AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 66

1. SUBJECT CLASSIFICATION

A. PRIMARY
Food production and nutrition — AP12-0000-GG40

B. SECONDARY
Drainage and irrigation--Near East--South Asia

2. TITLE AND SUBTITLE
Proceedings

3. AUTHOR(S)
(101) NESA Regional Irrigation Practices Sem. 2nd, Tehran,1958

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1958	273p.	ARC NEA 631.7 R336 1958

7. REFERENCE ORGANIZATION NAME AND ADDRESS
AID/NE/TECH

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

10. CONTROL NUMBER
PN-AAE-282

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Meetings
Near East
Personnel development
South Asia

13. PROJECT NUMBER

14. CONTRACT NUMBER
AID/NE/TECH

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

NEA
631.7
R336
1958

AD/NE/TECH
PN-AAE-282

UNITED STATES OF AMERICA

UNITED STATES OF AMERICA
INTERNATIONAL COOPERATION
ADMINISTRATION

SECOND REGIONAL IRRIGATION PRACTICES LEADERSHIP SEMINAR

TEHRAN, IRAN

A.I.D. HISTORICAL AND
TECHNICAL REFERENCE
ROOM 1656 NS

INTRODUCTION

Experience in the United States and many other countries has demonstrated that the application of modern research results to irrigation practices will almost invariably result in better crops, less damage to the soil, and saving water. Moreover, it has been found that without an organized effort to spread knowledge of the research results and of economic methods of application, progress is very, very slow. The logical place to initiate the necessary effort is in those governmental organizations where, on the one hand, agricultural extension or other technical farm aid is rendered and where, on the other hand, the irrigation systems are planned, constructed and operated.

Realizing the need for guidance, the United States Operations Missions in the Middle East and South Asia area planned a series of seminars at which the problems could be brought out and steps taken toward their solution. The first seminar was held under the auspices of the Government of Turkey and the United States Operations Mission to Turkey at Izmir in September 1956. The delegates to that seminar asked that similar meetings be held in the coming years. Later, the Government of Iran expressed the desire that the next seminar be held in Tehran.

THE 1958 SEMINAR

The prime purpose of the 1958 seminar is briefly and well stated in the authorizing document of the International Cooperation Administration, as follows:

> "To create interest in the need for disseminating widely through agricultural and engineering organizations concerned with irrigation in the participating countries and to the farmers of those countries an understanding of improved irrigation practices and the contribution such practices can make to the agricultural production of the countries concerned and to the standard of living of the farmers."

In order to secure closer cooperation between governments, His Excellency, the Minister of Agriculture of the Imperial Iranian Government, serving as host to the Irrigation Practices Leadership Seminar, joined the United States Operations Mission to Iran in extending an invitation to nine Near East and South Asia governments and the corresponding Missions to send representatives to a Regional Irrigation Practices Seminar to be held in Iran during the period May 3 through May 16, 1958. Delegates included high officials in both the public works and agricultural organizations of the different governments and both engineering and agricultural technicians and administrators from the Missions.

Table of Contents

Introduction

Technical Discussions

Causes of and Remedies for Excess Salinity and Alkalinity in Irrigated Soils	1
Use of a Limited Water Supply	49
Relation between Farm Irrigation Practices and Project Design and Management	66
Land Classification as an Aid to Proper Irrigation Practices	86
Development and Use of Ground Water	94
Design and Layout of Farm Irrigation Systems	113
Indian Experience in Promoting Better Farm Irrigation Practice	137
Irrigation Staff Development	151
Low-Cost Simple Equipment to Improve Tillage Practices and Soil and Water Conservation on Near East Farms	180

Field Trips

Varamin Valley and Mamazon	187
Karadj Dam and College	190
Garmsar Drainage Investigations	193
Agricultural Engineering Demonstration Farm and Ghazel Hesar Drainage Project	197

Reports of Discussion Groups

Group I	Operation and Maintenance	209
Group II	Drainage Investigations	213
Group III	Demonstration Fields and Farms	215
Group IV	Research Needs in Irrigation	218

Country Reports

Greece	221
India	235
Iraq	244
Turkey	254

Resolutions	261
Program	263
List of Delegates	267

CHAPTER I.

TECHNICAL DISCUSSIONS

TECHNICAL DISCUSSIONS

CAUSES OF AND REMEDIES FOR EXCESS SALINITY AND ALKALINITY IN IRRIGATED LANDS

by

Hussain Abid Awn
Drainage Engineer, Irrigation Directorate
Iraq

Salinity and alkalinity are common but oftentimes serious problems in irrigated areas. This is especially true for irrigated lands which are located in arid and semi-arid parts of the world.

Saline and alkaline soils are those which contain excessive concentrations of either soluble salts or exchangeable sodium, or both. Such soils require special remedies and management. Saline soils are those which contain a large amount of soluble salts, resulting in less productivity. On the other hand, alkaline soils are those which contain exchangeable sodium, which has the same effect on productivity. Soils which contain both soluble salts and exchangeable sodium are called saline-alkaline soils. Soluble salts create a danger to plants by increasing the saturation of exchange materials. Exchangeable sodium is very dangerous and sometimes is very hard to remove. The salt content of soils which will affect plant growth depends on: the texture of the soil, the distribution of salt in the profile, the composition of salts, and the species of plant present.

The soluable salts that occur in soil consist of different proportions of sodium, calcium and magnesium cations, and chloride and sulphate anions. There are some minor constituents such as potassium, bicarbonate, carbonate and nitrate.

The original source of all the salt constituents are the primary minerals which are found in the soil and in the earth's crust. During the process of chemical weathering, which involves hydrolysis, hydration, solution, oxidation, and carbonation, these constituents are gradually released and made soluble.

Saline soils also occur in areas that receive salts from other sources. The ocean may be the source of salts as in soils where the parent material consists of marine deposits which were laid down during earlier geologic periods. The ocean is also a source of salts in low-lying soils along the sea coasts. Salt, moved inland by wind-carried spray, is called cyclic salt.

Irrigation waters are also sources of salt. Other waters may add salt to soils under natural conditions, as when they flood low-lying land

or when ground water rises close to the surface. Restricted drainage is a factor that usually contributes to the salinization of soils and may involve the presence of a high groundwater table or low permeability of soil. Low permeability of the soil causes poor internal drainage, poor aeration, and retarded downward movement of water.

Regional Irrigation Practices Leadership Seminar in session at Tehran University Club.

Successful irrigation projects must supply irrigation water and also control the salinity and alkalinity of the soils if a permanent and intensive agriculture is to be maintained. In establishing an irrigation project, soils that are initially saline require the removal of the excess salts and may require chemical amendments. On the other hand, soils which are non-saline may become unproductive if excess soluble salts or exchangeable sodium are allowed to accumulate because of improper management. The selection of an irrigation method for applying water to the soil is related to salinity and alkalinity. The method best adapted to any particular case depends upon a number of conditions: the crop to be grown, topography, soil characteristics, availability of water, soluble salt content of water, and the salinity status of the soil. It is desirable, both for plant use and for leaching, to apply the water uniformly over the irrigated area.

Regardless of source, however, harmful accumulations of salts are usually associated with high water tables. The lowering of such water tables and the removal of excessive salts from the soil are tasks which confront the drainage engineer.

High water tables may result from seepage from canals, laterals, borrow pits, and other ponded areas. They may also result from deep percolation losses of irrigation water applied on irrigated fields and from floods and excessive precipitation. Seepage will take place through the sides, banks and bottoms of canals and laterals. This occurs in unlined canals excavated through earth materials. Some seepage losses occur in lined canals but when the linings have been properly constructed and main-

tained the losses are small in comparison with those that occur in unlined canals.

Seepage losses may be due to absorption and percolation. Absorption loss is due to the action of capillarity while percolation loss is due to the action of gravity. If, in a canal, capillarity alone were acting, then the loss of water through the soil would follow the laws of capillarity. The water would pass from the wet surface to the dry soil surrounding it, moving in all directions, vertically and horizontally. It would stop when it reached the maximum limit of capillarity, which will vary with the texture of the soil.

The water lost by percolation travels downward because of the force of gravity to the subsoil beyond the limit of capillary action. This water is distributed laterally by capillarity and the wetted area is increased. The water lost by percolation, which is not held as capillary water, will, if sufficient, reach the water table and pass as an underflow to drainage channels.

The following factors influence seepage losses in canals:

1. The texture of the soil and subsoil and the extent of the absorbing medium.

2. Position of the water table and drainage conditions of the soil and subsoil.

3. Temperature of the water.

4. Age of the canal and amount of silt carried by the water.

5. Depth of water in the canal and the distance the seepage water must travel to reach an outlet.

6. Velocity of water in the canal.

The absorption loss is greatest in fine-textured soils which have a large capacity for capillary water, but seepage loss is more dependent on the percolation loss and is therefore greatest for coarse-textured soils, which usually drain readily. A coarse subsoil not saturated with groundwater will usually produce a high rate of seepage.

A rise in the water table usually decreases the seepage loss and the extent of the loss will depend on the rate at which the groundwater finds its way to a drainage channel. The temperature of water and soil has some effect on the rate of seepage loss. An increase in temperature decreases the viscosity of water, which will increase the rate of percolation.

A canal will usually become more impervious with age, dependent to

a large extent on the amount of silt carried by water. The silt is deposited on the surface and drawn by the seepage water into the pores of the soil, forming a less pervious canal. The effect of the depth of water in the canal probably has been overestimated. It is sometimes assumed that the seepage loss varies directly with the square root of the depth of water. The loss must depend not only on the depth of water, but also on the depth of soil through which the seepage water percolates, the direction of flow of the groundwater, and the slope thereof. The velocity of water in the canal has several effects on the seepage loss. A high velocity may produce erosion of the canal and remove the finer material, thus leaving the bed and the bottom of the canal porous. This will have a tendency to increase the seepage loss.

In most project areas, deep percolation losses in the irrigated lands probably constitute the chief contributing factor to the rise of the water table. Soil water above the point of maximum capillary capacity and up to the point of saturation is called gravitational or free water. This is usually the water which is injurious to plant growth and which is removed by drainage. The rate at which gravitational water moves downwards through the soil depends on the size and arrangement of the soil particles, the size of the pore spaces, the granulation of the soil, the organic matter in the soil, and the openings in the soil made by cracks, burrowing of earth worms, and by decayed roots of plants. The first-mentioned factor is the most important. In coarse-grained soils, percolation is usually much more rapid than in fine-grained soils. Both the capillary movement and percolation are more rapid when the soil is wet. The rate of percolation is an important factor in the design of drainage systems. Since this varies for different soils, it is necessary to study soil structure in detail. Deep percolation losses resulting from floods or excessive surface runoff likewise contribute to the rise of water tables. The same is true with respect to marshes, depressions, borrow pits and other ponded areas.

While it is not always possible to prevent the occurrence of high water tables, the problem may oftentimes be alleviated through certain preventative measures. Seepage of water from canals and laterals, for instance, may be greatly reduced by the installation of proper linings. The materials most commonly used for this purpose are concrete, clay, asphalt, road oils and rock masonry. Where physically and economically feasible, excessive surface runoff resulting from floods can be eliminated by the construction of adequate flood control works.

Perhaps the two most effective measures for the prevention or alleviation of high water tables consist of a thorough land classification of the project area prior to development and proper irrigation practices following development. If a wise program of planning for construction, operation and maintenance is to be followed and measures taken to prevent salinization and alkalinization of irrigated or potentially irrigable lands, or for the remedy thereof, a determination of the facts through a survey of the lands in question must be made.

Be it called what it may - soil survey, land classification or drainage survey - reconnaissance, semi-detailed or detailed - a decision has to be made as to what factual data are needed consistent with the size of the project and preliminary estimated cost of the works required to maintain productivity of the land to the degree that returns will be in excess of cost of production. For example, cost of maintaining productivity of the land to the degree that returns will be in excess of cost of production. For example, cost of maintaining productivity per unit of area on irrigated lands devoted primarily to vegetables can be much higher than for pasture lands.

In this survey, which in reality should include the elements of soil, land, and drainage, an appraisal should be made of present conditions. It will also foresee future conditions when, through the proper design, construction, operation and maintenance of irrigation and drainage works, soil management will be effected. Future conditions should also be mapped or indicated in the survey if failure to carry through the foregoing items takes place.

To begin work in an area where salinity or related problems exist, the first step is to collect and analyze any and all reports, maps and other data which may have been obtained earlier. This may eliminate or reduce costly preliminary investigations, reduce the time needed to bring about land improvement, and point up problems needing detailed investigation while eliminating others. This is generally referred to as a reconnaissance type of survey. In the absence of any previous surveys, a reconnaissance survey is in order. This should determine the size of the area and the nature and extent of the problems involved. It should also recommend additional studies necessary to properly classify the project lands.

Aerial coverage is of inestimable value throughout most all phases of investigational surveys, as it points up access roads and trails, location and layout of irrigation systems, population distribution, cropping patterns (continuous or fallow, winter or summer, extensive or intensive as in grazing or fruit and vegetable lands), saline or alkaline lands, and depression areas where water tables are likely to be high. The aerial photos will show parts of the boundaries of many of these areas. However, one must spend considerable time in the field learning how to read the shadings on photos--what can be relied upon and what cannot for each area in which he is assigned to work.

With respect to the causes and remedies of salinity and alkalinity of irrigated lands, the land classification survey, in close coordination with the drainage survey, should evaluate such items as quantity, quality, and seasonal availability of the water supply, water table conditions and quality of groundwater (what portions of it can be reused for irrigation on lands further downstream), and the chemical and physical aspects of the land itself. In evaluating the soil, determination of the texture, depth, permeability or hydraulic conductivity, total soluble salts, exchangeable

sodium, gypsum, lime, soluble cations and anions, and toxic elements should be made at sufficient locations and to sufficient depths in the soil profile to provide the accuracy required. In evaluating the land, such determinations as elevation, slope, nearness to existing irrigation supply and drainage works, size and shape of fields, and climatic factors must be considered.

The facts found in the foregoing survey will indicate whether or not the excess salts can be leached from the soil and, if not, what is needed in the way of chemical amendments and management of irrigation waters to effect reclamation of the lands.

A saline soil, relatively low in exchangeable sodium, will not need chemical amendments as an aid to leaching, but an alkaline soil will need them if they are not already present either in the soil or in the irrigation water. A high water table will inhibit the rate of water infiltration in a permeable soil, whereas a low water table will add to the hydraulic gradient. Irrigation water with a low sodium percentage and a relatively high calcium concentration will percolate through the soil more readily than rain water.

It must not be assumed, however, that all problems involving drainage and salinity can be prevented. Although the above-mentioned preventive measures will greatly lessen the severity of the problem in most cases, the fact remains that either water logging and/or salinity, will at some time in the history of an irrigated area, become a problem which the engineer must face. Water logging and salinity can occur as separate problems, although in arid areas under conditions of sustained irrigation they usually occur as one combined problem. Where such is the case, the first step is to provide adequate drainage facilities. This will provide a ready and permanent means for maintaining the water table at a satisfactory elevation and for leaching the salts from the soil. Where a high water table exists, leaching cannot be accomplished unless drainage facilities are available.

Proper design of drainage systems depends, to a large extent, on data obtained from drainage investigations. Correct location, size, depth, and spacing of tile lines or open drains and the depth, size, location and capacity of drainage wells or other drainage facilities, all depend upon the proper interpretation of data obtained from such studies. Generally speaking, drainage investigations consist of a study of groundwater hydrology as related to irrigation. A properly designed grid of observation wells will provide much of the data needed for design purposes. The lithologic characteristics of the soils and sub-surface materials, the stratigraphy of the project area, the presence of vertical gradients in water pressures, the depth to the water table and the seasonal and annual fluctuations thereof and the quality of groundwater, can all be determined in this manner. Water table contour maps, for instance, will clearly show the direction of flow, which is an important factor in the design of drainage systems. Stratigraphic cross sections and water table profiles

will often provide the proper depth of drains and, to some extent, will aid in determining the spacing. The extent of natural drainage can be determined with comparative accuracy by correlating the rate of change of the water table with applications of irrigation water to the land. Finally, such studies will provide useful information on the amount of water which will have to be removed by means of artificial drainage. This amount of water is termed the "drainage requirement" and is usually the governing factor in determining the performance and capacity specifications for any type of drainage system. Studies are now under way in Iraq to determine the drainage requirement for several proposed projects.

At the present time, open drains are used exclusively in Iraq. It is anticipated that other types of drainage methods will be employed in the future, depending upon the results of investigations now in progress.

With the provision of drainage facilities and related works, the engineer is then faced with the problems of removing the excess soluble salts from the soil. Depending upon the facts found during the land classification and drainage surveys, he must choose the best approach, of which there may be a number, to the problem at hand.

If the soil, like the aggraded soils of the alluvial Mesopotamian Plain of Iraq, is low in expanding type clays, high in lime, and contains some gypsum, then no chemical amendments are needed. Leaching is merely a matter of irrigation management. An important factor in leaching is the stability of the soil structure with the removal of soluble salt. Is exchangeable sodium high? Is soluble sodium high, and is there danger of a considerable portion of it going into the exchangeable state during leaching? Will the soil structure break down?

If soils are low in lime and gypsum, then these amendments will be needed to replace the excess harmful portion of the exchangeable sodium. From leaching experiments in Iraq and elsewhere, one meter of water will normally remove about eighty percent of the soluble salts in the top meter of the soil profile, whereas nearly three meters of water are needed to leach to a two-meter depth. Exchangeable sodium will leach out if sufficient gypsum is present at about the same rate. Boron, however, when in soil concentration of only ten parts per million or thereabouts, requires four to seven times as much leaching water to reduce this concentration to one or two parts per million.

The kind and amount of chemical amendment to be used for the replacement of exchangeable sodium in soil depends upon the soil characteristics, the desired rate of replacement, and economic considerations.

Chemical amendments that are commonly applied to alkaline soils are of three types:

Amendments for Alkaline Soils	Chemical
Soluble calcium salts	Calcium chloride Gypsum
Acids or acid forms	Sulphur Sulphuric acid Iron sulphate Aluminum sulphate Lime - Sulphur
Calcium salts of low solubility and containing magnesium	Ground limestone By-product lime from sugar factories

While each type of amendment has a place in reclamation, effectiveness under different soil conditions is governed by several factors, the principal ones being the alkaline-earth carbonate content and the PH of the soil paste.

Application of Amendments

From the standpoint of efficiency in replacing exchangeable sodium, it is advantageous to leach most of the soluble salts out of the soil before applying chemical amendments. As a result of the removal of soluble salts, a higher proportion of the calcium supplied by the addition of the amendment is absorbed by the soil exchange complex.

The advantage gained by leaching prior to the application of amendments may be more than offset by the decrease in the soil permeability which usually accompanies the leaching of a saline-alkaline soil. Whether amendments should be applied before or after removal of soluble salts, therefore, will depend upon permeability relationships.

Such chemical amendments as gypsum, sulphur and limestone are normally applied broadcast and then incorporated with the soil by means of a disc or plow. Thorough incorporation is especially important when sulphur is used to insure rapid oxidation to the sulphate form. Because of the hazards in handling, the application of sulphuric acid is difficult under ordinary field conditions. However, special equipment is now available to spray the concentrated acid on the soil surface; deeper placement may be advantageous if exchangeable-sodium accumulation occurs uniformly in the subsoil. While there appears to be no information available on the subject, it is possible to obtain deep placement by distributing the amendments behind a plow or subsoiler.

Amendments are sometimes applied in irrigation water. Except where sulphur is used, saline-alkaline soils should be leached immediately following the application of an amendment. Leaching dissolves and carries the

amendment downward and it also removes the soluble sodium salts that form as a result of cation exchange. Soils receiving sulphur ordinarily should not be leached until sufficient time has been allowed for most of the sulphur to oxidize and form gypsum through the chemical reaction with limestone. In this case the soils should be kept moist, as moisture is essential to the process of microbial oxidation. Improvement of the physical condition of alkaline soils involves the rearrangement of exchangeable sodium. The rearrangement of soil particles in order to improve physical condition is facilitated by alternate wetting and drying, by alternate freezing and thawing, and by the action of plant roots.

Problems involving the accumulation of excessive salts in the soil cannot always be prevented. Likewise, high water tables may occur even under the best of management conditions. Fortunately, however, modern advances in salt removal methods, together with properly designed drainage systems, have accomplished much in reclaiming large areas in many parts of the world.

CAUSES OF AND REMEDIES FOR EXCESS SALINITY AND ALKALINITY IN IRRIGATED LANDS *

Formal Discussion

By

A. G. Asghar
Director, Land Reclamation
West Pakistan

Introductory

The various headings suggested for discussion seem to place the greatest emphasis on a high water table in causing salinity and alkalinity, whereas factors like location, topography, origin of soil material and prevalent agricultural practices also play an important part in salinization of land. Discussion of the causes of a high water table or the rise of a water table is strictly related to waterlogging, a subject quite distinct and separate from salinity and alkalinity.

Reference is invited to the Near East Regional Meeting on Irrigation and Drainage Practices held under the auspices of F.A.O. of the United Nations at Tehran, Iran, during November 1954, in which the various problems of irrigated agriculture were included for discussion. High water table conditions (referred to as water logging), occurrence and spread of salinity/alkalinity in the soil, seepage from canals, inefficient natural subsoil drainage, high salt content of irrigation water, over-irrigation or underirrigation, etc., in relation to problems of soil salinity/alkalinity were discussed. In the agenda of the present Seminar, although salinity and alkalinity of the soil is the major problem, yet under this heading details give point to a high water table as the major factor responsible for salinization and alkalinization. Under the heading "Causes, Prevention and Remedy", attention has been given only to the problem of the rise of the water table, although in most of the arid areas of the world, where salinization is not due to salts from irrigation water, the subsoil water reservoir is not the only source of salt accumulation. If the factors mentioned above had been included in the agenda for the Seminar, perhaps we might have done more justice to the discussions and understanding of the problem.

The justification for the above remarks will be gauged by the severity of the problem of salinity in Pakistan. The deterioration of

* The views expressed do not in any way represent those of the Pakistan Government, but are the author's own.

arable lands, as previously reported[1], has assumed still more serious proportions. The present condition in the Central Districts of West Pakistan, for which reliable figures are available, is that out of 15 million acres of canal-irrigated land, about 9 million acres have salts on the soil surface. Of these, 3 million acres are categorized as saline and show salt incrustation on more than 20% of each acre, which is the unit for revenue collection and irrigation operations, while 1.3 million acres have gone out of cultivation. There is a net increase of 0.7 million acres in salinization and 0.5 million acres in area gone out of cultivation over the last decade. The malady is now increasing faster, as there is an annual addition of 70,000 acres compared with the 40,000 acres previously reported.

It would be observed by going deeper into the problems that if proper care and management of the land is not effected immediately, there will hardly be enough land left for producing food and fibre for the increased population of the country. This does not augur well for a country whose economy is still based on what is and what can be produced from its lands. It is, therefore, very important for our country that the subject should be discussed from every angle. However, as it is not possible to suggest any revision of the proposed agenda, an attempt will be made in the following pages to deal with the problems according to the headings given in the program in the light of the experience gained, research conducted, and data collected in the western wing of Pakistan.

A. Surface Accumulations from a High Water Table

In Pakistan a high water table was considered the primary cause of the appearance of salt efflorescence at the soil surface when the problem was first noticed in the early twenties. A series of observations for correlating data on water table and salinity were undertaken in 1938-39[2]. Villages with different water-table depths were selected for study. The depth of water table varied from 9 to 40 feet from the soil surface. The rate of land deterioration due to salt accumulation on the surface was estimated to be 5% per annum of the cultivated area. Profiles were exposed down to the water table in both good and deteriorated lands. The soil crust was generally ten feet in thickness and rested upon sand in which the water table was situated. On analysis it was found that in deteriorated land a zone of salt accumulation existed within two feet from the soil surface. In good land this zone was situated at deeper variable depths. In no case was salt found in the sand layer. On the basis of these data it was concluded that the salines were not derived from the water table, and thus the nearness of the water table was not an essential factor in the salinization of land.

Taking the annual surface evaporation from a water table ten feet below the surface to be six inches, calculations were made that in an acre with ten feet of soil crust and 'first' ground water containing 90 parts per hundred thousand of soluble matter, the amount of salt added to the soil profile would be one-half ton per annum. On an average,

the saline lands with the same depth of soil crust contain more than 100 tons of salts. It will be seen, therefore, that a period of 200 years would be required, if the water table were considered the source of salt, to account for the present amount of salt in saline soils. There is evidence on record that there was no problem of salinity or waterlogging prior to the advent of the gravity flow irrigation system. The appearance of white incrustation of salts on the soil surface was not taken seriously till it started diminishing the yields of crops.(3)

In recent years, a study of the rate of evaporation from lysimeters, under meterological conditions representing the most seriously affected part of West Pakistan, showed that with a 10.5 foot subsoil water table, the average rate of surface evaporation over a period of five years is 1.5 feet per annum.(4) The I.C.A. experts who are working on an investigation of our soil and water problem are also of the opinion that under these water table conditions the evaporation varies between one and three feet per year. Calculating on these bases also, the amount of salts bears no relation to the rise of moisture from the water table. The conclusion would of course alter when the subsoil water level is considered as being within zero to five feet from the land surface, in which case the annual evaporation losses are considered to be as high as even ten feet. This figure is rather high, but no direct data are available at present. Under this condition the accumulation of salts at the surface is very rapid, yet the sub-surface soil does not contain very high salts and the concentration is proportional to the salts present in brackish water.

Causes

(a) Canal seepage. Addition to the subsoil water table from a canal irrigation system may take place from:

1. Main canal and branches
   These usually have no outlets or takeoffs for direct irrigation of fields.

2. Distributaries and minors
   These take off from main canals and branches and have outlets for delivery of irrigation water.

3. Water courses
   In these, water delivered through outlets is carried to the fields.

All the canals in West Pakistan constructed before 1936 are unlined, being earthen channels dug in the natural soil. In order to maintain the design of regime channels, certain slopes have to be maintained irrespective of slope of country, so that at certain points canals are in cut and in some reaches these are in fill. The nature of soil varies from clay to sand and usually a canal passes through all types of soils. In digging,

the heavier soil crust is sometimes eliminated and the canal leaks badly. Recent surveys of two big canals have shown that there are many such sites along their alignment. From Bombanwala to Nandi-pur on the Upper Chenab Canal a length of four miles is very pervious. There is no soil under the bed, which consists mainly of sand. Here the channel is mainly in cut. The next four miles have a thick impervious clay layer at the bed and very little seepage can be expected. Similarly, in the 60-mile length of the Upper Gugera branch of the Lower Chenab Canal there are eight such sites which are very pervious.(5)

Losses from the various components of an irrigation system have been estimated by various authorities from the earliest times. Sir John Benton's estimates in the canal system taking off from River Ravi are given below:

Table I

Absorption on Upper Bari Doab Canal System

Percent of discharge at Heads

	Canal	Distributaries	Water courses
Percolation	16.40	6.10	20.20
Evaporation	1.10	0.40	1.30
Total	17.50	6.50	21.50

Sir Thomas Higham estimated the losses in the Main Line Upper Bari Doab Canal as 12 to 14% on total discharge.

Kennedy estimated that in the Upper Bari Doab Canal, out of 100 entering the head, 20 were lost in the canal proper, six in distributaries, and 21 in field water courses. This left 53 on the fields, of which, according to his estimate, 25 were lost due to inefficient irrigation.

The statistical results for the canals on Chenab and Jhelum were carried out in 1933-36 to 1942-43 and are abstracted in Table II on the following page.

Table II

Name of Canal		Main discharge at head of canal	Discharge utilized in the distributaries of canal	ADDITIONS TO SUBSOIL WATERTABLE FROM			
				Main canal and branches	Distributaries and minors	Water courses	Total of columns 4-5-6.
1		2	3	4	5	6	7
Lower Chenab	K	9,315	7,736	1,372	465	571	2,408
	R	6,898	5,874	889	266	318	1,473
	Av.	8,106	6,805	1,130	366	444	1,940
Upper Chenab	K	9,143	3,516	215	211	228	654
	R	4,858	1,132	109	51	49	209
	Av.	7,000	2,324	162	131	139	432
Lower Jhelum	K	2,981	2,539	372	152	188	712
	R	2,561	2,210	309	100	120	529
	Av.	2,771	2,375	340	126	154	620
Upper Jhelum	K	5,626	1,283	329	77	102	508
	R	5,662	653	281	29	40	350
	Av.	5,644	968	305	53	71	429
Total:	Av.	23,521	12,472	1,937	676	808	3,421

These results indicate that 3,421 cusecs were added to the subsoil where a discharge of approximately 23.5 thousand cusecs was run, which gives a p centage of 14.4. This loss also included the evaporation losses. Certain experiments were also conducted to determine the evaporation loss, and the results indicated that it went as high as 10%. The losses in the distributaries and minors varied between 6% and 8%, and the losses from water-courses were calculated at 8 to 12 cusecs per million square feet of wetted perimeter.

