# An Irrigation - Drainage System for Salinity Control for a farm in the Mirpurkhas region of Pakistan.

by

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Abstract

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An irrigation - drainage system for salinity control is designed for a typical small scale farm in the region of Mirpurkhas, Pakistan. Land is developed by reclamation of the affected soil through leaching of salts from the root zone.

Inexpensive earth channels are designed to reduce losses due to seepage. Storage ponds to provide irrigation water according to the crop requirements, are included. Drainage is accomplished through drainage walls which pump saline ground water to lower the water table. The saline water mixed with the canal water is to be reapplied to the land as irrigation.

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# Chapter I

## Introduction

Salinity is the accumulation of soluble salts in the soil that tend to be toxic to a plant and its environment. The soils in arid and semi arid regions contains relatively large amounts of soluble salts. In most cases there is insufficient rain to leach the salts from the root zone.

Pakistan is one of the countries whose productive lands are threatened by the menace of salinity. Over a hundred years of irrigation development have resulted in the world's largest integrated system (Eckert et al 1975). The system harnesses resources from the Indus River and has converted deserts and barren land into lush green productive fields. But incomplete water management practices have led to the increase in salinity.

Research work and programs to control this menace have been conducted by the Government at a national level since 1954 (Clyma and Corey 1974). But physical and socio-economic problems have prevented the promulgation of these programs at a national level to a great extent.

Objective

The objective of this work was to find a solution for the individual farmer in order to control salinity through improved irrigation and drainage practices. A study of improved methods of water application and water management practices was also carried out.

General

The land under study is a 188 acre farm located about 8 miles south of Mirpurkhas city in the Province of Sind, Pakistan. The land is stone free and flat in topography (Fig.1). The texture of the soil is silty clay loam. The formation of soil is over subrecent deposits in the flood plain of the lower Indus River.

Precipitation in the region is less than 250mm (10 inches) annually. The climate is hot and temperatures range between 17 to 35$^{o}$C. throughout the year. The climate can be classified as semi arid, sub tropical, continental. Evapotranspiration rates are very high.

The land is irrigated by the Daulatpur minor canal and lies on the left bank of the canal. Water is received for 73 hours 30 minutes each week at a rate of 1.1 cusec. The canal is perennial and flows with water for 40 weeks every year. One week per month is used in cleaning waterways and for their maintenance.

Causes of Salinity

The soils of Sind have salts due to geological formation. These salts lie deep in the soil and are not present in the root zone. Previously the water table was low and the problem of salinity did not exist.

The introduction of low intensity irrigation by gravity flow was a blessing but the lack of drainage was a fault in design. The application of water for over a hundred years increased the water table depth. The groundwater is saline (3000 ppm of TDS) and with high evapotranspiration the salts were brought to the surface.

The poor design of canals and waterways led to excess seepage of water and low water delivery efficiency. This was one of the main causes of rising water table.

Farmers received water on a turn system called warabandi. The turn of the farmer comes once a week. One week every month the canal is closed for maintenance and cleaning. This system led to a bad practice of over-flooding of fields during the turns and not applying water according to crop requirements. The excess water, when evaporated and transpired, brought salts to the surface.

Irrigation canal water contains 100 times more salt than rain water. The total dissolved salts (TDS) in the canal water vary between 128 ppm in July and 278 ppm in March. The pH of canal water also varies from 7.5 in August to 8.2 in January. In the long run the salt content of the soil is also increased due to canal water.

Lack of levelling also increases the salt content in the soil. Old methods of levelling practices are still followed. This tends to leave depressions in the fields. These depressions are more prone to salt accumulation.

Wind and temperature also play their role. Fields affected by salinity have a loose structure at the surface. Winds then transport the salt at the surface to neighbouring fields and thereby create a salt problem.

# Chapter II
## Review of Literature

Cantor (1970) describes the Indus basin as containing the largest single stretch of irrigated land in the world. One-fifth of this 33 million acres is severely affected by salinity and waterlogging.

Ismail (1971) calculates an increase of 0.5 million tons of salt deposit through 2500 cusecs of canal water in the lower Indus basin.

Corey (1977) points to the problems as low yields, low water use efficiency, high seepage losses from canals, salinity and waterlogging. Control of these problems would lead to an increase in productivity by five times.

Choudhry (1975) lists the various soil surveys conducted in the Province of Sind and points out that the soils are calcareous in nature with a very high pH. Also, the potential calcium present would be useful in reclaiming the land through leaching and cropping practices.

The report of FAO on reclamation and management of calcareous soils (1972) shows that the presence of calcium and magnesium carbonates pose only a minor problem for plant nutrition. The presence of well humified organic matter (0.4 - 0.7% in a 100 cm soil profile) helps in overcoming the harmful effects. Application of farm-yard manure is also suggested.

El Gabaly (1977) observed that the concentration in groundwater in the lower Indus region could be as high as 30,000 ppm. If control measures are not adopted then salinity could affect the soil profile up to 6 feet in 12 years.

The International Source book on Irrigation Drainage and Salinity (1973) in discussing conveyance loss, states that "--- for preliminary estimates, it may be assumed that in typical earth channels, under usual conditions, about one-third of the total water delivered will be lost by seepage, operational waste and evaporation".

Eckert, Dimick and Clyma (1975) report that losses from canals due to seepage were measured and found to be between 30 - 50% of the water transported.

Clyma and Corey (1973) note that the flat Indus plain has a downstream drop varying from 9 inches to a foot per mile. Natural drainage is not readily apparent since most of the area has low rainfall and the runoff is minimal. Artificial drains have not been constructed and surface drains are virtually non-esistent for irrigation water.

Revelle (1964) discusses the need for an integration between supply and drainage of irrigation water for salinity control. The use of drainage wells was suggested as the permeability of the soil is high.

The irrigation, Drainage and Flood Control Research Council of Pakistan (1975) indicates that the first reclamation project was started in 1958 under the name of Salinity Control and Reclamation Project (SCARP). Under this scheme 33,000 tubewells were to be installed over a period of 10 years.

Ahmed (1962) points out that 10 per cent of the Government tubewells in Punjab went out of operation due to the pumping of very fine sand.

Dorfman (1966) shows that drainage wells are more effective than tile drains in Pakistan. This impact is seen also from the increase in private tubewells in Punjab which outnumber the Government operated wells by 15 times. He suggests the construction of drainage channels to transport groundwater, of high salt concentration, to the sea or to salt lagoons in the desert.

Lowdermilk, Clyma and Early (1975) show the increase in reclamation and efficiency of Government controlled tubewells. Losses through use of different methods of lifting water have been calculated.

Corey (1974) discussing practices that should be adopted for land improvement and water management suggests land levelling, water course rehabilitation and lining, tubewell installation for drainage and irrigation and storage facilities for water on the farm.

Johnson, Kemper, Reuss and Lowdermilk (1977) indicate through their studies, that watercourse losses are reduced by over 90 per cent if lined with cement and plastered water courses have a delivery efficiency of over 94 per cent.

Chowdhry, Ahmad and Shafique (1977) show that concrete and brick masonry lining is very expensive. Earthen improvement of water courses with concrete control sometimes is a cheap alternative that increases delivery efficiency by 50 per cent.

Abdur Rehman and Haq (1977) observed that two consecutive crops of Sesabania aculeata (jantar) reduce the salt content in the soil by over 75 per cent.

# Chapter III

## Design Information

### Topography

The topographic information was obtained from the detailed map of the Daulatpur minor canal prepared by the water distribution cell. A topographic map of the field under study was made at a scale of 1:2500. The land is flat and stone free. It has a 0.1% gradient. The area of the field is 188 acres, which is divided into small basins for flood irrigation. Twenty acres are divided into one acre plots and the rest are 1.5 acre plots.

The land lies on the left bank of the canal and the distance between the field and canal is 1205 metres (3950 feet). Irrigation water from the canal flows for 73.5 hours every week at the rate of 1.1 cusec. at the outlet. In all, 6.88 acre feet of water are delivered to the field every week.

