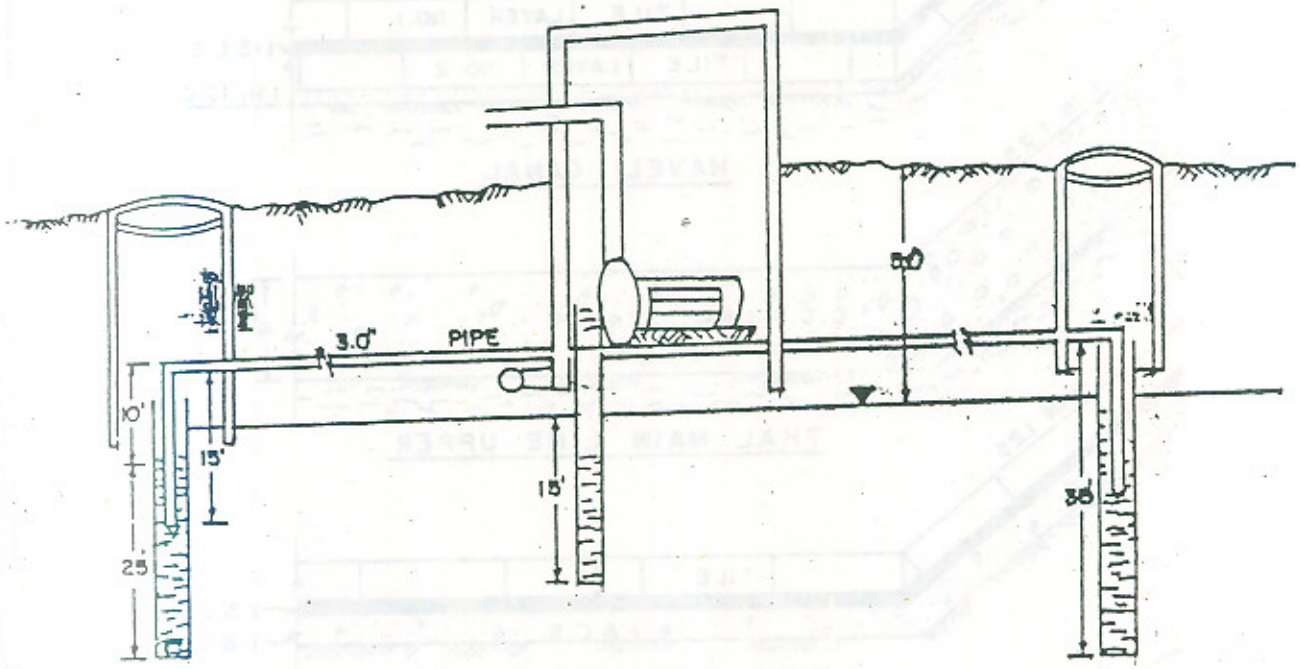
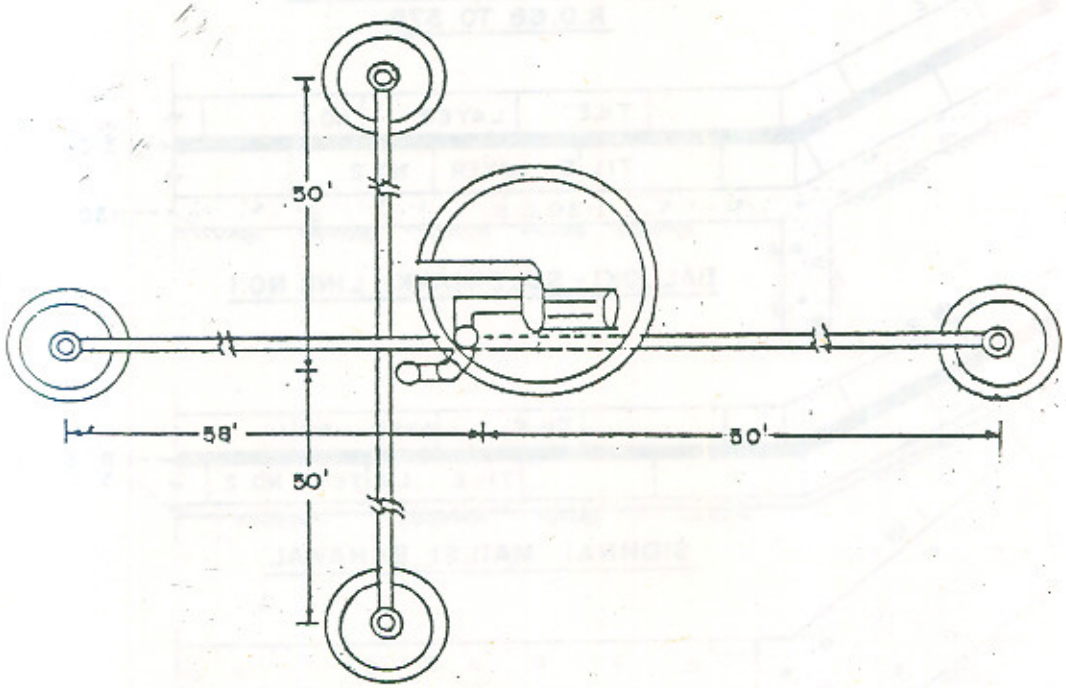