Blench in 1941-42 estimated the absorption losses on the Lower Chenab Canal system as 5%, 7% and 20% for main canal, branches, distributaries and water courses, respectively. These calculations were based partly on examination of direct and indirect evidence and partly on personal assumptions. An important assumption made in this respect was that, as the total absorption is equal to the estimated addition to the water-table, the canal system was considered responsible for the accretion of subsoil water.

There is no doubt that some work has been done but only on particular

sites or reaches of various channels, and the results cannot be taken to apply to the entire canal system.

The lysimeter experiments conducted for the last ten years show that in case of half a distributary and water course, net seepage losses per million square feet of wetted perimeter work out to be 1.1 cusecs and 1.4 cusecs, respectively.(6)

The results are not conclusive and are only empirical in nature, as the profile is comparatively unsettled and so far the water has not been brought in motion.

(b) Seepage of waste water from borrow pits and other ponded areas. Borrow pits are created along the canal and its branches as well as highways and other roads. During rainy seasons all these are filled with water and are a permanent source of seepage. The borrow pits along highways and roads are specially flooded as a result of seasonal floods in summer and spills from natural torrents and catchment areas.

Regular floods have visited our land in recent years. In the year 1948 the Jhelum and Chenab were in high flood and the devastation was great and widespread in the former Punjab area. Direct damage was of the order of 80 millions of rupees. The damage caused by the 1950 floods was much more, due to the Ravi, Chenab and Sutlej rivers all being in flood. As a matter of fact, there were two floods, one following the other with an interval of about 15 days. The devastation was, therefore, much more severe than it was in 1948. The total direct national loss was of the order of 230 millions of rupees.

Since 1950, the two rivers Ravi and Chenab have been again in flood in the years 1954, 1955, and 1957. The flood of 1955 in the Ravi river was the highest ever recorded. The flood in the Chenab in 1957 was higher than that of 1950, reaching yet another record. Apart from the great losses of property and crops, the more serious and alarming damage is that which is caused to the lands by an abrupt jump in the subsoil water table, as it eventually brings about the problem of soil salinization, locally known as 'Thur'. The jumps caused by the flood remain, to be added to further by subsequent annual rising due to permanent causes.

For illustration, the areas covered by floods during 1950 from different rivers, natural torrents and, overspills from drains are given in Table III, next page.

TABLE III

GROSS

Source	AREA FLOODED IN ACRES		
	Irrigated	Un-irrigated	Total
Sutlej River	64,000	-	64,000
Ravi River	1,437,920	-	1,437,920
Chenab River	1,666,560	106,880	1,773,440
Natural torrents	1,173,280	286,720	1,760,000
Overspilling of drains, etc.	114,560	-	114,560
Total:	4,456,320	393,600	4,849,200

Under these conditions there would be an addition to the subsoil water reservoir resulting in the rise of the subsoil water level to a very great extent.

In the Chuharkana Reclamation Project, a reference to which was made in the F.A.O. Seminar held in 1954, data have been collected correlating the various indices with the rise of the water table. Data shown in Figure 1 include the effect of rainfall as well as floods within the project area for the last four years. It is interesting to note that in spite of the working of 24 tubewells during the past three years, although not continuously as was scheduled in the project, the water table rose during the year 1957, when the area was severely affected by floods during the summer season. The data also point to two rises of water table corresponding to the two rainy seasons, winter and summer. The part played by these sources in the addition of water is still under investigation and it is expected that at a later date we will be in a position to report more exact information.(7)

In order to solve the soil and water problems of the country, investigations were started under the advice of I.C.A. in 1954 with the object of conservation, management, and utilization of the total water resources. A ground-water investigation is the first step toward attainment of these objectives. Attempts are being made to evaluate all the sources of available waters, which also includes the part played by the present canal system in building up the subsoil water reservoir. The work is in progress. Apart from the investigation on the contribution of canals to the subsoil water reservoir, the other subjects under investigation are:

1. Water quality
2. Total water potential
3. Drainage of agricultural lands, including salinity control

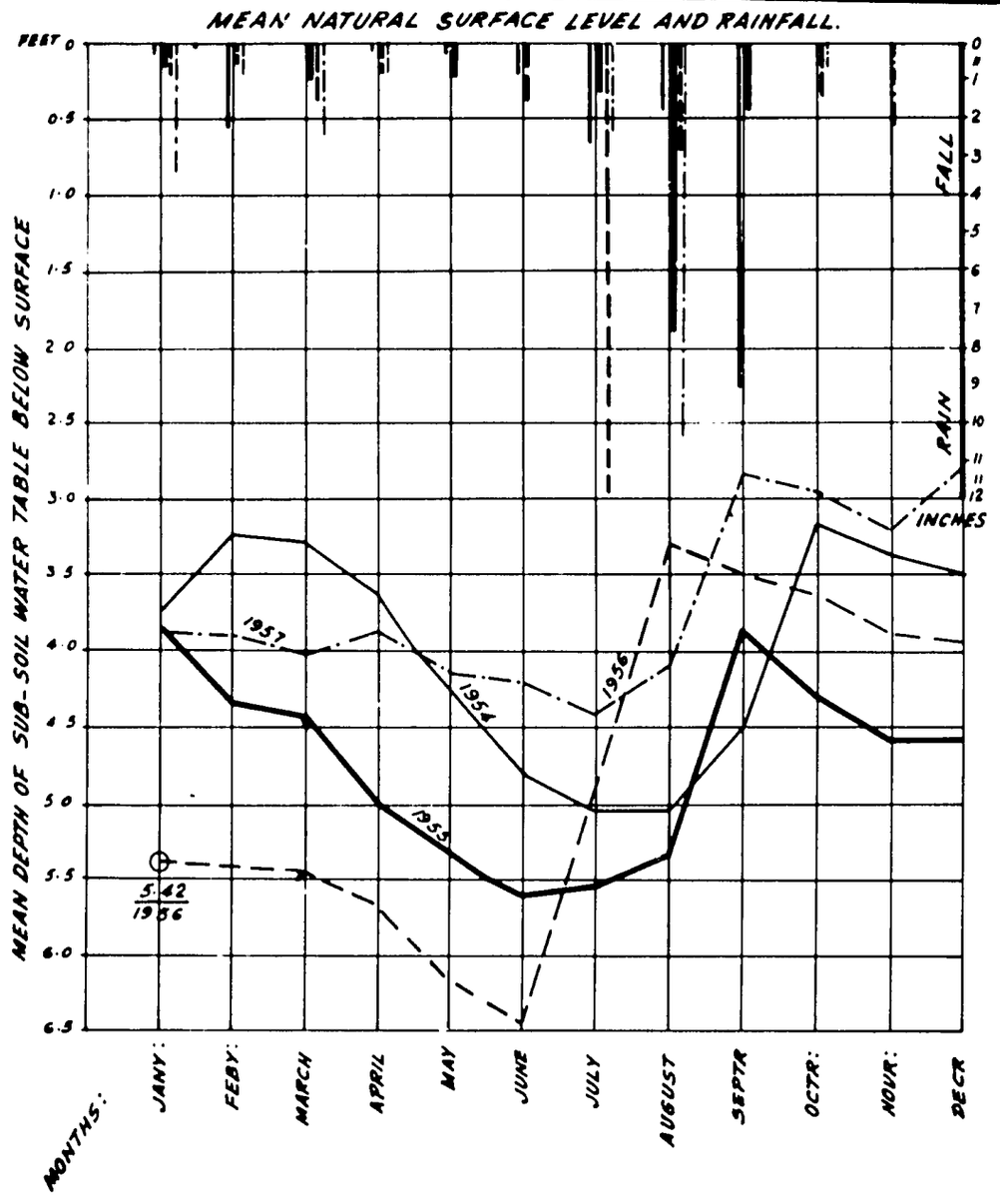

FIG. 1 – CHUHARKANA RECLAMATION PILOT PROJECT
Graph showing the effect of tubewell pumping on the sub soil water level

The project, although scheduled to be completed by 1959, is now expected to be prolonged to 1962. More detailed results will be available at the conclusion of this investigation program.

(c) Deep percolation from irrigated fields. When a field is irrigated, the water applied is disposed of by wetting soil, by evaporation from the soil surface, by transpiration through the plants, and if the water added is in excess, some passes through the soil profile and adds itself to the subsoil water reservoir to contribute to the rise of the water table. The principal factors influencing this distribution are initial soil moisture, depth of water table, meteorological conditions, nature of crop, and preparation of land. If the fields are well-graded and the irrigation practices based on scientific lines, the entire basin may be equally irrigated; defective grading results in wastage of water supply. Under ideal conditions, the whole of the water added to the field should be utilized by the factors enumerated above and, in addition, some should pass through the entire soil profile giving drainage to the soil material. If, on the other hand, the field conditions are not ideal, some loss can take place by a part of the irrigation water's escaping to the subsoil water table without giving any drainage to the soil material itself. This is an important factor and should not be mixed up with the additions to the subsoil water table during raising of crops in the form of drainage. It is our experience that due to defective water courses and inlets into the fields, there are appreciable losses of irrigation water during production of crops without giving the benefit of drainage to the soil profile. There does not appear to be any appreciable effect of the increase in cropping on the rise in water table.

For convenience in planning relief to the high water-table area and reclaiming the deteriorated lands, the depth of water table has been categorized into:

1. 0-5 feet
2. 5-10 feet
3. 10-15 feet
4. 15 feet and beyond

Available data permit an estimate of one type of area's passing into the category of higher water table during the last two decades. It may be observed that although a very small area has been added from the category 5 - 10 feet to the category 0 - 5 feet, yet large areas have passed from category three to category two. This means that there has been continuous addition to the subsoil water reservoir. The addition to the subsoil water reservoir is counter-balanced by evapo-transpiration losses from soil surface. This is not the case for the area under categories two and three. The data show continuous addition of water to the subsoil. The addition has not taken place as a function of drainage through the soil profile in cropped fields. This is evident from the ever-rising salinity figures in the area. If the addition has been through proper drainage, there should not have been any increase in the salinity figures. The addition has been made because of losses through

faults in the grading of the field. In our country the irrigation basins are of the order of an acre in area, which have only one inlet and with a very small head which does not give efficient spread of water, and, in most cases, while the water hardly reaches the farthest end of the field, a larger part of the water seeps through at the place of entry into the field.

The data referred to above are not specific and are only of a general type. Quite recently the Directorate of Land Reclamation has been experimenting on different crops in lysimeters and the usual information on depth applied, accretion to water table, and the part of water which evaporates, has been calculated. It is observed that under existing cropping practices and depth of water applied there are only two crops, rice and sugarcane, which give an accretion to the water table. In the case of rice, 24.5% of the surface application reaches the water table, while sugarcane adds 8% of the irrigation water to the water table. Cotton, wheat and gram on the other hand do not make any accretion to the water table. On the contrary, the duty applied being insufficient, these take moisture from the subsoil, thus causing a lowering of the water table.(4)

Work on this aspect of the problem is in progress and more data will be available in due course of time. The present understanding of the accretion of water to the subsoil water table as a result of intensity of cropping is that we are using insufficient water, with the result that there is an upward movement of moisture instead of a downward flow.

Prevention

The problem of a rising water table came to the front almost fifty years ago and has been engaging the attention of our scientists and engineers ever since. The measures tried for relieving the excess moisture in the past, or to be employed in future are:

1. Lining of channels;
2. Restriction of water supply for irrigation;
3. Lowering of full supply level of irrigation channels;
4. Seepage drains along canals;
5. Seepage drains away from canals;
6. Diversion of canals;
7. Surface drains;
8. Porous gallery and tile drains;
9. Pumping in local areas; and
10. Tubewell pumping.

The West Pakistan workers have, thus, experience in all the preventive and remedial measures for controlling subsoil water level. However, the subject is dealt with under the headings proposed for the Seminar.

(a) Canal lining. Canal leakage is a major cause of rise in the water table. If attempts are made to lower the water table by drainage or pumping, the canal seepage will also increase with the lowering of the

water table. In case the soil of the reach is pervious, the lowering in the water table is bound to be temporary.

Experiments on lining of channels in West Pakistan were first started in 1911 and since then various materials have been tried. Experiments on lining have been carried on with materials like oil, cement, kankar, lime, coal tar, clay puddle, crude oil, cement concrete bricks, bitumen, tar products, mastic, cement soil, bitumen impregnated fabrics, asphaltic lining, chemical lining, buried membrane, etc.

Those that have proved reasonably successful in practice are:

1. Kankar lining on the Gang Canal;
2. Brick lining on the Haveli Canal; and
3. Cement concrete lining on the Thal Canal.

The lining projects in West Pakistan embrace large canals with heavy water supply and long reaches. Recently-lined canals are the Balloki-Sulemanki Link with a total capacity of 15,000 cusecs and a length of 80 miles, and the Bambanwala-Bedian Link which is 20 miles long and carries 6,000 cusecs. Except for 30 miles of the Thal Canal where cement concrete was used, all the other canals are lined with bricks or tiles laid by hand and made impervious with different courses of cement sand.

The experience of lining in our country has not been too happy. The area around the Haveli Canal has shown a rise in the water table. The rise is of the order of 0.1 foot a year which, although less than in areas near unlined canals, is still regular. The same conditions have been observed on the Thal canal, where shotcreting of lining with 1/2 inch of cement sand (1:3) proved effective in reducing the seepage.

The main causes of failure of lining in our part of the world[5] are:

1. Settlement or swelling of sub-grades resulting in cracks in lining and/or compacted soil;
2. Deterioration due to salt action; and
3. Cracking due to seasonal changes.

The preventive measures adopted are:

1. Compaction of soil at a moisture higher than optimum and lower than the liquid limit, and adoption of a stable soil slope;

2. Adoption of an impervious lining (which has not so far been possible to achieve economically), or providing a filter behind the lining to take up excess moisture and instead of passing it into soil, pass it down into subsoil. This filter took the shape of 2-inch layer of sand installed at sides and connected to subsoil sand by 1-foot diameter holes filled with sand;

3. Use of pozzolanic cement or addition of 'Surkhi' to cement for resisting salt deterioration. Shellamac R.C. 3 or double-boiled linseed oil can be used on the portion where capillary water is expected to appear.

4. Increase in the thickness of course to have sufficient strength to expand and contract with change in temperature.

Without going into the details of cost, it can be stated that lining a channel in the first instance is fairly cheap and successful for checking seepage from canals. However, lining of old channels is four times more expensive, even if we do not take into account the nonfeasibility of long canal closure for construction at the cost of not producing crops. Moreover, it would be practically impossible to undertake lining of channels running through high water-table areas.

(b) Surface. With a view to expeditiously getting rid of the water collected through floods, overspills and drains, and bringing back the affected area to cultivation, a very serious attempt was made during the period 1908-18 by the construction of surface drains in West Pakistan. Heavy rains in 1933 and 1935 in the most productive districts had an adverse effect on the water table. To meet the situation, a large number of new drains were proposed and constructed from 1936-1941. Prevention of seepage from canals was a natural precaution and in some cases open drains were constructed along the canals as a protective measure for the area under cultivation. Such attempts have, in reality, been going on for the last 50 years, although the drains provided were hardly of the type which could serve as seepage drains. We, therefore, call such a drainage system a "storm-water drainage system."

There is no doubt that surface drains are expensive in first cost and subsequent maintenance, when considered from the viewpoint of the total discharge removed. In fact, a number of experts have advocated abandoning the use of surface drains in favor of tubewell pumping. The slope of the country being very flat (of the order of one in 5,000), these drains often have to be made to flow by pumping. Further, a part of the water removed from the upper reaches of the drain is absorbed lower down, a smaller quantity reaching the river. In an attempt to give relief to the flooded areas through drains, greater damage is caused. In spite of all these defects, these are essential as being the only means available for expeditious removal of local collections of water, which is necessary for putting in crops at the proper time.

The absorption of water in lower reaches can be prevented by providing an outfall into the river as early as possible or by pumping into a nearby channel. Under local conditions, the cultivator can provide labor for maintenance.

The surface drainage system in general can be subdivided according

to function, based on the depth and width of the drains, into the following classes:

1. Field drains (2' wide at the top, 1.5' at bottom with 3' depth) are the responsibility of the cultivator for digging as well as maintenance.

2. The field drains are connected to the collector drains (3.5' at the top, 2.5' at bottom and 4.5' deep), which are also the responsibility of the cultivator.

3. The collector drains discharge into subsidiary or branch drains which are constructed and maintained by the Government.

4. The subsidiary drains are part of the main drainage system and a number of main drainage systems are in operation.

The drainage systems are in relation to the various canal systems. The following table gives some details about the various types of surface drains for the canal systems of the central district of West Pakistan.

TABLE IV

The total mileage of drains in the Province is given under the following categories for the year 1952-53:

Canal	Length of Drain Canal in Miles			Remarks
	Seepage	Storm-cum-seepage	Storm water (Miles)	
Lower Chenab East	22	490	3	
Lower Jhelum	278.5	-	391.8	Every seepage drain is seepage-cum-storm water.
Upper Jhelum	107	141	114	
Upper Chenab (including Lahore Division)	519.5	38.2	202.7	
Central Bari Doab	33.8	-	-	
Nili Bar Circle	-	-	-	
Haveli Canals	1.2	1	-	
Lower Chenab West	115.0	184.7	17	
Derajat	3.4	29.2	-	
Lower Bari Doab	-	12.2	382.6	
Total	1080.4	896.3	1111.4	

The distances between the drains, of course, depend upon the soil type. With this drainage system the water table is not depressed to any appreciable extent, but by continuous removal of water from the natural surface of the soil through the soil profile and finally to the drainage system, it is possible to grow successfully all types of crops.

The cost of an open drainage system as that existing on the Chakanwali Reclamation Farm is shown in Appendix I.

(c) Improved irrigation practices. As already stated, according to Kennedy, 25% of the water supply may be wasted on the fields due to inefficient practices. This figure is not far from the truth. The levelling, grading and layout leaves much to be desired in irrigated fields. The water courses are, as a rule, very badly maintained; their banks and berms are full of weeds, resulting in heavy transpiration losses. Inlets into the fields are also defective. There is a great deal of seepage from the beds and sides of water courses. Improvement in this respect can only be expected if an extensive extension service is provided.

In the fields under reclamation operations, the importance of proper grading and layout is emphasized from the start. All fields are divided into four equal parts by 'dykes' one to two feet high. The water course comes right to the middle of the field, so that each portion receives irrigation from a separate inlet. After each season the dykes are reconstructed with fresh soil.

Under the existing system of water distribution, the management of water lies in the hands of a cultivator after it leaves the Government water-course. Each square of land is given a certain number of 'pahars' (three hours' supply of water), depending upon whether the turn is fortnightly, weekly or every ten days. Usually in the turn (Wari) of ten days, a 12-hour supply is allowed or, when the Wari is fortnightly, ten hours of irrigation are permitted for 25 acres. In the Punjab an ideal economic holding is 12½ acres for a family of five members, consisting of two adult males, one adult female and two children. A cultivator family must complete the irrigation of the holding within the specified period so as not to encroach upon the rights of other cultivators sharing the supply from the same channel.

The cultivator in this country has adopted that size of compartment in various tracts according to what has suited his soil, irrigation, economic and social conditions. In the well-irrigated tracts, the source of water supply is small but continuous. Instead of waiting for his turn, the cultivator considers the moisture requirements of the soil and uses his independent source of water. In the canal colonies, water is available on a fixed turn and, considering the necessary labor and time, the cultivator always arranges the various agricultural and irrigation operations accordingly. He divides an acre area into as many as eight compartments, or sometimes into a smaller number.

Whenever the discharge in the water course is high, as is the case

in the upper reaches of a channel, he can easily irrigate his fields and avoids manipulating too many water inlets by decreasing the number of compartments. In the well-irrigated areas, t size of the compartment is kept very small, sometimes as low as 1/16 of an acre, to effect proper irrigation with a discharge from a Persian wheel. The cultivator in the canal colonies, however, finds this practically difficult and economically unsuitable. It will be observed in Table V that the average cultivator has to put in four man-days to provide dykes (bunds) and small water-courses to make 16 plots in an acre. He would, therefore, require 50 days to complete the job, or 25 days when he has an adult son. The job of making bunds and water-courses must be repeated twice a year. A good deal of supervision during every irrigation is also necessary.

TABLE V

Development of a One-Acre Tract

Size of compartment in acres	Total length of land in feet	Total length of small water-courses	Man-Days required to construct bund and water-course	Land thrown to waste by bund and water-course (Sq. Ft.)	Land Lost, per cent
1	800	-	0.75	1320	3.00
1/2	1100	220	1.25	2200	5.00
1/4	1320	220	1.50	2530	5.80
1/8	1760	220	2.00	3190	7.30
1/16	2200	880	4.00	5500	12.60

Apart from the labor requirement consideration, a cultivator has great difficulty in carrying out operations like ploughing, interculture, planking, etc., in a small compartment and most probably would not accept the change even if it would be better irrigation practice. Bunds and water-courses occupy a considerable area which remain out of cultivation, giving no direct crop return to the cultivator.

With a flow of $1\frac{1}{2}$ cusecs of water, the time generally at the disposal of a cultivator is about three hours for first irrigation and two hours for subsequent watering for an acre area. It is evidently impracticable to operate more than eight inlets. The water duty in the area is 264-350 acres per cusec and is already very high, resulting in the creation of a huge problem of soil salinity.

Economy in the use of irrigation water by reducing the size of basins can be considered from another angle which is more important than simply fixing up an economical water duty. It has been experimentally verified that in sun-dried soil the depth up to which a profile may be wet is as given below:

Depth of Water (in inches)	Depth of wet soil profile (in inches)
1	9.6
2	14.4
3	19.2
4	24.2
5	33.6

If, however, the same intensity is repeated, say bi-weekly, the depth wet would be more. Therefore, it is evident that under lighter irrigation, if repeated very often, the moisture may reach those lower layers which could contain salts, and then if the soil is not kept covered the year round, the salts would be brought up under the effect of surface evaporation. Naturally, a 12-month covering must be provided on the soil to reduce the amount of surface evaporation, which would otherwise help in the appearance of salts at the surface. This can only be achieved if 200% cropping intensity is adopted, which would naturally increase the water depth per year.

The irrigation water is not at the disposal of the farmer at all times under our present system of distribution from canals. Therefore, he cannot make use of lighter irrigation after smaller intervals. Lighter irrigation can only be made use of if the water distribution is done on a volume basis, the source being available to the cultivator throughout the year on demand. As long as our present Wari system exists, the cultivator is bound to use a higher depth of water in a single irrigation. Therefore, with four inches of irrigation he will wet the soil profile to a depth of two feet if there is only one irrigation, and to a deeper depth if it is repeated after a week or ten days.

During the year 1950 there were 11 inches of rain during one week. There is always a possibility of such a downpour, which may wet the soil profile to a very great depth. In cases where the water table is at ten feet the entire soil profile may be raised to field capacity. If the soil is then allowed to remain uncovered, as is our present practice--of having 33% of the area during winter and 66% during summer left fallow--the salinity is bound to increase at the surface.

For 200% intensity of cropping the area will be kept under crop and given irrigation for a period of at least ten months, leaving the remaining two-month period for sowing and harvesting. Calculations for water duty would be as below:

1. Depth for each irrigation ..... 3 inches
2. No. of irrigations for ten months.. 30
3. Total depth of water required..... 90 inches

= 97.5 acres water duty

It is clear from the above that in order to achieve 200% cropping intensity under a canal irrigation system, the water duty would have to

be far lower than practiced at present. No reduction in the water applied is possible until the source of supply is at the command of the farmer.

In America the irrigation stream is large and outtake openings are long, which facilitate irrigating the fields, usually in long strips which sometime cover large areas.

Spreading of water equitably over a field is of primary importance, as it saves water and helps in keeping the soil in proper moisture. In an experiment at a departmental farm the flooding method was compared with the syphon system. The results achieved after the first year's experimentation showed a moisture conservation of 50% through the use of syphons. The economic aspect of the experiment is still to be worked out.

Before making any recommendation to cultivators, there are other factors for consideration. A cultivator in a democratic country will have to be convinced before making any change or improvement on his land or in the system of his working. When a change recommending a reduced size for the compartment is made, it is not possible to convince him because he has more arguments in favor of existing practice than a new practice would offer him.

Improvements can, however, be expected by the following:

1. Proper grading of fields;
2. Increase in the irrigating stream in a watercourse; and
3. Wider water inlets instead of short-cuts for irrigation.

These would no doubt help in allowing the irrigation water to move in the form of a sheet rather than a small stream and would really be advantageous to the cultivator.

Remedy

(a) Drainage. All the remedies for a rise in the water table tried so far have already been listed. The remedial measure for salinity would naturally include copious irrigation, which apparently is likely to be considered as promoting a high water table. Experiments on leaching out the salt without a surface drainage system were undertaken in an area with a high water table (within five feet), and the effect on subsoil water level showed that although there is a seasonal rise in subsoil water level, yet it subsides during the dry period which follows in winter.(8) On the other hand, the soil was brought back to cultivation and it gave a very high yield of crops during the period of reclamation as well as in subsequent years.

However, one question is very important. How far could such a temporary relief measure keep the land under production when it reverts to

its share of normal water allowance, which is roughly one-sixth of the water allowed during the period of treatment? It is our experience that with a water table depth of five feet, the land develops salinity after three years under the prevalent high water duty in Pakistan areas. Land having the water-table five to ten feet or deeper may remain under production for five and eight years, respectively. It is thus essential that for better salinity control, as related to high water table, drainage should be adopted so that the subsoil water level is kept at a depth of ten feet or more.

The above conditions cannot be achieved by surface drainage or by an open deep drainage system, due to difficulties in maintaining in proper shape the drains constructed in alluvial soils, where there is a great tendency of the bank sides to fall in and of weeds to grow due to improper slopes. There are two alternatives--tile drainage or tubewell pumping systems. It has already been mentioned that we have experience of porous gallery, tile drains and mole drains, which are either costly or not so efficient. The most modern method of tubewell pumping is our next choice. It would be out of place to make a comparison between the various systems for drainage, as this is a vast subject which should have a separate reference.

In order to provide an efficient means of drainage there is hardly any one method applicable in all cases. Future progress in West Pakistan must, therefore, be based on a combination of tubewells, surface drainage and local pumping, whichever combination is feasible.

Tubewells were first used as an anti-waterlogging measure in 1911 and 1917, when 15 tubewells with a gross discharge of 28.5 cusecs were sunk. However, the discharge rapidly fell off and there was no appreciable effect on water table. The experiment was finally abandoned in 1936. A couple of other experiments with three and five tubewells were also conducted but did not give encouraging results. These failed because the discharge pumped was too small.

With the construction of the Rasul Hydel projects, large-scale installation of tubewells was undertaken, but these were placed along the canal and thus helped only in interception of seepage. Initially these were located only 60 feet away, but as the experiments proved that 80% of the discharge pumped came from the canal itself, the distance was increased to 600 feet and more.

With the attainment of independence, the canal-irrigated areas of West Pakistan were faced with a very serious shortage of water supply. There being no hope of increased water supply from rivers, the only alternative sources left were surface storage and ground water reservoirs. For immediate irrigation and reclamation needs tapping of the ground water reservoir was the only solution. Prior to undertaking a large-scale program of tubewell sinking, it was essential to have hydrologic and ground water data. In 1954 a Ground Water Development Organization was set up in cooperation with I.C.A. to make ground water observations, undertake

hydrologic studies, carry out soil surveys and test the quality of subsoil water. Data have been collected for areas lying between the rivers Ravi and Chenab and between the Chenab and the Jhelum. As a preliminary measure, based on the data available, it is proposed to install 1800 tubewells over a period of three years. Tubewells would serve a dual purpose--that of supplementing the existing meagre supplies from river canals and dewatering the area. As has already been pointed out, surface drainage would be provided wherever necessary.

Provision of surface storage would no doubt help in making up the deficiency in normal irrigation supplies and thus reduce soil salinity. However, it is to be kept in mind that this would not help in combatting waterlogging. The tubewells provide, on the other hand, not only additional water for reclamation but also a system of irrigation and subsoil water control which lends itself to easy manipulation. The main advantages listed by experts in favor of tubewells are that they would develop irrigation water from the ground water reservoir, a source that has been relatively neglected so far. The cost of the water would be sufficiently low. Tubewells do not take valuable land, as in the case of surface drains, and the construction time would be shorter. The cost-benefit ratio would also be favorable. Thus, a tubewell irrigation supply system is expected most nearly to meet all requirements for successful control of salinity and waterlogging in West Pakistan.

(b) Land treatments-leaching-amendments. There is no doubt that rise of salines to the surface is accelerated in areas of high water table. Leaching with copious supplies of water is the only remedy known to soil science for the removal of harmful salts from the root zone of crops. The method evolved by the Land Reclamation Department, the one which has been in vogue for the last 20 years or more, consists of washing down the salts by excessive leaching and rice cultivation during summer, when enough discharge is available in the rivers, followed by a leguminous drop in winter to restore nitrogen balance. The reclamation water supply at 45 acres per cusec is made available for this purpose during summer. Evidently the successful leaching down of salts depends upon the continuous movement of water from the soil surface toward the water table.