To maximize field efficiency the land should be precision levelled. A standard of ± 2 cm of levelling saves 40% of irrigation time and gives an increase in yield of 20% as compared to traditional levelling (Johnson et al, 1977). The traditional way of levelling is by using a flat, long board, which does not achieve the standard precision levelling. This can be easily achieved by a tractor and scraper. The cost of precision levelling is Rs $4/m^3$ of soil. ($\$0.40/m^3$). Precision levelling will also save a lot of water and increase the water application efficiency.

Seepage losses in the waterways are as high as 30% (Eckert et al, 1975). Seepage loss has to be reduced to control salinity. Lining by brick or concrete would reduce the seepage loss by 94% and the initial cost is very high. Improvement of earth channels by compaction would reduce initial investment but the maintenance costs are high.

Soil Analysis

The soil analysis of the soil profile is given in Table 1. The soil texture varies from silty clay loam to clay loam. The soil is classified under Shikarpur series (Appendix A). The hydraulic conductivity of the soil is 0.3m/day (0.98 ft/day).

The total soluble salts (TSS) vary from 0.6% to to 1.52% at the surface. This will have to be reduced by leeching and by growing salt tolerant crops. The soil has a h high pH and is calcareous in nature. The presence of calcium and good cation exchange capacity of the soil will help in leaching the salts. The Ca + Mg : Na ratio is greater than 2 which is a good feature as the Ca helps to form soluble salts that can be drained (Hagen et al, 1967).

Table 1. Physio - Chemical Analysis of the Soil

| | Profile Depth cm | | | |
|---|---|---|---|---|
| | 0-15 | 15-30 | 30-60 | 60-90 |
| Sand (%) | 42 | 30 | 18 | 22 |
| Silt (%) | 28 | 33 | 46 | 40 |
| Clay (%) | 30 | 37 | 35 | 38 |
| Texture | Clay Loam | Clay Loam | Silty Clay Loam | Clay Loam |
| Water holding capacity (%) | 45.3 | 50.8 | 49.9 | 44.5 |
| Organic matter content (%) | 0.68 | 0.66 | 0.65 | 0.55 |
| pH | 8.2 | 8.4 | 8.2 | 8.3 |
| Total soluble salts (%) | 1.52 | 0.76 | 0.88 | 0.6 |
| Ca $Co_3$ (%) | 9.6 | 12.5 | 12.4 | 9.8 |
| $Co_3$ (meq/l) | Nil | Nil | Nil | Nil |
| H $Co_3$ (meq/l) | 0.62 | 0.88 | 0.68 | 0.72 |
| Cl (meg/l) | 14.0 | 7.0 | 9.0 | 5.0 |
| $So_4$ (meq/l) | 26.2 | 14.2 | 15.0 | 10.1 |
| Ca (meq/l) | 7.6 | 1.6 | 3.4 | 2.0 |
| Mg (meq/l) | 4.8 | 1.5 | 2.6 | 1.64 |
| Na (meg/l) | 27.0 | 16.5 | 17.5 | 14.0 |
| K (meg/l) | 0.51 | 0.24 | 0.24 | 0.20 |
| Cation exchange capacity (meg/l) | 13.5 | 14.0 | 13.0 | 9.0 |
| Exchangeable $Ca^{++}$ & $Mg^{++}$ (meq/100gm of soil) | 9.4 | 9.8 | 9.2 | 7.2 |
| Exchangeable $Na^{++}$ (meg/100gs of soil) | 3.50 | 3.25 | 1.75 | 1.25 |
| Exchangeable $Na^{+}$ (%) | 25.9 | 23.2 | 13.4 | 13.9 |

The groundwater table varies from 1.83 to 2.48 m (6 to 8 ft.). It contains 3000 ppm of total dissolved salts (TDS). The depth of a deep sand aquifier varies from 12 to 20 m (40 to 65 ft.).

The low organic matter content is due to low rainfall and high temperatures in which it is readily oxidized. Chaudhry (1975) suggests the plantation of trees along canals and roads to act as wind breaks and thereby decrease evaporation rate and increase humidity. All this will eventually contribute to higher organic content in the long run.

Climatic Data

Climatic information for the Mirpurkhas region was obtained from the Pakistan Metereological Services (see Appendix B). The annual precipitation is 213 mm and mean monthly temperature ranges between 17 to 34$^{o}$C. The relative humidity varies from 47 to 66%, the wind velocity is high during summer.

The evapotranspiration rate was calculated using the Blaney - Griddle method, as shown by Doorenbos and Pruitt (1977). See Table 2.

$$E_t = E_{tp} \cdot K_c$$

$$E_{tp} = C_p \,(0.46T + 8)$$

Where $E_t$ - Evapotranspiration mm/day

$K_c$ - Crop coefficient

$E_{tp}$ - Potential evapotranspiration mm/day

C - Adjustment factor for relative humidity and sunshine hours.

p - Mean daily % of total daytime hrs.

T - Mean monthly temperature $^{o}$C

Table 2 - Monthly Evapotranspiration Rates*

| Month | Mean temp. | p** | p(0.46T+8) | $E_{tp}$ mm/day | $K_c$** | $E_t$ mm/day |
|---|---|---|---|---|---|---|
| Jan | 17.17 | 0.24 | 3.82 | 2.8 | 1.05 | 2.94 |
| Feb | 19.66 | 0.26 | 4.43 | 3.1 | 1.05 | 3.26 |
| Mar | 24.66 | 0.27 | 5.22 | 4.0 | 1.05 | 4.20 |
| Apr | 31.17 | 0.29 | 6.48 | 6.0 | 1.05 | 6.30 |
| May | 34.47 | 0.30 | 7.16 | 6.7 | 0.80 | 5.36 |
| June | 34.03 | 0.31 | 7.33 | 7.0 | 1.15 | 8.05 |
| July | 31.08 | 0.31 | 6.91 | 6.0 | 1.10 | 6.60 |
| Aug | 31.45 | 0.29 | 6.52 | 5.5 | 0.65 | 3.58 |
| Sept | 29.62 | 0.28 | 6.06 | 4.5 | 0.55 | 2.48 |
| Oct | 28.25 | 0.26 | 5.46 | 3.8 | 0.80 | 3.04 |
| Nov | 23.04 | 0.25 | 4.65 | 3.4 | 0.65 | 2.21 |
| Dec | 18.24 | 0.24 | 3.93 | 2.6 | 1.05 | 2.73 |

* Blaney - criddle method as shown in Crop Water Requirement by J. Doorenbos and W.O. Pruitt (1977). FAO Irrigation and Drainage Paper #24.

** Estimated values of p, c and $K_c$ can be obtained from the above mentioned paper.

Table 3 - Seasonal Cropping Pattern

| Month | Crop and Cropping Operation |
|---|---|
| Jan | Wheat ; Sugarcane |
| Feb | Wheat harvest ; Sugarcane |
| Mar | Wheat harvest ; Sugarcane, harvest |
| Apr | Cotton planting; Sugarcane, harvest |
| May | Cotton planting; Sugarcane, harvest |
| June | Cotton ; |
| July | Cotton ; |
| Aug | Cotton harvest ; |
| Sept | Cotton harvest ; Sugarcane, planting |
| Oct | Cotton harvest ; Sugarcane, planting |
| Nov | Wheat planting ; Sugarcane |
| Dec | Wheat ; Sugarcane |

The crops that are to be grown are wheat, cotton and sugarcane. The cropping season pattern of these crops is shown in Table 3. According to this cropping pattern the annual evapotranspiration rate is calculated to be 1545 mm (60.8 in.) as shown in Table 2. The minimum monthly irrigation requirement is calculated by subtracting monthly rainfall from the monthly evapotranspiration rate (Table 4). The minimum annual irrigation requirement would be 1331 mm (52.4 in.).

