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WATER MANAGEMENT STRATEGIES FOR OPTIMIZING PRODUCTIVITY

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ABSTRACT

Irrigation water management is a complex problem. In order to maintain the productivity of irrigation projects, efficient and effective water management is very necessary. The subject is achieving greater importance as irrigatioon competes for limited water supplies and as lands throughout the world degrade and decline in productivity because of poor water management.

For Pakistan the problem is equally serious, because of country's limitged water resources. At present nearly 75 percent of the total rive inflow of 140 MAF is being diverted into irrigation canal system and the rest flows into the sea. Out of this diversion abut 45 to 50 percent is lost in transmission of water from head to the farmer headgate.

The biggest constraint in not increasing food production in the country is the water deficiency. Efficient management and utilization of the water resources is, therefore, highly necessary. In this paper several suggestions have been put forth for meeting the optimum water requirements. Developments in water use-crop productin technology have been highlighted Ways and means have been discussed for achieving greater efficiency at individual farm units including management and the use of poor quality water.

Introduction

Irrigation is the application of water to soil, to supply water essential for plant growth that is not provided by natural precipitation. Application of optimum amount of water at the needed time results in increased crop production. Excess water application may result in waterlogging and reduced production, whereas sub-optimum application

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may cause water stress in plants and accentuate the soil salinity problem.

Surface water resources of Pakistan are limited. Efforts are, therefore, being made to exploit the ground-water storage as much as possible. However, even after full harnessing of the surface water resources and exploitation of the ground-water, it may not be possible to meet the optimum requirements of the arable lands of the country. This calls for effective management for meeting the optimum water rquirements, better efficiency and improvement in on-farm irrigation system and greater reliance on the use of comparatively inferior quality water.

The subject matter of the paper has been divided into three parts :

I. Measures for meeting the optimum water requirements.

II. Improvement in On-Farm Irrigation Efficiency.

III. Use of poor quality water.

I. Measures for Meeting the Optimum Water Requirements :

Agriculture in Pakistan mainly depends upon irrigation. Per acre yield of various crops in the country is one of the lowest in spite of favourable conditions of soils and climate. The biggest constraint in not achieving the targets is the failure to meet the optimum irrigation requirements of crops. Of late a number of research studies on consumptive use and irrigation water requirements have been conducted in the country and many research papers and reports containing these data have been published. These studies have shown that irrigation requirements are far in excess of the available supplies. This can be seen from the data (1) given in table 1.

Table 1:

WATER REQUIREMENTS AND ITS AVAILABILITY FOR THE PRESENT IRRIGATED AREA

1.		Water availability at farm gate (from all sources)	= 81.4 MAF
2.		Crop-water Requirements at Farm Gate :	
		a) At existing intensity of 105 percent	= 112.2 MAF
		b) At enhanced intensity of 150 percent	= 160.1 MAF
3.	(a)	Deficit at 105 percent intensity	= 30.8 MAF
	(b)	Percent deficit at 105 percent intensity	= 38 %
4.	(a)	Deficit at 150 percent	= 78.7 MAF
	(b)	Percent deficit at 150 percent	= 97 %

The data indicate that there is a deficit of 38% of water at the farm gate at the existing intensity of 105 percent. If the intensity is increased to 150 percent the corresponding deficit rises to 97 percent. This calls for both generation of new resources of water and adoption of such management techniques which would result in saving of water losses so as to meet the optimum requirements of the crops.

Ground Water

Out of a total average inflow of 140 MAF of the rivers of Pakistan about 104 MAF is presently being diverted into canal system. On the average 50 percent of the diverted water is lost as seepage and evaporation. In addition floods, rainfalls and unscientific irrigation practices are adding to the underground formation, causing the water table to rise and creating water-logged conditions in many areas of the country. This can be gauged from the fact that the watertable which was around 90 to 100 feet about 100 years back in Rechna Doab before the start of the irrigation system has risen to within five feet in Faisalabad. At present nearly 30 percent of the area possesses groundwater within 0-5 feet and 55 percent within 10 feet of the natural surface. The data of depth to water-table for the year 1988 are given in Table-2.

Table - 2

DEPTH TO WATERTABLE JUNE 1988

MA/Percent

Province/ country	0 - 5	5 - 10	More/than 10	Total
Punjab	2.92/11.9	6.92/28.1	14.77/60.0	24.61
Sindh	8.49/59.9	3.10/21.9	2.57/18.2	14.16
Balochistan	0.23/23.4	0.16/16.5	0.59/60.1	0.98
NWFP	0.16/11.3	0.34/24.0	0.89/64.6	1.39
Pakistan	11.80/28.68	10.52/25.57	18.82/45.75	41.14

The percolating water is fresh and consequently can be utilized for development of agriculture. It is estimated that above 48 MAF of good quality canal water is percolating and is adding to the sub soil (2). A part of this percolation is being recovered by tubewells. Presently about 15,000 large capacity public tubewells and over 2,50,000 low capacity shallow tubewells in the private sector are functioning and adding to the country's water resources.

The quality of the ground water as assessed by WAPDA (3) is given in Table-3 and shown in Fig. 1.

Table - 3

QUALITY OF GROUND WATER IN PAKISTAN

Water Quality	Pakistan %	Upper Indus Plains (Punjab) %	Lower Indus Plains (Sind) %
Usable	40	49	26
Marginal	17	22	7
Hazardous	43	29	67

It is recognized that scientific management of this ground water reservoir is the key to the permanent irrigated agriculture in Pakistan.

Measures designed to meet the optimum water requirements of crops are discussed below :

i) Fractional Tubewells

Fractional tubewells are getting very popular with the farmers because of their obvious advantages. They are low capacity (discharge less than[1] cfs) and limited to a shallow depth of about 70 - 80 feet. These cost about Rs. 8 to 10 thousand without pumping set. A diesel operated pumping set of 1/2 cusec costs another Rs. ten thousand. The cost of a cusec pumping set is around Rs. twenty thousand. Fifty percent subsidy is provided by the Agriculture Deptt: on the purchase of these pumping sets and their installation every year. Thus a fractional tubewell operated by diesel engine can be commissioned at a real low cost. For an electric operated tubewell the farmers have to pay heavy charges of Rs. thirty thousand for power transmission besides the difficulties of getting timely electric connection. The fractinal tubewells will play a big part in meeting the optimum water requirements of the plants over and above the canal supplies.

500 cs with slope of 0.0005, higher than normal slope for this discharge, produce a silt factor, velocity and Froude Number equal to 1.77, 2.706 and 0.261 respectively. For a channel designed on Lacey's approach. Bank scour takes place when Froude Number exceeds 0.3 (Ref. 13). It is clear that a typical irrigation channel in Punjab has a Froude Number well below 0.3. A higher limit of 0.3 and a lower limit given by Equation (22) has been used in ACRP.

Width and depth of the section is computed by solving a quardratic equation constructed from equations of area and wetted perimeter. The resulting discriminant becomes negative for small discharges (for instance Q=7.5 & S=.0002), and simultaneous computation of B & D is not possible. Such a situation arises for Lacey's approach as well. For small discharges of the tail reach, depth of flow is governed by the authorised head at the tail. The Design Engineer, in such a case can compute bed width after selecting a suitable depth.

It may be mentioned that the questions regarding type of lining and the value of roughness coefficient for Punjab Canals are beyond the scope of this paper. Only a separate paper can address these issues in required details.

4.9. COMPARISON OF RESULTS

The design outputs of three approaches namely, Simon-Albertson, Lacey and ACRP have been compared in Tables T3 & T4 for discharges varying from 20 to 1000 Cs. The equations used are as follow;

1. SIMON - ALBERTSON

$P = 2.6\ Q^{0.5}$

$A = 1.144\ Q^{.86}$

$V = 16\ R^{2/3}\ S^{1/3}$

2. LACEY

Equations (1), (4) and (5) given in section 4.3.

3. ACRP

Equations given is section 4.8

The three out puts match quite closely. Lacey gives a slightly wider and shallower channel than the one given by Simon-Albertson. ACRP produces channel sections marginally wider and shallower than those given by Lacey. This is partly due to a flatter side slope of ACRP (0.65:1) than that (0.5:1) adopted by Lacey.