While proposing measures to check the rise of subsoil water, the additional water supply provided for reclamation was considered to be a contributary cause of accretion of subsoil water and, as a consequence, reclamation of saline lands in high water table areas was suspended. Experiments on a field scale conducted from 1951 to 1953 on the Lower Chenab Canal system already referred to, however, showed that the rise in the water table during the reclamation period was seasonal and that the water table receded after the cessation of the reclamation supplies. It was also observed that there was no rise in the water table, even if no field drainage was provided, if the water duty was raised to 60 acres per cusec.

At Chakanwali Reclamation Farm, where saline lands existed with a water table depth of one to four feet, shallow drains three to three and

a half feet deep have proved very helpful in maintaining the water table under heavy leachings. It has been possible to produce normal crops on more than three-fourths of the total area (3645 acres), and about half of the area has been completely reclaimed. The average yields of crop obtained compare favorably with those of adjacent normal lands. Apart from the above, fruit trees have been successfully tried and are giving normal yields.

The soils of the high water table area are characterized by high sodium salts and high alkalinity. Such soils consist of laminated surface horizon overlying a deep layer showing a columnar or prismatic structure. The rounded tops of the columnar elements and the vertical sides frequently carry a white deposit of salts. Such lands respond to treatment with gypsum during the leaching operation. The sodium being very high in the clay complex, the replacement by calcium is effected and the sodium clay, which is de-floculated and impervious to water, is changed to calcium clay, which is floculated and thus pervious.

B. Surface Accumulation From Fertilizers, Subsoil, and Irrigation Water

The use of artificial fertilizer has not been adopted on a large scale in West Pakistan. Therefore, contribution from this source to the increase of salines in soils is practically nil. The participants from other countries where this forms a substantial source of addition to salines are in a better position for contribution.

A brackish subsoil water table exists at some places and may be a minor factor in salt accumulation under certain conditions. Except in the case of areas having a water table within five feet of the soil surface and still under cultivation by irrigation from a canal system, the first ground water is brackish and, therefore, quite a good part of the area which is being irrigated from shallow wells is likely to develop salinization. These waters are comparatively inferior to river water and are not fit for raising crops under the usual high water duty practiced in the canal-irrigated systems. Cultivators usually supplement their meagre canal supply by lifting water by a Persian wheel. For the sake of illustration, some data are presented comparing first waters from various sources in one of the reclamation project areas.

Waters from almost all the rivers have been used for irrigation and are of excellent quality. In fact, the average salt content of river water is 19 parts per 100,000 and in no case does it exceed 30 parts per 100,000. On the other hand, drainage water is not always fit for irrigation purposes and is many times inferior to river water. A comparison may be made from the results given in Table VI.

TABLE VI

SUMMARY OF WATER ANALYSIS

SUMMARY OF ANALYSIS OF RIVERS AND DRAINS OF WEST PAKISTAN

Lab. No.	Date sampled	Source	MILLIEQUIVALENTS PER LITRE								PPM D.S.	$E_{c}x10^{6}$ at 25°	pH	Res CO_3 me/l	S A R	Salt (index)
			Ca	Mg.	Na	CO_3	HCO_3	Cl	SO_4	Total Cations / Anions						
C.W.										RIVERS						
3646/57	Oct.57	Kabul River	1.70	1.28	0.36	0	2.46	.30	3.50	3.34	190	325	7.5	0	.3	-48
4290/57	Nov.57	Indus at Attock	1.78	.92	.29	0	1.92	.35	.72	2.97	200	270	7.6	0	.2	-41
4300/57	-do-	Indus at Chacharan	2.14	.76	.65	0	2.29	.40	.86	3.55	228	329	7.7	0	.5	-48
4288/57	-do-	Jhelum at Mangla	1.74	.46	.21	0	1.82	.15	.44	2.41	140	230	7.4	0	.2	-39
4284/57	-do-	Chenab at Marala	1.84	.36	.64	0	1.56	.25	1.03	2.84	168	270	7.8	0	.6	-42
4312/57	-do-	Ravi at Lahore	2.30	1.03	.46	0	3.32	.30	.15	3.79	236	332	7.5	0	.4	-51
4294/57	-do-	Sutlej at Gandasinghwala	1.84	.41	1.15	0	2.18	.40	.82	3.40	228	340	7.9	0	1.1	-42
										DRAINS						
744/57	Mar.57	Mona Drain at RD-131000	1.76	2.04	5.14	.72	5.46	1.37	1.39	8.94	488	790	-	2.38	3.7	-35
828/57	-.	Nabi Shah Drain	1.20	3.46	13.83	1.09	8.37	4.01	5.00	18.49	1160	1740	-	4.80	9.0	-14
1072/57	Mar.57	Bhakhar Drain	1.66	3.29	6.68	0	3.33	5.30	2.99	11.63	756	1150		0	4.3	-44
5254/57	Nov.56	Jaranwala Mian Drain	1.00	2.56	10.96	2.94	3.32	2.32	5.94	14.52	832	1280	8.8	2.70	8.2	- 3
801/57	Mar.57	Dhilwan Drain	.95	1.25	10.09	1.27	5.82	1.17	3.99	12.29	668	1020	-	4.89	9.6	- 7
		Rechna Drain at RD-56000	-	-	-	-	-	-	-	-	-	1100	-	-	-	-
		Salar Drain	-	-	-	-	-	-	-	-	-	646	-	-	-	-

(a) High salt content of soil with little or no subsoil drainage. In the case of West Pakistan, the major factor responsible for soil surface salinization is the high salt content of the soil. It is considered that the major portion of the Indus Valley, which constitutes West Pakistan, was once a gulf which has receded to the south as a result of the silting up of the basin due to the delta--forming processes of the Himalayan rivers. A portion of sea salts left in the profile during drying up of sea water intermixed with the soil.

Along the western margin of the Indus Alluvium, later tertiary (Manchhar) rocks are found containing remains of mammalia and precisely resembling the Siwalid formation. In the Indus region, the distinctive features of the stratum of the Siwaliks passed downwards into Miocene marine beds. In the lower Sind, the Manchhar formation itself becomes interstratified with beds containing marine shells, and not very far to the west there is a very thick marine pliocene formation in Baluchistan, so that there is evidence in abundance of the sea's having occupied the area in later tertiary times.(9)

While weathering produces many complex compounds, it brings about considerable simplification as well; such cations as calcium, magnesium, sodium and potassium, as well as many others, get dissolved in water, which is universally present with rocks and parent materials, in the course of their transportation. These cations when in solution are generally associated with such anions as chlorides, sulphates, bicarbonates, carbonates and the like. These salts may be the result of soil-forming processes that took place initially at the site of rock material or later on at the site of alluvial deposits, which now constitute the soil profile itself. The view is supported by Oldham(10) that where water was used on a smaller area, the salts were washed down to a certain depth and formed a zone of salt accumulation. Later, with development, the intensity of irrigation was continuously increased as the cultivators tried to grow crops on larger areas with the same quantity of water. An examination of the intensity of irrigation in the Lower Chenab Canal area showed that in a 30-year period the intensity (percentage of culturable commanded area irrigated) increased during summer from 25 to 45. At the same time, depth of water applied per acre during summer decreased from four and a half feet to two and a half feet.(1) This tendency to mature more crops on less water has been the curse of soils in this part of Pakistan. With the decrease in depth applied per acre there was a general tendency for the salts to move toward the surface, as the water applied was insufficient to counterbalance evapo-transpiration.

The net result of practicing extensive irrigation in preference to intensive irrigation has increased movement of moisture and therefore of salts from various depths in a soil profile to the land surface. This is in reality the major cause of salinization in lands with a deep water table. However, the present position could not be helped because of the Government's having already tapped most of the feasible water resources for enhancing the water allowance, and it would take many a decade to build up any

storages to supplement our existing supplies. On the other hand, the cultivator cannot restrict his efforts to practice extensive agriculture because of the heavy demands placed on him for producing more and more for the increasing population.

Prevention

Land classification before construction of systems. In the light of the description of the formation of alluvial deposits in West Pakistan given in the foregoing, it is obvious that the possibility of land deterioration due to salt accumulation cannot be precluded in the case of any single area. In fact, it is necessary to study and take account of not only the water requirements of crops but also the water requirement of the soil itself with respect to salinization and alkalization. The present water duty of three cusecs per 1000 acres practiced in our country is abnormally low, the water allowance in advanced countries of the world being three times this. Soil surveys and land classification, therefore, are essential prerequisites to construction of any irrigation system. In the past our irrigation systems were mainly based on sound financial returns and on feasible revenue-earning prospects. This has been the main basis for proposing any canal irrigation project and, although nature helped us in most cases, yet quite recently there have been instances which may not be considered as failures but are not very favorable propositions. In reality, soil survey and land classification not only help in planning crop patterns and assessing total water requirements, but also are a necessary step for installation of drainage systems, which, although not given proper importance in the early twenties, are now considered to be an essential part of an irrigation project.

A pertinent example of the harm caused by the absence of a soil survey can be cited in the case of the Lower Bari Doab Canal system, where, on introduction of canal irrigation, it was found that cultivators were not prepared to take water for an area of about 50,000 acres which was highly alkaline, devoid of all vegetation, and scattered in two important administrative districts.

Soil surveys of a utilitarian nature were carried out in a part of the province, namely Thal, to make provision for the solution of reclamation problems on saline and alkaline lands. As a result of a preliminary soil survey of the Thal Project in 1938-40, followed by a detailed examination of one soil profile for every 1000 acres and subsequent examination of the soil samples after every foot interval of the soil up to a depth of ten feet, the soil of this area was classified into the following categories:

		Acres
1.	(a) Flat land free from sand dunes lying over salt-bearing soil	336,000
	(b) Flat land as in (a) above but highly alkaline	166,000

		Acres
2.	Flat land mixed with sand dunes occupying less than 40% of the area	588,000
3.	Flat land mixed with sand dunes occupying more than 40% of the area	636,000
4.	Flat wind-blown sand over alluvial sand	1,106,000
5.	Red clay containing salts or hard clay alkaline in reaction	140,000

Practically the whole of the Khushab area in the northeast corner of the Thal tract falls in category (5) above. Lands under category (5) are further classified into two main types: (a) with hard soil throughout the soil profile, and (b) with surface layers permeable but underlain with an impervious stratum.

The latter type can again be sub-classified into two sub-types, viz. (a) medium textured top-soil and (b) surface layers exceedingly light and covered with continuously moving sand dunes.

A major part of the Khushab area represents type (a) and has very deep soil profiles. The lands of sub-type b (a) were easily colonized, as these offered bright agricultural prospects and immediate returns. The land of subtype b (b) area, however, is a problem for the colonization agency as well as for the irrigation authorities, as the irrigation channels passing through such tracts are filled with wind-blown sand.

In type (a) the problems are the high alkalinity and low permeability of the tight soil. Stagnation of water occurs after every application of water by irrigation or a shower of rain, thus producing surface waterlogging.

The soil of type b (a) presents the problems of a perched watertable, which may be called a false waterlogging condition, as well as of salinity. In the case of b (b), the stabilization of moving sand dunes and the building up of the soil profiles in the top root zone of crops are the problem, apart from the salinity and perched water table hazards.

With the creation of the Ground Water Development Organisation, soil surveys and land classification form an integral part of the investigations and are being conducted on an international system. This subject is going to be discussed in greater detail in one of the sessions of this Seminar.

From the results of lysimeter experiments and field trials it is observed that in high water table areas it is necessary to ensure ten to twenty feet of drainage, while in the case of an area with a low water table, drainage provided may be 5 to 10 feet. Washing down of salts after their appearance on the soil surface is more difficult and involves

greater cost, labor, and larger quantities of water. If suitable drainage is provided when the salts are in a lower soil layer, they can be carried away more efficiently and at lesser cost. Crop patterns worked out and recommended for adoption in areas with a low water table to keep a downward trend of soil moisture are:

1. Chari Guara-Wheat-Maize-Wheat
2. Maize-Wheat-Bajra-Turnips
3. Maize-Wheat-Chari-Berseem
4. Chari Guara-Wheat-Cotton-Berseem
5. Guara (green manured)-Wheat-Maize-Senji-Sugarcane
6. Sugarcane-Sugarcane
7. Chari Guara-Gram-Cotton-Sugarcane
8. Maize-Wheat-Chari Guara-Gram-Cotton-Berseem
9. Sugarcane-Cotton-Maize-Senji

The first two rotations have 200% cropping intensity and by keeping the soil covered throughout the year are expected to keep the surface evaporation low. These are, however, suitable for areas where salts exist at a great depth. We have data to show that sugarcane is cultivated with advantage when salts are two feet below the soil[11] surface. Rotation No. 6 is, therefore, adapted to soils where salts occur near the surface.

Cotton in rotations 4, 8, 7 and 9 is to receive a higher depth than normally applied. Experiments in the field and laboratory trials indicate that this crop is capable of withstanding fairly heavy depths of water without substantial decrease[12] in yield. Growing of rice on 8% of the area is also recommended. It should be rotated in such a manner as to insure that every field carries this crop within a suitable period.

In high water table areas, rice growing has to be a regular feature. Due to nearness of subsoil water, which is usually highly impregnated with salts, rice should occupy 25-33% of the area every year. The rotation suggested for such areas is:

1. Rice-Berseem-Chari-Guara-Wheat-Maize-Senji
2. Rice-Lentil-Chari Guara-Wheat-Bajra-Senji-Sugarcane
3. Rice-Shaftal-Chari-Moong-Oats-Guara-Wheat

4. Rice-Berseem-Sugarcane-Sugarcane

5. Rice-Gram-Guara-Toria-Sugarcane-Chari-Senji

Crop patterns have been worked out on these considerations and it is expected that these can be adopted with a water allowance of 150 acres per cusec.

The general reclamation procedure for saline soils is based on the application of enough water to ensure necessary leaching. This is a sort of temporary relief measure and cannot be considered as adaptable in long-term development projects. To deal with the problem on a more scientific basis, development projects have been proposed on vast areas, of which details of two were described in the Near East Meeting on Irrigation and Drainage Practices. Further progress has been made in this respect by formulating additional projects covering an area of 1.5 million acres. Some particulars are shown in Table VII.

Remedy

Drainage if necessary. The surface drainage system having already been discussed in the foregoing for lands of high water table, the only facility for drainage in deeper water table lands is through tubewells. In cases of soils with deep water tables, drainage is advantageous although it may not be necessary in the initial stage of development, as has happened in the case of West Pakistan, when water tables were as deep as 50 feet or beyond. However, drainage facilities are necessary when the water table reaches within 10 feet to 15 feet of the natural surface. It is not recommended that the water table should be lowered to a very great depth if the existing subsoil water level is high. Tubewells have to be employed for providing additional water for increasing the water allowance, which in turn would keep the soil profiles free from salt accumulation within the root zone of crops. The development of ground water is very valuable for a country like ours, to keep the land under continuous cultivation and also to meet the drainage requirements of the soil. With enhanced water supply the cropping pattern should be so proposed that after meeting plant requirements there should be drainage, as already explained.

However, there is an important point in this drainage-cum-irrigation use of tubewells. The quality of tubewell water should be suitable for irrigation purposes; otherwise the tubewells would serve the purpose of drainage only, without any increase in water resources. The work of testing water quality in central areas is in progress, in cooperation with I.C.A.

Land treatment, leaching amendment. The method of soil treatment would be the same as for high water table areas except that drainage would not be emphasized to the same extent. Prior to independence, the general belief was that a field capacity zone existed in the soil profile at a depth of about six feet, and the salt, if once pushed down to a depth of

TABLE VII

Area	Culturable area	Supp. water requirements (Cusec)	Approximate percent of area with depth to water table in feet below land surface			
			0-5'	5-10'	10-15'	Over
1	2	3	4	5	6	7
Rechna Doab						
Jaranwala	83,200	334				
Pindi Bhattian	8,000	56				
Chichokimallian	7,000	27				
Shahkot	231,000	1,000				
Kgangah Dogran	100,000	605				
Hafizabad	60,000	210				
Zafarwal	220,000	788				
Shadman	35,000	158				
Sangla Hill	110,000	420				
Beranwala	85,000	336				
Thatta	22,000	158				
Harse Sheikh	100,000	394				
Total	1,061,200	4,536	11.7	52.8	22.7	12.8
Per cent			5.8	62.2	22.2	9.8
Chaj Doab						
Maghowal	35,000	111				
Lalian	300,000	1,470				
Total	335,000	1,581				
Sind Sagar (Thal)						
Muzaffargarh	85,000	299				
Bari Doab						
2-L Dhaya	19,250	68				
Renala	96,500	347				
Total	115,750	415				
Total, 17 areas	1,597,450	6,831				
Use	1,586,000	6,830				

Number of Wells 1,800 Avg., 3.80 cusecs each

ten feet or more, would not return to the soil surface.[13] Later work in the field and lysimeters have revealed that under our conditions the surface evaporation can cause upward movement of moisture from depths greater than ten feet. It is therefore not feasible to return to the previous water allowance after completion of reclamation, and measures have to be adopted to permanently increase the water supply to cultivators for irrigation. Hence the recent projects of land development by the Soil Reclamation Board.

A reference has been made to a saline-alkaline area on one of the canal systems. This area resisted all attempts at development and management until a deeper insight into the soil complex was obtained through experimentation and basic research. Apart from high exchangeable sodium, the soil was so compact that nothing could be grown and water would not percolate through it. Treatment with gypsum resulted in improvement but not to the desired extent. Subsequently a legume, Sesbania Aculaeta, came to the rescue, being of great help in opening up the soil profile by its deep-rooted system, and ameliorated the nitrogen-hungry soils. The management of this soil type is different from the handling of other problem soils during the first two years when Sesbania Aculaeta is grown. The rest of the treatment is the same as in the case of typical saline soils. With this amendment, the rate of water percolation improves. If gypsum is applied as a chemical amendment, the results are obtained in a shorter period. A six-year period is required for proper development of this soil.

The progress achieved on this project is given below:

TABLE VIII

PROGRESS OF DEVELOPMENT OF ALKALINE/SALINE SOILS ON LOWER BARI DOAB CANAL

Name of distributary	Alkaline/saline area	Area taken up for development				Area developed during				Total area taken up to date	Total area developed up to date	% area developed so far on area taken up
		Before 1947	1947-49	1952	1953	1953	1954	1955	1956			
1	2	3	4	5	6	7	8	9	10	11	12	13
	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	(ac.)	Units
4-R	116	-	-	-	-	-	-	-	-	-	-	-
6R	440	138	-	70	13	111	-	29	6	221	146	66
6-AR	75	-	-	-	-	-	-	-	-	-	-	-
Bahab	51	-	-	-	-	-	-	-	-	-	-	-
7-R	25	-	-	-	-	-	-	-	-	-	-	.
9-L	11530	4633	590	1655	784	3067	196	465	398	7662	4935	53
9-AL	921	160	54	55	25	180	20	12	15	294	227	77
10-L	2377	-	183	-	109	38	50	27	15	292	131	45
11-L	1406	562	-	200	50	226	-	50	72	812	348	43
12-L	2179	286	142	597	182	268	49	91	214	1207	622	51
15-L	9757	-	-	606	1049	-	57	170	367	1655	594	36
15-AL	38	-	-	-	-	-	-	-	-	-	-	-
16-L	561	-	-	100	93	-	-	9	56	193	65	34
10-R	8697	-	-	-	-	-	-	-	-	-	-	-

The basic requirements of a program for treatment of saline and alkaline soils on a permanent basis, as worked out after research and trials extending over almost a quarter of a century, are: (1) augmentation of existing irrigation supplies, (3) provision of adequate and efficient drainage, and (2) adoption of scientific cropping patterns based on a detailed soil survey and land classification.

APPENDIX I

EXPENDITURE STATEMENT FOR CONSTRUCTION AND MAINTENANCE OF FIELD AND COLLECTOR DRAINS

CONSTRUCTION OF DRAINS

1. FIELD DRAINS

Length		3300 feet
Width		Bottom 2 feet, Top 4 feet
Depth		3 feet
Earth work.....		29700 cubic feet
Cost of Earth work at Rs.6/9/- per cu.ft..	Rs.	195/-/-
Cost of Field Drains for 15 Acres.....	Rs.	195/-/-

2. COLLECTOR DRAINS

Length		440 feet
Width		Bottom 3 feet, Top 5 feet
Depth		3.5 feet
Cost of earth work.....	Rs.	40/-/-
Cost of collecting Drain for 15 Acres.....	Rs.	40/-/-
Cost of Collecting Drain per Acre	Rs.	2/11/-

COST OF FIELD AND COLLECTING DRAIN PER ACRE Rs. 15/11/-

MAINTENANCE OF DRAIN

One man can maintain 15,840 feet of field drains.
At 220 feet per acre, this amounts to field drains on 75 acres.
At Rs. 45/-/- per month, one man for a year gets Rs. 540/-/-.
Thus, the cost of maintenance of field drains is Rs. 7/8/- per acre per year.

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CAUSE OF AND REMEDIES FOR EXCESS SALINITY AND ALKALINITY IN IRRIGATED LANDS

Formal Discussion
by
Engineer M. Ayazi, Assistant Director
Agricultural Engineering Department, Ministry of Agriculture
Iran

The practices of irrigation and drainage of arid-region soils are closely related. The needs for drainage of irrigated soils depend on the depth of irrigation water applied, the climate, depth of rainfall, and soil properties, both physical and chemical. Soil texture, structure, compactness and permeability are classed as physical properties. The quantities and qualities of soluble salts in soils represent chemical properties. These and other chemical properties are influenced by irrigation and drainage practices in arid-region areas. There is an unfortunate tendency in irrigated regions to talk freely about irrigating orchards and grain, forage and other crops, and little or nothing is said about irrigating the soil. Irrigation practices are of course influenced by the crops grown, but the soils are the dominant influencing factors.

Sources of Excess Water in Soils

In irrigated areas of light annual rainfall (10 inches or less), irrigation water from two major sources causes the rise of the water table and the waterlogging of root-zone soils. These sources are: (1) Seepage losses from irrigation canals, and (2) applications of excessive depths of water to the irrigated lands.

Control of Excess Water Sources

It is very important to progress in arid-region agriculture that we develop efficient and economical control of the sources of excess water. The two dominant water sources that we should learn to control, as stated, are canal seepage losses and excessive water applications to the land.

Lining canals reduces seepage and waterlogging

During the quarter century past, there has been great progress in the development of materials for and methods of lining canals to reduce or prevent seepage losses. Concrete lining is very favorable, although high in first cost. The different agencies have made both field and laboratory studies of many canal linings which support the conclusion that rock, concrete, clay, bentonites, asphalt, oil and many other compounds can be used successfully. It is a well-established fact that lining of irrigation canals reduces seepage losses from the canals and the waterlogging of irrigated soil.

Efficient irrigation of soils reduces water losses

One of the most important elements in world irrigation progress is to develop and use methods of water application that will enable irrigators to fill the root-zone soils of their farms to full capacity with minimum losses of water by surface run-off or by deep percolation.

Reasons for Drainage of Irrigated Lands

As a general rule, arid-climate soils contain larger contents of soluble salts that retard plant growth than do humid-climate soils. The fundamental reason for the difference is that in humid-climate soils, the soluble salts are leached out of the root-zone soils by the rain water and the waters from melted snow. In some arid climates, the rains do not sink deep enough to go through the root-zone soils and hence soluble salts stay in the soils.

Irrigation, Drainage and Land Reclamation in Iran

Several of the larger modern irrigation projects in Iran, and some of the older projects, are confronted with the problems of soil waterlogging and resulting salinity and alkalinity and sterility of the root-zone soils. Very few of the managers of projects have given serious attention to control of the sources of excess water from canal seepage losses or from over-irrigation of the root-zone soils. There are new irrigation projects in Iran in which the interrelations of irrigation and drainage, and also land reclamation, are of real importance. Crop losses due to soil waterlogging and to the concentration of soluble salts in the root-zone soils have in recent years been very large on several projects. Perplexing conditions have developed in the Shabankareh project area near the Persian gulf. Some other areas for which efficient irrigation practices and drainage and land reclamation are essential are listed herewith:

No.	Project Area	Ostan (Province)
1	Garmsar	Tehran
2	Ghezelhessar	Tehran
3	Sistan Area	Sistan
4	Karkheh	Khuzistan
5	Ahoudasht	Khuzistan
6	Golpayegan	Central Ostan
7	Dorodzan Valley	Fars
8	Gorgan (Gomishan)	Gorgan
9	Mahsad Area	Khorasan
10	Zayandehrud (Key Motamed)	Isfahan

The Shabankareh Irrigation Project

A brief description of the Shabankareh Project, together with a statement of plans for better irrigation and for drainage, follows:

Background information

The old men of the area say that there were in former times canals taking water from the Shapoor River to irrigate the right side area, which is a part of the area now under irrigation. There are traces of three old canals which can be seen at their intake points along the Shapoor River. One of these canals, say the old men, was called Nahr Khadjeh, and it brought water to irrigate the lands of the village of Tchahar Bordj. In the villages of Grogazy and Seconar, not far from Tchahar Bordj, there were then date palms growing, it is said; but the water table became high, and the date palms died. For a long time after that the land went uncultivated. When the lands were no longer irrigated, the water table gradually went down, the condition of the soil became better, and it was again suitable for cultivation.

Recent years

The Shabankareh Project Dam was completed in 1940 to divert water from the Shapoor River to irrigate these lands. The canals were designed and located to provide water for the irrigation of an area of approximately 25,000 acres. Irrigation was begun in 1941, but no more than 12,500 acres have been irrigated each year. During the first few years of irrigation, production of grain crops and of date palms was satisfactory. There was no regulation of the depth of water to be used by the farmers, however, and drainage was not provided for the area. The water table began to rise, some lands became waterlogged, and portions of the waterlogged area have been abandoned. It is estimated that about 6,500 acres are waterlogged because of seepage losses from irrigation canals and excessive application of water to the lands. Of approximately 300,000 date palms planted, 15,000 are dead, and about 120,000 are adversely affected and in real danger under present conditions. The total losses of crops, including date palms, due to waterlogging and salinity are approximately one-half million dollars. Drainage and land reclamation investigation was started in 1954 in this area, and a plan for a pilot project has been prepared to drain and reclaim about 2,500 acres of land.

To Show The Importance of Drainage and Land Reclamation In Iran, Some Problems with Which We Are Already Confronted Will Be Discussed:

Garmsar drainage and land reclamation project

The Garmsar area, which is situated about 80 miles to the east of Tehran, is a very important agricultural center. This area is famous for its good cotton, melons, figs and pomegranates. In this irrigated area

the farmers are confronted with three main problems:

1. The land needs to be drained because of the high water table (about two to three feet deep)

2. The land needs to be reclaimed because of salinity and alkalinity (sodium chloride-sodium sulfate-sodium carbonate)

3. The irrigation water contains a considerable amount of salt (about 1100 p.p.m.)

The salt is picked up from the rocks and soils over, or through, which the river water flows in reaching the irrigated lands.

Investigation has shown that the causes of the high water table are:

1. Excess irrigation and faulty irrigation practices

2. Water losses from canals by seepage

Fortunately, because of the existence of gypsum in the soil, it is not hard to drain the soil and reclaim the land to prepare it for cultivation. The drainage and land reclamation investigation was started in 1957 and, in addition, a soil survey and land classification are being carried on. The original plan is to drain and reclaim about 2,500 acres of the public domain land and establish a demonstration farm.

Land reclamation in Ghezelhessar area

This is the area visited by the delegates on May 13, 1958, and is described in connection with that trip.

Leaching experiment in Khuzistan area

For the establishment of permanent agriculture on some of the saline soils in the Karkheh Project area of Khuzistan, a coordinated reclamation program is essential. Leaching, drainage and other ameliorative measures have therefore to be considered as a whole. Leaching alone without adequate drainage, either natural and/or artificial, may prove detrimental rather than beneficial. Even after leaching has produced favorable results, the follow-up by sound methods of irrigation and soil and water management are the key to sustained irrigated farming on these newly reclaimed lands.

No data existed regarding the leaching and drainage properties of these soils. A preliminary plot experiment was, therefore, conducted in the summer of 1955. The saline soils on which the experiment was done had heavy to very heavy texture for most of the layers of the profile. The leaching by increasing amounts of water decreased the salt content from the soil horizons, whose depths increased roughly in proportion to

the quantity of water applied.. The maximum water applied, i.e., 120 cms. in eight irrigations, was able to leach most of the salt from about 100-130 cms. in depth of soil. The depth to groundwater changed very little, even taking seasonal fluctuation into consideration. It remained below four meters.