## Table 4 - Minimum Monthly Irrigation Requirement

| Month | Rainfall mm/month | Evapotranspiration mm/day | Evapotranspiration mm/month | Minimum Irrigation Requirement mm/month |
|---|---|---|---|---|
| Jan | 2.54 | 2.94 | 91.40 | 88.86 |
| Feb | 5.08 | 3.26 | 91.28 | 86.20 |
| Mar | 2.54 | 4.20 | 130.20 | 127.66 |
| Apr | 5.08 | 6.30 | 189.00 | 183.92 |
| May | 5.08 | 5.36 | 166.16 | 161.08 |
| June | 10.16 | 8.05 | 241.50 | 231.34 |
| July | 101.60 | 6.60 | 204.60 | 103.00 |
| Aug | 60.96 | 3.58 | 110.98 | 50.02 |
| Sept | 15.24 | 2.48 | 74.40 | 59.16 |
| Oct | 0.00 | 3.04 | 94.24 | 94.24 |
| Nov | 2.54 | 2.21 | 66.30 | 63.76 |
| Dec | 2.54 | 2.73 | 84.63 | 82.09 |
| | 213.36 | | 1544.49 | 1331.33 |

## Chapter IV

## Salinity Control

### Seepage

Seepage is a major contributor in the cause of salinity. Its control prevents loss of valuable water and deterioration of the soil. The least expensive measure is to compact the earth in the channels. This alone will minimize percolation of water from the channel to the soil by 70%.

The existing channels should be demolished and new improved channels constructed. The bottom of the channels should be 15 cm (6 in.) higher than the field. The soil should be put in layers and compacted by a sheepsfoot roller. A 1:1 side slope should be maintained to prevent embankment failure. The settling of silt, which is suspended in the canal water, will also seal the channel over a period of time.

The design dimensions (Fig.2) were based on a rate of flow of 1.1 cusec. The base width is 30 cm with a depth of 45 cm, giving it a free board of 15 cm. The length of the main channel from the land to the field is 1204 m (3950 ft.) and from the pond to the end of the field is about 1200 m (3935 ft.).

Drainage

Drainage is one of the main features through which salinity can be reduced. This is accomplished by leaching the salts from the root zone and lowering the water table.

The amount of leaching required is determined from the leaching ratio. (International Source book on Irrigation, Drainage & Salinity, 1973).

$$L.R. = \frac{EC_{iw}}{EC_{dw}}$$

where L.R. - Leaching ratio.

$EC_{iw}$ - Electrical conductivity of irrigation water in mmhos/cm

$EC_{dw}$ - Electrical conductivity of drainage water at permissible salt level in mmhos/cm

The electrical conductivity of the canal water is 0.98 mmhos/cm and that of the drainage water required is 4 mmhos/cm. Hence, the amount of leaching required is 0.25 or 25% of irrigation water.

This can be accomplished by sinking drainage wells and pumping the groundwater. The equation for hydraulics of wells taken from Schwab (1966) is:

$$Q = \frac{T\ K\ (H^2 - h^2)}{\log_e (R/r)}$$

where Q - rate of flow in cfd

K - hydraulic conductivity in fpd

H - height of static water level at well measured from bottom in ft.

h - height of water level at the well measured from the bottom in ft.

R - radius of influence in ft.

r - radius of well in ft.

The radius of influence is taken to be 300 feet. For a leaching requirement of 0.25 a minimum of 0.18 ac. ft. per day (7840.8 cfd) should be pumped. Using the equation values for different radii and depths can be calculated (Table 5). A minimum of 6 feet of height of water level in the well was assumed.

Irrigation

Irrigation is the other feature for salinity control. To leach the salts, extra water has to be applied. For a 0.25 leaching ratio the minimum monthly irrigation requirement would have to be adjusted accordingly. (As shown in the International Source book on Irrigation, Drainage & Salinity).

$$I = \frac{EC_{dw}}{EC_{dw} - EC_{iw}} \quad Et$$

where I - Irrigation requirement

$E_t$ - Evapotranspiration

EC - Electrical conductivity

subscript - iw - irrigation water

dw - drainage water

Table 6 shows the adjusted minimum monthly irrigation requirement taking leaching into account.

Table 5. Required Radii and Depths of Wells

| r, ft. | H, ft. | Q, cfd. | No. of Wells Required |
|---|---|---|---|
| 0.25 | 80 | 2763 | 3 |
| | 90 | 3501 | 3 |
| | 100 | 4327 | 2 |
| | 140 | 8495 | 1 |
| 0.33 | 80 | 2876 | 3 |
| | 90 | 3644 | 3 |
| | 100 | 4503 | 2 |
| | 140 | 8842 | 1 |
| 0.5 | 80 | 3062 | 3 |
| | 90 | 3881 | 3 |
| | 100 | 4796 | 2 |
| | 130 | 8116 | 1 |
| 0.75 | 80 | 3270 | 3 |
| | 90 | 4144 | 2 |
| | 125 | 8011 | 1 |
| 1 | 80 | 3437 | 3 |
| | 90 | 4355 | 2 |
| | 125 | 8418 | 1 |

Table 6. Adjusted Minimum Monthly Irrigation Requirement

| Month | Evapotranspiration, $E_t$ mm/month | Irrigation Requirement, I mm/month |
|---|---|---|
| Jan | 91.4 | 121.06 |
| Feb | 91.28 | 120.90 |
| Mar | 130.20 | 172.45 |
| Apr | 189.00 | 250.33 |
| May | 166.16 | 220.08 |
| June | 241.50 | 319.87 |
| July | 204.60 | 270.99 |
| Aug | 110.98 | 146.99 |
| Sept | 74.40 | 98.54 |
| Oct | 94.24 | 124.82 |
| Nov | 66.30 | 87.81 |
| Dec | 84.63 | 112.09 |
| | | 2045.95 |

Flood irrigation has been used to irrigate the fields. It is less expensive in operating costs. The distribution of water will have to be controlled by gates and concrete command structures. Figure 3 shows the design features of the command structures. A total of 14 such structures would be required along the main water channel from the pond. The previous distribution channels could be used with improvements by means of compacting the soil with a sheepsfoot roller.

The groundwater pumped could be used as additional irrigation water. The groundwater is usually saline with a concentration of 3000 ppm. In such a case it should be mixed with the canal water and then applied. The ratio of the mix can be calculated by the equation given by Dorfman et al (1966).

$$Ca = \frac{Da - E_t T}{Da} \cdot \frac{D_F - E_t T \times C_T}{D_F}$$

Where Ca - Salt concentration is water applied

$C_T$ - Maximum concentration in soil water

Da - Depth of applied water in ft/week

$D_F$ - Equivalent depth of water in a soil column at field capacity

$E_t$ - Evapotranspiration rate in ft/week

T - Irrigation time periods between watering in weeks

For an increase in irrigation rate by 25% and reduction in watering period to 1.5 weeks, with field capacity of 0.8 $ft^3/ft^2$, the salt concentration of applied water $Ca = 0.39 C_T$.

This mixed water should be applied to salt tolerant crops such as <u>Sesabania aculeata</u> (jantar), Castor, Rice, Sugarcane, etc.

<u>Storage of Water</u>

Storage of water is a necessity which enables water application according to crop requirement. If water received from the canal is stored and is used when required, then the application efficiency increases tremendously, resulting in better crop management and yields.

Two storage ponds have been designed, one for canal water with a capacity of 14 ac-feet and the other for ground water with a capacity of 3.0 ac-feet. The capacity is designed for the critical time between maintenance and cleaning of the canals. This period is 15 days.

The design is shown in Figure 4. A side slope of 1:1 is maintained for both ponds. The canal water pond measures 142 x 54 m (465 x 175 ft.) at the top and the groundwater pond measures 40 x 40 m (125 x 125 ft.) at the top. The depth of both the ponds is 2.45 m (8 ft.). The ground is scraped and compacted with a sheepsfoot roller to minimize seepage. Inlets at the canal pond should be screened and have a trash rack at an angle so that any debris cannot hinder the flow and be cleaned away easily.

Pump requirements

For drainage wells the pump requirement can be calculated, using the USDA pump type selection chart (Appendix C). The equation for calculating the pump horsepower required is Schwab (1966).

$$hp = \frac{Q\ w\ h}{33000\ E_p}$$

Where hp = horsepower

Q - Discharge rate gpm

w - specific weight of water 8.34 lb/gal

$E_p$ - pump efficiency as a decimal

The volume of water that should be pumped every day is 0.18 ac-feet (7840.8 cu.ft/day). From Table 5 we see that two wells at a depth of 100 feet are required for radii 0.25, 0.33 and 0.5 feet to give such a flow rate. These values are suggested as local drillers could do the job, otherwise professional drillers have to be located. Therefore, each well requires a 2 horsepower motor and an 80% efficient pump.