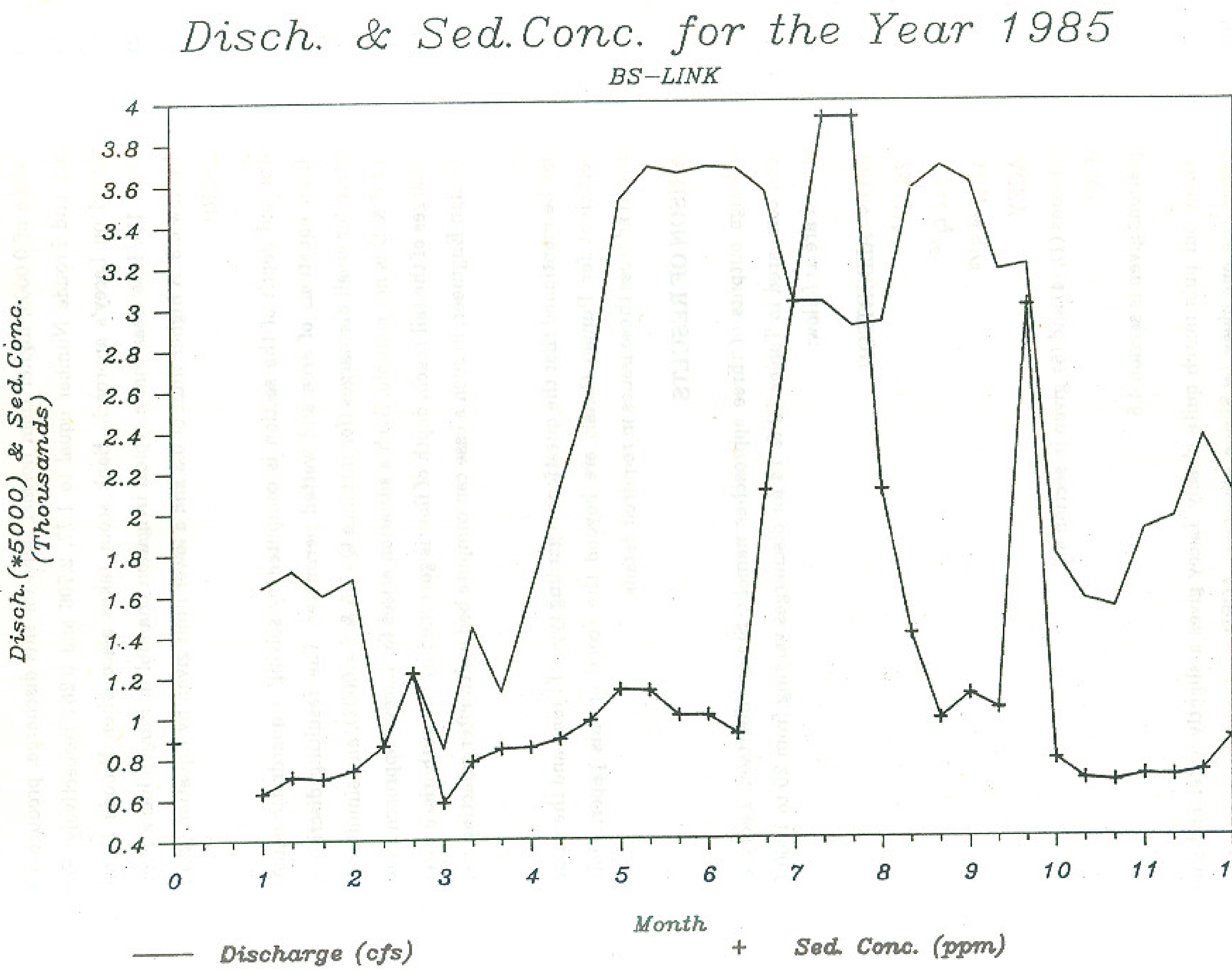

Disch. & Sed.Conc. for the Year 1985
BS—LINK
Disch.(*5000) & Sed.Conc. (Thousands)
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
Discharge (cfs)
Sed. Conc. (ppm)

FIG:4

ii) Cavity wells

Cavity wells are tubewells without stainers and are developed at low cost. These can be installed in areas where-ever there is a reasonable thick clay layer (about 5 feet) located at any depth between 50 - 100 feet with ground water of usable quality. This layer is punctured and blind pipe is introduced for pumping water from a cavity which is created below the clay layer (Fig-2). As there is no stainer consequently there is no problem of any deterioration. A cavity well will last as long as an open well.

In the Indus plains there are many areas which possess suitable formation to construct a cavity well. In Kasur, Chunian, Pattoki, Bahawalnagar and Fordwah canal areas, there exist several thousands of such wells installed by the farmers. They are about 50 - 70 feet deep and yield water just like a tubewell. Some of these wells are as old as 20 - 30 yeas and are running without any problem. Many more sites can be selected in the Indus Basin on the basis of boring data alredy available in the country.

It may not be out of place to mention that in Hariana (India) innumerable cavity wells exist. As compared to the cost the pay off is quite high. They result in assured optimum irrigation supplies at the time of need resulting in increased crop production.

iii) Water Use-Crop Production Technology.

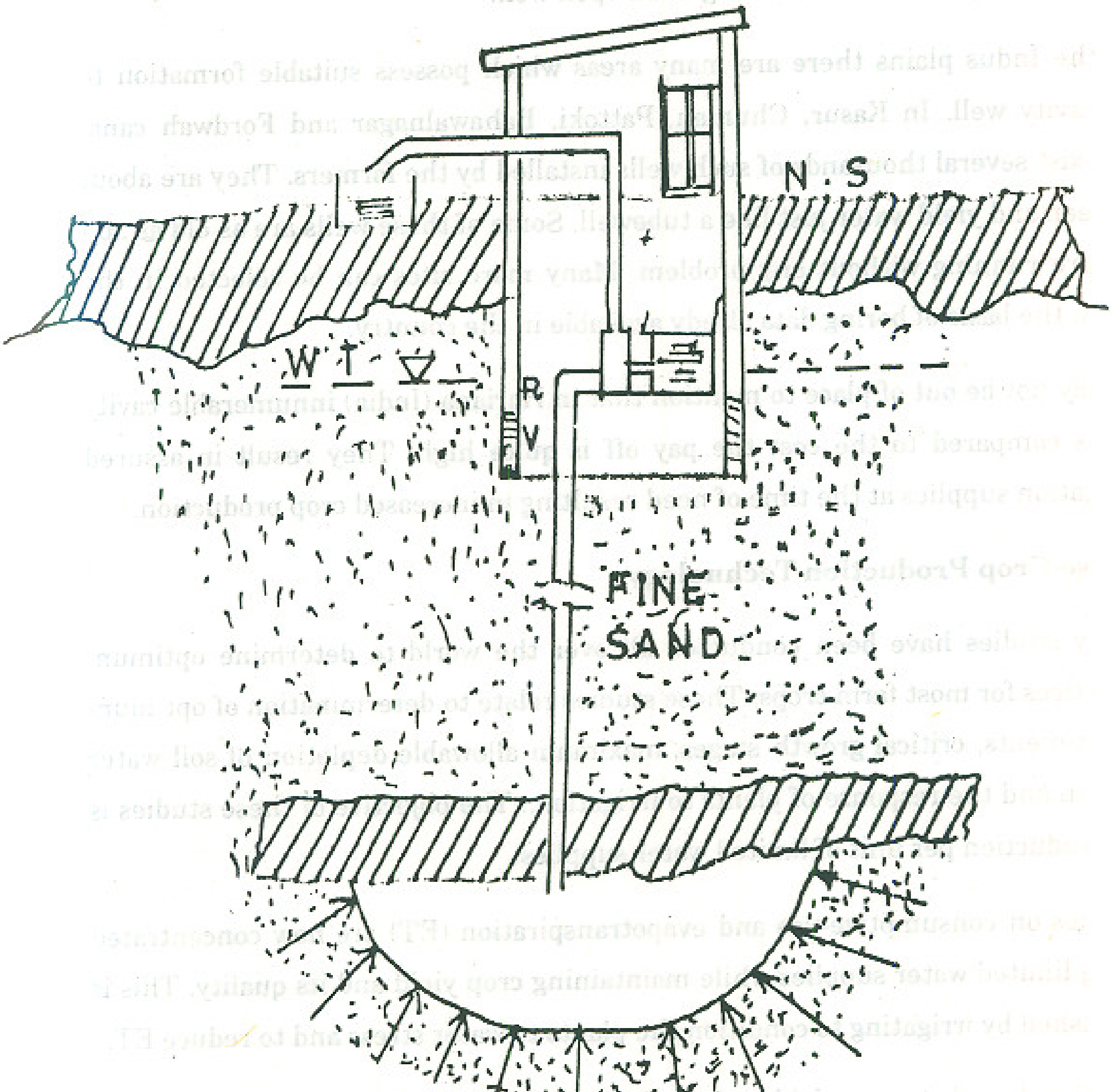
Many studies have been conducted all over the world to determine optimum irrigation practices for most farm crops. These studies relate to determination of optimum water requiremments, critical growth stages, maximum allowable depletion of soil water before irrigation and the response of plants to irrigation.. The objective of these studies is to maximize production per unit of limited water supplies.