Two further plot experiments were conducted in winter and spring of 1956, to accumulate further knowledge on the leaching properties of soils with layers of varying textures; and especially

(a) to determine the requirements of water for leaching of soils with varying degrees of salinity when leaching is to be obtained to varying depths of soil,

(b) to study the permeability of the profile and its changes, if any, during and after the experiment, and

(c) to study the natural drainage of the area, and the rate of rise of groundwater.

Leaching by increasing amounts of water decreased the salt content from the layers whose depths increased roughly in proportion to the quantity of water applied. For example, as an average of four replicates, 50-60 cms. water (four irrigations) were able to leach the salt from the first 70 cms., 100-120 cms. or so, and 200 cms. of water from over two meters in depth of the soil (Table I). The attached graph indicates the salt movement by different amounts of application.

A test crop (barley) grown in connection with Karkheh leaching experiment No. 1 (KL1-1955) showed a significant correlation of the growth and the yield with the amount of water applied for leaching. Table II gives a summary of barley yields in plots with different degrees of leaching. The attached graph indicates the yields of grain with degree of leaching.

Soil Survey and Land Classification in Iran

Many problems have arisen in recently-developed irrigation projects in Iran. These problems are mostly due to soils and also to quality of irrigation water. To prevent further damage, soil surveying and land classification in Iran were started in early 1953. The aim of the first project was to determine the irrigability of the land, but land use, waterlogging, salinity and alkalinity, and drainage investigation were also gradually started for the areas needing them.

The extent of the areas which have been surveyed is as follows:

Kind of Survey	Scale of Map Prepared	Extent in Hectares
Broad reconnaissance	1:250,000 - 1:500,000	3,000,000
Reconnaissance	1:50,000 - 1:100,000	340,000
Semi-detailed	1:20,000 - 1:50,000	1,200,000
Detailed	1:3,000 - 1:10,000	8,500

Some more reconnaissance work has been done in Azarbayejan and the Caspian area, and also about 200,000 hectares have been given a semi-detailed survey in Khuzestan.

TABLE I

Salt content of soil samples

Experiment KL1

PLOT NO. 13 D

Depth of Sample	Before experiment	% TOTAL SOLUBLE SALTS After Different Numbers of Irrigation							
		1	2	3	4	5	6	7	8
0-10	0.29	0.17	0.26	0.23	0.22	0.21	0.20	0.21	0.21
10-40	0.87	0.52	0.55	0.33	0.32	0.23	0.27	0.24	0.24
40-70	1.50	1.33	1.30	0.34	0.50	0.26	0.28	0.25	0.24
70-100	2.20	2.70	2.50	0.68	0.90	0.43	0.35	0.24	0.25
100-130	2.45	3.50	3.20	2.60	0.30	0.57	0.45	0.33	0.30
130-160	2.50	2.85	3.00	2.85	3.25	1.80	0.67	0.48	0.42
160-190	2.30	2.35	2.55	2.50	2.95	3.10	1.60	0.60	0.61
190-220	2.05	2.25	2.30	2.40	2.60	2.20	2.00	0.86	1.25
220-250	1.95	2.20	2.30	2.35	2.45	2.10	1.95	1.20	1.75
250-300	1.90								1.25
300-350	1.55								1.20
350-400	1.10								1.40
400-430	0.21								1.25

TABLE II

Summary of barley yields in plots with different degrees of leaching

Experiment KL1

Treatment	Volume of Water for Leaching	Average yield per Plot of 150 square meters		Yield per Hectare	
		Grain	Straw	Grain	Straw
	Cubic Meters	Kilo Grams	Kilo Grams	Kilo Grams	Kilo Grams
A	Check Plot	0.81	1.27	54	86
B	30	5.80	6.20	387	670
C	60	8.65	10.00	577	670
D	120	14.00	14.80	933	980

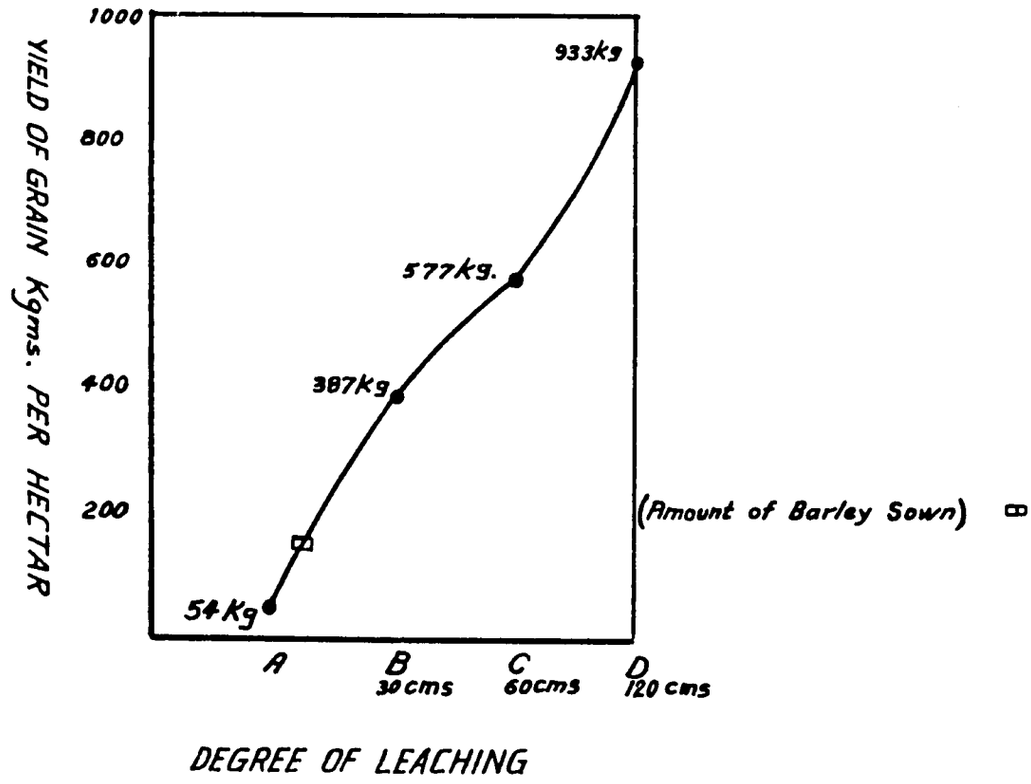

FIG. 2 - YIELD OF BARLEY GRAINS IN PLOTS WITH DIFFERENT DEGREES OF LEACHING

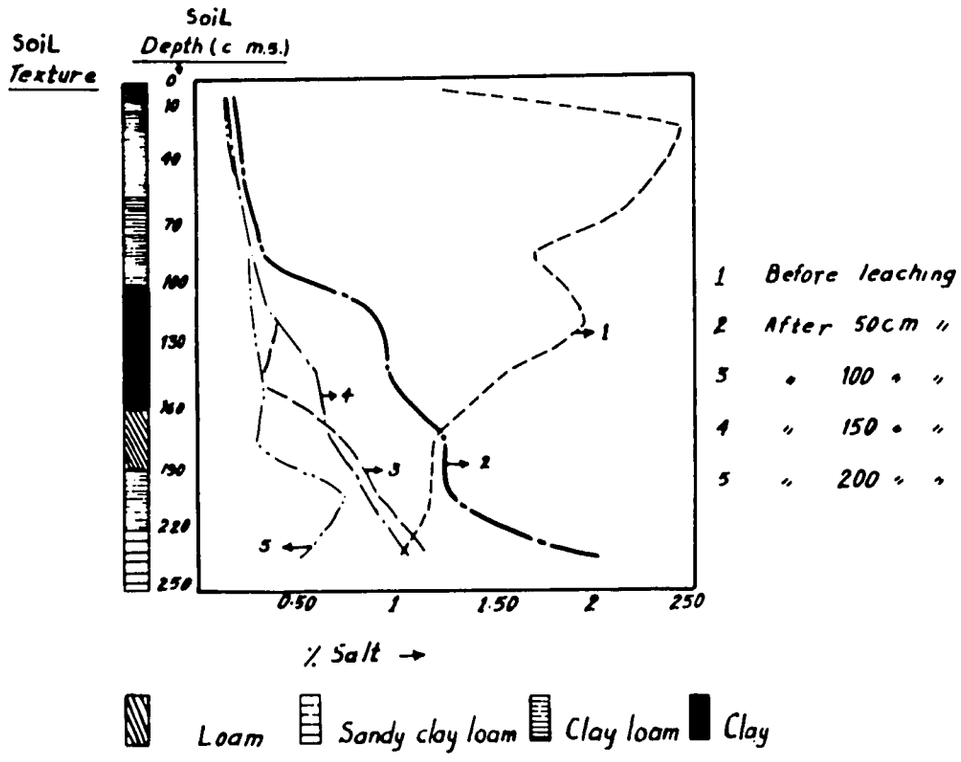

FIG. 1 – KARKEH LEACHING EXPERIMENT NO. 2 (1956) SALT CONTENT OF PROFILE 200 C.M.S. LEACHING (AVERAGE OF PLOTS)

USE OF LIMITED WATER SUPPLY**

by

Dr. A. G. Asghar
Director, Land Reclamation
West Pakistan

Crop Production as a Measure of Irrigation Efficiency

Importance of concept

Crop production in terms of yield per acre can be considered a measure of the success of any farming method or soil management practice. Irrigation can, therefore, be no exception, and a ratio between the unit weight of crop produced and the volume of water used may guide us to some standard for evaluating farming efficiency. This concept of correlating irrigation efficiency with crop yield is a new one, and we must analyze the facts to systematize our reasoning and knowledge before recommending its adoption for wide application.

The term 'duty of water' has been often used with varying meanings in irrigated agriculture in order to relate crop production to the amount of irrigation water required or used on land. The main utility of this term is to evaluate the economic use of irrigation supplies, and its crop relationship is only indirect.

A more direct relationship in use is the water requirement of a crop, which is defined as the water cost of producing a unit weight of dry matter. In other words, it is the amount of water in pounds required to produce a pound of dry matter, excluding the roots of a crop.

For new irrigation projects, proper allocation of water for various areas or farms presents a problem, and water needs are calculated according to consumptive use and irrigation efficiency. Both these terms have only engineering significance and show an indirect relationship with crop production. A large portion of irrigation water is consumed either by evaporation from land under non-crop vegetation or without any crop and from free water surfaces. A large portion is also utilized by transpiration from plants. The total evapo-transpiration in a specified time is termed "consumptive use," while "irrigation efficiency" is the ratio of water used on land for producing crops to the water diverted from river or canal.(1)

In short, the existing concepts for evaluating water use-crop relationship lay stress on one side of the problem involving minimum use of irrigation water, and do not take into consideration any other factor.

** The views expressed in this paper are the author's own and do not in any way represent those of the West Pakistan Government.

In the field management of soils and crops, a large number of other important characteristics are responsible for increasing yields more than the overall ratio of water required to produce dry matter. To correlate water used and the crop produced for determining the optimum amount of water required to give largest yield would mean obtaining a highest ratio figure with two variables only. This naturally limits application, and the degree of variation in other soil factors would give misleading ratios for even the same plot of land. In order to evaluate the true significance of the ratio of water use and crop produce, all other factors such as climate, soil fertility, salinity, soil texture, influence of trace elements, water quality, etc. would have to be kept constant or eliminated, which is not possible.

Soil salinity

This new concept has a very limited useful application in West Pakistan, where the problem of soil salinity has assumed high proportions as revealed by figures cited in the paper on the technical subject, "Causes of and Remedies for Excess Salinity and Alkalinity in Irrigated Lands." In any relationship or concept which involves use of water on land, due importance has to be given to the problem of salinity. For saline soils attainment of an entirely different moisture regime is required. If we are considering yield and water use relationship for a certain soil which is not affected by salinity, we may get a certain ratio, which would naturally decrease progressively with the onslaught of salinity, and for the same amount of water used the yield returns are bound to be low.

Another aspect of salinity control measures would involve giving initial leachings to wash down excessive salts before sowing a high-requirement crop. A general reclamation technique for saline soils which is universally accepted consists of giving two feet of water for preliminary leaching and five feet of normal irrigation for raising one rice crop. In areas under perennial irrigation one to two feet of water are also used in winter for maturing leguminous crops. The water duty given in summer is as low as 45 acres per cusec. It has been established through field and laboratory trials that after reclamation, resalinization occurs after a period depending upon soil and water table conditions. In order to prevent this, it is necessary to have a water allowance which would ensure 10-20% drainage in areas where the water table is below ten feet. This drainage aims at a uniform downward movement of moisture through the soil profile, and a higher water use figure must be used if there are some local porous faults. Water duty has to be modified with the provision of field drains, which result in an increase of water allowance for obtaining similar crop returns.(2)

Experiments on growing cotton on saline or partially reclaimed soil indicate that although an average yield of cotton is taken as 800 lbs. per acre, yet higher yields can be obtained by increasing depth of irrigation. The yield-irrigation relationship is shown on the next page:

TABLE I

Irrigation Depth	Location of salts below soil surface in feet					
	1	2	3	4	5	
	(Yield of seed cotton in lbs. per acre)					
21"	156	574	754	1140	910	
31"	213	640	968	927	1040	
41"	271	927	927	1238	1180	
51"*	656	1140	1040	1353	1180	*Additional supply in July-August
51"**	689	1040	1222	1353	1197	**Additional supply in June-September

If it is desired to grow cotton to obtain maximum yields from lands which contain more salts than are normally tolerated by the plant, a varying amount of water will have to be given, depending upon the location of the salt accumulation zone. If the salts are present in the top foot, normal cotton yields cannot be expected, though yields are increased by enhancing irrigation depth. In case salts are present below the second foot, 20 inches of water over and above the normal depth used for cotton will have to be applied. In case of soils containing salts below the third foot, ten inches of water more than the normal depth would be needed. However, if the salts exist at a depth lower than four feet, the average water depth can be used.(3) This picture shows how yields vary with different conditions of salinity as well as water application. The concept of keeping yield as a measure of irrigation efficiency may therefore serve as a guide for better production but cannot be used as a standard to determine farmers' efficiency.

Climate and other soil factors

Climate, nature of crops, and farm management are other factors which would determine the water needed for maximum yields. In the Canal Colonies in West Pakistan, when fixing the water duty or the irrigation requirements for crops, which is about three cusecs for 1000 acres, the only consideration was to obtain as great a revenue as possible, without any regard for long-term consequences. This area is in a semi-arid and arid region and requires much lower water duty than countries having a humid climate.

In the Thal, which lies between the River Indus and the River Jhelum, the soil is predominantly sandy. The rainfall is very low and unevenly distributed, with long droughts and heavy downpours. The temperature is very high during the day, sometimes going as high as 120°F. in summer. Sand storms carrying a huge quantity of sand are of great frequency. In the year 1949 they were 64 in number, occurring 46 times during the summer months of April to July. Under these conditions every field under summer crop needs water after each sand storm, which is not possible. Thus, the extreme meteorological conditions of the Thal area present a very grave problem for development.

Many of the ills and drawbacks due to extraordinary conditions of soil and weather can be overcome and removed by adoption of scientific irrigation practices as a result of detailed study of the irrigation requirements of the area. A systematic study, therefore, of the extent and duration of irrigation in the Thal tract was undertaken. Generally, in the old canal colonies water is made available to the farmer every 10 or 15 days. However, even this system is not ideal for crop or soil. The unsuitability of both these intervals has been shown and as a consequence the yields of crops are very low compared with more advanced countries. These intervals of water availability to the farmer will not be suitable to the Thal tract where the conditions are more acute and warrant a separate and exceptional treatment. Experiments were, therefore, laid out at three experimental farms (Kundian, Bhakkar and Leiah) representative of different soil types and climatic variations to determine suitable intensity of irrigation and proper interval between successive irrigations of crops, so that favorable moisture conditions could be created for use of crops during the summer season.(4) The irrigation depth used for cotton and sugarcane was 48 inches and 102 inches respectively, compared with 24 inches and 70 inches generally used in the canal colonies. The irrigation intervals tried were weekly and bi-weekly, and the depth of irrigation varied between three and eight inches at a time. The soils at Kundian are highly sandy and represent the flat wind-blown sand over alluvial deposits which forms the major portion of the Thal area. The Bhakkar soils are heavier than those of Kundian and contain more clay and less coarse sand. The soils at Leiah are hard alkali soils rich in clay content and consequently of low permeability due to greater dispersion of clay. Similar irrigations have given higher yields in Bhakkar and Leiah soils compared with Kundian soils. Also, more frequent and deeper irrigations are needed in the Thal in comparison with other places. It is thus evident that high depth gives better yield on heavier soils, but in order to obtain the same yield on lighter soils still higher depth would be required. The experiments, although not conclusive, have definitely given indications that the water requirements in the Thal area are greater than in the old canal colonies, and while planning any system of irrigation for a similar tract this point must be kept in view.

Research all over the world has shown that the water allowance determination has to be based on fertilizer application as well. Recent

manurial trials conducted at one of our farms have confirmed that higher yields are obtained by combining heavy doses of fertilizer with increasing irrigation. To increase fertility of soil where an excess of boron is present, higher irrigation depth is used to remove the more persistent toxic mineral.

There is a considerable loss in the manganese, nitrogen and phosphate status of soil during heavy application of water, which means that whenever depth of irrigation is increased, the probability of losing valuable soil nutrients also increases.(5) If increased production is desired by increasing irrigation, the net result is that we are striking at the balance and promoting loss of valuable elements which are directly responsible for increasing crop yields. Again, a simple irrigation/yield relationship betrays its utility if other factors are ignored.

Cropping pattern and water requirements

It would be of interest to compare water requirements and development of cropping patterns in two areas of West Pakistan, differing in the factors discussed in the foregoing. The calculations are based on actual experience for the past many decades. The study reveals the importance of all these factors in relation to water needs for optimum crop production.

Lower Chenab Canal. The whole of the area has not been subjected to soil survey. However, a small area surveyed shows that the soil is generally loam and clay loam in texture. Clay and sandy soils are also found but to a very small extent. The major portion of the area has a high water table. The salinity incidence is to the extent of 21%, with an approximate annual increase of 1%.

Following are the cropping patterns which have been developed, depending upon the availability of water. The average water duty is 345 acres per cusec:

i) Wheat-Toria-Cotton
ii) Wheat-Wheat-Toria-Cotton
iii) Wheat-Maize-Senji-Cotton
iv) Wheat-Senji-Cotton
v) Wheat-Maize-Senji-Sugarcane
vi) Chariguara-Gram-Cotton
vii) Wheat-Cotton
viii) Gram-Wheat

Keeping in view scientific land and water use, the following cropping patterns are recommendable:

TABLE II

Rotations	Water duty (acres per cusec)
(a) For normal soil	
1. Chariguara-Wheat-Maize-Wheat	219.00
2. Maize-Wheat-Bajra-Turnips	206.12
3. Maize-Wheat-Chari-Berseem	148.50
4. Chariguara-Wheat-Cotton/Berseem	153.70
5. Guara (green-manured)-Wheat-Maize-Senji-Sugarcane	149.30
6. Sugarcane-Sugarcane	109.50
7. Chariguara-Gram-Cotton-Sugarcane	191.80
8. Maize-Wheat-Chariguara-Gram-Cotton-Berseem	165.30
9. Sugarcane-Cotton-Maize-Senji	152.80
Average duty	166.22
(b) For waterlogged soil	
1. Rice-Berseem-Chariguara-Wheat-Maize-Senji	120.00
2. Rice-Lentil-Chariguara-Wheat-Bajra-Senji-Sugarcane	146.60
3. Rice-Shaftal-Chari-Moong-Guara-Wheat	162.40
4. Rice-Berseem-Sugarcane-Sugarcane	92.90
5. Rice-Gram-Guara-Toria-Sugarcane-Chari-Senji-Senji	144.80
Average duty	134.34

Dialpur Canal. Generally, good loam soils predominate in this area. A peculiar type of soil is also met with which seems to have been deposited under water, as shells of some aquatic animals are observed. A layer of soluble salts forms 'A' horizon, as when water evaporated they formed a layer over the top. Following are the cropping patterns which have been developed, depending upon the availability of water:

i) Wheat-Toria-Cotton
ii) Wheat-Cotton-Sugarcane
iii) Wheat-Cotton-Fallow
iv) Wheat-Cotton-Senji

The average water duty is as high as 917 acres per cusec. Recommended cropping patterns and water allowance are:

ROTATIONS	Water duty (Acres per cusec)
1. Chariguara-Wheat-Maize-Wheat	219.0
2. Jantar (green manured)-Wheat-Maize-Senji-Sugarcane	149.3
3. Maize-Wheat-Chariguara-Gram-Cotton-Berseem	165.3
4. Sugarcane-Cotton-Maize-Senji	152.8
Average duty	171.6

Method of attaining high efficiency

With normal water supplies: The suggestion of avoiding overexpansion of the area or decreasing the area to promote intensive irrigation has been often made by workers with little experience of conditions prevalent in over-populated countries. In West Pakistan the density of rural population is high, with an average figure of 466 persons per square mile, and therefore with a high water duty, as already mentioned, viz. three cusecs per 1000 acres, one is tempted on first thought to suggest a decrease in area under irrigation to increase agricultural production per unit area. Out of 198.8 million acres the gross area of West Pakistan, 35% is considered arable and only 19.2% is cultivated. The population density would therefore increase by five times the figure quoted above in order to spread it on the basis of cultivated area; therefore, any land retirement program must take into consideration the economic and social impact on the lives of more than 2000 persons per square mile of land. Moreover, the unproductive areas where withdrawal of irrigation supplies may be considered feasible are widely scattered or exist in blocks of five to ten acres or even less. The basis of agriculture as practiced in Pakistan is not commercial, but subsistance agriculture is a necessity inasmuch as the majority of cultivators are peasant proprietors who have to produce their basic needs of food and fibre from very small farm units.

Eliminating land retirement as our treatment for attaining high irrigation efficiency, the other possible courses of action are:

1. Improved methods of cultivation
2. Evolution of suitable crop rotations
3. Application of fertilizers (artificial-natural)
4. Proper grading and layout of land

Improved methods of cultivation. A description of the layout evolved as a result of field trials at one of the Department Farms in Thal would be of interest in this connection. Considering 25 acres as a suitable unit area, provision has to be made so that a cultivator can grow various summer and winter crops according to his needs. The ratio between summer and winter crops is generally 1:2, depending upon the water supply and the means of the cultivator to operate the land. An area of eight acres which is to be put under crops during summer is to be further subdivided for cash crops, cotton and sugarcane, and fodder crops for livestock. It has been observed that generally a single family of cultivators has the means to cultivate not more than one acre of sugarcane and four to five acres of cotton. It is, therefore, suggested that, keeping in view the means of a cultivator and the water supply available, an acre side may be divided into strips of 10, 32, 32, 32, 32, 32, 32, and 10 feet in width and of any desired length, running even into several lengths of 220 feet. The crops for these strips should be in the order of

Jantar-Cotton-Jantar-Cotton-Sugarcane-
Jantar-Cotton-Jantar

The side strips of ten feet in width of Jantar (Sesbania aculaeta) would serve as hedges on both sides of an acre width. The remaining width, i.e., eight feet, is to be left for water ditches. The recommended layout would achieve the objects of protecting cotton by a Jantar (Sesbania aculaeta) hedge, green-manuring in rotation to improve soil profile, and the growing of sugarcane.(6)

Evolution of suitable crop rotations. In contrast to growing the same crop year after year on the same piece of land, various crops are sown by a cultivator in succession so that he can maintain the fertility of the land and his profits are not reduced. The choice of crops is governed by water supply, physical and chemical composition of the soil, availability of manure, prevalent prices and social customs. The usual crop pattern followed for areas irrigated from canals is:

TABLE IV

Seasons	Crops	Areas in acres
Winter	Wheat	10 to 12
	Gram	2 to 3
	Toria	1 to 2
	Fodder	2
Summer	Cotton	5 to 7
	Sugarcane	1
	Maize	1
	Total:	24 to 28 acres

The cropping intensity is usually 100-120%. Water supply is the main limiting factor; the farmer is able to sow in winter as much as twice the area sown in summer because the summer crops require more water. In view of the above, the new development projects in this country have taken due cognizance of the need for sufficient water and suitable crop patterns. A specific example may be quoted of the first Pilot Project at Chuharkana.(7)

The total canal supply available for the scheme area is 16 cusecs. This supply is to be supplemented from 24 tubewells with an average capacity of 1.5 cusecs each, making the total supply 52 cusecs for the whole area. This would naturally mean that the water allowance to the area would be 154 acres per cusec, with 200% irrigation intensity.

Mr. F. O. Youngs, F.A.O. Soil Specialist, has designated the criteria for selection of proper crop rotations in his report, which are as follows:

> "The key to really good farming is the proper rotation of succession of crops, to keep the land busy and producing the year round and to maintain soil fertility at high level. Single-crop farming with periods of fallow cannot accomplish either of these objectives and can only result in deterioration of the soil and decrease in yields.
>
> "A satisfactory system of crop rotation must include the right combination of crops, each crop in its season; with so-called 'soil building' crops such as the legumes (Lucerne, Berseem and Shaftal), and cash crops such as the cereals, sugarcane and cotton. Examples of several possible crop rotations are shown in Table V.
>
> "The first four rotations would apply to those of the medium to heavy soils that are not very saline at the start of the period. Rotation 5, with rice grown the first summer only, would apply to rather heavy, strongly saline soil that requires prolonged leaching the first year. Rotation 6 applies to the sandier soils that contain no salts and are especially adapted to such crops as potatoes and sweet potatoes. Rotation 7 applies only to small areas and includes sugarcane for two years. Rotation 8 is devoted to lucerne for parts of four years".

TABLE V

Suggested crop rotations for five-year periods

Rotation No.	First Year		Second Year		Third Year		Fourth year		Fifth year	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
1	Juar	Berseem	Maize	Wheat	Cotton	Senji	Maize	Wheat	Juar	Berseem
2	Mash	Wheat	Guara	Wheat	Cowpeas	Gram	Juar	Wheat	Mash	Wheat
3.	Maize	Senji	Juar	Gram	Mash	Wheat	Cowpeas	Wheat	Maize	Senji
4	Jantar	Wheat	Juar	Wheat	Mash	Wheat	Maize	Berseem	Juar	Wheat
5.	Rice	Berseem	Cotton	Senji	Maize	Wheat	Cotton	Senji	Juar	Wheat
6	Jantar	Wheat	Sweet Potatoes	Sweet Potatoes	Juar	Gram	Cotton	Senji	Cowpeas	Potatoes
7	Cotton	Senji	Sugarcane	Sugarcane	Sugarcane	Sugarcane	Mash	Wheat	Cotton	Senji
8	Juar	Lucerne	Lucerne	Lucerne	Lucerne	Lucerne	Lucerne	Potatoes	Maize	Wheat

The crop patterns suggested by the F.A.O. expert are theoretically acceptable but absence of sugarcane and rice from the first four rotations makes these unattractive to local cultivators. Suitable amendment to these rotations thus becomes inevitable.

The following cropping patterns are adapted for four different soil types. The holding unit is taken as 12.5 acres. A cropping intensity of 180% is achieved by the additional water supply made available from the tubewells.

Crop pattern for heavy soils with less salts

Summer		Winter	
Rice	4.0 acres	Wheat	5.0 acres
Cotton	2.0 acres	Gram	2.0 acres
Sugarcane ..	1.0 acres	Lentil & Barley.	0.5 acres
Maize	1.0 acres	Senji in cotton.	2.0 acres
Fodder	2.0 acres	Fodder	1.0 acres
		Toria	1.0 acres

Crop pattern for heavy saline soils

Summer		Winter	
Rice	6.0 acres	Wheat	4.0 acres
Fodder	1.5 acres	Gram	3.0 acres
Maize	1.0 acres	Berseem	2.0 acres
Sugarcane ...	1.0 acres	Senji in Cotton ..	1.0 acres
Cotton	2.0 acres	Taramira	0.2 acres

Crop pattern for light soils with less salts

Summer		Winter	
Mash	4.0 acres	Wheat	6.0 acres
Bajra	3.0 acres	Gram	3.0 acres
Juar	1.0 acres	Fodder	2.0 acres
Fodder	2.0 acres	Lentil & Barley ..	1.0 acres

The crop pattern for light saline soils is the same as for light soils with less salts with preliminary leachings.

Use of fertilizer (both artificial and natural). The use of fertilizers for increasing agricultural output has universally been recognized. A point of caution may, however, be added in this connection, which may limit the utility of such a treatment. If 'normal irrigation' means sufficient volumes of water to be made available for producing crops, then the results obtained from the use of fertilizers would be as expected. On the other hand, if the water supply is short or less than needed to keep a satisfactory water balance in soil, the use of fertilizers may be harmful.

Field trials have shown that supplementing amonium sulphate with P_2O_5 has been very beneficial in increasing yields in high water-table areas. It has been observed that green manuring with leguminous crops like sesbania aculaeta or Egyptian clover is helpful in ameliorating soil, and increased yields can be expected due to addition of nitrogen.