FIGURE-9

FIVE STRAINER TUBEWELL

NOT TO SCALE





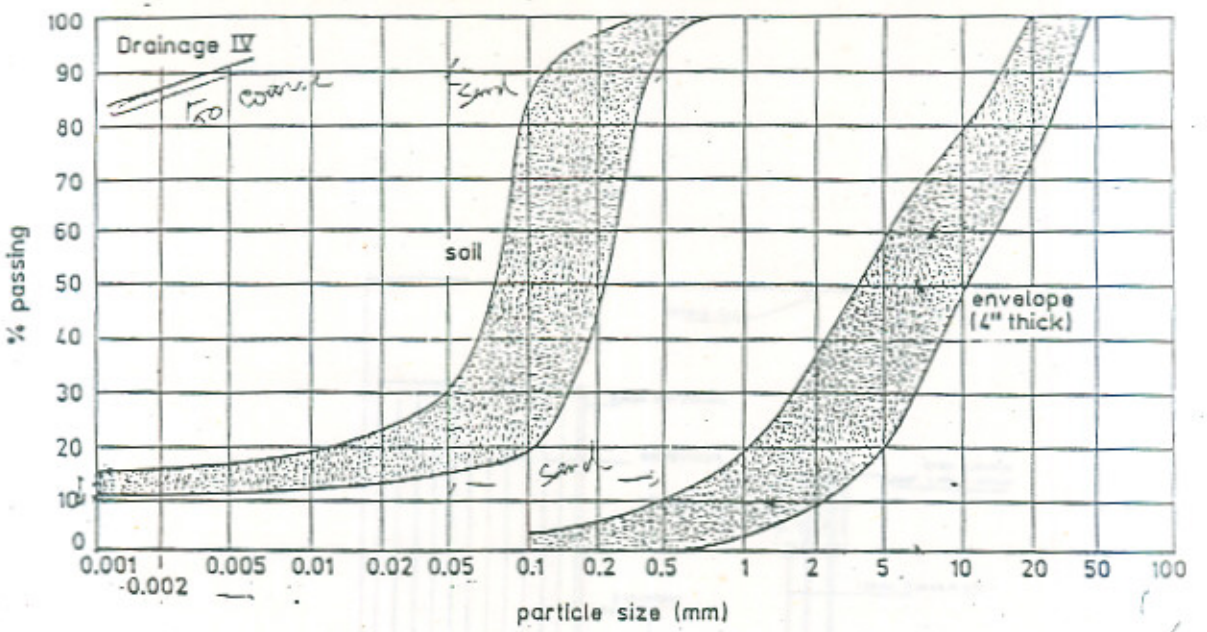


Fig. 10 Grading specifications for gravel envelope (USBR).