Studies on consumptive-use and evapotranspiration (ET) are now concentrated on distributing limited water supplies while maintaining crop yield and its quality. This is being accomplished by irrigating to condition the plants to water stress and to reduce ET.

Relationships between yield and total irrigation water is generally curvilinear though for some crops yield responses can be approximated by linear relationships. Typically the return from increasing increments of irrigation water diminishes as maximum yields are approached.

Advances have also been made in irrigation scheduling technology. Irrigation scheduling is predicting the time and the amount of the next one or more irrigations. The

FIG: 2



CAVITY WELL

management objective is to eliminate water as a production limiting variable. Negative effects of excess water application are avoided by delaying irrigation until soil water depletion is sufficient to permit efficient irrigation with the existing system. Many standard procedures and guides for irrigation scheduling are now available. These procedures depend on soil moisture sampling, soil probing, using soil moisture blocks, tensio-meters, pan-evaporation and the climatic data. The general procedure, however, for providing irrigation scheduling is based upon climtic data, for which computer programmes have been developed in many countries.

In Pakistan data on optimum water requirements, critical growth stages, maximum allowable depletion, and irrigation scheduling technology are now available for some areas of the country (4,5). There is a need to adopt these technologies for these areas. Research should be initiated for other areas of the country to develop the basic framework data.

In order to adopt these technologies an independent and assured means of irrigation water supply is very necessary. Development of ground water can serve this purpose and put in the desired flexibility in the hitherto rigid canal water distribution system.

iv) Conjunctive use of surface and ground water.

To meet the optimum water requirements of crops, conjunctive use of surface and ground water is being made in SCARP areas by public tubewells. Mixing of the two waters is being done at the outlet heads. Studies conducted in this connection reveal that this practice is not conducive for getting optimum results (6). There are problems of proper mixing, questionable quality of pumped water and daily shut-down of the tubewells for four hours besides the electrial/mechanical faults. In order to overcome these problems it has been suggested that waters of the tubewells should be discharged into the distributory for proper mixing. The resultant water can then be withdrawn from another gated outlet, discharge of which can be regulated according to the requirements. With this technique water will be made available according to crop requirements and operation of the outlet will continue to be regulated through the warabandi system. The quality of water will improve after mixing with greater discharge of the distributory. The benefits and miseries of the system will be shared equally by all the shareholders.

The suggestion may be given a trial on any one distributory, after installing fractional tubewells along the channel.

v) **Shifting of canal closures.**

Annual canal closures are presently being practiced from mid December to the end of January for the purposes of repairs and maintenance. During this period Wheat planted in November/December requires 1st/2nd irrigation for its proper growth. It has been shown that timely availability of water is a critical variable for higher crop yield. Any moisture stress at this stage adversely effects crop production. It is, therefore, suggested that the canal closure period may be shifted to 2nd week of April to mid May which is a period of lean utilization of water.

This suggestion may need some adjustment in period of closure for Sindh and NWFP.

vi) **Storage of Canal Water.**

Studies on the growing of various crops versus available canal supplies indicate that the month of April is a period of lean utilization. In August the demand of canal water is low because of natural precipitation. During these months the canal water is in excess and is not fully utilized. It is suggested that surplus water of this period may be stored in existing ponds and depressions. Weeds may be removed and pond capacity improved to store large volume of water. The infiltration of the ponded water is generally low because of clay deposition. With proper management these ponds can serve as a good source of additional water supply.

vii) **Storage of Surface Water in village ponds**

In almost every village there exist one or two ponds which store water for the village animals and other purposes. Canal and rain water is usually stored in these ponds. Each pond is spread over an area of about 2 acres. In Pakistan the number of villages run into about 50,000. Assuming the average depth of 3 feet for each pond nearly 0.3 million acre feet of good quality water is stored in these ponds. With the excavating machinery now available it is possible to increase the depth of these ponds and remove weed growth. In this way the storage capacity of these ponds can be increased. The seapage losses in these ponds are low as the bed becomes practically impervious with the settling of clay in the bottom. This water can also be used to supplement the existing irrigation supplies.

viii) **Use of Drains/Streams Water**

Surface drains/streams either removing storm water or lowering the subsoil water table mostly discharge the effluent into the adjacent river. The quality of this water wherever usable can also be pumped for meeting the part requirements of crops. The cultivators should be encouraged to lift this water at no charge.

ix) Water Management under Shallow Water Table Conditions

A revised management strategy need to be adopted in areas where the water table is high. It has been observed that in high water table areas ground water can meet a part of irrigation requirements of the plants and results in coresponding decrease in surface water application. Field studies on Wheat revealed that 78,65 and 45 per cent water was saved when water table depth was 2, 3 and 4 feet respectively (7). The water thus saved can be utilized in bringing more areas under crops.

In another study on Wheat (8) in high watertable areas it was established that a modified technique should be adopted instead of normal flat sowing. The modified technique consisted of making of broad beds 3 feet wide and 9 inches raised from the flat surface as shown in Fig. 3. With this improved technique 15 percent increase in yield was observed where the watertable was less than 2 feet in addition to 80 percent saving of irrigation water.

x) Conservation of Surace Water in Underground Formation.

There are prospects of conserving surface water in underground formation particularly at sites where ground water has declined. In the commands of Pakpattan, Sidhnai and Mailsi canals, areas exist where the water table has gone down to 30-40 feet and unsaturated formation has been created to store and conserve fresh water. Another striking example is the city of Lahore where the ground water has receded from 14 feet to about 70 feet depth. Large volumes of surface water can be recharged into the depleted acquifer and provide an easy source of fresh water supply for the residents of the area. Greater Thal is still another area where ground water can can be similarly conserved. In this connection mention of the Cholistan may not be out of place for undertaking similar works. Scanty rainfall and occassional floods gets accummulated in depressions. This water is used by the residents for drinking as well as for their stock of animals. The quality of this water gradually deteriorates because of constant evaporation at the bare surface of water. The ground water exists at a depth of 50-100 feet and is saline. It is suggested that the water from these depressions may be stored in small concrete tanks. The sediments will settle down and the supernatant water should be recharged to the ground water by a system of shallow stainers as shown in Fig. 4 and 5. This water can