Proper grading in layout of land. Good irrigation management would include prevention of any waste of water. Preparation of land in a suitable way, including land levelling, is helpful in uniform spreading of water. Uniform grading and reshaping is useful in giving proper slope for the spread of irrigation water. Land preparations have to be made after due consideration of the normal slopes of the area. Fields sometimes have to be divided into rows or plots to make the use of water economical. The grading of fields in our country, if not ideal, can be very favorably compared with that in any of the advanced countries.

Special needs with limited supplies

Since water is the limiting factor in crop production, making best use of water is essential.

Fit crop plans to water supply

1. This can be achieved by growing crops requiring less water in conjunction with those requiring larger values in rotation, in order to have drainage as well as saving of water. The usual crops of our country, with their present-day practiced water depths, are given below. However, these depths need revision in the light of new advances in soil management.

Name of Crop	Water depth in inches
Rice	60
Cotton	24
Berseem	45
Maize	28
Sugarcane	70
Wheat	16
Gram	13
Barley	16
Indian Rape	16

2. We have tried selection of crops which have their critical growth before the hottest or the driest periods. This can be achieved by shifting the time of sowing of a crop to a slight extent. An example can be quoted of cotton and sugarcane in Thal, where shifting of sowing periods toward the winter period was beneficial. The usual time of the sowing period, and of the growing and harvesting of important crops, is given in Table VI.

3. Proper cultural practices should be followed, such as contouring in order to conserve the maximum amount of moisture, especially from natural precipitation.

4. Planting protection to avoid the dessicating effect of hot winds and sand storms should be practiced. Sesbania Aculaeta and sugarcane have been used for this purpose very successfully in Thal, as cited previously.

5. Using artificial and natural mulch to reduce surface evaporation will be another useful measure for moisture conservation. In experiments on departmental farms it has been possible to avoid irrigation toward the end of the growing season of the cotton crop by use of artificial mulches such as gram and rice straw, etc.

6. We have experience in growing cotton on ridges in which a 50% saving in water was effected.(8)

Maintenance of salt balance in soil and ground water

Provide sufficient irrigation water to carry off excessive salts. The idea of providing copious water at the surface and removing the concentrated soil solution through subsoil drainage is a practical one. It has been observed that to keep the cycle of moisture movement from the surface through the soil, finally to be taken off by drains, needs a tremendous amount of water. In countries where demand for irrigation water is greater than available supplies, it becomes very difficult to maintain water moving through drains. Thus, the need for accomplishing such a program is to increase irrigation resources. In West Pakistan the salinization of the soil is naturally the result of an adverse salt balance, where more salts have been added to the soil at the time of deposition of alluvium and through other sources such as run-off and floods in later periods. Attempts have been made to offset this adverse balance by provision of an extensive open drainage system in the province. These drains are removing very large quantities of harmful salts.(9)

Name and site of the drain	Average discharge in cusecs	Average total salts per 10^5 parts	Total salts removed per year (in tons)
Lower Rani-wah at R.D. 42,000	16.2	722.0	$10^5 \times 1.03$
Mona drain at R.D. 13,200/14,000	14.3	74.4	$10^3 \times 9.4$
Wagh drain at R.D. 30,000 Ahmadpur	97.6	52.95	$10^4 \times 4.55$
Mona drain at R.D. 327,500	44.0	78.0	$10^4 \times 3.02$
Ahmadpur Kot Nika drain at R.D. 50,000	32.5	73.20	$10^4 \times 2.01$
Head Jurian Kassoke drain	3.6	27.6	$10^3 \times 0.87$
Marh Salar drain at R.D.	14.0	46.3	$10^3 \times 5.7$
Sukheki drain at R.D. 2,000	2.8	225.6	$10^3 \times 5.6$
Marh Chiniot drain at R.D. 16,000	50.1	124.3	$10^4 \times 5.5$
Gujranwala drain at R.D. 1,000	11.4	58.0	$10^3 \times 5.8$
Tail Shorey drain	47.5	34.0	$10^4 \times 1.4$
Tail Mangoki drain	4.0	72.4	$10^3 \times 2.6$
Tail Jhatanwali drain	21.5	40.1	$10^3 \times 7.6$

However, in the absence of a proper field drainage system, these are useful only to carry surface or rainfall run-off and the process of removal of salts is extremely slow. Again, the bottle-neck in the maintenance field drains is the lack of water supply, and as a consequence the farmer is unable to keep his drains functioning.

West Pakistan has most inadequate surface storage sites and it is not economically feasible to develop any in the immediate future. The ground water is a major reservoir, which can be tapped for increasing water supplies. A survey is being carried out to assess the quantity and quality of this source. The lifting of ground water at a later stage and development of recharge will present many problems for coming generations. The need for draining away concentrated soil solution will become more pressing when ground waters of higher salt content than the present surface supplies are used for irrigation. There is a possibility of increasing recharge to ground water from existing surface channels, due to tubewell pumping, which would effect improvement in the existing quality of water. The experience on a departmental farm has revealed that by increasing the tempo of drainage the recharge increases, resulting in the dilution of subsoil water.

Permit sufficient outflow from valley or basin to prevent accumulation of excess salts. This suggestion will find little practical application in Pakistan, although it may be reasonably feasible in other countries. The Indus valley is handicapped by natural features which hinder outflow through subsoil. The land is more or less level, having a down valley slope of one in 5,000 with an underground rock ridge running across the upper region. The soils are porous near the foothills and the porosity shows a progressive decline toward the sea as the soil becomes finer.

The area is, however, visited by frequent floods, due to overspills from rivers and streams and sometimes through breaches of major canals. These, no doubt, carry away considerable quantities of salts present on the surface, but disturb the salt balance of the area in the adverse direction by leaving huge quantities of water in the valley. Generally, the developed areas are devastated and the slow evaporation of accumulated water containing salts creates salinization. It is thus clear that even if such surface removal of salts in large quantities is effected in the early stages of floods, more quantities are left behind, resulting in salinization. The source of salts being the parent rock, there is no favorable salt balance for the Indus Valley. However, we are studying salt balance in an area between the rivers Ravi and Chenab. The area selected is a closed basin and all water sources which bring in and those which remove salines can accurately be measured. The area is frequently visited by floods and receives its irrigation through surface supplies. After completion of the study in due course of time, useful data on maintenance of salt balance will be available.

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GLOSSARY

		Botanical Names
1.	Toria	Brassica Campestris
2.	Senji (Melilot)	Melilotus Parviflora
3.	Chari or Jauar (Great Millet)	Andropogen Sorghum
4.	Guara (Vetch field)	Gyamposis Psoralioides
5.	Gram	Cicer Arietinum
6.	Bajra (Bulrush Millet)	Pennisetum Typhoideium
7.	Berseem (Egyptian Clover)	Trifolium Alexandrinum
8.	Shaftal	Trifolium Resupinatum
9.	Moong	Phaseolus Aureus
10.	Jantar	Sesbania Aculeata
11.	Mash	Phaseolus Mungo
12.	Taramira (Rocket)	Eruca Sativa

1.	Thur	Saline area
2.	Sem	Waterlogged area
3.	Kharif	Summer
4.	Rabi	Winter

TABLE VI

SHOWING PERIOD OF SOWING AND HARVESTING OF PRINCIPAL CROPS GROWN IN CANAL COLONIES OF WEST PAKISTAN

	April	May	June	July	August	September	October	November	December	January	February	March
HARVESTING	Gram Mixed Gram Wheat	Millet	Wheat- Melons	Italian Millet		Cotton Great Millet Maize Rice Sugar- cane Hemp	Water Melons Cowpea Melons Minor Millet	Egyptian clover Carrots peas	Lucerne	Potatoes Indian Rape	Persian clover Millet Oats	Barley
SOWING	Cotton		Maize Rice	Water melons Melons Hemp		Egyptian clover Carrots Gram Potatoes Indian Rape	Persian clover Peas Oats Barley Wheat Lucerne				Potatoes Melons Tobacco	Common Millet Millet Maize Sugar- cane Italian Millet

RELATION BETWEEN FARM IRRIGATION PRACTICES and PROJECT DESIGN AND MANAGEMENT

by

Engineer Asghar Azarnia
Irrigation Agronomist, Director of Irrigation
Units of Ostan 10. Assistant Director
of Kuh Rang Irrigation Society

Introduction

It is worthy of consideration that in the creation of a vast new irrigation project the difficulties do not lie only in the preparation of the plans for construction. Nowadays, as a result of scientific advances, calculations for the construction of a dam, the dimensions of river control gates, etc. are simple, and by the application of a certain number of mathematical formulas these will be easily solved. In making such calculations, biological or social parameters have no part. For planning proper utilization of a dam or other technical works, not only the classical hydraulic and hydrologic technical requirements must be observed but also the following basic studies must be made:

1. Social and economic environment of the region, degree of the farmers' acquaintance with irrigated farming, financial condition of the farmers, kind of land-ownership, interest of big land-owners in making their real estate flourish, etc.

2. Investigation and study of the various crops and livestock in the region and their development from the viewpoint of creating high economic returns.

3. Agricultural, hydraulic and drainage experiments. Consideration of the results obtained from soil studies and investigations of the hydrodynamic and hydrostatic properties of the soil of the region are vital necessities.

   Therefore one of the questions deserving special consideration in the preparation of plans for irrigation projects in a region is an investigation of how to utilize irrigation water for various crops.

Measures to be taken for drawing up a program for distribution of water in a district

My aim in setting forth the requirements is not repetition of the instructions and recommendations in books and technical pamphlets, but discussion of questions and difficulties which have arisen in various

districts and the methods used to overcome them.

As a whole, the procedures of the newly-established Irrigation Investigation Organization of the Independent Irrigation Bongah in the drawing-up of a program for the development of a river basin and proper distribution of its waters for irrigation purposes are as follows:

1. Topography. In order to prepare a plan and determine the course of the network of irrigation canals and drainage ditches of a district, a map with a contour interval of 20 to 50 centimeters (depending on the relief of the land), and a scale of one to 5,000 or a minimum of one to 10,000 is prepared, and then the whole area of the district, of cultivable and irrigable land as well as of land actually under cultivation, and the boundaries of every farm in the district are accurately marked on the map.

2. Soil investigations and classification of land from irrigation and agricultural viewpoints. To learn the characteristics of the soils of a given district, soil experts of the Soil Section and of the Bongah Laboratory make necessary studies on the spot. On the basis of the structure, texture and composition of the soil, they classify the various sections from the viewpoint of suitability for cultivation and irrigation. In a special publication prepared by the Soil and Laboratory Section of the Bongah, studies made on soil have been explained and can be used in this classification.

3. Hydrostatic and hydrodynamic properties of soil. The porosity, capacity for retention of water, wilting point, permeability, etc., of soil in every type of land involved are studied and determined.

4. Collection of agricultural data in a given district. In the determination of the quantity of water necessary for various crops, in general, the following investigations are carried out:

   a. An accurate survey of agriculture in the villages and farms of the district.

   b. Local farmers' methods in planting, cultivation and harvesting of different ordinary crops, and the output of the district are studied on the spot. It must be pointed out that since, for thousands of years, irrigated farming has been practiced in Iran, most farmers as a result of inherited experience have succeeded in solving difficult irrigation and agricultural problems. A study of methods of farming and of har-

vesting crops in these regions will help in the arrangement of programs of rotation cultivation and will increase the knowledge and experience of officials. Data to be collected on farming consist of: the way the ground is prepared and the proper time for it; the time and method of sowing; quantity of seed sown per hectare; quantity and kind of manure used per hectare; number of irrigation applications and their proper time; care during crop growth; time, system and quantity of harvest per surface unit.

c. Systems of irrigation and the quantity of water used on different crops are studied and recorded, because by experience it has been proved that, in regions where farmers have been acquainted since ancient periods with irrigation farming, an attempt to install new irrigation methods would meet great obstacles and difficulties. Fixing the quantity of water to be used for each crop following the technical results obtained on demonstration farms as a basis for irrigation of a district would certainly be impracticable in the first two or three years of operation of a project. Forcing such farmers to use new technical methods would not be an easy job and the quantity of water designated would not meet their requirements. It goes without saying that the least discrepancy in the distribution of water in a district would be sufficient to so entangle the officials charged with water distribution that eventually an amendment of the project would be inevitable. To avoid this difficulty, the quantity of irrigation water used by irrigators each time for each species of crop is separately and accurately measured by Parshall flume.

d. While studying the irrigation methods of the farmers in different sections of a district, the real water requirement for each section must be determined on experimental farms during the months that each crop is growing. The results obtained must be compared with the amounts used by farmers in each section and an intelligent policy adopted for reducing the waste of water to a minimum.

e. A percentage ratio of the different cultivated crops in each village or independent farm of a district will be recorded.

f. The quantity of water necessary for each crop in each village or independent cultivated farm, with due attention to investigations mentioned in paragraph c, can be determined and the ratio of water necessary in a section as compared to the entire water in a district can be specified.

5. Investigation of economic and social problems of a district. In addition to the above studies, another important investigation to be carried out in a district is on the social and economic condition of the people in the area. Special enquires must be made and all information in that respect must be gathered. The responsible engineer on a project, as a consequence of his experience, must realize that he must adopt a separate suitable policy in each district, giving due attention to the economic and social condition of the people. Care taken in this respect will have a real effect in the proper arrangement of a suitable program, and consequently in the fair distribution of water in each district.

6. Investigation of existing water resources. Though results of investigations made on surface and underground waters in various sections of the country are not always within the reach of interested engineers and experts, nevertheless irrigation investigation teams are under obligation to determine water resources in a district. They must ascertain the water discharge and salt content in each river, fountain, ghanat, deep well, shallow well, draw well, etc.

7. Investigation of underground waters in different sections of a district. Investigation teams should study the depth to the water table as well as the salt content in the underground water of the different regions. When they find that the underground water is near the surface of the lands under consideration, they should study the hydrodynamic properties and the kind and quality of soil of the region and take necessary precautions with respect to the way in which the water will be distributed. If necessary, drainage studies must also be made.

8. Determination of water losses from irrigation channels. In Iran water has a vital value for improvement of agriculture, so attention to water losses from irrigation canals and efforts toward minimizing such losses are considered to be basic. Furthermore, in certain regions the infiltration of water from the beds of canals will cause a rise of the water table and render adjacent low sections swampy, as can be observed in the Shabankareh project area. The classical method of estimating water losses from canals and irrigation networks consists of finding the product of the wetted perimeter of the canal and its length and multiplying the product of these by the average of the coefficients of water percolation in the soil of the region through which the canal passes. It must be stated that the method used by the investigation teams of the Bongah in this connection is very simple, as follows: A Parshall flume is installed at the end of every kilometer in every canal and the loss is measured by the difference in discharge of the waters. The reason for adopting this method is because the determination of wetted area

in old canals not having specified geometrical forms is very difficult, and as the shape of the cross-sections of the entire course of each canal is not uniform, in practice, the result of calculation is not accurate.

The above method is used by the study teams of the Bongah in regions where irrigation practices have been carried out since centuries ago, but in regions where, lately, underground water or water from a dam or a branch canal is used for irrigation, water losses are estimated by classical calculations.

9. Inquiries and investigations on acquired and relief rights on land and estates of regions under investigation with respect to existing water resources. For thousands of years irrigation has been practiced in Iran. Names of water-users with quantity of flow of most of the rivers in the country, the distributed shares designated by rulers or Kings for villages and farms, have been mentioned on scrolls or orders. The distribution of water has not been similar everywhere: for example, the water-rights on the Karaj River for farms and villages are mentioned on rolls similar to those made by Amir Kabir, in which the unit quantity is designated as the "sang". Following the roll, a sang (stone) of water consists of a quantity of water flowing in a square channel measuring 26 centimeters by 26 centimeters with a speed of 26 centimeters per second--i.e., 17.5 liters/sec. In contrast, the waters of Zayandeh Rud of Isfahan have been divided into 33 shares, and each of the six districts in the area own a number of shares which are in turn subdivided into smaller shares for the various subdistricts or farms. In addition, most of the villages and farms have one or more ghanats of their own which they use for their specific purposes. A number of villages, according to special regulations, have carried water through a channel jointly, and pay cleaning charges, repairs, etc., by special arrangements made among themselves. This method continues to the present time. In some cases, water mills have been installed along canals and their owners, from ancient periods, have gained certain rights for using the water for their mills.

The collection of information concerning acquired or relief rights of villagers and farmers in the existing water resources of a region where investigations are being carried out is one of the most important duties of the investigation teams and those in charge of preparation of the irrigation plans. These persons must respect any of the above-mentioned rights and see that none of the rightful claims is prejudiced. After the necessary studies are executed, then technical advisors and irrigation experts, by taking into consideration the results of the enquiries, will be able to prepare the plan of the

irrigation network and the program for the proper distribution of the water of the district.

In principle, measures to be taken for preparation of the plan of the irrigation network and the program for the distribution of the waters of a district must be as follows:

1. The places where a dam or a series of dams must be built for the diversion of water into a main canal must be chosen with due regard to all technical and economic aspects.

2. The courses of the main and secondary canals of grades 1 and 2 must be determined with due regard to the conditions and situation of the lands which are to be irrigated.

3. The flow of all of the main and secondary canals must be determined with due regard to the amount of water necessary to supply the needs of the areas to be irrigated.

4. The diversion points of secondary canals of grades 1 and 2, and irrigation streams, must be properly selected with due consideration of the condition and situation of the land.

5. The dimensions of the canals are calculated in accordance with the slope of the land and the quantity of flow in each canal.

Note: It must be stated that the purpose of inquiries, investigations and experiments as above outlined in regions where, since remote days, irrigation farming has been practiced is to discover and remove existing defects as well as to endeavor, as much as possible, to create new irrigation networks of canals under technical principles and thus prevent loss of water from the canals and economize as much as possible in the use of irrigation waters.

Program for distribution of irrigation water to individual farms.

Assuming that after completion of the above investigations and inquiries, the amount of existing utilizable water, the yield of any of the main or secondary networks of water distribution, and the amount of land under cultivation are known, then one problem still remains to be solved; namely, to draw up a program on how to distribute properly the water among the plots of cultivated land. Needless to say, the aim of the program is to enable the owner of every farm to get in time the amount of water necessary for his farm and to be in a position to control it without any difficulty.

It must be granted that, owing to various factors (such as variety of soil in different sections of a district, different water re-

quirements of various crops, condition of the surroundings, etc.), the arrangement of such a program is not an easy task. Nevertheless, when the results of the above studies are in the hands of the engineers and experts responsible for preparing the program, the work will be greatly facilitated. As a general rule, water distribution to individual farms is accomplished in three ways: continuous flow, rotation flow or distribution by turn and on demand by farm owners.

1. Water distribution by continuous flow. It is self-explanatory that by this sort of water distribution a continuous flow of water is delivered to a farm or village during the whole irrigation period. Now, supposing that the land under cultivation in a given farm receiving continuous flow is 200 hectares and the average flow of water for various crops is .70 liters per second per hectare, the quantity of water supplied to such a farm or village during the entire irrigation season would amount to 140 liters per second.

   Distribution of the waters of the rivers around Tehran (Karaj, Jajrud and Gardan) is similar and can be compared to the continuous flow distribution method, with this difference. Because in Iran, as a general rule, the area of cultivable land is larger than irrigation water rules in the past have specified, special water rights for farms and villages located in the river basins must be established for different periods or the whole of the year.

   In a number of places, such as that of Golpayegan, the canal water is divided into portions and each village or farm gets, according to arrangement, one or more portions of the actual flow. It goes without saying that from an administrative point of view this is a very simple method of water distribution. Officials charged with water distribution allocate the portion of every village or farm to the owners or their representatives. Then the distribution of water to the various plots under cultivation becomes the duty of the cultivators themselves. The officials will not do anything in respect to water distribution within a village area except give some guidance, and that only when asked by the farmers to do so. One of the advantages of such a distribution method, especially in arid regions where irrigation has been practiced for centuries and farmers have solved difficult irrigation problems by experience, is that the individual farmer, within the limitations as to quantity and time of his water-right, is free to use it where and when he likes. Because as a rule he has more land than he can irrigate, he does the best he can to save as much water as possible in order to enable him to cultivate more land. But in the newly-irrigated regions and in places where farmers are used to dry-farming principles, this sort of distribution gives an opposite effect. If the distribution of water is not

controlled attentively, the land would be over-irrigated due to lack of proper knowledge by the farmers, thus causing good cultivated land to become swampy.

2. Rotation system of water delivery. As we are aware, a farm is irrigated once every few days in order to secure the water necessary for growth of crops. The irrigation intervals between various crops, as well as the quantity of water released to a farm for each irrigation, differ and are related to the kind of soil, atmospheric conditions, etc. Furthermore, in order to secure the maximum benefit from every irrigation sub-lateral, as a rule a number of neighboring farmers arrange among themselves to irrigate their farms in turn for a few hours each. But in certain places this kind of irrigation is executed only in the distribution of the waters of sub-canals Nos. 1 and 2, and rarely in the case of the main canals. In most villages and farms in Iran which have fixed water-rights from a river or are in possession of private ghanats, the turn of each water-user is designated in hours per six-day period. The entire cultivated area in a farm or village is divided into 72 Habeh, each generally not exceeding a few hectares in size, which will have about two hours of water-right in each six days. Thus, in a village a farmer who has a two-hour water-right in a week must accomplish his whole irrigation during those two hours.

   In a number of regions during years of drought when the quantities of water are greatly reduced, several villages join hands, put together their water-rights and benefit in turn, taking into consideration the amount of water-rights due each. This, in reality, is a combination of the above two methods.

System of distribution of water of Zayandeh-Rud River of Esfahan according to Sheidh Bahaee

Here, in order to obtain some notion of the precautions and considerations which were taken account of in the old days in the distribution of water, we explain the way the water of Zahandeh-Rud River was distributed among the water share-holders.

This system was started 15 centuries ago and amended by Sheikh Bahaee, three and a half centuries back. He was an Iranian mathematician in his time. It is a combination of continuous flow and rotation systems of irrigation in which the determining factors are period of time, quantity of flow, and the weather and agricultural conditions of each area under irrigation. The calendar year was considered as 360 days. During a period of 195 days, i.e., from the 22nd of November to the 5th of June, the river is in flood, and there is more water available than is needed and it can be used freely by the water-users. During the dry years this arrangement is altered and the water is distributed by the decision of a committee formed of the heads of the villages and of land-owners.

During the remaining part of the year (i.e., from 5th of June to 22nd of November), which is 165 days, the river water is divided into 33 shares each of five days.

How different areas obtain their shares of water.

The lands situated at the downstream end of the river have six shares, i.e., 30 days of flow, 15 days from 5th of June till 21st of June and 15 days from 6 November to 21st of November. These periods coincide exactly with the sowing season in this region and the irrigation of wheat and seed products. During the remaining 135 days (i.e., from the 22nd of June till 6 November), the water in this river must be divided into 27 shares. The water-shares are divided according to the following schedule:

Lanjan -- 10 shares	Alanjan -- 7 shares
Jee -- 4 shares	Marbeen -- 6 shares

Total -- 27 shares

In order that the water be distributed regularly and be useful for agriculture, these four regions have made an arrangement among themselves, which is locally called "Vonesh." They are divided into two groups:

1st group - Lanjan and Alanjan has 17 shares;

2nd group - Jee and Marbeen has 10 shares.

In the meantime, as the Lanjan region is far from the river and this causes the water to reach it late, and the Jee and Marbeen regions are still farther, one more share is given to the first group and two shares to the second group, thus making the two groups share in the ratio 9:6. The water in the Zayandeh-Rud from 22nd of June is divided in the proportion of nine and six days between the Lanjan and Alanjan and Jee and Marbeen regions. This system is continued until 23rd of September.

From 23rd of September till 10th of October river water is dedicated for irrigation of grass crops and is distributed under the same name as follows:

1st group -- for Alanjan and Lanjan -- 11 days;

2nd group -- for Jee and Marbeen -- 7 days.

From the 10th of October until the 6th of November, which is the planting period for cereal crops, the water, in case of abundance, is distributed according to the shares and when the water is low it is divided according to the following arrangement:

Alanjan	--	4 days
Lanjan	--	6 days
Marbeen	--	4 days

Jee	--	6 days
Gowarej	--	3 days
Bara-an	--	4 days
Total	--	27 days

3. Distribution of water by demand. This system of irrigation is carried out in areas where the water is obtained by pumping from shallow or deep wells. The water is paid for by liters per second of flow, or per hour of flow, or with respect to the area which is under irrigation. Each farmer or landowner who needs water for irrigation of his farm applies to the water agent, pays for the water he needs and the water is delivered to his land.

In rivers where a part of the water is not yet dedicated to farmers or landowners, the water is sold to the latter and the river administration concerned collects payment for it. The sale of such water is practiced in the following manner:

a. The buyer presents his purchase request to the river administration 24 hours before the water is needed for irrigation.

b. The minimum quantity of water which can be sold for each irrigation is 25 liters per second for a period of 12 hours.

c. The price of the water is calculated on the basis of 50 liters per second for a period of 24 hours, and the rate changes with the time of the year when it is purchased.

RELATION BETWEEN FARM IRRIGATION PRACTICES AND PROJECT DESIGN AND MANAGEMENT

Formal Discussion
by

Saifuldine Wahbi
Chief Engineer, Ministry of Agriculture, Iraq

Introduction

Irrigation may be defined as the application of water to fertile regions on which the rainfall is inadequate, in the quantities and at the times required by the crops. The most successful irrigation engineer is the one who contributes to bringing to maturity the largest amount of crops in a given area. Naturally, the best results are obtained by close cooperation between the irrigation service, the agricultural service and the farmer. The agricultural service plays its part in determining what quantities of water are required for the different regions and for the different crops, and also the times at which it is wanted; this includes such considerations as the duration of the agricultural season and rotation.

Irrigation Practices in Iraq

The duty of the Irrigation Service in Iraq is to supply and control available water so that each region receives its proper share. It will be clear, then, that the responsibility of the Irrigation Service ends at the outlets from the public canals to the field channels, and that if water is supplied at these outlets in the proper time and quantity any failure to produce good crops must be attributed to unsuitable land, unsuitable crops, poor agricultural methods or pests.

There is subterranean water beneath the cultivable plains in most parts of the world. The plains where irrigation is possible are for the most part low-lying, and the water table is comparatively close to the surface of the land. If irrigation water is applied to such lands, the tendency is to raise this water table, and if no means are provided for removing the surplus, eventually the land goes out of cultivation. The remedy for this is land drainage. Therefore, every scheme for the development of lands by irrigation should include provision for a system of drains if natural drainage does not exist, and in most cases it does not.

If we consider this question of water-logging, we see that it is not desirable to make the water levels of the canals any higher than is strictly necessary to command the majority of the area. The higher lands which are not commanded, that is to say those which would not receive free-flow irrigation, should be irrigated by means of lifting machines such as pumps, water wheels, etc. Some irrigation authorities have advocated running all canals at levels below that of the land and doing all the irrigation by lifting machines, thus abolishing free flow. Amongst

those who have suggested this was the late Sir William Willcocks, who was closely associated with the beginning of irrigation in Iraq and the builder of the Hindiya Barrage on the Euphrates. Here we may say that it is good practice to design canals with water levels about 25 cm above average land levels, and drains with their water surface one and a half meters below average land levels.

A complete irrigation system is a very complex thing which requires careful control and coordination at all stages. Not only this, but it requires in the engineer a wide knowledge and experience of construction and hydraulics. In Iraq available water supplies will be insufficient for the total possible cultivable area even in years to come when all possible sites for storage reservoirs have been fully exploited.

Let us return to the outlet on our canal and see where the duty of the irrigation engineer to provide the right quantity of water at the right time and at the right level may lead him before he fully satisfies the requirements. In the first place, the outlet must have a size, and in fixing its size the engineer does not only consider the area it has to serve, he has to think about the duty of water, the size of stream and the rotation, and then decide at what level it must be placed in relation to the water level in the channel. The irrigation of the land through which a main canal passes is done through a series of branch canals running parallel to the main and controlled from cross regulators; these parallel channels are known as Gannabias.

Returning to our distributary canal, the irrigation engineer has to know how to align it and design it. For very obvious reasons, canals are located on the highest ridges and drains along the lowest depressions. For this purpose he requires contour maps, and after getting the general alignment fixed on such maps, he has to transfer them to the ground, making such adjustments as are required by actual conditions. Canals are necessarily designed on the basis of the actual area they serve, and on an average water duty applied to the whole area. In Iraq also water distribution to individual farms is accomplished in three ways: continuous flow, rotation flow and by lifting machines (pumps).

I may say a word about lifting machines; in Iraq you will find these installed on the banks of rivers and canals, and the important thing from the point of view of the Irrigation Service is the outlet. Having delivered the required amount of water to the downstream end of this outlet, it is theoretically a matter of no concern to the Irrigation Service how the landowners get the water on their land; that is to say, whether it is by lifting machine or free flow or any combination of these. But it will be equally clear that the machine must be installed on a well-established intake outside the limits of the bank and not drawing directly from the channel itself, otherwise it is very difficult to maintain control over distribution. Unfortunately, in Iraq nearly all lifting machines draw direct from the canal and rivers and this in course of time will have to be altered.