The same equation could be used to calculate the pump requirement for irrigation. Here too we need two pumps. One for the canal water tank and the other of saline groundwater to be used with mixing of canal water.

A total volume of 267 acre feet of canal water is to be lifted 8 feet annually. The power requirement of the pump would be 1.25 hp. For water from the groundwater pond, 0.4 hp would be sufficient. These were calculated at an operation period of 12 hours per day.

## Chapter V

## Cost Analysis

1. <u>Capital Investment</u>

a. <u>Seepage Reduction Work</u>

| | | | |
|---|---|---|---|
| (i) | Cost of 7900 ft. improved channel @ Rs 3/ft. | = Rs. | 23700 |
| (ii) | 14 control structures @ Rs 500/structure | = Rs. | 7000 |
| | Sub-total for seepage control | Rs. | 30700 |

b. <u>Cost of pump</u> @ \$ 150/hp (Rs 1500/hp)

| | | | |
|---|---|---|---|
| (i) | Cost of 2 irrigation pumps of 1.25 + 0.4 hp/ @ Rs 1500 hp | = Rs. | 2475 |
| (ii) | Cost of 2 drainage pumps of 4 hp @ Rs 1500/hp | = Rs. | 6000 |
| (iii) | Cost of 3750 feet of PVC pipe @ Rs 5/ft | = Rs. | 18750 |
| | Sub-total: | Rs. | 27225 |

c. <u>Storage pond</u>

| | | | |
|---|---|---|---|
| (i) | Cost of excavation canal water storage 141 x 54 x 2.45 m @ Rs. 4/$m^3$ | = Rs. | 69075 |
| (ii) | Compaction @ Rs 80/acre | = Rs. | 1120 |
| (iii) | Cost of excavation of drainage water storage 40 x 40 x 2.45 m @ Rs 80/acre | = Rs. | 250 |
| | Sub-total: | Rs. | 85245 |

d. <u>Pump House</u>

Therefore, total capital cost = Rs. 144,670.

If the total capital cost is amortized for 20 years at 12% interest the annual cost works out to be Rs. 19368.42.

Therefore, cost per acre per year = Rs. 103.02

2. Operating Cost

For 12 hour operation, the power required is 11232.2 kw hr. At a cost of Rs. 0.50/kw hr the cost of power = Rs 5616/year.

| | | |
|---|---|---|
| Cost of power at Rs 0.50/kw wk | = | 11232.2x0.5 = Rs 5616 |
| Maintenance cost @ 0.05% cost of pumps | = | 0.05x5.65x1500 = RS 424 |
| Therefore, total operating cost | = | Rs 6040/year |
| Cost per acre per year | = | Rs 32.13 |

3. Total Annual Cost

The total annual cost of the system per acre = Rs. 103.02

= Rs. 103.02 + Rs. 32.13

= Rs. 135.15

( 1 US dollar ≅ 10 Pakistani Rupees (Rs.) )

# Chapter VI
## Discussion

The main objective of the design was to find a way of reclaiming land and increasing productivity of lands affected by salinity on a small sized farm. The design of the system should be such that it can be accomplished by using local tools and materials for construction and labour.

Horizontal drainage using a network of tile drains could have been designed, but due to the water table, which lies at a depth of 8 feet, it would require heavy machinery which would have to be imported. Also the plastic drainage tubing is unavailable in Pakistan.

The depth of tubewells has been limited in the design for 100 feet as this is the maximum depth that can be achieved by the local well diggers. In Punjab, depths of over 350 feet, with over 2 feet diameter, are carried out using power drills. This could be done with a slightly higher cost.

Flood irrigation is practiced in Pakistan which has a low operating cost and is cheaper to use. It is beneficial in leaching soils and is very effective. Sprinkler irrigation is an alternative but the limiting factors are non-availability of locally manufactured equipment and high energt costs for pumping. This means import of equipment which also has a high operating cost. However, for future developments a travelling gun sprinkler would work very well.

Most of the excavation and compaction work could use the cheap labour rather than going to heavy machinery. Excavation of the ponds could be done by using a tractor with a blade and compacted by a sheepsfoot roller or many passes of tractor and tanker filled with water. The soil should be compacted in layers. Earth channels could be excavated and compacted by hand equipment and labourers, which would reduce the costs.

## Chapter VIII

### Conclusions and Recommendations

The climate and soil in the region provides conditions favourable for agriculture. The potential of intensive crop production with high yields is possible through better water management practices. The problem of salinity is mainly created due to bad management and irrigation practices followed by both the Government and the farmers. However, as much cannot be done at the Government level, a lot could be achieved by the individual.

Management of water on the farm would result in an increase in yield by at least 300%. The application of farmyard manure in large quantities should be done frequently. Straw mixed with manure could also act as a mulch which would reduce evaporation and also increase fertility.

The land should be levelled precisely to increase water application efficiencies. The standard for levelling should be ± 2 cm. The use of an engineer's level would be beneficial. Better design of bullock drawn levelling boards should be made to maintain the level.

Trees should be planted along the road, channels and plot boundaries, in order to act as windbreaks. This would also help in reducing the rate of evaporation. These wind breaks would also prevent, to an extent, the wind blown salts from settling on fertile land.

The use of wind power in pumping water would be beneficial as the region falls in a wind belt which has an average velocity of 10 - 12 miles per hour for a reasonable amount of time during the year. The initial cost of construction of wind operated pumps may be high but the increasing cost of diesel or electric pumps might make the installation feasible.

Filters for tubewells should be very fine to prevent sand from being pumped. Locally produced filters are very good and inexpensive.

The total annual cost per acre is estimated to be Rs. 135.15 per acre. This is feasible, considering the fact that productivity would be increased and land developed. Besides this, the supplementary water provided by drainage would increase the area of land that can be irrigated every year

A great deal of stress should be given to the cultivation of salt tolerant crops such as Jantar (Sesabania Aculeata), barley, rape, etc. Heavy leaching for two consecutive crops of Jantar can reduce salts by over 75%. Salt could also be a by-product of the land and could be used by humans and animals for consumption and also in research, etc. The practice of retrieving salt is very old in this desert region of Thar. But irrigation development has reduced it considerably.

Regular maintenance of water channels should be done in order to keep them in shape and reduce future expenses.

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Figure 1. Layout plan of irrigation channels and drainage wells on Abedeen farm, Mirpurkhas.


N
15·25
15·0
14·75
14·5
15·25
15·0
14·75
14·5
P
KEY
CONTOURS (0·25 m INTERVALS) 15·0
PLOT BOUNDARY
ROAD
EXISTING CHANNELS
PROPOSED CHANNEL
COMMAND STRUCTURES
PUMP HOUSE
PROPOSED DRAINAGE WELL
PROPOSED STORAGE PONDS
EXISTING VILLAGE POND
VILLAGE
0 50 100 200 metres
REVISION | DATE | DESCRIPTION
AGRICULTURAL ENGINEERING DEPARTMENT
MACDONALD CAMPUS, MCGILL UNIVERSITY
SAINTE ANNE DE BELLEVUE, QUEBEC, CANADA, H9X 1C0
LAYOUT PLAN OF IRRIGATION CHANNELS
AND DRAINAGE WELLS
ABEDEEN FARMS, MIRPURKHAS, SIND, PAKISTAN.
SCALE 1:2500
DRAWN Kazi A.M.
CHECKED
REVISED
DWG. NO.