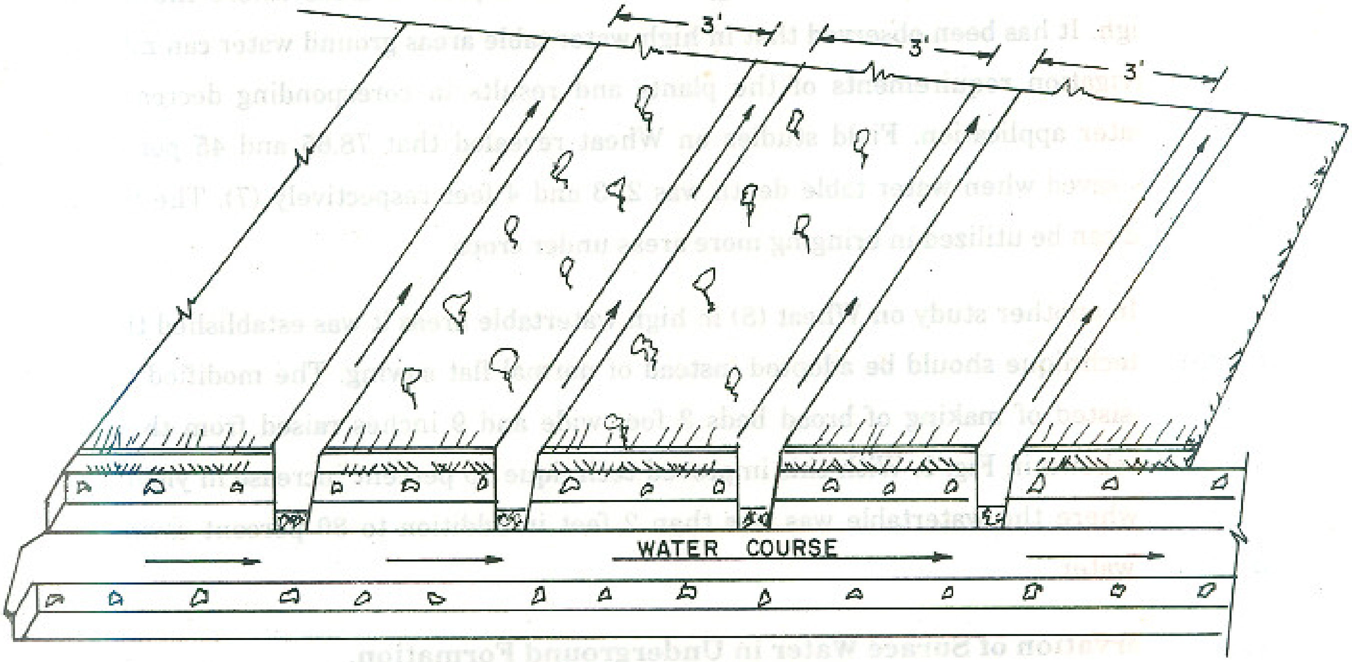


FIG. 3 RAISED BEDS 3Ft. WIDE
IRRIGATED WITH DITCHES
TAKEN OUT OF FARMER
WATER COURSE
GROUND WATER AT VERY SHALLOW DEPTH

create a fresh water aquifer which will not be lost by evaporation and can be a source of fresh water supply for the inhabitants of the area.

xi) Sprinkler Irrigation

Sprinkler irrigation is an effective technique of supplying water to the crop roots and is highly efficient and results in saving of farm labour. It, however, requires clean water and source of cheap power. The technique is particularly useful in areas having undulating topograph. In tracts like grater Thal where sand dunes exist sprinkler irigation pumped from ground water can result in bringing large areas under crop production.

In the Punjab nearly 70 Percent tubewells are diesel operated. Farmers have been using 20 HP slow speed diesel operated engine. In some of the electric operated tubewells motors of 15/16 HP are being used. Thus sufficient power is available with some farmers pumping ground water which can be used to operate a sprinkler system without arranging for any additional power supply. The technique requires to be given a trial even in the present irrigated areas.

xii) Trickle/Drip Irrigation

The trickle or Drip irrigation method is a lateral spread of water on the irrigated suface by conducting the water under pressure to relatively closed spaced grid of outlets and discharging the water through these outlets at virtually zero pressure.

The system is adaptable to a wide variety of soils and topographic conditions including uneven and sandy soils. In areas where water is scarce, and land levelling either is impossible or very costly, trickle irrigation has many advantages, over surface irriagation mehods. As the installation of the system is expensive, therefore, growing of high value crops can be economical.

In Balochistan where water is scarce, several studies have ben started on trickle irrigation. In Pothwar area also there exist a great potential for giving this technique a fair trial.

xiii) Farmer Motivation

The measurs narrated in the foregoing on the use of ground water through fractional or cavity wells and the use of stored canal or rain water and other measures can result in reducing the mismatch between the crop water requirements and the available supplies and result in increased crop yield. However, farmers need to be motivated and

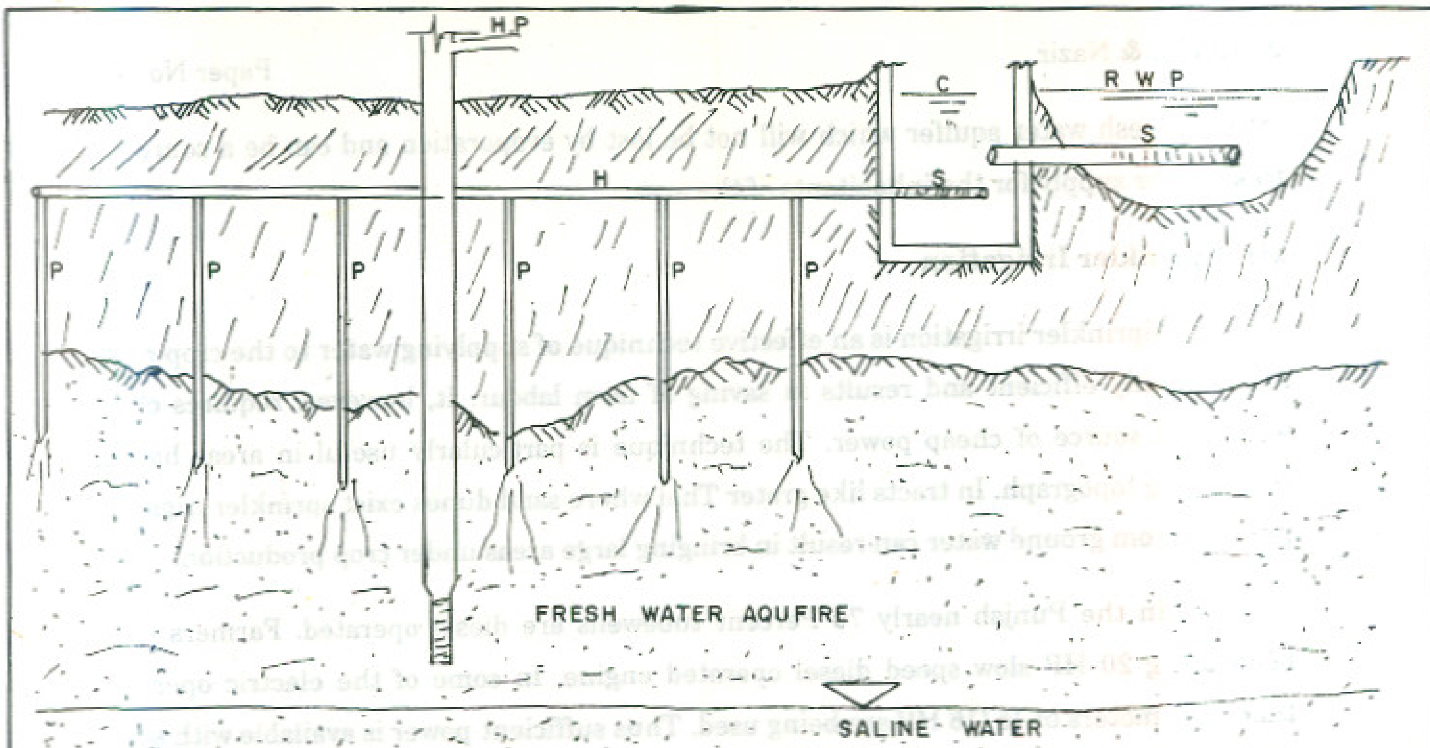


FIG. 4

CHOLISTAN AREA RECHARGE

S = STRAINERS RWP = RAW WATER PIT
C = CONCRETE TANK, H = HEADER PIPE, 2 or 3 INCH
P = G.I. PIPE 1 1/2 INCH, HP = HAND PUMP FOR DEEP GROUND WATER