Now we come to a great problem. Silting of the canals in Iraq has always been one of, if not the, greatest of all its irrigation problems.

Silt that is deposited in the beds of the canals reduces their capacity and tends to raise water levels, both of which are undesirable. The desilting of the canals, therefore, must never be neglected. It is usually sufficient to do this once a year. Some canals silt badly, others do not. Silt may be divided into two categories; the coarse material, which is usually some form of sand, and the fine material, which is carried in suspension in the water and gives it the color associated with floods. The sandy material is found in the lowest layers of the water and the coarsest kinds are rolled along the bed; this is the way that gravel also is moved. It is not possible to close the canals annually to make silt clearances and we have to resort to mechanical means of getting out the accumulation of silt. The machines used for this purpose are floating dredgers or land machines of the dragline type. The dragline is one of the most useful types of earth-moving machine and its use for the purpose of canal maintenance in Iraq is very wide; it is obtainable in many sizes and can be used on the great majority of our canals. We have about 35 of them working on canals, where they have given good service and done excellent work.

RELATION BETWEEN FARM IRRIGATION PRACTICES AND PROJECT DESIGN AND MANAGEMENT

Formal Discussion
By

B. R. Shori,
Superintending Engineer, Central Water Power Commission, India.

Introduction

The paper on this somewhat abstract subject of relationship between farm irrigation practices and project design and management has been ably presented by the delegate from Iran. He has detailed the procedure for preparation of an irrigation project and the difficulties met with. This is more or less the procedure adopted in India, too. The whole project design is indeed dictated by farm practices. It is on the basis of the requirement of water in the field that the whole project is to be designed, and this in turn depends on farm practices, too, the aim being to assess the minimum water requirements for obtaining maximum production. This in turn requires reduction of wastage of water by better field management and agronomic operations.

The duty or the water requirement of crops is the fundamental from which the total requirements are calculated. These water requirements again depend on the method of applying water in the field, such as border method, basin method or furrow method, etc. Again, the requirements vary according to the crop pattern. In fact, with the introduction of irrigation some changes in the cropping pattern are inevitable. The best possible pattern has to be intelligently arrived at from past experience or through experimental farming, wherever possible. From the field requirements the sizes of the water courses, etc., are determined. From a consideration of these requirements--the cultivable commanded area and duty, etc.--the sizes of the main canals are determined after making due allowances for losses. These total requirements then form one of the main bases for determining the reservoir capacity and the height of dam, etc.

Among measures required for drawing up a program, topographical surveys are necessary. On our projects usually maps to a scale of four inches to one mile, with a contour interval of a foot, are prepared which enable the engineers to plan the layout of the distribution system. The village water courses are usually constructed by the villagers themselves.

Soil investigations and classifications are very desirable features. For planned development of controlled irrigation supplies for agricultural land, a knowledge of the different types of soils, their distribution and their main features is indispensable. It has been generally the policy in our country to carry out scientific soil surveys of areas to be commanded by various irrigation schemes to assess the suitability or other-

wise of the land for development. To give an idea of the work already done in my country, I would point out that soil surveys have been carried out on some of our projects covering total areas of over 22 million acres. In these surveys soil profiles are generally examined up to ten feet or up to bed rock, whichever is less.

Regarding collection of agricultural data, it is very desirable to get all the data but it is always difficult to make the farmer agree to a changed crop pattern or use of water. He has to be educated; otherwise full utilization of irrigation waters would not be possible. This, as the delegate from Iran has pointed out, is best done through demonstration farms. However, where demand for irrigation is high no trouble is experienced in utilization of waters. A separate paper on utilization of irrigation waters in India is being presented at this Seminar which gives suggestions for obtaining better utilization.

A study of underground water conditions is another necessity before taking up a project, as this has a direct relationship with salinity and alkalinity and water-logging, etc., and is thus connected with irrigation practices in the field. Wherever the water table is high, the intensity of irrigation may require variation or the water requirements may have to be altered. In our country usually underground water levels in the commanded area are observed before and after the monsoons for as long a period as practicable before taking up a project.

Next comes the question of transit losses while conveying water to the fields. It has been estimated that between the head works and the fields the canal losses due to seepage, leakage and evaporation vary within a wide range of from 10 to 50% of the supply entering at the head. In the distributaries, minors and water courses absorption losses are equal to or often larger than the losses in the main canal and the branches. Thus, it will be seen how variable this factor is, and elimination of these losses by lining, etc., would reduce the water requirements. Though these losses generally affect the economics and design of the project, they do not affect farm practices to any substantial degree. In fact, farm practices are not directly dependent on transit losses at all.

Lastly, the paper recommends the drawing up of a program of water distribution for the plots in the field. Whether this is practicable in advance is a point to be considered, and whether it is desirable to confine the project to a specified distribution system; in fact, some flexibility would be more appropriate to take care of future changes.

RELATION BETWEEN FARM IRRIGATION PRACTICES AND PROJECT DESIGN IN CEYLON

Discussion
By

A. E. C. de S. Gunasekera, M.I.C.E.
Director of Irrigation (Ceylon)

and

H. de S. Manamperi, B.E., M.S., A. M. I. C. E.,
Divisional Irrigation Engineer

Location

The Island of Ceylon lies between 5° .42' and 81° .53' E. longitude. The maximum length of the Island is 270 miles and the maximum width 140 miles. It covers an area of roughly 25,000 square miles.

Topography

The Island consists of a central massif sloping down from Piduru-talagala (8292 ft.) through three peneplains, at approximate elevations of 100 ft., 1600 ft. and 6000 ft., to the sea.

Geology

For the most part, Ceylon is composed of very ancient Archaen rocks consisting of a fundamental basement complex of gneisses which is overlain in the central and northeastern areas by thick metamorphosed sediments such as quartzite, crystalline limestone, leptynite, granulite, and garnet-silimenite rocks. The other important rock type is the Tertiary sedimentary limestone of the Miocene age which forms a belt extending from the northwest of the Island and covering the entire Jaffna Peninsula.

Temperature

The temperature of the Island varies but little during the year. The mean temperature in Colombo varies from 82.4° F. in May to 79° F. in December. The temperature, however, drops as one proceeds toward the hills in the central massif - At Nuwara-Eliya (elev., 6200 ft.) the annual average is 56° F. with a maximum of 58.4° in February.

Rainfall

The prevalent wind directions are southwest from mid-March to mid-September, and northeast from mid-September to mid-March. Corresponding to these periods of the northeast and southwest monsoons, there are two

seasons of rainfall. The southwest monsoon brings rain to the southwestern part of the Island. There is widespread rain all over the Island during the northeast monsoon. The Island is thus divided into two zones, the wet zone and the dry zone. The southwestern part of the Island, receiving more than 75 inches of rain during the year, forms the west zone. The dry zone receives less than 75 inches per annum, and this area covers the northwestern, northern and eastern parts of the Island.

The average annual rainfall varies from a maximum of 230 inches at Carney in the hill region to 44 inches at Hambaneota and Puttalam in the southeastern and northwestern dry zones. Monthly averages at four typical stations are as follows:

MONTH	WET ZONE		DRY ZONE	
	S.W. COASTAL REGION GALLE	HILL COUNTRY WATAWALA	CENTRAL DRY ZONE ANURADHAPURA	S.E. COAST HAMBANTOTA
	AVERAGE RAINFALL IN INCHES			
January	3.87	5.05	5.78	3.99
February	3.32	3.53	1.69	1.45
March	5.35	7.25	4.19	3.39
April	8.69	10.94	6.38	3.90
May	12.64	25.72	3.50	4.27
June	8.47	38.75	0.70	2.10
July	6.29	14.15	2.69	2.03
August	6.15	25.85	1.61	1.43
September	8.78	25.34	3.78	2.72
October	8.02	24.01	9.76	4.79
November	12.01	15.43	10.64	7.61
December	7.85	7.37	7.55	5.57
Total	91.44	203.99	58.27	43.25

Soils

Resulting from the bedrock and climatic features, the soils of the various parts of the Island are evolved. The southwestern portion of heavy rainfall has cabook (laterite soil) and gravelly loam. The dry zone has red loam. Small areas in the southeastern highlands have humic soils. Grey loams and calcareous soils cover the northwestern portion and the Jaffna Peninsula. The valleys of the larger rivers contain alluvial soils. Small areas of lagoons along the west coast have peaty soils.

Cultivation Practices

The major irrigated crop in the Island is rice. The total paddy

extent in Ceylon is 1,031,611 acres. (Monograph 9 of the Department of Census and Statistics, Government of Ceylon).

Irrigated under Major Irrigation Schemes	-	270,282
Irrigated under Village Irrigation Schemes	-	292,978
Rain-fed	-	468,351
Total		1,031,611 Acres

Small areas of land under onions, chillies, vegetables and fruit are irrigated. Recently a few sizeable sugarcane plantations are being irrigated for the development of a sugar industry.

The crop seasons are governed by conditions of rainfall, and cultivation practices by the amounts of rainfall during the crop period, and by the soil types. There are two crop seasons, the "Yala" (southwest monsoon) and "Maha" (northeast monsoon). These two seasons vary greatly in different parts of the country. The "Yala" sowing may last from February through June and the harvesting from July through October. The "Maha" sowing may last from July through November, and the harvesting from February through May.

The cultivated areas may be classified under:

Rain-fed		Irrigated	
Single Crop	Double Crop	Single Crop	Double Crop
Yala	Maha	Yala	Maha

In the wet zone, non-irrigated lands may have two crops a year if the rainfall distribution is suitable. More often, however, only one crop may be raised, especially in lands which are too boggy for cultivation during the wetter seasons. In the dry zone, a single crop is raised in rain-fed lands or those irrigated under small tanks. Under the larger irrigation schemes, especially the older ones, two crops are reaped annually. In the newer schemes, only one crop is reaped for Maha (wet season in the dry zone).

In the northwestern and eastern dry zones, the first ploughing of rain-fed fields is done with the first shower of the northeast monsoon in August or September. A cross ploughing is done in the dry. The fields are prepared and sown and a turnover ploughing is done. The heavy rains of October to December water the crop, which is harvested late in January or in February. Although these lands are termed rain-fed, in practice the cultivators of these areas are very efficient in the use of water, and when they cultivate land under irrigation, they use water economically. The duty of irrigation water for a Maha crop varies from one and a half to two acre feet per acre, while the Yala crop needs from three and a half to four acre feet per acre. These low requirements of irrigation water are also due to the clayey nature of the soil of the rice fields.

In some areas of the wet zone, a stick dam stystem of cultivation has been evolved. At the beginning of each cultivation season, the cultivators build stick dams on the drainage lines passing through their fields, raising the water to submerge their lands. The water is used by them and drains back to the drainage line, where it is picked up by the next stick dam and so on. A highly developed stick dam system in the Attanagala Oya Basin, where some 200 stick dams irrigated about 7000 acres of land, has now been replaced by a system of 23 diversion weirs and a channel system to command almost the entire area.

Everywhere in the Island except in the two regions referred to in the last paragraph, the Ceylon cultivator is notorious for prodigality in the use of irrigation water. As much as six acre feet may be utilized for a Maha crop and nine acre feet per acre for a Yala crop. From 1900 onwards, almost every Director of Irrigation has drawn attention to the excessive application of water which, apart from limiting irrigated acreage, actually tends to reduce the yield. It is the experience of irrigation engineers that in years of drought, when water supplies are scanty and rotational issues are made, the crop is much better than in years of plentiful rainfall.

The reasons for the high expenditure of irrigation water are:

1. Cultivators begin cultivation operations long after water issues have commenced. The result is that the early issues of water merely run into the drainage lines.

2. Cultivators have an idea that not only should water stand four to five inches deep on the fields, but water should flow through their land continuously.

3. The ridges in the fields are not high enough and wide enough, with the result that they breach frequently, and boring animals such as crabs and mice frequently dig holes right through them.

4. The practice of wet ploughing, while easier in labor, is very expensive in the use of water.

5. Poor distribution within the fields themselves.

6. Poor leveling of the fields between ridges, so that to submerge the higher areas a few inches, water has to stand much deeper in the lower areas.

These current farm practices are, however, changing, principally due to the introduction of mechanized ploughing. The tractors used cannot work in wet fields, and ploughing has consequently to be done in the dry. This saves roughly 12 inches of water which is required for wet ploughing. This system of ploughing is finding greater use in the country. But it

has not yet been sufficiently widely adopted to indicate an appreciable reduction in the use of irrigation water.

The Attanagala Oya Irrigation Scheme referred to above provides an excellent example of the impossibility of "planting" an irrigation scheme in a given area, however successful that system may have been elsewhere. In the 1930's, the cultivators of the Attanagala Oya Basin, who were fed up with the continuous reconstruction and repairs of the stick dams after each flood in the river, requested the government to replace their primitive scheme with a system of permanent structures. Accordingly, in 1939, a scheme was evolved providing eight anicuts (diversion weirs) and a channel system commanding the whole area. When a few of these anicuts had been constructed, it was found that the channel systems were unable to carry water to the areas in the lower reaches of the system. On further investigation, it was found that the soils of the valley were very porous and therefore there was considerable loss of water through the channels. Besides, the duty of six acre feet per acre of paddy did not hold for the valley because of the considerable loss of water by seepage through the soil in the paddy fields themselves. One other difficulty, however, was that cultivators were not prepared to economize on the direct irrigation water issues, as under the stick dam system they had been used to obtaining unlimited supplies of water.

Fifteen more anicuts have been introduced into the system, making 23 in place of the eight originally provided for. The scheme is now functioning satisfactorily, although there still is some difficulty in equitable distribution of water during periods of drought.

Conclusions

In the majority of the paddy areas in Ceylon there is an excessive use of irrigation water. A major cause of this is that the water is not paid for by volume. Irrigation rates are levied per acre irrigated. The current rate varies from Rs.2/ - to Rs.5/- per acre (U.S. $0.40 to $1.00). Indeed, the size of land holdings, averaging three acres per cultivator, makes it impracticable to introduce an economic metering system.

The excessive use of water has resulted in the irrigation projects being more expensive than they should be. With proper husbanding of water under major schemes, it may be possible to extend cultivated acreages up to 50%.

We have seen also that a careful study has to be made of existing irrigation systems indigenous to a valley before designing more modern ones for their replacement.

LAND CLASSIFICATION AS AN AID TO PROPER IRRIGATION PRACTICES

by

Dr. N. A. Halkias

Irrigation Specialist, Land Amelioration Works of Macedonea
Ministry of Agriculture, Greece

I. Basic Principles

Land classification is the scientific appraisal of lands and their separation into groups on the basis of similar characteristics. This paper is concerned with land classification as conducted for the specific purpose of estimating the extent and degree of suitability of land for irrigation. In Greece such land classification is carried on simultaneously with and in connection with studies of the physical, economic, demographic and social conditions of the project under consideration.

Factors considered in land classification

The major controlling factors are the following:

A. Physical factors

1. Soil conditions
2. Topographic characteristics
3. Drainage conditions
4. Climatic conditions, and
5. Water supply

B. Economic factors

1. Productivity capacity
2. Costs of production
3. Costs of land development
4. Payment capacity

Land classes

A land class identifies a group of lands having similar physical and economic characteristics which determine the suitability of land for irrigation. It is an expression of relative level of payment capacity and an index for rating the agricultural value of soils.

The purpose of this paper is to illustrate the use of land classification for proper irrigation practices.

II. Land Classification as a Means for Avoiding Inclusion of Land Unfit for Irrigation Practices

The following main classes are appropriate for detailed land classification on an irrigation project:

Class I Most suitable lands for irrigation, with a relatively high payment capacity, appropriate for diversified crops.

Class II Suitable lands for irrigation with intermediate payment capacity, appropriate for most farm crops.

Class III Less suitable lands for irrigation which, under proper management, are expected to have adequate payment capacity. Lands of this class may give good results with special crops, such as clover, olive trees and vines.

Class IV Lands of limited use which would require special economic and engineering studies to decide on their suitability for irrigation. Lands of this class in Greece usually have excessive salt content, requiring extensive leaching and adequate drainage. They may be used for growing rice but they require excessive development costs.

Class V Non-arable lands under existing conditions or lands whose arability is dependent upon additional land development.

The designation of Class V is tentative and after special agronomic, economic or engineering studies they may be changed to a proper irrigable class or Class VI.

Generally, Class V lands are segregated only where an abundant supply of water or shortage of better lands exists.

Class VI Non-arable waste lands. They should not be included in the area that is to be irrigated.

The above analysis shows that land classification is a valuable and very useful means through which we avoid the inclusion of land unfit for irrigation in an irrigation project.

The total area surveyed in Greece for the purpose of estimating the extent and suitability of land for irrigation is about 1,500,000 acres. Our land classification showed that about 5% of this area is unfit for irrigation. Irrigable lands cover about 80% of the surveyed areas, while 15% belong to Class V.

III. Land Classification as a Means of Assuring The Use of Limited Water Supplies on the Best Land

Water supplies are often limited. In such cases, the irrigable area should be restricted to a total acreage that can be adequately irrigated. The restricted area should include the better classes of land because of their higher payment capacity and greater suitability for irrigation. Less suitable classes must be left out of the irrigation project. Land classification will indicate which parts of the total area are of the better classes, and thus helps us to assure the use of limited water supplies on the best land. Such was the case on the Velvendos irrigation project in Greece.

In designing and laying out irrigation projects it is necessary to determine the water requirements of the project. Overestimating these requirements may result in excluding good lands that might have been irrigated. On the other hand, underestimating may result in including lands that may be less suitable for irrigation. The available water supply was about 16 c.f.s., which is adequate for the irrigation of about 1900 acres of the crops prevailing in this project. On the other hand, land classification was carried out on an area of about 5,000 acres. Land classification of this area showed 500 acres in Class II, 800 acres in Class III, 2,500 acres in Class IV and 1,200 acres in Class VI. Because the water supply was limited, we had to restrict the use of water to Classes II, III and part of IV. Particular tracts of Class IV to be included in the restricted acreage of 1900 should be determined on the basis of their accessibility and relative water requirement.

Beside the soil conditions, topography and drainage, which are the basic data for land classification, farm water requirements are also very important, especially when water supplies are limited. For the appraisal of farm water requirements we used the following table:

TABLE I

Farm water requirements appraisal sample project, Velvendos, Greece

Appraisal	Description
A Low	Average moisture equivalent in upper 1.20 m. of soil 20%. Basic or final infiltration rate 2.5 c.m per hour
B Medium	Average moisture equivalent in upper 1.20 m. of soil = 10-20%. Basic or final infiltration rate = 2.5-7.5 c.m per hour
C High	Average moisture equivalent in upper 1.20 m. of soil 10%. Basic or final infiltration rate 7.5 c.m. per hour

According to the table above, the classes were divided into three categories: low, medium and high farm water requirements. The tracts with the lower farm water requirements of Class IV were included in the restricted area. In this case a detailed land classification was useful in assuring the best use of the limited water supply.

IV. Land Classification as an Aid in Planning Distribution Systems

Land classification maps help to determine the irrigable tracts for which water supplies can be secured and for which irrigation distribution systems should be planned. The type and size of the distribution systems may be determined by: (1) the amount of project land classified as irrigable and its location; (2) the type of land in different classes; and (3) the amount of water that can be obtained for project use. Main canals are usually located along one or both sides of a valley, from the diversion dam to the irrigable lands, then along the higher boundaries of these lands. Laterals and sublaterals must convey water to different parts of the irrigable areas and are located along ridges or contours so that maximum acreages of suitable lands can be supplied with water.

Because of grade limitations, canals seldom can be located along property lines. Farm properties, usually of about four to seven acres in Greece, are divided into small pieces in three, four or more different places in the irrigable area. It also happens that the shape of most of these small pieces of land is irregular. These reasons make it even more difficult to plan and locate distribution systems along property lines, and it is therefore necessary to substitute for all these pieces of land, which usually belong to different classes, a larger farm of regular shape which should be of equivalent land value.

For the foregoing reasons land classification in Greece is more necessary than in other countries where the properties are larger and in single units. Thus, it is proved that the following steps should be followed under existing conditions in planning distribution systems:

1. Designing the distribution systems according to the topography of the land.

2. Redistribution of the lands in accordance with the land classification to concentrate each property into a larger single farm.

3. Adjustment of the single farm to the irrigation distribution system.

V. Land Classification as an Aid in Designing and Laying Out Farm Irrigation Systems

The project land classification map, along with the field sheets, provides the basic soil, topographic and drainage data upon which detailed project irrigation surveys are made. This in turn may be the basis for designing and laying out irrigation systems on the farm. Soils vary widely in their infiltration and permeability rates and in their available moisture capacities, primarily because of differences in texture and depth. These factors affect water requirements, depth and spacing of drains and also length of run and size of stream.

In most irrigable areas in Greece the average coefficient of permeability is about 7.5 c.c./cm 2/hr., and the average moisture equivalent is about 10%. By using Donnan and Neal's methods, for a drain tile depth of about 1.80 m. and a drain tile spacing of about 150 m. we obtain an average rate of drop at mid-point between the drain lines of 0.25 m. per day, which is found to be satisfactory for the crops prevailing in these areas. Because of the favorable values of the permeability coefficient, the moisture equivalent and the resulting large spacing of drains, open ditches as well as tile lines are applicable for underdrainage. These results should be considered in connection with the studies on irrigation systems.

The furrow irrigation method is most widely used in Greece. The ideal furrow system would wet all of the soil occupied by the crop roots, with a minimum of tail waste, with avoidance of waterlogging and with no soil erosion.

To design such a system, two basis elements must be fixed:

a. Length of run
b. Size of irrigation stream

The length of run is affected by three major factors:

a. Texture of the soil
b. Slope of the field
c. Size of the stream

Our observations on the irrigation systems of Macedonia, Greece, over many years of practice in the field led us to accept the following table of suggested lengths of run and sizes of stream for different textures of soils with the slope of about 0.5% usually existing in most irrigable areas in Greece, unless more extensive research results in different findings:

TABLE II

Suggested standards for estimating length of run and size of stream

Length of run m.	Soil texture	Slope of field %	Maximum allowable furrow stream l/sec.	Depth of irrigation application cm.	Suggested basis for
200-250	Fine	0.5	0.8	6	Slow flow of water, maximum possible length of run, and small size of stream
150-200	Medium	0.5	1.0	8	Moderately rapid flow of water, medium length of run and size of stream
100-150	Coarse	0.5	1.2	10	Rapid flow of water, minimum possible length of run and max. allowable size of stream

The above analyses indicate that in most irrigable areas in Greece the drain spacing must be about 150 m. and the length of run for medium-textured soils must be about 150 - 200 m.

Therefore, in designing and laying out irrigation systems on the areas mentioned above, we should take into consideration that the distance between the farm irrigation canals should be 150 - 200 m.

All data required for the studies mentioned above are obtained through land classification surveys and they may, in turn, be very useful in designing and laying out farm irrigation.

Summary

1. Land classification is not only useful but necessary for establishing irrigation projects. In general, it is valuable for determining: (a) the suitability of land for irrigation, (b) the payment capacity, and (c) the agricultural value of soils.

2. Land classification is very useful in avoiding the inclusion of land unfit for irrigation in the total area under consideration.

3. In cases of limited water supply, it is better to use this water on the best land. Land classification is a means of indicating which parts of the total area are the best land; therefore land classification is very important in assuring the best use of limited water supplies.

4. Because of the small size and usually irregular shape of properties in Greece, distribution systems cannot be planned along property lines. In these cases, land classification helps us to redistribute the lands and concentrate the properties in larger, single farms and then to adjust these to the distribution systems.

5. In most irrigable areas in Greece the drain spacing should be around 150 m. and the length of run for medium-textured soils should be about 150 - 200 m.

   These data are obtained through land classification and may in turn be used in designing and laying out irrigation projects.

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DEVELOPMENT AND USE OF GROUND WATER

By

George C. Koumbarakis
Agricultural Engineer, M.S. in Irrigation
Technical Advisor of Agricultural Bank of Greece

Introduction

Ground water has been used by man since his first appearance on earth, and ground water development has been referred to in history since the earliest recorded time. Primitive man was taught to dig for water, possibly by observing the actions of wild horses and wolves in search of water. As soon as he learned to domesticate and to rear cattle and sheep, the well became his most important possession. There are many references where one can find that many of the ancient civilizations had ample supplies of both ground water and surface water, and many where ventures failed for lack of water. It is a matter of common knowledge that in many countries the well is still the center of rural and urban life and of feminine activity and gossip. In recent years ground water has become recognized as a source of great value, and much scientific work is being done in the investigation of its source, occurrence, quantity and quality.

The purpose of this paper is to present briefly the basic principles of ground water hydrology and the techniques most commonly used today in developing and pumping ground water. Also, a brief discussion is given of the economic considerations which are coupled with the physical problems, and there are presented the most important results obtained in a study of irrigation pumping costs, when ground water was pumped by different types of power plants.

Origin and Occurrence of Ground Water

The origin of ground water was a subject of debate for many years, but it is now generally accepted that the greater portion of this water is meteoric, i.e., water which came from the atmosphere and reached the zone of saturation through infiltration and percolation (Fig. 1). That part of subsurface water which is in the zone of saturation is called "ground water" (Meinzer, 1923). Meteoric water reaches the zone of saturation largely by percolation from precipitation and by influent seepage from streams. Some water from almost any rainfall reaches the ground water through rock crevices and channels left by decayed roots, but significant recharge from precipitation can be expected only when the

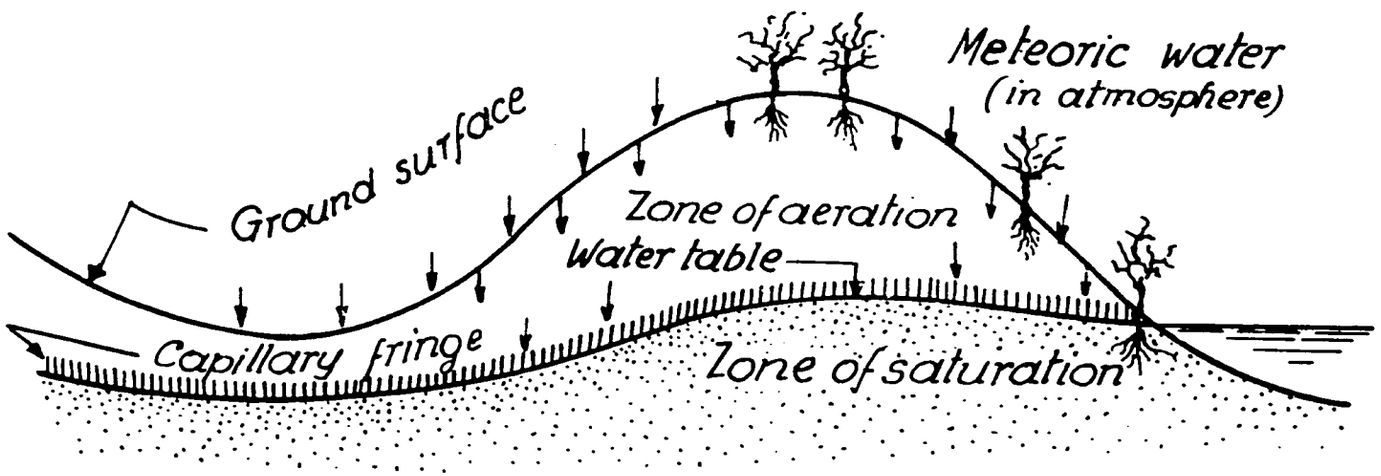

Fig. 1. The location of the water table

soil mantle above the water table is brought to field capacity. Hence, isolated rainfalls of small magnitude and short intense rains yielding considerable surface runoff cannot be expected to result in important recharge of ground water. For the most part, ground water recharge by percolation from precipitation can be significant only during extended rainy periods. Since snow melt rates are relatively low compared with rainfall intensities, sustained periods of snow melt may be expected to yield a high contribution to ground water. Sandy soils having rather low field capacities are particularly favorable recharge areas.

Water Table

The upper surface of the zone of saturation in ordinary permeable soil or rock is called the water table (Meinzer, 1923). When the upper surface of the zone of saturation is under atmospheric pressure, it is free to rise and fall with changes in the volume of stored water. Water found under these conditions is called free or unconfined water. If the upper surface of this zone is under hydrostatic pressure because of an overlying impermeable formation, the water is termed confined ground water, or artesian water. The elevation of the water table is indicated by the water level in a well penetrating the zone of saturation. When a well penetrates a body of confined ground water, however, the water will rise in a well to a height that corresponds to the hydrostatic pressure under which the water is confined (Fig. 2). An imaginary surface that coincides everywhere with points to which this confined ground water will rise is called a piezometric surface or pressure surface.

Fluctuations in elevation of a water table indicate changes in the volume of storage of free ground water. Fluctuations in elevation of a piezometric surface indicate, essentially, changes in pressure within the body of confined ground.