Area = 0.34 $m^2$/metre of length
(3.75 sq.ft./ft. of length)

Depth of channel includes 15 cms. of freeboard

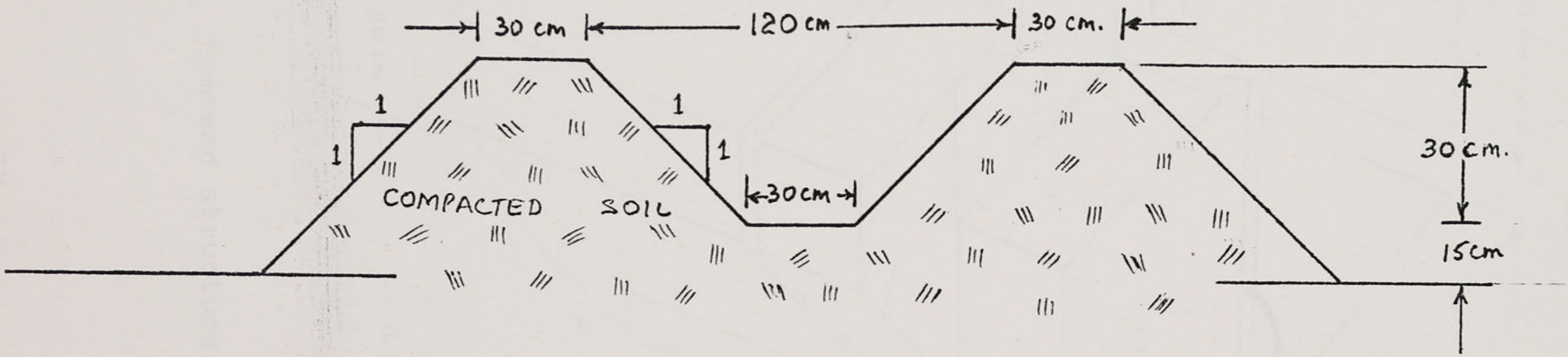



Figure 2. Cross section of water channels.