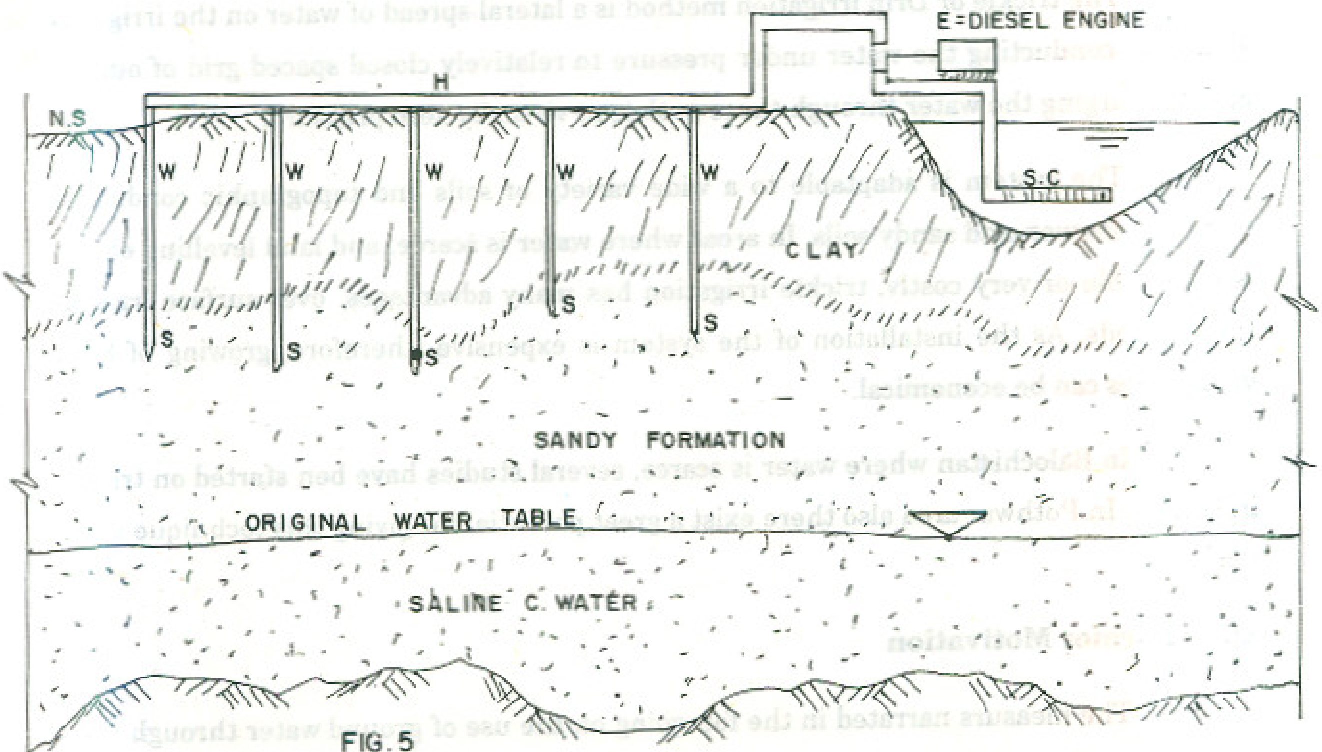


FIG. 5

CONSERVING RAINFALL RUN OFF UNDERGROUND FORMATION

P = PUMP, E = ENGINE, H = HEADER PIPE 3 Ft.
SC = COIR WOUND STRAINER, S = STRAINER
W = G.I PIPES, 1 1/4 INCH.

encouraged to adopt the new technologies wherever possible. For this purpose the facility of cost subsidy on purchase of pumps and installation of fractional tubewells may be extended to cover all areas of the country. Similary the existing credit facilities may be enlarged to benefit maximum number of the cultivators.

II. Improvement in On-Farm Irrigation Efficiency

Maximizing water use efficiency is an important objective for water deficient areas. The effectiveness of an irrigation water supply can be increased by improving the efficiency of water application. In surcace irrigation, water application irrigation efficiency is influenced principally by the amount of water applied, the intake characteristics of the soil and the rate of advance of water over the soil surface. However, the ability to uniformly distribute water water over a field and to control the amount applied is a key factor in achieving efficient irrigation. Without this control very low efficiencies are inevitable.

For achieving higher efficiencies various problems to be considered are as under:

i) Farm layout and location of farm water courses.

ii) Field layouts and appropriate sizes of the plots for efficient irrigation.

iii) Land levelling

iv) Method of surface irrigation

v) Farm Water Management

i) Farm Layout and Location of Farm Water Courses

In order to achieve high efficiency of water application, save land and water within the farmer's fields, the layout of farm water courses should be changed. The layout system approved by the Irrigation Deptt: involved construction of five subsidiary Zamindara water courses in a square of Land. These water courses are placed at half acre length perpendicular to the main water course (Sarkari Khal) as shown in Fig. 6. This layout results in waste of Land and water. An improved design consists of constructing three subsidiary water courses after one acre lenght as shown in Fig.7. The total length of the water course can be reduced from 4455 feet to about 2821 feet. This would not only save about 34 percent of land used for field water courses, construction cost and maintenance charges but also reduce water losses to a considerable extent and thus

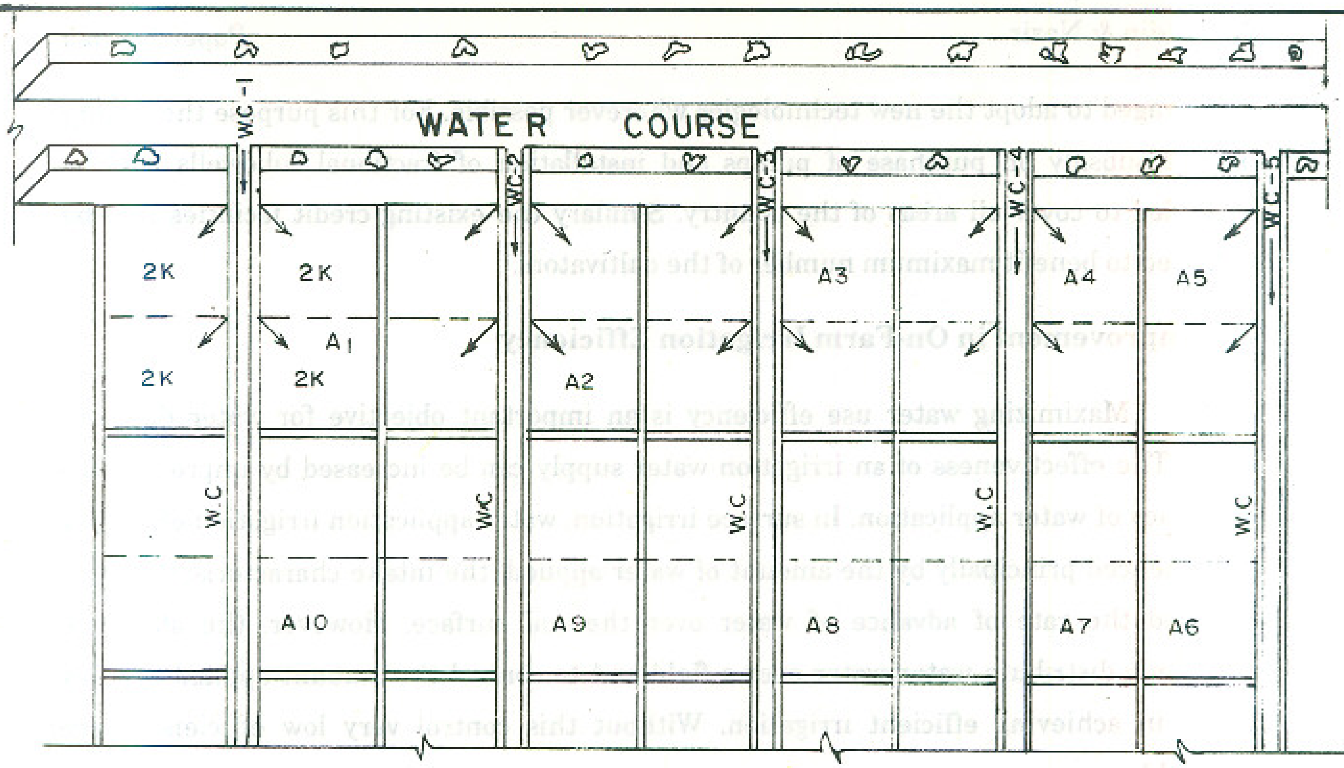
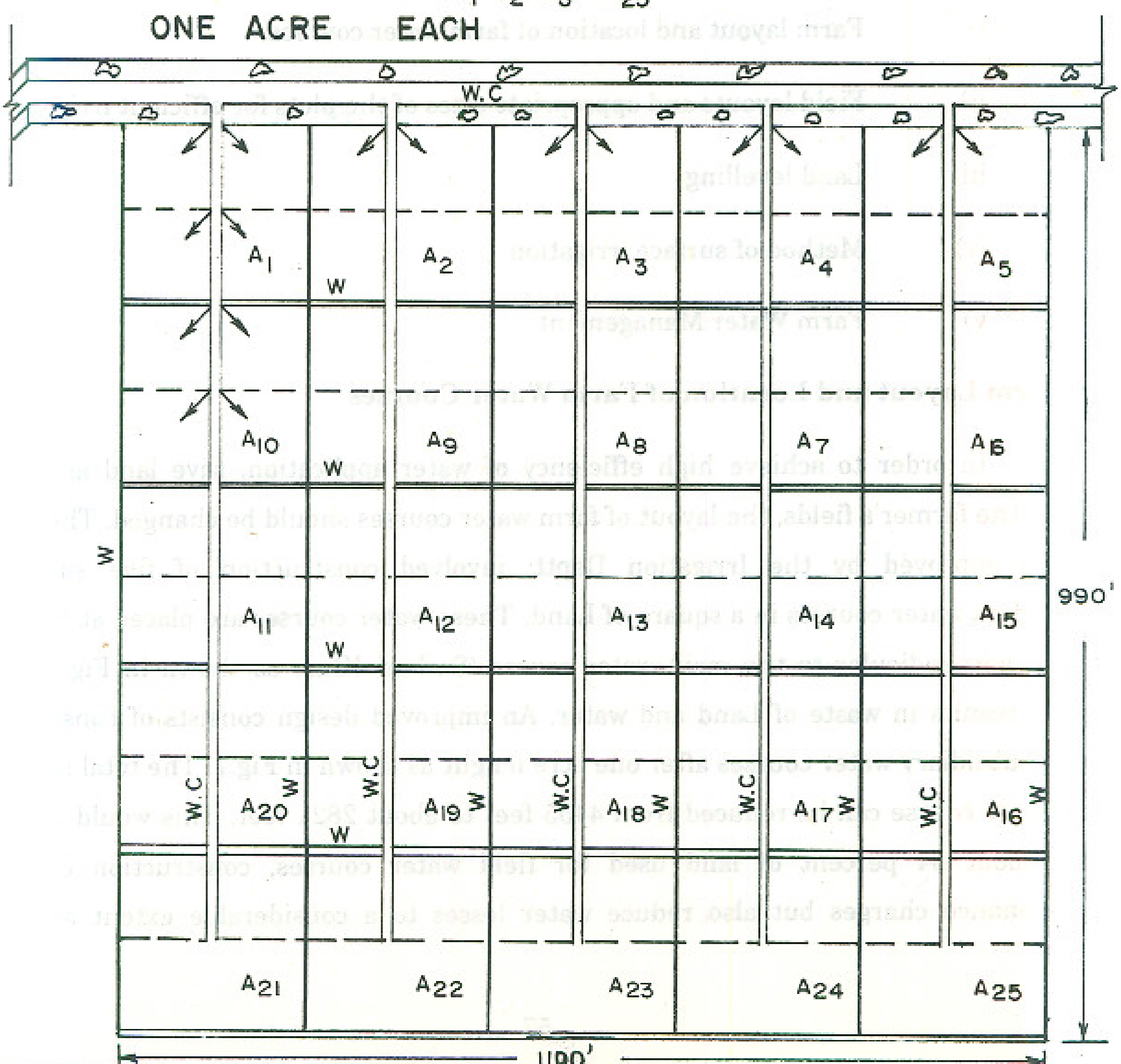