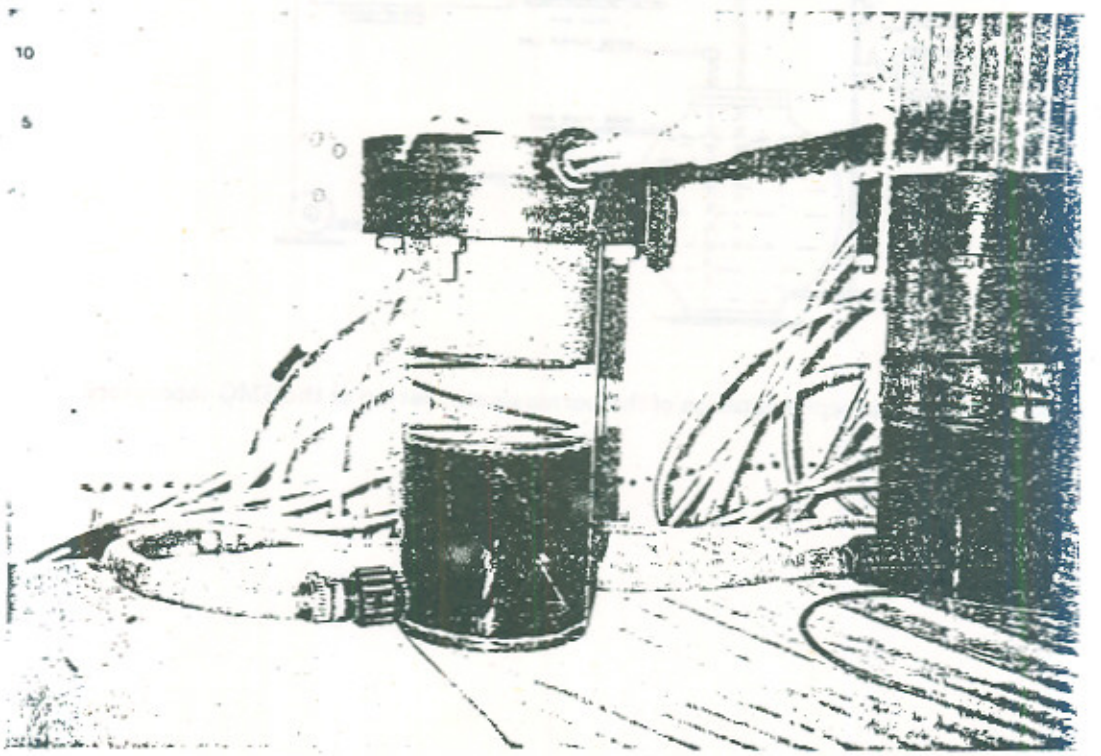


Figure . 11 - Photographs of the permeameter set-up at the SMO-laboratory.

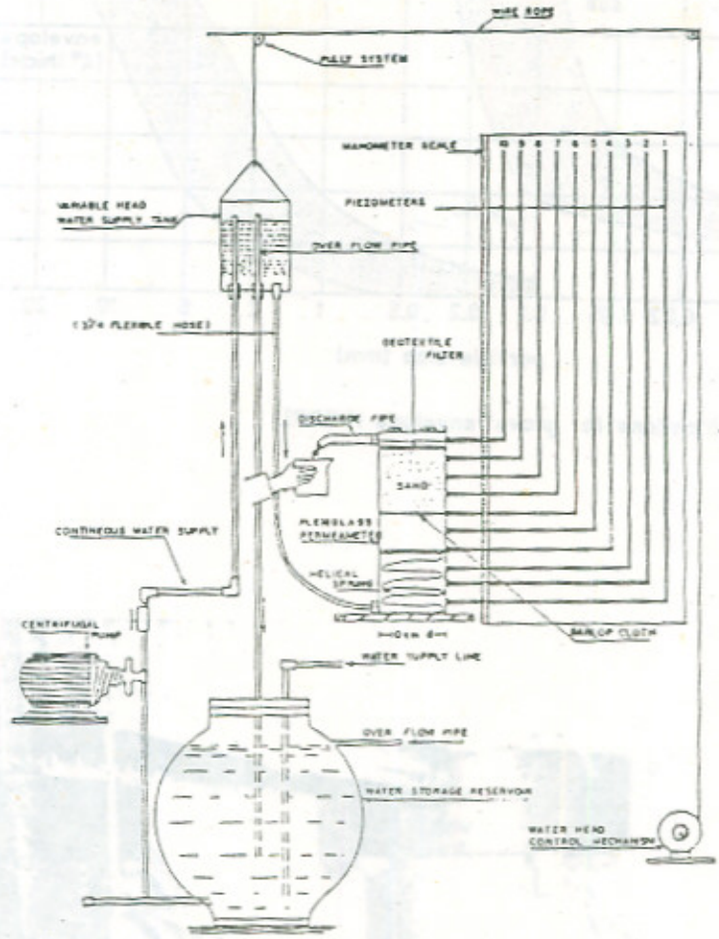


Figure - 12 Schematic representation of the permeameter set-up at the SMO-laboratory.