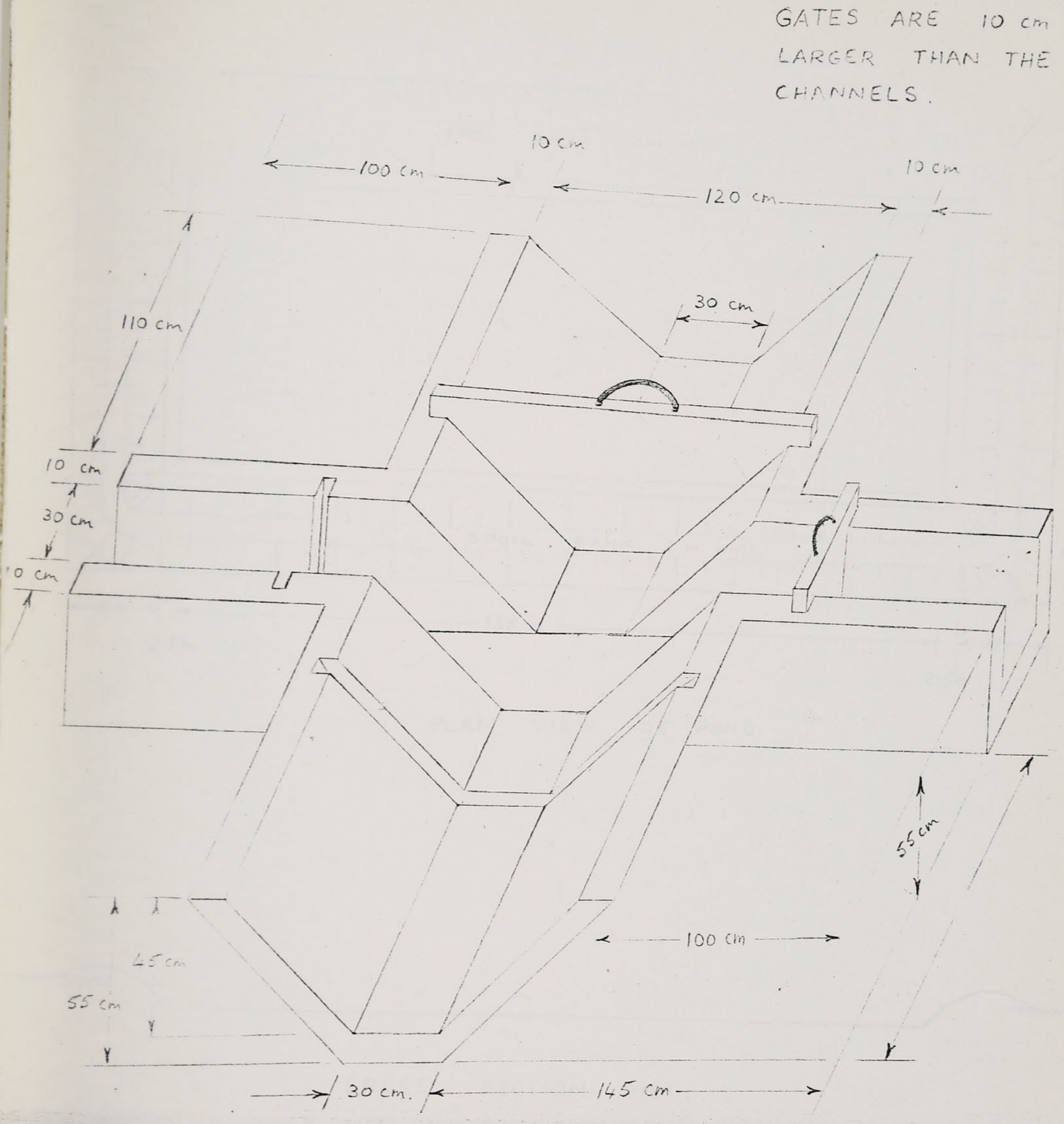



Figure 3. Command structures

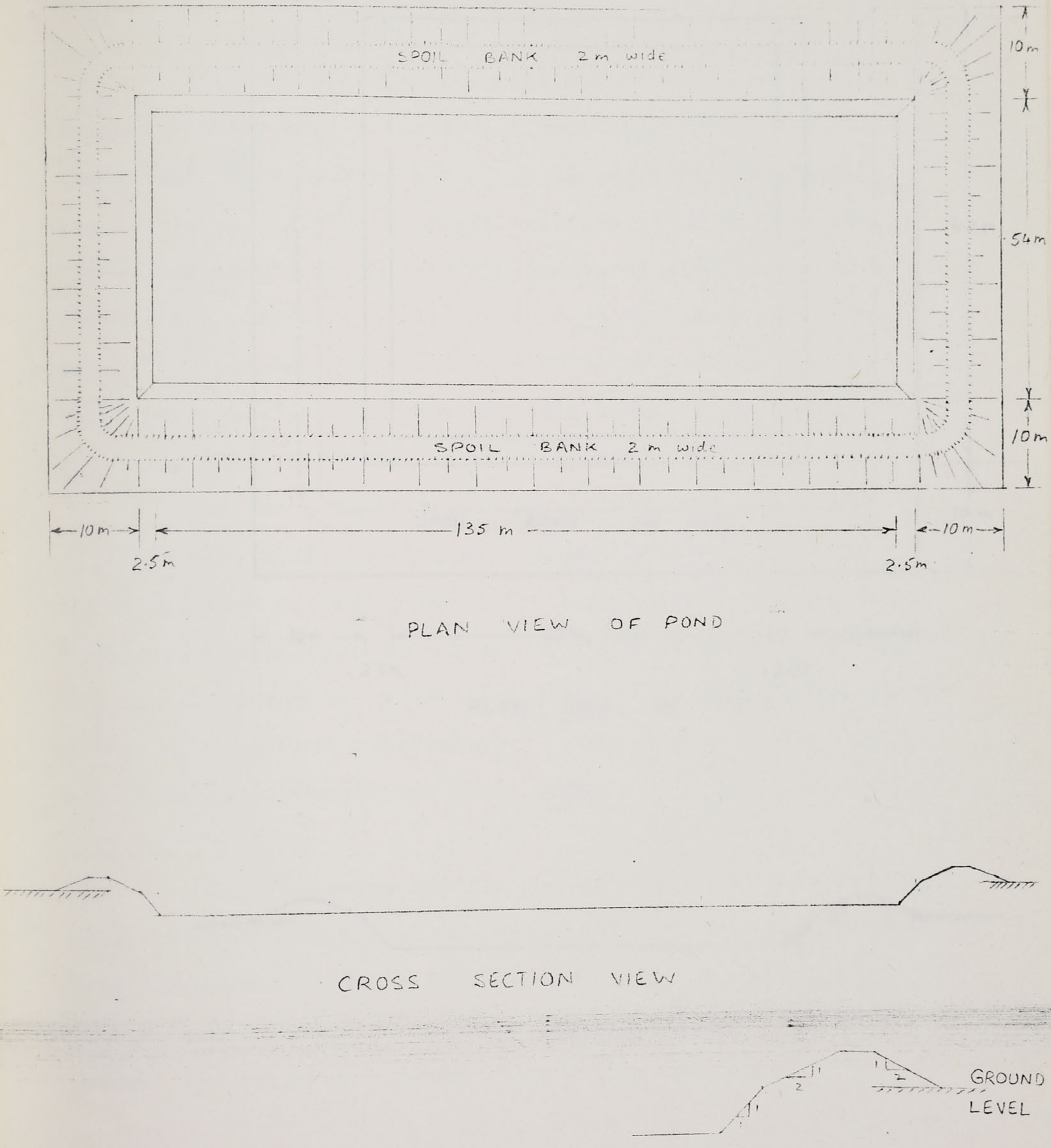



Figure 4. Storage Pond for Canal Water

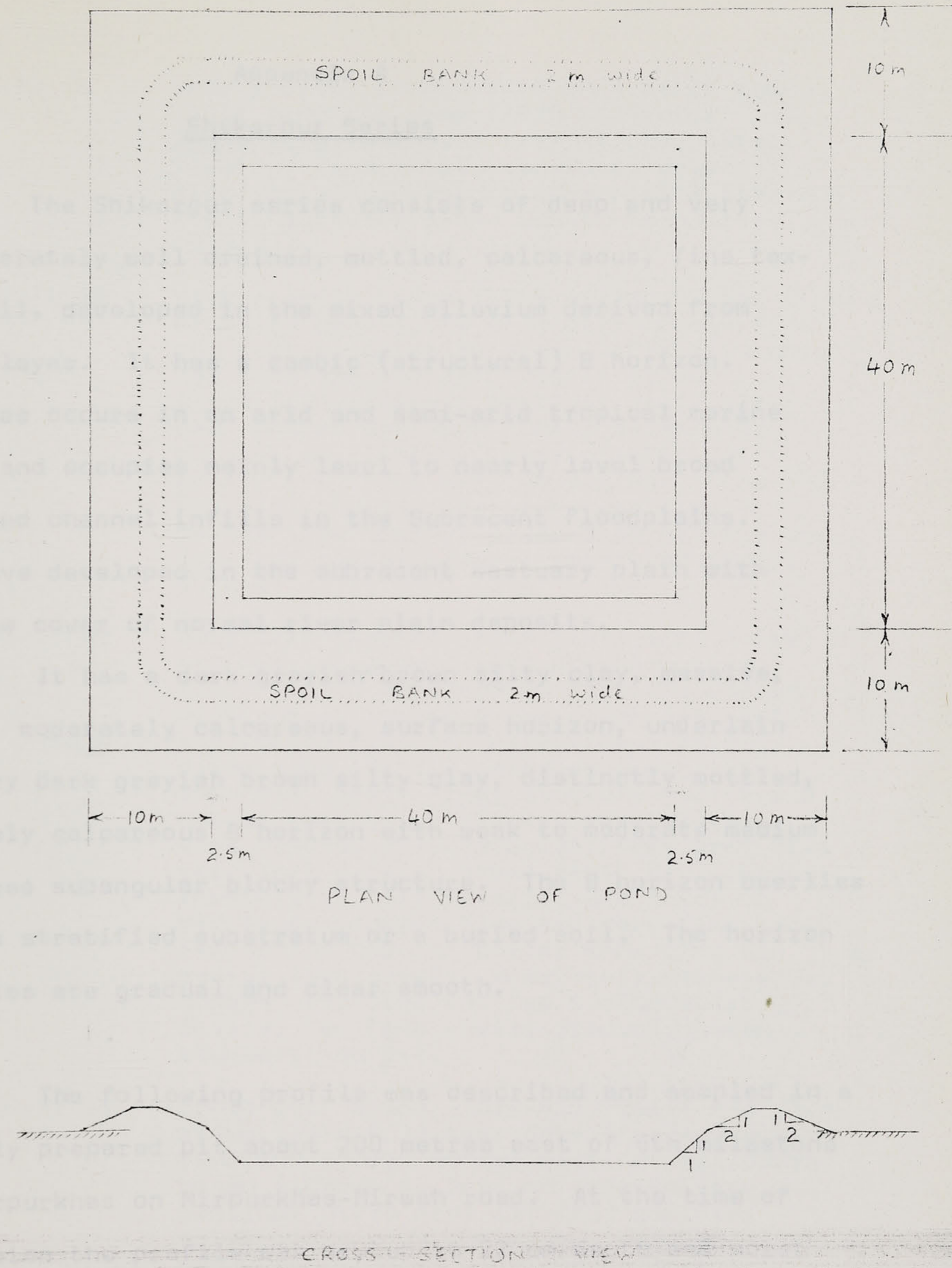



Figure 5. Storage Pond for Groundwater

## Appendix A

## Shikarpur Series

The Shikarpur series consists of deep and very deep,moderately well drained, mottled, calcareous, fine textured soil, developed in the mixed alluvium derived from the Himalayas. It has a cambic (structural) B horizon. The series occurs in an arid and semi-arid tropical marine climate and occupies mainly level to nearly level broad basins and channel infills in the Subrecent floodplains. Parts have developed in the subrecent eastuary plain with a shallow cover of normal river plain deposits.

It has a dark grayish brown silty clay, massive, friable, moderately calcareous, surface horizon, underlain by a very dark greyish brown silty clay, distinctly mottled, moderately calcareous B horizon with weak to moderate medium and coarse subangular blocky structure. The B horizon overlies either a stratified substratum or a buried soil. The horizon boundaries are gradual and clear smooth.

### Profile

The following profile was described and sampled in a specially prepared pit about 200 metres east of 6th milestone from Mirpurkhas on Mirpurkhas-Mirwah road. At the time of examination the profile was dry up to 22 cm depth and moist below. The field was fallow after cotton harvest.

| | | |
|---|---|---|
| AP | 0-12 cm | Dark greyish brown (10YR 4/2) moist and light brownish grey (10YR 6/2) dry; silty clay; massive; very sticky, very plastic, firm moist, very hard dry; moderately calcareous; common very fine and few fine roots; clear smooth boundary; PH 8.2. |
| B1 | 12-22 cm | Dark greyish brown (10YR 4/2)moist and light brownish grey (10YR 6/2) dry; common fine and medium yellowish brown (10YR 5/6) and few fine and medium brownish yellow (10YR 6/6) distinct mottles; silty clay; weak coarse and very coarse subangular blocky; very sticky, very plastic, firm moist, very hard dry; common very fine and few fine tubular pores; common fine and medium lime specks, moderately calcareous; few fine roots; gradual smooth boundary; pH 8.2. |
| B21 | 22-60 cm | Very dark greyish brown (10YR 3/2) moist and greyish brown/light brownish grey (10YR 5.5/2) dry; common fine and medium distinct yellowish brown (10YR 5/4, 5/6) and common fine and very fine distinct olive grey (5Y 5/2) mottles along root channels; silty clay; moderate medium and coarse subangular blocky; very sticky, very plastic friable moist, very hard dry; very dark greyish brown (10YR 3/2) cutans possibly of soil material and humus on ped faces; common fine and very fine and few medium tubular pores; many fine and medium lime specks,,moderately calcareous; common very fine and few medium snail shells; few fine roots; gradual smooth boundary; pH 8.2. |
| B22 | 60-85 cm | Brown/dark brown (10YR 4/3) moist and pale brown (10YR 6/3) dry; many fine and very fine and common medium distinct yellowish brown (10YR 5/4, 5/6) and common fine distinct olive grey (5Y 5/2) mottles; silty clay; weak coarse subsangular blocky; very sticky, very plastic, friable moist, very hard dry; patchy thin dark greyish brown (10YR 4/2) cutans possibly of soil material and humus on ped faces; common very fine and fine and few medium tubular pores; few fine lime specks, moderately calcareous; few fine roots; clear smooth boundary; pH 8.2. |

B23 85-105 cm Dark greyish brown (10YR 4/2) moist many fine and medium olive grey (5Y 4/2) and common fine and medium yellowish brown (10YR 5/4, 5/6) distinct mottles; silty clay; moderate medium and coarse sub-sangular blocky; very sticky; very plastic, firm moist, very hard dry; broken thin dark greyish brown (10YR 4/2) cutans possibly of soil material and humus on ped faces; common very fine, few fine and medium tubular pores; common fine and few medium lime specks, moderately calcareous; common very fine snail shells; few fine roots; abrupt smooth boundary; pH 8.2.