FIG. 6 ONE SQUARE IRRIGATED BY FIVE WATER COURSES (W.C) ENLARGED VIEW A_1 A_2 A_3 -- A_{25} ONE ACRE EACH



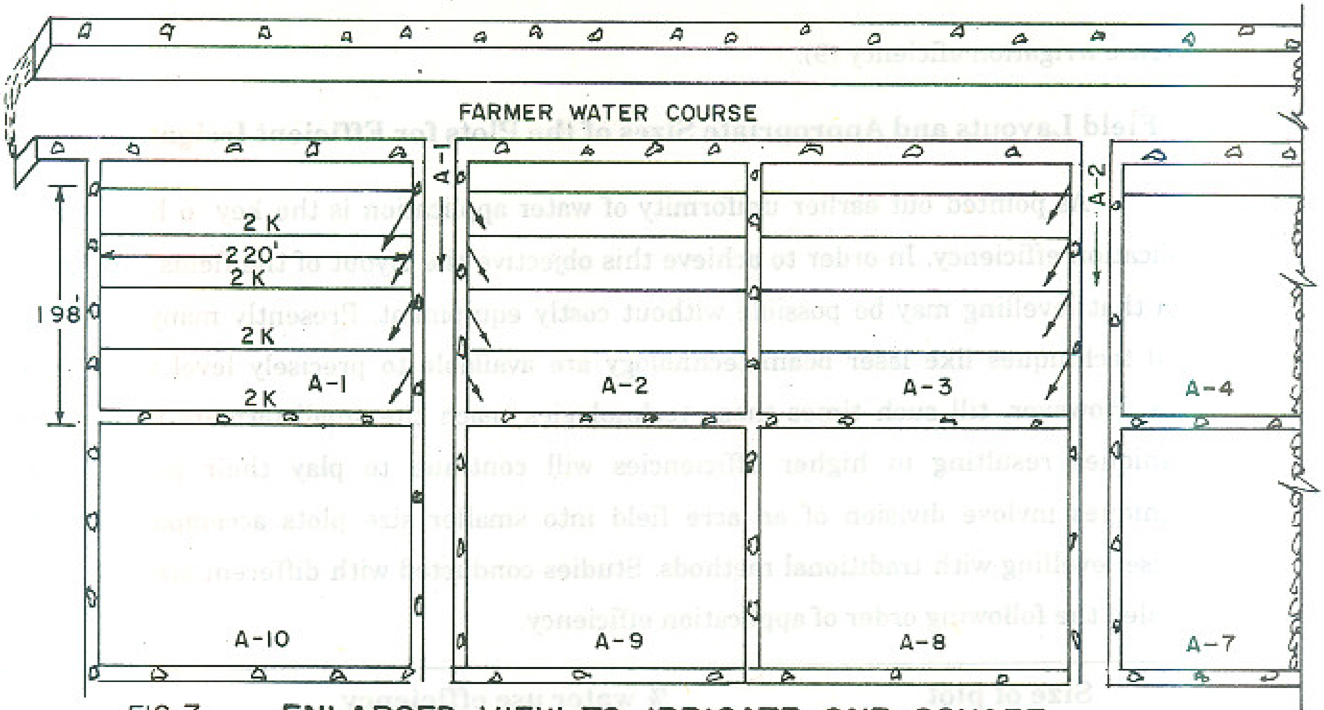
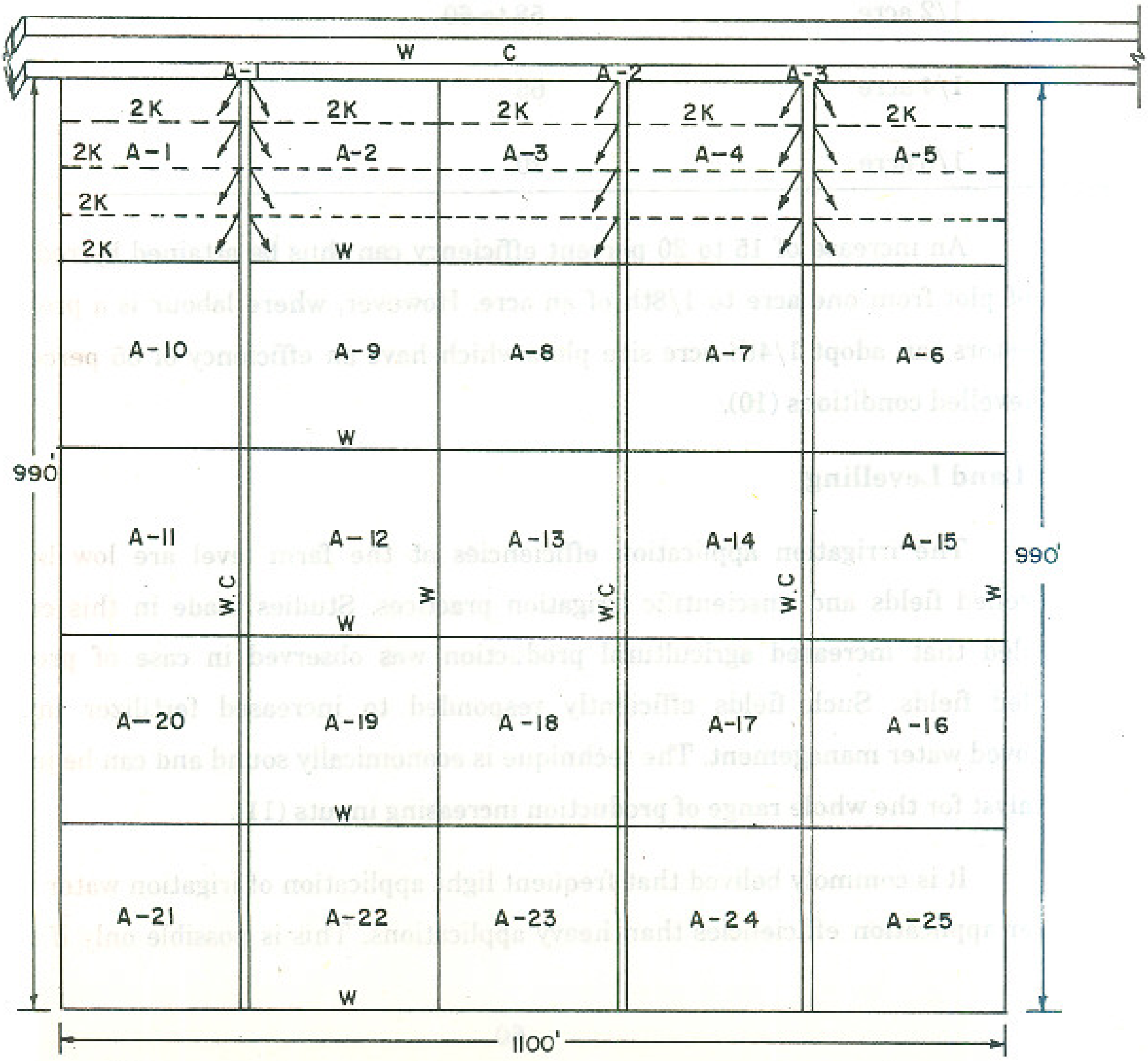