Water-bearing Formations -- Movement of Ground Water

The movement and behavior of ground water depend largely on the size, number, shape, and distribution of interstices or voids in the rock formation of the earth. The rate of movement is directly proportional to the hydraulic gradient. A formation which transmits water in sufficient quantity to support wells or springs is called an aquifer. In contrast, an aquiclude may contain large volumes of water but does not permit its movement at rates sufficiently high for economical development by pumping, or to support large springs. An aquifuge is a formation which has no interconnected openings and hence cannot absorb or transmit water. In addition to the geologic description of an aquifer in terms of its constituents and history, the ground water hydrologist is interested in its porosity, its yield, or the volume of water it will yield by gravity drainage, and its permeability, or capacity to transmit water.

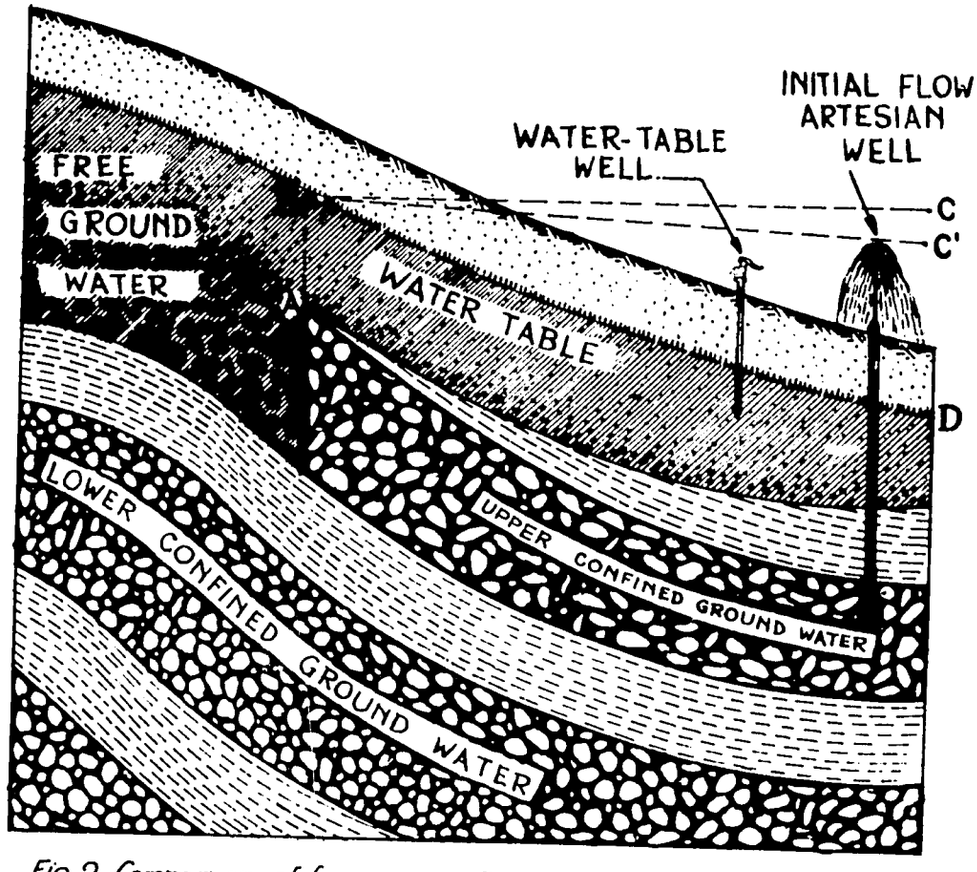

Fig. 2. Comparison of free and confined ground water. BC, theoretical static level of confined water body; BC' pressure gradient, indicates actual static level in wells piercing the conduit.
(After Tolman, 1937)

Porosity is the ratio of the total volume of interstices in a given mass of material to the total volume of such mass expressed as a percentage. The porosity of a given mass of material depends chiefly on the shape, arrangement, and degree of assortment of its constituent particles; the extent to which cementation has taken place; the degree of compaction to which it has been subjected; and the amount of fracturing that has occurred. Porosity determines the amount of water a material will hold. It does not determine the amount it will yield. Porosity varies widely, ranging from as low as 1% in some internal rocks to as high as 80% in fresh delta natural deposits. Porosities higher than 40% are quite rare in undisturbed natural deposits.

The total water content of an aquifer may be computed by multiplying its volume by its porosity. However, some of this water is not available for springs and wells but is permanently retained in the aquifer by molecular forces. The quantity of such dead storage depends largely on the dimensions of the interstices. The volume of water that a unit volume of permeable rock or soil after being saturated will yield when drained by gravity is called the specific yield. The volume of water that a unit volume of permeable rock or soil after being saturated will retain against the force of gravity when drained is called the specific retention. In coarse sands the specific retention is not large, but in fine sands it may equal the specific yield and in clays and silts the specific yield may be nearly zero. Specific yield plus specific retention are equal to porosity. Specific yield is useful in determining from water level changes the quantities of water extracted or necessary to recharge a ground water reservoir. The average quantity of water per unit of time which can be produced continuously from a ground water reservoir over a prolonged period of time, by pumping or other artificial means, without completely depleting the supply of water in the reservoir is called safe yield.

The ability of an aquifer to transmit water is called permeability. Permeability is closely related to yield, since those find-grained deposits which have small interstices do not release water readily and hence do not transmit large volumes of water. Large interconnected interstices result in high permeability.

Among all kinds of rocks, the best water bearers are deposits of gravel. Next to gravel come sand, sandstone, limestone and basalt. The most completely unproductive of all materials are the true clays and fine silts.

Ground Water Investigations

The earth's crust consists of layers, or strata, of rocks of various kinds lying one upon another and massive or foliated bodies of rock that underlie or intersect these stratified series. Formations differ from one another in their water-bearing character, and there

are also likely to be important differences in the same formation at different horizons and in different localities. Therefore, a study of the ground water of a region involves, among other things, a study of the surface distribution of each formation and of its character, thickness, and depth below the surface in each locality.

The principal clue to the ground water conditions of a locality is its geologic section. The character, thickness, and succession of the underlying formations give the most important data as to existing aquifers and the depths at which they can be tapped. A geologic section may be given by an excavation, either natural or artificial, such as gorges cut by streams or road cuts. A dug well or other excavation that is large enough for a man to enter has the great advantage that successive deposits can be carefully examined as they exist in place; a drilled well gives much less detailed and less accurate information but has the advantage that it can readily be sunk much deeper than larger excavations. A ground water hydrologist will utilize all kinds of opportunities to collect data from which to construct a geologic section of the region he is studying. He will examine natural outcrops and the exposures in artificial excavations and will also obtain available records of the progress in drilling wells (logs), especially deep wells that extend to formations not reached by other excavations.

For studies of ground water conditions, well records are especially valuable because they give direct information, whereas all these properties can be forecast only with considerable uncertainty from examination of exposures alone. Much can be foretold about the water-bearing properties of a formation by examining its exposures and applying the above-mentioned fundamentals for assessing ground water condition; but there is generally considerable difficulty in making hydrologic forecasts based entirely on lithologic characteristics. Perhaps the chief difficulty lies in the fact that in most available exposures, especially in natural exposures, the rocks are not seen in their unmodified condition but greatly altered by weathering.

The satisfactory solution of most ground water problems usually involves the putting down of either prospect or test holes. Many times only one hole is put down, and it is assumed that the ground water conditions are the same all around. Unless it is definitely known that ground conditions are uniform over a considerable area, estimates based on one test hole may later be found to be 100% wrong. It is for this reason that three test holes are considered the minimum number required to secure sufficient data. The analysis and interpretation of information secured from test holes is oftentimes the most important phase of a ground water development and unless done by someone who has had considerable experience may lead to erroneous conclusions which may or may not prove to be serious later.

Wells

Constructions for the purpose of extracting ground water are mostly a vertical excavation, either a shaft or borehole. These constructions are known under the name "wells". Other excavations for collecting ground water include tunnels, drifts from shafts, horizontal boreholes from wells, drainage ditches, and various types of engineering works for collecting spring water.

Such constructions have been known from the beginning of time, but the most extraordinary works of ancient man for collecting ground water are the ghanats of the Persians. The ghanats connect the bottom of shafts, conspicuous over all the high central valleys of Persia, and are dug by human moles working over long periods of time (Tolman, 1937). But there is no need to go into details about ghanats from references. We are lucky because this Seminar is taking place in this city and all of us will have the opportunity to see and hear more about these extraordinary constructions by which the people of this country have been developing ground water for over a thousand years.

Water Table and Confined Wells

The two types of wells which require separate hydraulic treatment are water table wells and well tapping confined water. The former draws on free ground water below the water table and the latter on confined ground water below a confining formation. Pumping of the former lowers the water level in the wells, extracts water from the immediately adjacent water-bearing material, and produces a cone of water table depression surrounding and tributary to the well. Water outside of the cone of depression but within the area of influence is diverted to replace the body of ground water which is moving into the pumping well.

Pumping of confined water reduces pressure in the water-bearing conduit and causes movement of water in the conduit toward the well.

If a well taps both free and confined water, or if the confining formation leaks, both extraction of water from the free ground water around the well and pressure relief in the confined aquifer occur. If the well taps several confined water-bearing strata, a composite pressure effect is produced in all the aquifers.

Types of Wells

If we are to attempt to classify wells according to methods of construction, they may be classified as: 1. dug wells, 2. bored wells, 3. driven wells, and 4. drilled wells.

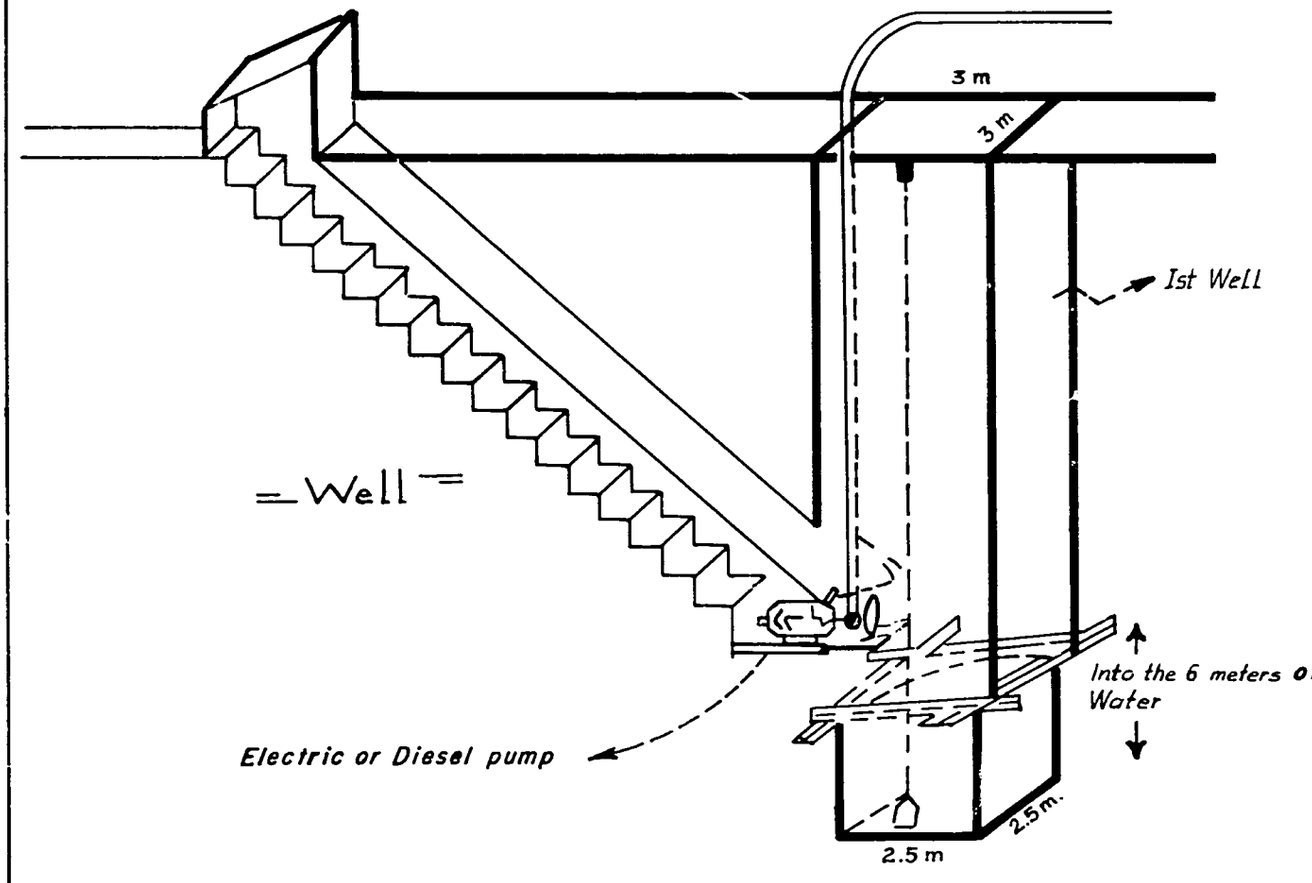

FIG. 3 - SKETCH OF ORDINARY WELL

1. Dug wells are frequently used as a source of water supply for the home, ranch, or private estate where the water table is reasonably close to the surface. Dug wells are usually excavated by handwork, using a pick or shovel. The excavated material is placed in buckets and raised to the surface and the hole is followed down with well cribbing where the formation will not stand by itself. The well is lined with wood, rock, concrete, brick, or metal, depending upon the cost and availability of material.

The diameter of these wells usually is 1.20 meters to 2.50 meters and the minimum depth is the depth to water, the idea being to go to water and then penetrate the water-bearing formation for some meters, if possible, so as to allow for drawdown and changes in the static level. When constructing wells of this kind, pumps are used after the water table is reached to keep the water down and allow further excavation.

A type of dug well in which greater storage capacity has been provided are open cuts, i.e., pits or excavated ponds. They usually are rectangular and are excavated into water-bearing strata at depths of three to six meters. They are not always dependable because the water level may drop in the shallow strata in dry periods, but sometimes they provide water at a lower unit cost than do the impounding type of ponds. The water in the pits sometimes may be increased by recharging them with clear drainage water.

2. Bored wells are often bored in soft unconsolidated materials by means of an auger turned by hand, or mechanical power. The size of hole may vary from five to 70 centimeters in diameter, but this method is more frequently used for shallow wells in diameters of up to about 30 centimeters. Casing is required soon after the well reaches the water table unless drilled in cemented material.

3. Driven wells are shallow wells, three to 15 centimeters in diameter, which may be constructed economically by driving a well point and casing into the ground until an aquifer is reached. Because such wells can be placed rapidly and easily pulled for redriving, they are useful in prospecting for water near the surface or for temporary supplies.

4. Drilled wells. In constructing drilled wells the excavation is made by either percussion or rotary drills and the excavated material brought to the surface by means of a bailer, sand pump, suction bucket or hollow drill tool, or by hydraulic pressure, The term "drilled wells" is universally used in the well-drilling industry. Casing of from 15 to 40 centimeters in diameter is economically used in these wells. Casing is riveted, lap-welded steel or cast-iron pipe and is made up in sections varying in length from two and a half meters to six meters. Usually a test hole is first drilled to determine the geologic and hydrologic character of the formation encountered.

A well usually must be developed after it is drilled to achieve maximum flow, especially when it is in formations containing sand, silt or clay. Development consists of the removal of sand, silt and clay particles and rearrangement of the remaining material around the well screen by surging, backwashing, or hard pumping with quick starts and stops. If sufficient gravel is not already present in the aquifer, gravel may be placed around the well screen artificially to aid in development of the well. Sustained pumping tests, to determine the yield of a well after several days of pumping, are necessary to establish its true capacity and dependability. Expensive pumping units should not be installed until yield under sustained pumping is determined.

The Use of Ground Water

The most outstanding uses of ground water are domestic and agricultural uses. Many millions of people all over the world depend on wells for their water supply. In the United States alone, about one-half of the population in towns depend on ground water for domestic use, and in the country more than one-half of the people use ground water. In California, which contains the largest irrigated area in the United States, about 2,000,000 hectares are under irrigation, most of which secure water from wells. The use of ground water for irrigation is developing rapidly and with improvements in pumping equipment water is being pumped economically from great depths. Naturally, this has led to studies of the types of water that are best for different crops and soils, and also to studies of pumping costs and equipment.

Domestic Use

If ground water is used for domestic purposes, it should be kept in mind that the water should be free from pollution and not hard. If the water is hard, common soaps do not readily form suds in it. Many people building wells do not realize the importance of well sanitation. Some states in the United States have ruled that no well, either public or private, may be constructed without first securing the approval of the State Board of Health. Other states have made great advances in the matter of construction of sanitary wells by providing rules and supervision under which wells may be built. It is well to know that there is nothing more dangerous to the health of a community than a polluted well.

If a well is constructed for domestic water supplies, every caution and care should be used to provide a sanitary well. In dug wells for domestic purposes the upper portion of the well lining should be made impervious, to prevent bacterial pollution of the water by eliminating surface seepage through or down the outside of the well casing. Great care should be taken in locating a dug well with reference to possible pollution because such wells intercept water at or close to the water table, and near-surface ground water is likely to be polluted. A domestic dug well should never be placed in the down slope direction of the water table from a

refuse disposal point. If it is desired to shut off contaminated surface water in a drilled well, conductor pipe is run into clay stratum and cemented. If the job is successfully carried out, the water behind the conductor pipe is shut off from entry into the well. When ground water is to be used for domestic purposes, water quality analysis should be carried out to determine the hardness and whether the water is free from contamination.

Agricultural Use

Ground water is usually used for irrigation if the water from streams is already completely utilized or, if surplus water is still available, the cost of bringing it to the land is too high.

Factors to be considered in developing successful irrigation enterprises by pumping from wells are the supply of ground water, the land, the well, the pump and accessories, the crops and the markets. No hard and fast rules can be laid down as to the depth to water beyond which pumping is no longer feasible for irrigation. It depends primarily on the value of the crops produced. In Southern California, where fruits, cotton and vegetables are grown, ground water is pumped from wells of a depth of 1,000 meters where the static water level is at a distance of 130 meters to 170 meters.

The water that is to be used for irrigation need not be potable, but it must not contain high concentrations of salts injurious to plants or soil. Well water, or ground water, contains minerals in varying proportions, depending upon the type of material through which the water percolates. Water may enter water-bearing materials -- generally coarse sand and gravel strata- -and as it slowly flows or percolates through the strata, it dissolves minerals from the rock and soil in varying quantities. If the minerals dissolved are calcium and magnesium salts, the water is known as hard water. This type of water is usually considered good for irrigation purposes, as only occasionally do the calcium and magnesium salts reach a concentration toxic to plant growth. Salt water, on the other hand, may contain a high percentage of sodium salts. These salts may reach a concentration toxic to plants, but even at low concentrations they cause a deterioration of the soil structure, and with their continued use the surface soil will seal and prevent the wetting of deeper layers. Therefore, when water is to be used for irrigation, it should be tested to determine which alkalies are present and the percentage of each.

In draining agricultural lands, the excess of subsurface water is removed by means of conduits, or other water-conveying devices. The interest in such cases centers therefore on lowering the water table to a depth below the effective root depth of the plants grown. When ground water development takes place in areas with a high water table, drainage may be an important by-product provided that sufficient volumes of ground water are used for other purposes. On the other

hand, the water recovered in a drainage project may be an important by-product, but in that case special precautions should be taken with respect to the quality of the water, because drainage waters are of poor quality and very often their use for irrigation should be avoided.

Pumping Plants

Well water is lifted to the ground surface in various types of containers by hand or mechanical devices, or water is raised by pumps or by natural hydraulic pressure. For irrigation purposes, several types of pumps are available for use in wells. The horizontal centrifugal pump can be used where suction lift does not exceed eight meters at sea level and less at higher altitudes. Piston pumps can be used for small flows and high lifts. For pumping water from deep wells, deep-well turbine pumps are used.

The choice of power unit to drive the pumps is usually restricted to internal combustion engines and electric motors. Windmills do not provide sufficient power, except for small plants such as are used to irrigate gardens.

Pumping Cost

The cost of pumping consists of the fixed charges (interest, depreciation, insurance, and taxes) and the operating charges (power or fuel, repairs, lubricants, and attendance). Fixed charges are relatively invariable and do not depend on the output of the pumping plant. They recur from year to year regardless of whether the plant is operated continuously or only occasionally. Operating charges are variable costs bearing a definite relationship to the number of hours of operation. They are the sum of power or fuel costs, repairs, lubricants, and attendance. If the pump is operated for only a short period, the fixed charges will be the major items in the cost and may be excessive. The lowest unit costs will be obtained if the plant operates for a long period each season.

During 1954 the author made a study in California, together with a professor of the University of California, Mr. Verne Scott, with the objective of evaluating the various factors which influence the cost of pumping. Plants with different types of power (electric, diesel, and natural gas plants) were selected in three areas of the State where cropping pattern, hours of plant operation, and ground water conditions varied considerably from one to another. The average pumping lift in the three areas for the wells included in the study was 24, 66, and 142 meters. Field tests were conducted and additional data obtained from operators, owners and electric power and gas companies. The results obtained will assist in making comparisons of operation by different drive power units under varying water level conditions.

When a comparison was made among the average pumping costs for the different types of drive power, the results obtained indicated that when electric and diesel plants were operated under similar conditions, such as pumping lift and hours of operation, diesel plants cost more than electric plants. The pumping cost of diesel plants per unit of water pumped (acre-feet) was 20.6% higher than that of electric plants. The higher cost of diesel plants is attributed to their high initial cost, on which fixed charges were computed, and because of their higher maintenance and attendance cost.

When natural gas and electric plants were operated under similar conditions, natural gas plants cost less than electric plants. The pumping cost of electric plants per unit of water pumped was 57% higher than that of natural gas plants. Although the initial cost of natural gas installations was higher, their pumping cost was less than that of electric plants because of the low rates at which natural gas was supplied.

When the data for the fixed and operating charges were considered, it was found that the range of values was rather great and varied with the total pumping cost of the different plants. In the electrically-operated wells, fixed charges varied between 29 and 40% and operating charges varied between 60 and 71%. In diesel and natural gas-operated wells, fixed charges amounted to 40-46% and operating charges varied between 60-54%, respectively.

One of the most important factors affecting the cost of pumping water is the over-all efficiency of the pumping plant. The over-all efficiency of the plant has a direct relationship to the amount of power or fuel consumed. It also influences, in the final analysis, other costs for the following reason: if efficiency is low, the pump must operate more hours to irrigate the same area. Consequently, the useful life of the plant is decreased and cost of maintenance and attendance is proportionally increased. In the study referred to above, a decrease in the over-all efficiency of an electric plant from 70 to 50% while operating under the same conditions increased the power cost 51%; a decrease from 15% to 12% in the over-all efficiency of a natural gas and a diesel plant increased the fuel cost 39% and 23% respectively. The relationship between over-all efficiency and power cost or cost of fuel consumed is shown by graphs (Figures 4, 5 and 6).

Ground Water Conservation

When ground water is used for irrigation or other purposes, it should be kept in mind that this water is not inexhaustible. If we do not take care to regulate and conserve it, overdrafts and shortages will be unavoidable. To conserve ground water does not mean to stop using it. It means proper use within the limitations of the

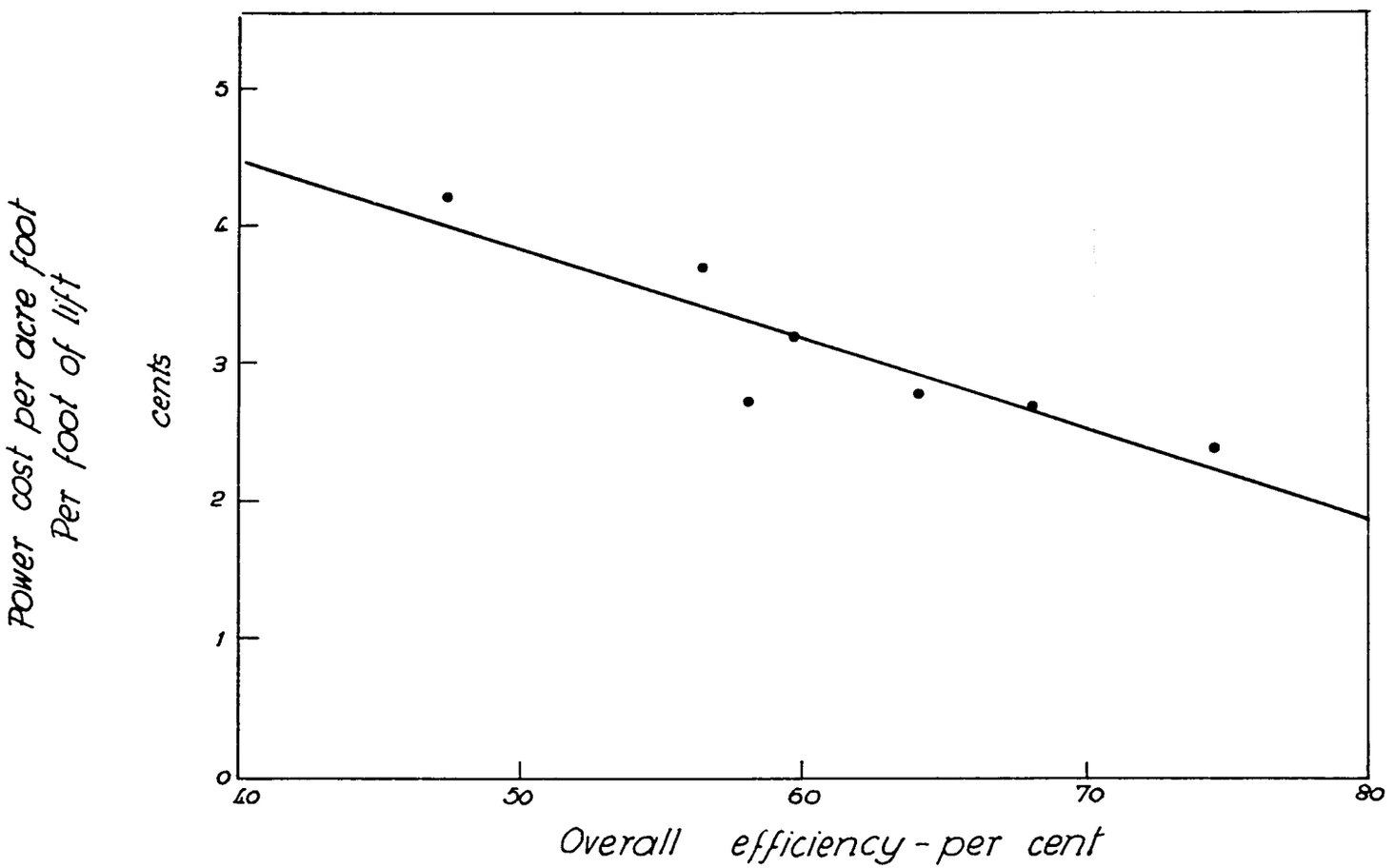

Fig. 4. Relationship between power cost and overall efficiency, Yolo electric plants.