IIA1b 105-120 cm Dark greyish brown (2.5Y 4/2) moist and light brownish grey (2.5Y 6/2) dry; common fine faint and few fine distinct yellowish brown (10YR 5/4, 5/6) mottles; very fine sandy loam; very weak coarse subangular blocky, slightly sticky, slightly plastic, very friable moist, slightly hard dry; common fine and very fine and few medium tubular pores; moderately calcareous; few fine snail shells; common very fine charcoal pieces, few scattered pottery pieces; common very fine and few fine roots; gradual smooth boundary; pH 8.2.

IIB2b 120-160 cm Greyish brown (2.5Y 5/2) moist and light brownish grey (2.5Y 6/2) dry; common fine and medium distinct yellowish brown (10YR 5/4, 5/6) and few fine and very fine distinct olive grey (5Y 4/2) mottles (along root channels); very fine sandy loam; very weak coarse subangular blocky; slightly sticky, slightly plastic, very friable moist, slightly hard dry; common fine and very fine tubular pores; moderately calcareous; few krotovinas; few fine roots; pH 8.1.

Range of Characteristics

a. Profile characteristics. The surface horizon ranges in thickness from 10 to 15 cm; in colour from very dark greyish brown to dark greyish brown (10YR 3/2, 4/2); in texture from silty clay loam to silty clay or clay; structure is massive and is moderately calcareous. The B horizon ranges in thickness, usually from 76 to 120 cm; in colour from very dark greyish brown to dark greyish brown (10YR 3/2, 4/2, 4/3 and 2.5Y 4/2); in mottles from common fine to medium distinct yellowish brown to olive grey (10YR 5/4, 5/6, 6/6 and 5Y 4/2, 5/2); in texture from silty clay or clay, in structure from weak coarse to moderate medium and coarse sub-angular blocky; and is moderately calcareous. Few to common fine to very fine lime specks, few fine iron-manganese concretions and few fine to very fine snail shells may be present. The C horizon ranges in colour from very dark greyish brown to brown/dark brown (10YR 3/2, 4/2, 4/3); in mottles from few to common fine and very fine distinct yellowish brown to olive grey (10YR 5/4, 5/6 and 5Y 5/2); in texture from silt loam or very fine sandy loam to silty clay loam to silty clay or clay; in structure from massive to weak thin to medium platy; and is moderately calcareous. Few to common fine to very fine lime and gypsum specks may be present. A buried soil may be present below B or C horizons. The pH of the entire profile ranges between 8.0 to 8.3.

b. <u>Environmental Characteristics</u>. The series occupies level to nearly level basins or channel infills in the Subrecent floodplains under arid and semi-arid tropical marine climate with a mean annual rainfall of 125 to 225mm, most of which falls during the monsoon season (mid June to mid September) and some in winter (December to March). The mean annual temperature is about 79°F: the mean summer (May, June and July) temperature is about 92°F. and the mean winter (December, January and February) temperature is about 64°F. May is the hottest month with a mean maximum temperature of about 107°F. and January is the coldest month with a mean minimum temperature of about 44°F. Normally there is no frost but in some years it may occur for a few days during December and January.

The natural vegetation in the uncultivated parts is comprised of <u>Acacia arabica</u> (kikar), <u>Prosopis spicigera</u> (jandi), <u>Alhagi camelorum</u> (jawan), <u>Tamarix diocca</u> (lai), <u>Cynodon dactylon</u> (khabbal grass) and <u>Calotropis procera</u> (ak).

<u>Distribution and Extent</u>

The Shikarpur series is very extensive in the Subrecent floodplains of the Indus and Nara rivers within the survey area.

## Present Land Use

The series is mainly used for general cropping with perennial canal irrigation. The main crops are cotton, sugarcane, wheat and fodders. At places it is also used for mango orchards.

## Associated Soils

It is associated with Pacca, Bahalike and Bagh series. Bahalike and Bagh occur on relatively higher physiographic positions than Shikarpur series.

## Similar Soils

The Shikarpur series is similar to Pacca and Shahpur series. Pacca differs in being moderately deeply homogenized (less than 90 cm) and Shahpur is not mottled.

## Remarks

In addition to the Shikarpur normal, the following phases were recognized:

Shikarpur saline surface (slightly to moderate salinity in patches at the surface).

Shikarpur medium surface (10 to 15 cm thick cover of silt loam or very fine sandy loam).

Shikarpur high watertable (water-table within 75 to 120 cm depth, generally adjacent to the irrigation channels).