FIG. 7 ENLARGED VIEW TO IRRIGATE ONE SQUARE WITH THREE WATER COURSES A_1 A_2 A_3 etc. ONE ACRE & EACH DIVIDED INTO 2 KANALS, W.C= WATER COURSE.



increase irrigation eficiency (9).

ii) Field Layouts and Appropriate Sizes of the Plots for Efficient Irrigation.

As pointed out earlier uniformity of water application is the key to high water application efficiency. In order to achieve this objective the layout of the fields should be such that levelling may be possible without costly equipment. Presently many sophisticated techniques like laser beam technology are available to precisely level very large areas. However, till such times these technologies reach the small farmers indigenous techniques resulting in higher efficiencies will continue to play their part. These techniques invlove division of an acre field into smaller size plots accompanied with precise levelling with traditional methods. Studies conducted with different sizes of plots revealed the following order of application efficiency.

Sr. No.	Size of plot	% water use efficiency
1.	One acre	50 to 55
2.	1/2 acre	58 to 60
3.	1/4 acre	65
4.	1/8 acre	70

An increase of 15 to 20 percent efficiency can thus be attained by reducing the size of plot from one acre to 1/8th of an acre. However, where labour is a problem, the cultivators can adopt 1/4th acre size plots which have an efficiency of 65 percent under well levelled conditions (10).

iii) Land Levelling

The irrigation application efficiencies at the farm level are low because of unlevelled fields and unscientific irrigation practices. Studies made in this connection revealed that increased agricultural production was observed in case of precise land levelled fields. Such fields efficiently responded to increased fertilizer inputs and improved water management. The technique is economically sound and can be justified as a catalyst for the whole range of production increasing inputs (11).

It is commoly belived that frequent light application of irigation water results in higher application efficiencies than heavy applications. This is possible only if the fields are precisely levelled and respond to uniformity of water application.

iv) Methods of surface Irrigation

Irrigation is presently being applied to the crops by flooding the basins or borders. The flood method is an inefficient technique where water is wasted in runoff and in unlevelled fields. Studies have revealed that if the application method is changed from flood to furrow, the application efficiency increaes and substantial amount of water is saved. Furrow method is particularly useful in case of row crops like Maize, Cotton and Sugarcane etc. Although labour is required for making the ridges, yet the corresponding increase in yield and saving of water makes it quite economical. The increase in yield of Maize and Cotton by the furrow method as compared to conventional flood method was as under:

Crop	Increase in yield by adopting furow method
Maize	19 percent in case of high water table and 16 percent under deep water table conditions.
Cotton	20 to 28 percent under deep water table conditions.

In additon to increase in yield there was substantial amount of water saving by the furrow method.

v) Farm Water Management

One of the main causes of low yield levels is poor water management and water control especially at the farm level. Inefficiencies in the distribution system and the uncertainities in the irrigation supplies were found quite common. In order to overcome these constraints On-Farm Water Management (OFWM) Projects were initiated with a view to improve water management at the farm level and provide extension. The diagnostic studies focussed attention on the crucial role water management and control at the farm level can play to increase crop yields and optimize investments in irrigation and other agricultural inputs such as fertilizers and high yielding varieties.

The Directorates of OFWM created for undertaking the job have improved water courses, undertook land levelling and a programme of training of technicians of different categories. This will result in saving of irrigation water, improving of efficiency at the farm level and consequently will result in increased crop yield.

Under the Command Water Management, work on sub projects initially covering an area of approximately 0.5 million acres have been initiated. Under this programme physical improvement in the water distribution system have been undertaken to reduce losses and ensure increased supply and reliability at the farmgate. To optimize the crop yields adequate agriculture and extension supported by integrated agro-services have been assured.

III. Use of Poor Quality Water

The surface water resources of Pakistan are limited. Poor quality ground water is, therefore, being used increasingly for optimizing crop growth and to bring unirrigatied area under crop production. Presently about 40 MAF of ground water is being pumped and added to the surface water. As the quality of ground water is inferior, therefore, special measures are required for ths use of this water. The criteria of usability and the techniques required to be adopted for the utilization of this water viz. leaching, crop selection and management practices are disussed below:

i) Criteria of Irrigation Water Usability

All ground waters cannot be used for irrigation because of the presence of soluble salts beyond permissible limits. The criteria of usablility is based on salinity, sodicity and toxicity of irrigation water. The releveant parameters determining these criteria are, Total Dissolved Salts (TDS), Sodium Adsorption Ration (SAR) and Residual Sodium Carbonate (RSC). The criteria adopted in Pakistan is given in Table 4.

Table.4

GUIDELINES FOR INTERPRETATIN OF WATER QUALITY FOR IRRIGATION IN PAKISTAN

Parameter	Units	Usability		
		Usable	Marginal	Hazardous
Salinity (TDS)	mg/1	< 1000	1000 - 2000	> 2000
Sodicity (SAR)	-	< 10	10 - 18	> 18
(RSC)	me/1	< 2.5	2.5 - 5	> 5

Internationally many improvements have since been made in the quality criteria. The concept of RSC is no longer being used. In order to predict the sodium hazard associated with carbonate and bicarbonate waters a revised concept of adjusted sodium adsorption ratio (Adj RNa) has been proposed. Another concept of infilteration rate of water into the sil as evaluated by TDS and SAR has also been introduced (12). The U.S guidelines of water usablity are given in Table 5.

Table - 5

GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION IN USA.

Parameter	**Units**	**Degree of restriction on use**		
		None	**Slight to moderate**	**Severe**
Salinity (TDS)	mg/1	< 450	450 - 2000	> 2000
Infiltration : (Evaluate EC and SAR together)				
SAR = 6 - 12 and EC	dS/m	> 1.9	1.9 - 0.5	< 0.5
= 12 - 20	dS/m	> 2.9	2.9 - 1.3	< 1.3
Specific ion toxicity				
Sodium	SAR	< 3	3 - 9	> 9
Chloride	me/1	< 4	4 - 10	> 10
Boron	mg/1	< 0.7	0.7 - 3.0	> 3.0

EC = Electrical conductivity.

TDS = Total dissolved salts.

SAR = Sodium adsorption Ratio.

mg/1 = milligrams per litre.

dS/m = Decisimens per meter.

me/1 = millie quivalent per litre.