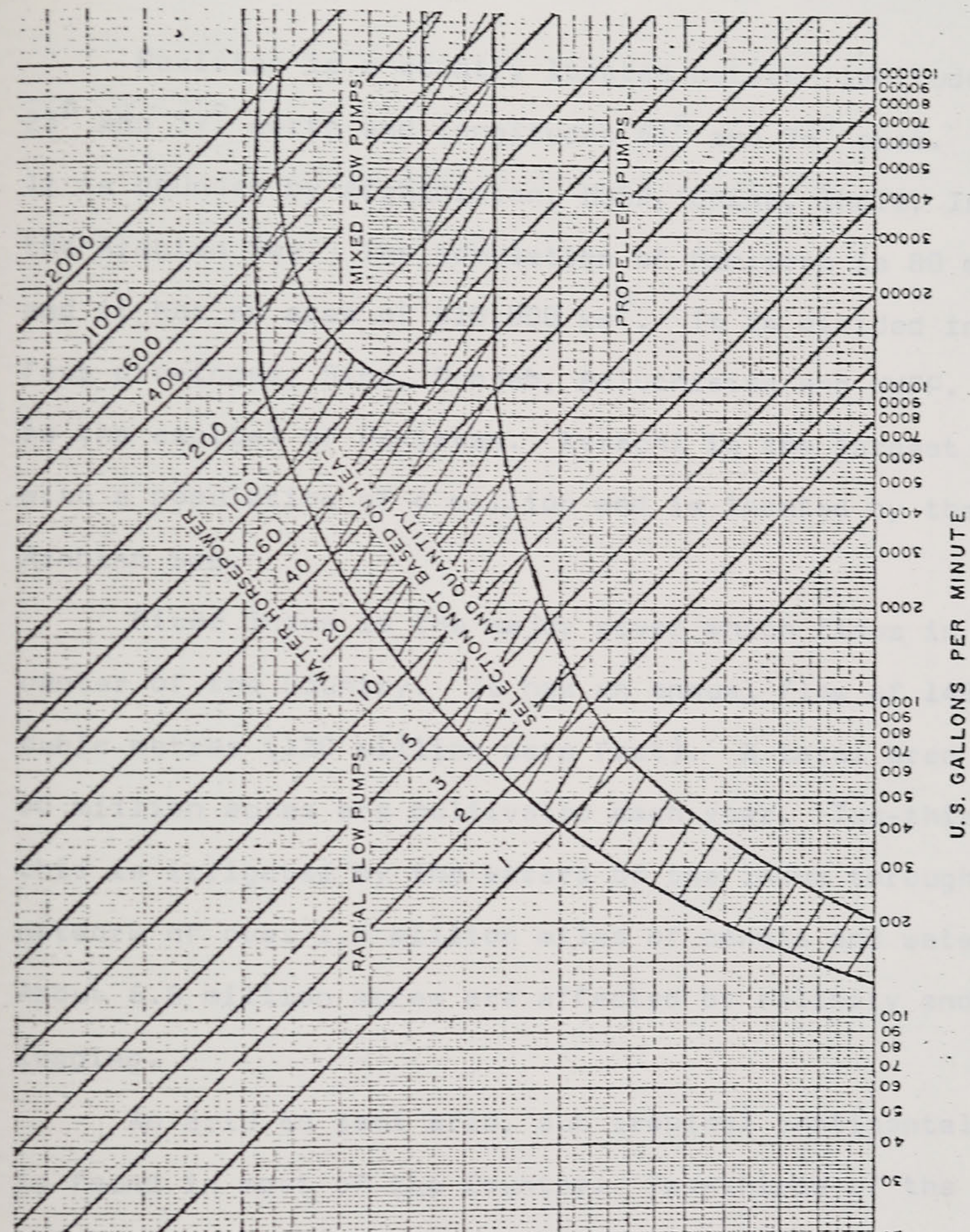
Appendix B

Metereological data for Mirpurkhas (10 years)*

| Month | Temperature °C Max | Min | Mean | Rainfall mm | Relative Humidity % | Wind Velocity m/s | Age of bright sunshine hours % |
|---|---|---|---|---|---|---|---|
| Jan | 24.08 | 10.26 | 17.17 | 2.54 | 51.7 | 1.46 | 74 |
| Feb | 26.80 | 12.52 | 19.66 | 5.08 | 47.4 | 1.89 | 75 |
| Mar | 33.14 | 16.18 | 24.66 | 2.54 | 48.3 | 4.23 | 69 |
| Apr | 38.70 | 23.64 | 31.17 | 5.08 | 47.7 | 6.08 | 65 |
| May | 41.58 | 27.35 | 34.47 | 5.08 | 64.9 | 8.33 | 60 |
| June | 40.13 | 27.93 | 34.03 | 10.16 | 61.0 | 9.15 | 55 |
| July | 34.68 | 27.47 | 31.08 | 101.60 | 66.2 | 7.61 | 55 |
| Aug | 35.00 | 27.90 | 31.45 | 60.96 | 64.2 | 4.72 | 54 |
| Sept | 35.15 | 24.08 | 29.62 | 15.24 | 64.3 | 2.34 | 68 |
| Oct | 35.87 | 20.63 | 28.25 | - | 55.6 | 1.57 | 76.5 |
| Nov | 30.95 | 15.13 | 23.04 | 2.54 | 51.4 | 0.63 | 79.5 |
| Dec | 25.87 | 10.60 | 18.24 | 2.54 | 52.6 | 0.23 | 81 |

*Pakistan Metereological Services,
Karachi, Pakistan.

# PUMP TYPE SELECTION CHART




| REFERENCE | U. S. DEPARTMENT OF AGRICULTURE<br>SOIL CONSERVATION SERVICE<br>ENGINEERING DIVISION - DRAINAGE SECTION | STANDARD DWG. NO.<br>ES - 724<br>SHEET 1 Of 1<br>DATE February 1971 |
|---|---|---|

## Appendix D
## Facts about Pakistan

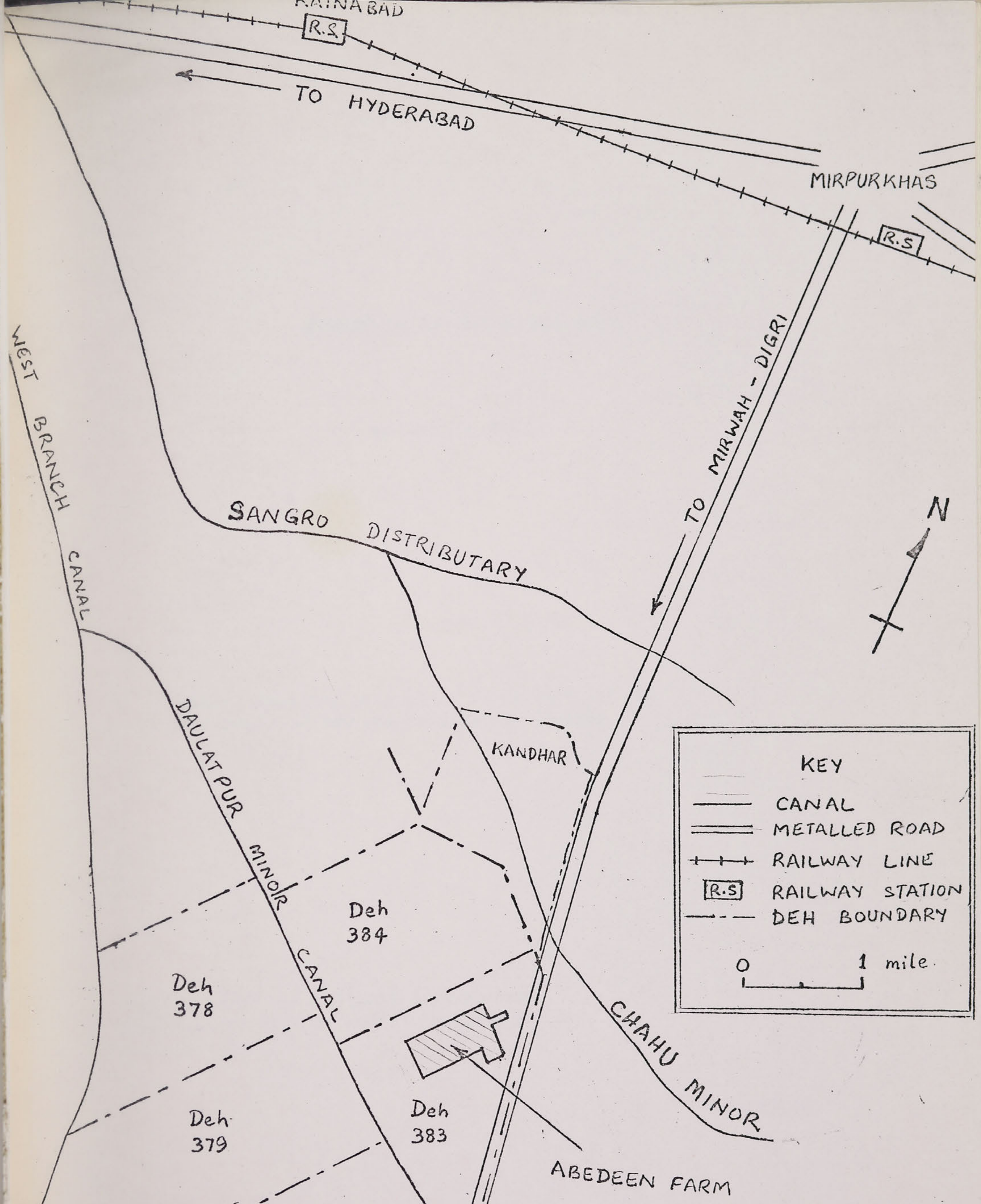
Pakistan is a country located between latitudes $23^{o}$ and $37^{o}$ north and longitudes $61^{o}$ and $76^{o}$ east. It is bounded by Afghanistan, USSR, China, India, Iran and the Arabian Sea. The population of Pakistan is 80 million and it has an area of 810,000 $km^2$. It is divided into four provinces, Sind, Punjab, Baluchistan and NWFP. Islamabad is the capitol of Pakistan. Karachi is the largest city with a population of 4 million and is located by the Arabian Sea.

River Indus is the major river which flows in the center of the Country. It has an annual flow of 148 billion cubic metres (120 million acre feet). A total area of 50 million acres are cultivated each year. Two-thirds of this is irrigated by the waters of the Indus through a network of over 1.5 million miles of canals and water courses. About 6.6 million acres are affected by salinity and water-logging.

An arid to semi arid, sub tropical continental climate is found in most of the Country. Two-thirds of the Country gets less than 200 mm of precipitation. Most of this minimal rain occurs as downpour during July, August and September. Temperatures range between 40 - $45^{o}$C. in the summer, to 10-$15^{o}$C. in winter. The northern region, however, receives a great deal of snow in the Himalayan mountain ranges.

The major crops grown in Pakistan are wheat, cotton, rice, sugarcane, barley, rape and mustard, tobacco, maize, gram, sesame, millet, sorghum, mango, banana and citrus fruits.

The languages spoken are Urdu, English, Sindhi, Punjabi, Baluchi and Pushto.




APPENDIX E. Location Map of Abedeen Farm, Mirpurkhas, Sind, Pakistan.