The guidelines given in tables 4 and 5 need to be kept in view before using a particular type of water. Studies conducted in Pakistan and elsewhere suggest that marginal quality waters having slight to moderate effects on crops and soils can be successfully used provided improved soil and water management practices are adopted.

Studies in Mona Project revealed that waters upto 2600 ppm and SAR less than 4 can be used with no adverse effects on soils in case of Wheat, Cotton and Sugarcane (13).

In another study in SCARP-I it was established that water of the composition TDS=2300 ppm and SAR=11 under good management practices like the inclusion of leaching component, levelling and proper layout did not have any adverse effects on soil and yield of Wheat.

Similar studies made in other countries of the world indicate that salt tolerant crops like Wheat, Barley and Cotton can be raised on waters of high salinity without causing any deleterious effects.

The studies listed in the foregoing and similar other data lead us to the conclusion that marginal quality waters upto 2000 ppm and SAR less than 10 can also be used under good management conditions.

ii) Leaching for Salinity Control

The build-up of soluble salts in soils can be controlled by applying more water than that needed by the crops during the growing season. The extra water moves the salts below the rootzone. If the amount of water required for leaching is included in the irrigation application, the accumulation of salts in the soil profile may not occur. The general equation used for calculating the irrigation and leaching requirements (consumptive use of water + leaching) is given as under:

$$D_{iw} = D_c \frac{1}{1 - \frac{EC_{iw}}{EC_{dw}}}$$

Where

D_{iw} = Irrigation requirements

D_c = Consumptive use of water

EC_{iw} = Electrical conductivity of irrigation water.

EC_{dw} = Electrical conductivity of drainage water.

Studies conducted in SCARP-I and II confirmed the assumption that the build-up of salinity with poor quality water can be controlled if leaching component is included in the irrigation requirements (14).

iii) Management Techniques

The management techniques which need to be adopted for controlling the salinity of irrigation water includes land levelling for better water distribution, timing of irrigations to prevent crusting and water stress, placement of seed to avoid area likely to be salinized and care in selection of material, rate and placement of fertilizers.

iv) Crop selection

All plants do not respond to salinity in a similar manner. Some plants are more tolerant than others. Guidelines are now available which give relative salt tolerance of most fruit plants and agricultural food and forage crops. For example Kallar grass and Sesbania Aculeata (Jantar) are highly tolerant; Barley, Cotton, Sugarbeet and Date are tolerant; Wheat, Rice, Oats, Sorghum and Clover are moderately tolerant; Berseem, Corn (Maize) and Sugarcane are moderately sensitive; and Beans, most vegetables and citrus are sensitive plants. The planting of these fruit trees and agricultural crops can, therefore, be adjusted keeping in view the salinity of the available irrigation water. (15,16)

Conclusions

Irrigation water management has acquired new proportion in Pakistan because of extremly limited water resources of the country. Presently only 50 percent of the canal diversion is utilized for raising crops and the rest is lost in transmission. Some loss is also occuring in the fields on account of inefficient irrigation techniques and poor land levelling. Generation of new resources and effective management of existing supplies is, therefore, highly necessary.

In order to meet the optimum requiremens of crops at the farm level several suggestios have been made. Installation of cheap fractional and cavity wells pumping comparatively good quality water from shallow depths has been stressed. Shifting of canal closures from January to April, storage of rain and surplus canal water in ponds, use of agricultural drainage water, conservation of surface water in underground formation, sprinkler and trickle irrigation and water management under shallow water table conditions are the other measures which if implemented can result in reducing the mismatch between the crop water requirements and its availability. Adoption of recent techniques in water use-crop production technology and strategies designed to deliver optimum amount of water at the time of need at on-farm level have been suggested.

For achieving greater irrigation efficiency at individual farm units adoption of measures like improved farm layout and appropriate sizes of plots for efficient irrigation, land levelling and furrow method of irrigation have been emphasized.

It has also been stressed that greater reliance should be made on the use of comparatively inferior quality water. The criteria of usability have been given and measures for managing saline water have been highlighted.

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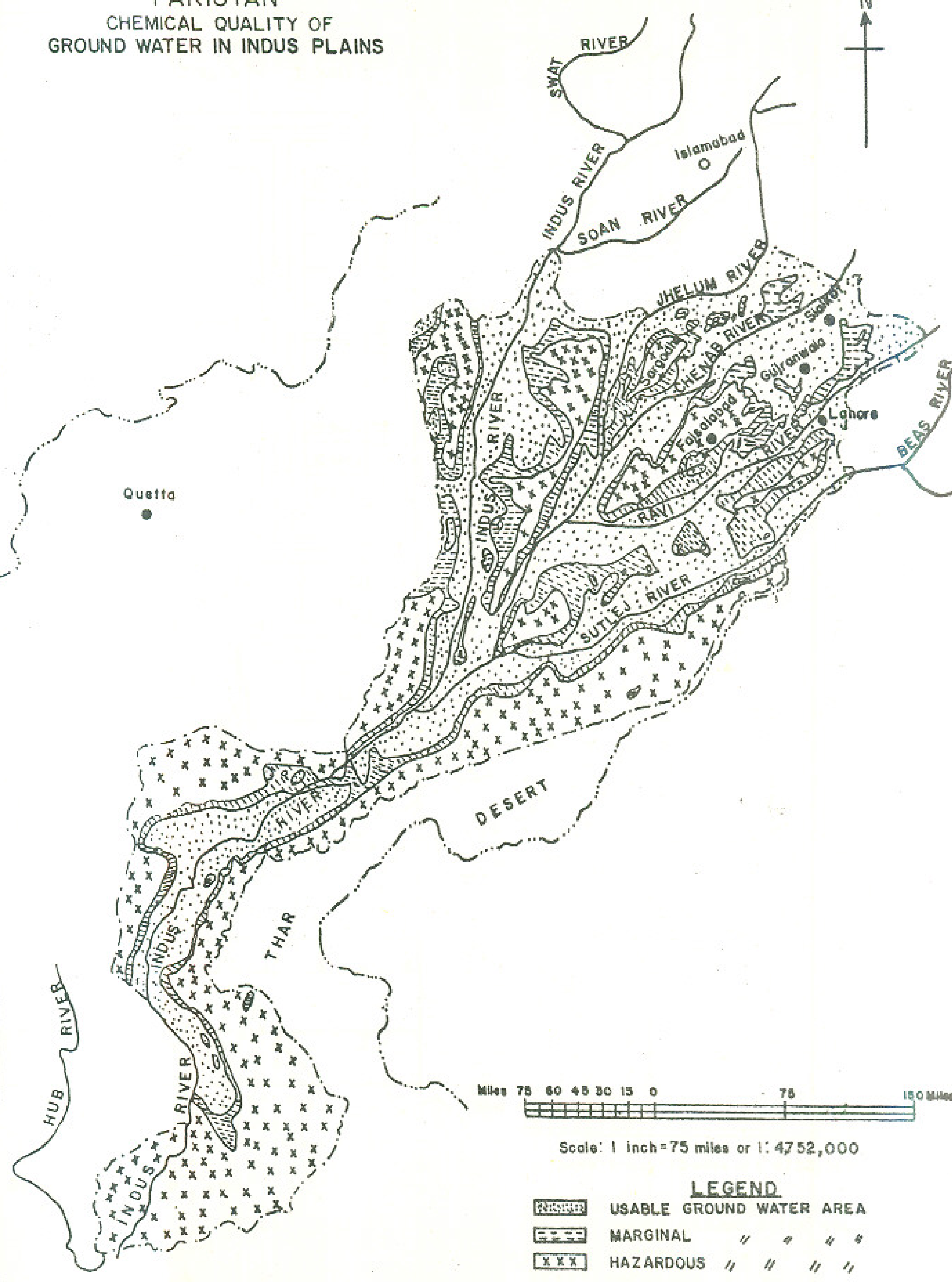
FIG: 1

PAKISTAN
CHEMICAL QUALITY OF GROUND WATER IN INDUS PLAINS



Scale: 1 inch=75 miles or 1: 4752,000

LEGEND
USABLE GROUND WATER AREA
MARGINAL " " " "
HAZARDOUS " " " "

Source: Scarps Monitoring Organization, WAPDA.

(Photo Copy)