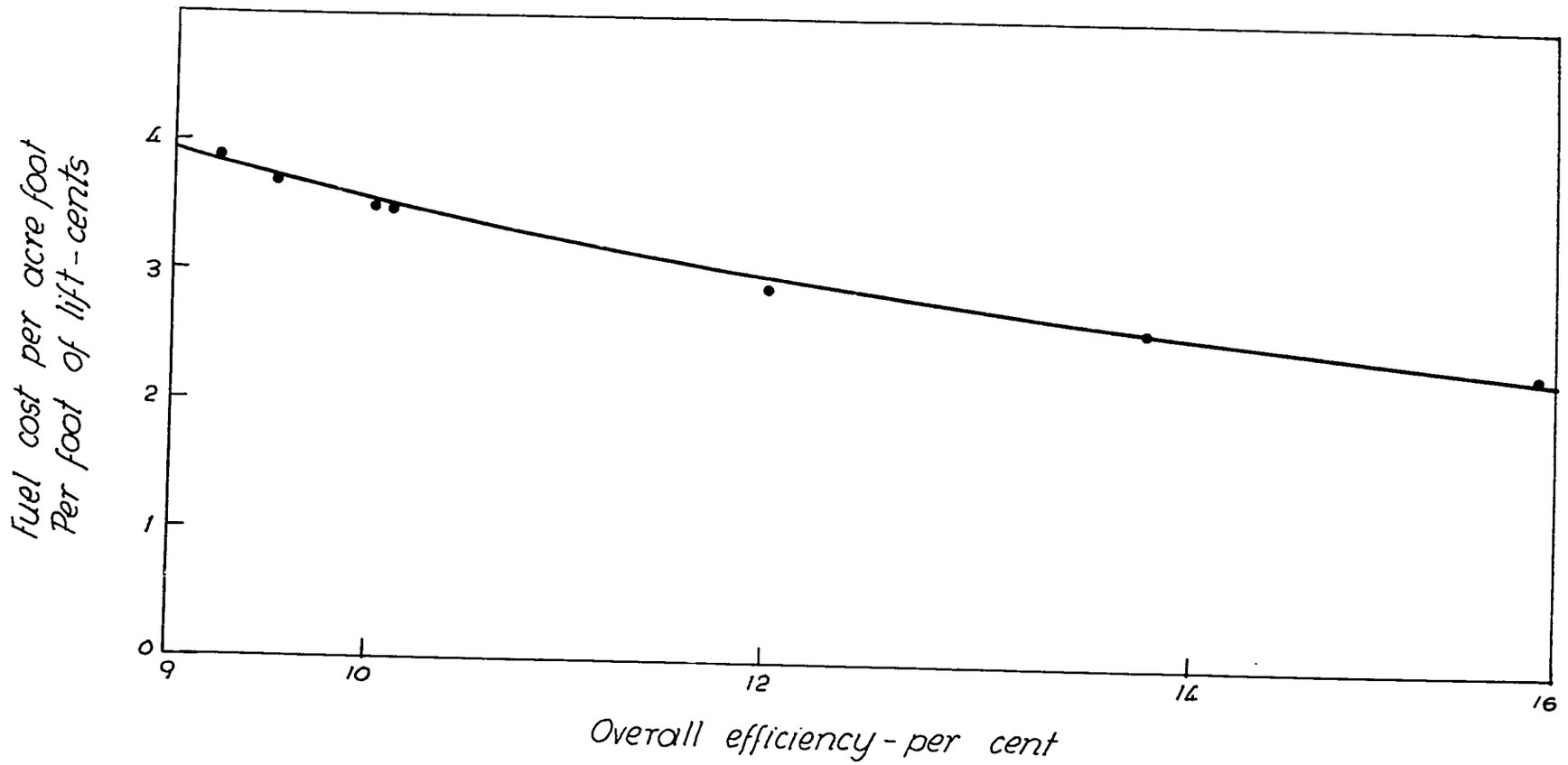

Fig. 5. Relationship between fuel cost and overall efficiency, Yolo diesel plants.

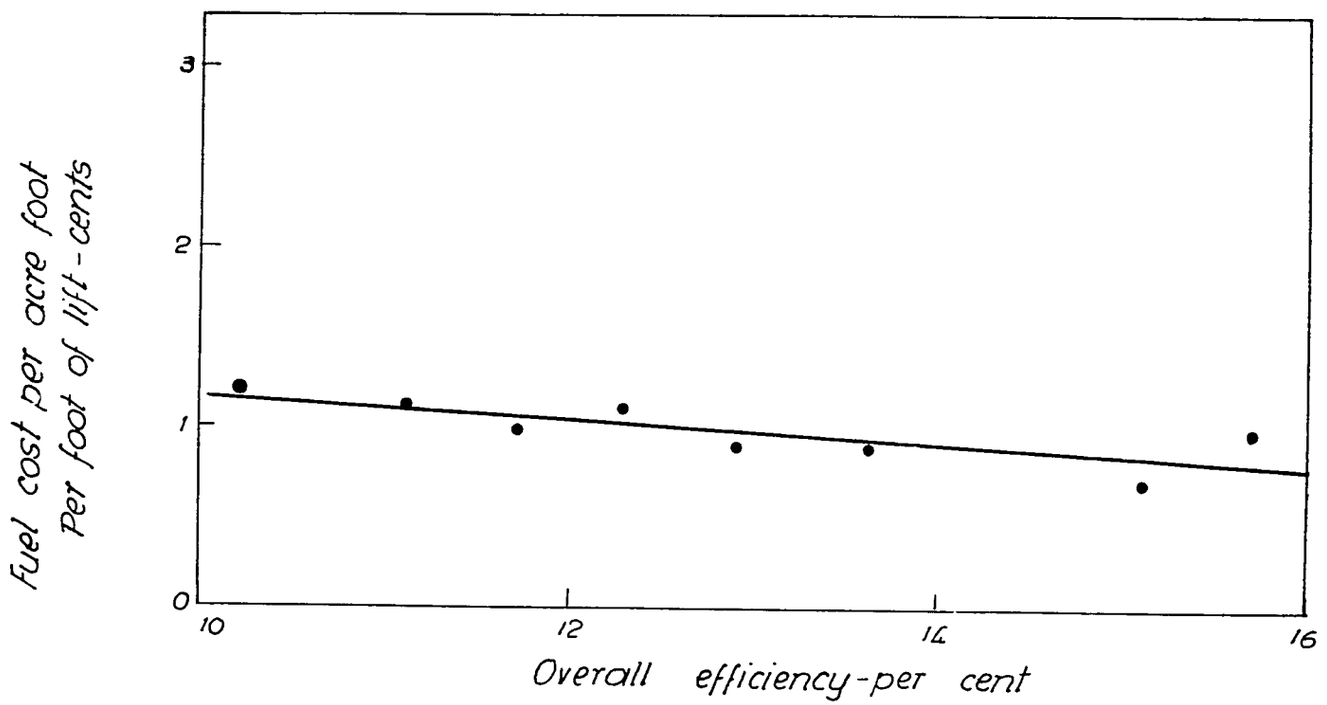

Fig. 6. Relationship between fuel cost and overall efficiency, Riverside natural gas plants.

known supply and its replenishment. Overdrafts and shortages of ground water are local and are caused by concentrated pumping within an area that may or may not cover a ground water basin or reservoir. An overdraft exists when the extractions from the whole ground water basin exceed the safe yield.

To estimate ground water storage from the movements of the water table, measurements are made at wells or observation holes. The measurements should be made regularly over as long a period as possible and, if done accurately by establishing elevations, contour maps of the water table can be made. By comparing these maps at various periods, estimates can be made of the gain or loss in the ground water reservoir. It is necessary, of course, to consider the porosity and the specific yield at the formation when using this method. But what can be done to avoid overdrafts? The question is not a simple one to answer. Basically, if the entire ground water reservoir is considered, the extraction by pumping must not exceed the net safe yield. The net safe yield of a ground water reservoir is equal to the annual net draft over a long period that does not or will not exceed the annual recharge. Determination of the net safe yield requires extensive study and usually is not undertaken until an overdraft already exists.

The basic hydrologic equation of a ground water reservoir is: recharge equals discharge. Where pumping occurs, the draft must be over a long period, at the expense of natural discharge, and the equation can then be written: Recharge equals natural discharge plus artificial discharge. When, over a long period, natural plus artificial discharge exceeds recharge, the excess is supplied from accumulated storage and a condition of overdraft exists. The only solution of the problem is to increase the recharge side of the equation or reduce the discharge side to bring about a balance. The recharge items are: surface inflow, subsurface inflow, and precipitation on the area. The discharge items are: surface outflow, subsurface outflow, and consumptive use in the area. Increase of recharge may be accomplished by importing water to the area either for direct consumption to relieve the pumping draft or for artificially recharging the ground water reservoir, and through spreading or injection of water into wells. Decrease in the discharge side of the equation may be accomplished by eliminating consumptive use and evaporation losses from uneconomic plants and swamp or waste areas. Areas of high ground water, such as may be found at the outlet of some ground water reservoirs, tend to waste water. This waste can be eliminated by removal of vegetation or by lowering the water level through drainage. If drainage is used in this sense, the drainage effluent must be put to beneficial use. All water conservation practices within the area will also serve to reduce the natural discharge.

However, in the majority of the areas where ground water overdrafts and shortages occur, it is the economic limit rather than the complete physical depletion of ground water resources which presents

the main problem. When we are to solve this problem by applying the above-mentioned technical methods, legal control will be necessary. If there is a lack of adequate laws, new laws may have to be adopted before any general program of conservation by legal control can be carried out. When a ground water reservoir is operated under such a planned program, the full use of the water will be obtained and no permanent overdrafts should be expected.

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DESIGN AND LAYOUT OF FARM IRRIGATION SYSTEMS

By

Naki Uner
Regional Director of Soil Conservation
and Farm Irrigation, Izmir, Turkey

I. Irrigation Requirements

The main purpose of irrigation is to obtain high production by using water in the proper way. The broad requirements for the best results under irrigation farming are as follows:

1. A well drained soil profile.

2. Good soil conditions maintained to provide fairly consistent ability to take water into the soil.

3. Good quality of water for irrigation.

4. A stable water supply adequate to meet the irrigation requirements of the cropping plan to be followed.

5. Water applied to the soil:

   a. Without erosion.
   b. Without excessive surface losses.
   c. Without excessive deep percolation losses.
   d. Without waterlogging.
   e. Without harmful alkali accumulation.

II. Factors Affecting Layout and Design of Farm Irrigation

To satisfy all of these requirements, careful consideration must be given to the basic land factors involved. These factors are:

1. Soil:

   a. Affects types of crops and yields.
   b. Determines rate of infiltration or permeability.
   c. Influences selection of irrigation grades.
   d. Sometimes limits amount of land preparation
   e. Sometimes influences choice of irrigation method.

2. Topography Influences:

   a. Choice of irrigation method.
   b. Direction of irrigation and regularity of layout.
   c. Amount and type of land preparation which may be feasible.

3. Slope Influences:

   a. Choice of irrigation method.
   b. Choice of irrigation grade.
   c. Direction of irrigation.
   d. Amount and type of land preparation which may be feasible.

4. Farm management practices, crops, equipment available, etc. influence:

   a. Choice of irrigation method.
   b. Subdivision of field.
   c. Amount and type of land preparation.
   d. Erodibility of soil.

5. Irrigation Grade and Size of Irrigation Stream:

   a. These two factors largely determine velocity of flow on the field.

   b. Should be considered concurrently so that desired velocity will be obtained.

6. Established Boundaries Influence:

   a. Length of runs.
   b. Regularity of layout.

III. <u>Objectives to be Sought in Designing and Planning of Farm Irrigation</u>

1. A layout which will be suitable for the crops to be grown.

2. A layout which will permit irrigation in a reasonable time and at low cost.

3. A layout which will not unreasonably interfere with farming operations.

4. A layout of field into "runs" on selected grades so that the farmer is enabled to apply water uniformly without excessive waste.

5. A layout which can be installed at justifiable expense.

6. A layout which will provide for use of different methods of irrigation on each field if required by crop rotations.

7. A layout which will provide for measurement of water at different points of the farm.

8. A layout which will provide for division of water between fields.

9. A layout which will have capacity to handle the maximum required rate of flow to each part of field (if water is delivered on a rotation basis with a given rate of flow and length of time, the system must be able to handle the maximum quantity received).

10. A layout which will provide for the re-use or disposal of unavoidable waste water.

11. A layout which will provide delivery with minimum losses in the system itself.

IV. Layout of Field - Needed Information for Layout of Farm Irrigation System

1. Topographic map.

2. Soils information.

3. Size of irrigation stream.

4. Irrigation methods to be applied.

5. The right size and dimensions of border and basin.

6. Length of run.

7. Crops to be grown.

After getting this information, most of the planning may be done on the maps. The soils information should be recorded on the topographic map to assist in the planning. The ditch locations may be shown on the map and grades taken from the contour lines. After the plan is laid out on the map, the ditches and structures are then located and staked out in the field with surveying instruments.

The point of beginning for any farm system will be the location of the point of delivery of the water to the farm. This is the highest point on the farm except where water is obtained from a pump. In the latter case, the pump location becomes the point of beginning.

The capacity of the system can be determined by the information furnished by the experiment stations. If there is no information available, the table shown may be used.

Peak Use of Water of Some of the Common Crops in a Day With Continuous Flow

Crop	COOL CLIMATE mm/day	COOL CLIMATE lit/sec/ha	MODERATE CLIMATE mm/day	MODERATE CLIMATE lit/sec/ha	HOT CLIMATE mm/day	HOT CLIMATE lit/sec/ha
Alfalfa	3.8	0.44	5.1	0.59	6.4-7.6	0.74-0.88
Pasture	3.1	0.36	4.1	0.48	5.1-6.4	0.59-0.74
Grains	3.8	0.44	5.1	0.59	5.6	0.65
Potatoes	2.5	0.29	3.1	0.36	3.6	0.42
Beets	3.1	0.36	3.8	0.44	5.1	0.59
Evergreen orchards	3.8	0.44	5.1	0.59	6.4	0.74
Orchards with cover crops	5.1	0.59	6.4	0.74	7.6	0.88

These figures indicate continuous flow which will be sufficient to irrigate one hectare of land. So we can determine the rate of flow for our distribution system.

In designing and laying out a distribution system, the size of the irrigating stream should be considered interdependently with selection of irrigation grade. When the irrigation stream is divided, it should be so arranged that total flow can be utilized. Theoretically, length of run is determined by permeability and length of time water can be allowed to run without penetrating below desired depth. Higher velocities enable water to travel greater distances in a fixed time and therefore should provide for longer runs. Practically, length of run should be determined by trial irrigations. After a number of trials on the same soil in a given locality, a good estimate can usually be made. Runs should be as long as is possible consistent with securing fairly uniform penetration. With shorter runs, ditches occupy more land, require more maintenance and hamper tillage operations. Slope, topography, established boundaries and farm practices may influence the selection to the extent that the ideal layout will not be the most practical.

Size and shape of basins, borders or benches are also very important. Width can often be determined by the cross-slope of land. Farming equipment on hand may influence width. Width of border should be adjusted to length of border and size of irrigation stream so that the desired amount of water can be applied in the length of time required to secure proper penetration. Thirteen to 20 meters is a common figure where land leveling is not the limiting factor. Wide borders are desirable from a farming stand-point. Areas of basins are determined by the size of the stream of water available. Basins should be filled to the desired depth of water in a very short time where efficient irrigation is desired.

Specifications for Border Method

Soil Texture	Land slope	Flow per m. Width of strip liter/sec.	Depth of applic. cm.	Strip width m.	Check length m.
		(Deep-rooted crops)			
Light	0.002-0.004	10.5-14.5	10	12-18	60-90
Light	0.004-0.006	9.5-10.5	10	9-12	60-90
Light	0.006-0.010	5.0-9.5	10	6-9	60-90
Med. light	0.002-0.004	5.0-7.0	13-15	12-18	90-180
Med. light	0.004-0.006	4.0-6.0	13-15	6-12	90-180
Med. light	0.006-0.010	2.0-4.0	13-15	6	90
Medium	0.002-0.004	3.0-4.0	15-18	12-18	180-330
Medium	0.004-0.006	2.0-3.0	15-18	6-12	90-190
Medium	0.006-0.010	1.0-2.0	15-18	6	90
Heavy	0.002-0.004	2.0-4.0	18-20	12-18	380
Very heavy	0.002-0.003	0.5-2.0	18-20	12-18	380
		(Shallow-rooted crops)			
Med. light	0.0015-0.006	5.0-7.0	5-10	4.5-18	90-180
and	0.006 -0.015	4.0-6.0	5-10	4.5-6	90-180
Light	0.015 -0.040	2.0-4.0	5-10	4.5-6	90
Heavy	0.0015-0.006	3.0-4.0	10 -15	4.5-18	180-330
Very heavy	0.006 -0.015	2.0-3.0	10 -15	4.5-6	180-330
	0.015-0.040	1.0-2.0	10 -15	4.5-6	1180-330

V. Maintenance and Operation of Farm Irrigation System

1. Maintenance of land surface to uniform grade

   a. Requires floating whenever field is plowed.
   b. Will require releveling when silty water builds up the upper ends of runs.
   c. A level field requires some releveling after first year of irrigation.

2. Operation

   a. Good farm management practices should be adopted.
   b. One-way plow should be used.
   c. Operation should be according to plan and established schedule.
   d. Weeds and rodents should be controlled, particularly on bench-terraced land.

3. Farmer should not consider that operations are perfect but should be encouraged to develop improvements through his own experiments.

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1. Engineering Handbook, SCS, USDA.

2. Irrigation Practices, Dr. Israelson.

3. Irrigation in the Southwest, SCS, USDA.

4. Farm Irrigation Systems, Naki Uner.

SPECIFICATIONS FOR FURROW AND CORRUGATION METHOD

THE MAXIMUM LENGTHS OF FURROWS AND CORRUGATIONS (METERS)

Soil Class	Heavy						Medium					Light				Very Light		
Depth of water applied (cm.)	17.5	15	12.5	10	7.5	5	15	12.5	10	7.5	5	12.5	10	7.5	5	10	7.5	5
Slope																		
0.0025	650	600	550	500	425	350	465	415	385	325	275	258	233	200	166	108	91	75
0.0050	450	416	383	333	291	241	316	291	258	225	183	175	158	133	108	75	58	50
0.0075	350	325	300	266	233	191	250	233	208	175	141	141	125	108	91	58	50	41
0.0100	300	283	258	225	200	158	216	191	175	150	125	118	108	91	75	50	41	33
0.0150	250	225	200	183	158	125	175	158	141	125	100	91	83	75	58	41	33	
0.0200	200	191	175	158	133	108	141	133	118	100	83	85	75	66	50	33		
0.0250	180	166	158	141	116	100	133	116	108	91	75	75	66	58	41			
0.0300	170	150	141	125	108	91	116	108	100	83	66	66	58	50	41			
0.0400	150	133	116	108	91	75	100	91	83	66	58	58	50	41	33			
0.0500	125	116	108	91	83	66	91	83	75	58	50	50	41	33				
0.0600	108	100	91	83	75	58	83	75	66	50	41	41	33					

DESIGN AND LAYOUT OF FARM IRRIGATION SYSTEMS

Formal Discussion

By

T. J. Mirchandani
Director, Agronomic Survey Experimentation,
Council of Agricultural Research, India

Introduction

The aim in properly designing and laying out an irrigation system is to convey, distribute and spread irrigation water on the land or in the soil as uniformly as possible consistent with the best utilization of land, labor and water, leading collectively to maximum net economic returns. In the course of development of irrigation, three main systems of farm irrigation - viz., surface, sub-surface and overhead or sprinkler - have emerged. In surface irrigation, water is conveyed through main water courses or ditches at ground level, is discharged into laterals and is ultimately let into strips, basins or checks of varying size and shape. The ditches are mostly open, formed by earth excavations, and are sometimes lined with pacca bricks and cement mortar in sandy soils of high porosity. In sub-irrigation, a well-planned system consisting of main ditches, field ditches and spud ditches with structures is provided below the ground level with adequate outlet for drainage of excess water. Dams are provided in the lateral ditches and baffles in the spud ditches to maintain an artificial water table at high level for rapid vertical and lateral capillary movement of water. The ditches also act as drains and the excess water is collected and pumped up into the main stream. In sprinkler irrigation, water is conveyed under pressure from a main pipeline to lateral pipelines and is discharged through perforated pipes or through nozzles or sprinkler heads mounted on risers connected to the lateral pipes. Each sprinkler head applies water on a circular area and, therefore, the spacing between the lateral pipes and the position of sprinkler heads are adjusted to provide an overlap.

The sub-surface irrigation and sprinkler systems make economic use of water. The former helps in reducing evaporation losses and the latter eliminates deep percolation and runoff losses and obviates the need for leveling. Notwithstanding these advantages, the high initial cost of these systems has limited their use to special conditions

only; e.g., sprinklers have been successfully employed principally for supplemental irrigation in some of the advanced countries, mainly of land of irregular topography or under conditions of scarcity of water. Surface irrigation methods continue to be the most widely used in the world. In India, where irrigation has developed mainly in the plains and soils are fairly deep, irrigation is almost exclusively by surface methods, although there are possibilities of the use of sprinkler irrigation in high-value plantation crops on sloping hills, etc.

Methods of Surface Irrigation in Relation to Design and Layout for Irrigation

Many forms of surface irrigation are in use and among these mention may be made of wild flooding, border strip, check-basin irrigation, contour checks, and furrows. Reference may be made to Phelan and Criddle (1955) and to Smith (1956) in regard to advantages, disadvantages and limitations of each of these methods. The methods adopted in India may be classified as follows:

Flooding:
1. Wild flooding
2. Check-basin or bed
3. Border strip

Furrow :
1. Narrow furrow and ridge method
2. Narrow furrow, broad-ridge method

Wild flooding

Water is often applied by this method in the early stages of new irrigation projects. As the land is not properly levelled, an adequate number of water courses is not provided and their position is often not correctly located. The farmer is not accustomed to handling large volumes of water, so water is let on undeveloped land and considerable wastage occurs. However, as land development proceeds, leveling improves, and this method yields place to other methods of irrigation such as check-basin or bed irrigation.

Check-basin or bed irrigation

This consists in flooding quickly a more or less level irrigation bed, bounded by bunds, checks or dikes so that a uniform depth of water is impounded on the soil surface. The size of bunds depends on the size of beds, which in turn is generally related to the size of discharge. Thus this method differs from wild flooding in that the basins or beds are more or less level within. Fig.9 shows an idealized layout plan of a block of land under canal irrigation in undivided India. (Roberts and Kartar Singh, 1947). A more or less similar pattern is followed in the canal-irrigated areas in the present India. Each block of lands designated as a square or rectangle covering an area of

27.8 or 25 acres, respectively, was divided into five columns of five units each. One lateral water course ran in the middle of a five-acre column, dividing it into two strips, in order to irrigate plots of one-eighth to one-half in acre size on either side of the water course. Thus, a block of 25 units was provided with five water courses fed from the main water course. The actual number of water courses was, however, usually less than the idealized plan; e.g., five water courses per two blocks or three water courses where a cultivator owned only one block of land, were provided.

Under tube well or well irrigation, the size of check-basin and channels is considerably reduced in conformity with the size of the discharge. The number of field water courses and check-basins is correspondingly increased.

Border strips

As stated by Marr, the border strip method is the most popular in California and the method has been described by the American Society of Agronomy as a method of applying water to land between parallel ridges or borders. The strips of land between adjacent borders have no cross slopes but may have a grade in the direction of the irrigation. The method is illustrated in Fig.10. The strips may be 200 to 2,000 feet long, depending on the texture of soil, slope and discharge. The breadth of strips is 20 to 30 feet only. Strictly, there is no use of such long and narrow strips in India. However, long and narrow plots or strips of smaller dimensions are often used. These strips are generally level or have a slight downward slope.

Furrow irrigation

This is a very common method of irrigation in vegetable crops where inter-row spacing is more than 15 inches. Figure 11 illustrates the method as generally adopted by growers in India. Furrows and ridges, alternating with each other, are first drawn up parallel to the field water-course. The furrows and ridges are almost of equal width and the average distance between the consecutive furrows varies from one and a quarter to two and a half feet. The ridges are then divided up transversely into convenient lengths by a cross ridge and furrow at a distance of about 10 to 20 feet. Water flows from the ditch into the spreading or equalising groove or furrow, from whence the water distributes itself into the furrows. Thus, contrary to the practice in the U.S.A., where furrows of 200 to 2,000 feet in length are individually irrigated by a siphon or gated pipe, etc., a series of furrows of shorter length, ten to 30 feet, are generally irrigated through a spreading furrow. The design of spreading furrow followed in India is very similar to that described by Francis and Turelle (1953) for irrigating corn. Whenever a larger discharge of irrigation water is available, the length of the furrows is increased to 30 feet or so,

but in most cases the discharge is subdivided and distributed over more water courses instead of increasing the length of rows, and the shorter length of furrows is commonly adopted. The Bombay Department of Agriculture is, however, advocating a long-furrow method of irrigation for sugarcane planted at a row distance of four feet instead of the two to two and a half feet.

The choice of irrigation system, the method of irrigation, the size of main water courses or of laterals, and the size and shape of check basins depend on a large number of factors. These are described below, with particular reference to Indian conditions.

Factors Influencing Design and Layout of Irrigation Systems, Etc.

Soil

Mention has already been made of the possibilities of the use of sprinkler irrigation on undulating, sloping lands. The system is also likely to be of use on very sandy soils of high intake rate. Heavy soil may not be suitable either for sprinkler or flood irrigation on account of the danger of runoff in the former case and the tendency of the soil to cake on drying in case of flood irrigation. Furrow irrigation would appear to be most suited to heavy soils.

As water is applied at one end of a strip or a check basin, the upper end is subject to considerable soaking by the time water reaches the lower end. The extent of soaking will depend on soil type and slope. Marr has reported (for conditions in California) 200 to 300 feet to be the optimum length for irrigation of deep sandy soil, whereas 2,000 feet would do in the case of heavy soil of a low intake rate.

The presence of salts in the soil also influences the choice of the method of irrigation. As flooding helps in the washing down of salts, this method, in conjunction with paddy cultivation, was employed in the management of salty soils in the Pubjab. None of the other methods, such as sprinkler or sub-surface irrigation, can be serviceable under these conditions, as the salts would accumulate in the soil surface with rise of moisture by capillarity.

Furrow irrigation too would not appear to be suitable for saline soils, as the salts are subject to leaching in the furrows only. This has been clearly shown by Wadleigh and Fireman (1949) in their studies on the distribution of salts under furrow irrigation for soils initially salinised to 0.2% salt and irrigated with water of medium salinity. However, a modification of planting method may minimize the accumulation of salts in the vicinity of plants; e.g., the crops planted directly in furrows instead of in the ridges and water applied in furrows.

Climatic factors

The distribution and amount of seasonal rainfall have a bearing on the layout and method of irrigation. Slope and length of strips or checks should be such that excess water from rain drains away without causing erosion. This is particularly important in the case of crops growing during the rainy season when the fields are subject to water-logged conditions.

Another factor of some importance is the direction of wind, which influences the direction of plant rows and therefore the layout of the field in furrow irrigation.

Crops

From the point of view of irrigation, crops may be classified into three groups:

1. Close-growing crops
2. Row crops
3. Crops liable to be damaged by direct contact with water

Close-growing crops such as rabi cereals (wheat, barley, oats) paddy, rape seed and mustard, linseed, fodder crops (berseem, sorghums), onion, can be grown by check-basin irrigation. These crops are generally not given any after-cultivation with animal power and, therefore, lend themselves to basin irrigation under Indian conditions. The size of basin is small, being particularly small (e.g., six by ten feet) in onions, which is a shallow-rooted crop. The size may be as large as one-half acre in wheat under canal irrigation. In California, the border strip method is commonly adopted, probably because of the ease with which after-cultivation operations, such as harrowing, rolling and harvesting, can be done, in long narrow strips.

Row crops such as potatoes, maize, cotton, sugarcane, cauliflower, tobacco and tomatoes lend themselves admirably to furrow irrigation. In India the method is adopted in case of most vegetable crops only.

The crops in the third category - e.g., cucurbits - should be irrigated by furrow irrigation. Here the narrow furrow-broad ridge method (Fig.12) is the most suitable. Only a very small fraction of the soil surface is wetted and the broad ridge is always surface-dry. Not only is there a great saving in water, but the produce is not damaged by contact with water. The relative area occupied by furrows and ridges varies with the spreading habit of the crops. The ridges may be three to 12 feet wide, depending on the crop, intercepted by one and a half-foot-wide furrows. The method suits summer vegetables particularly, as they are grown in the hot, dry period. Other crops such as ginger, turmeric and elephant foot and occasionally chillies, are also irrigated by the narrow furrow-broad ridge method as a means of water economy.

In orchards, circular basins are formed in rings so that water does not directly touch the stems of fruit trees and only a portion of the soil is wetted instead of irrigating the entire surface.

In regard to the size of check-basins, it can be generalized that a small size is provided in the case of vegetable crops and a large size in the case of farm crops.

Skill and resources of the farmer

An ideal system of irrigation requires land preparation and leveling to grade, irrigation control equipment and knowledge of the use of such equipment. The skill of the farmer and availability of resources are therefore important factors in the choice of irrigation method.

As mentioned earlier, the border strip method is the most popular in California, while the check-basin system is generally adopted in India. There is need for the development and trial of cheap bullock-drawn irrigation equipment and - for introducing these in irrigation practice wherever possible, after demonstration.

Size of the farm

A large farm lends itself to the design of a unified well-planned layout based on topography, etc. The continuity of water courses and bunds can be maintained easily and longer runs can be utilized, consistent with the minimum leveling and minimum wastage of land under water courses. The choice of design in a small farm is limited.

The size of farm also influences choice of crops and the intensity of cropping, and these in turn affect the design of the irrigation layout. Small and scattered holdings further aggravate the problem in old districts in some parts of India. However, the Government is undertaking a simultaneous program of consolidation of holdings.

Water supply and mode of delivery

Under canal irrigation, water supply in India may be perennial or seasonal. The latter is restricted to periods when rivers, which are the source of water, have enough water to supply; e.g., during the kharif season. The cultivators utilize the available supplies on the warabandi system - i.e., each cultivator gets his supplies in turn (wari) at an interval depending on the discharge of the outlet, area commanded by the outlet, and duty of water fixed for a canal. The discharge at the outlet for farm deliveries generally varies from one to three cusecs. The duration of the wari depends on the size of the holding and is fixed in accordance with the duty of water on a particular canal. The water rates are charged on the basis of area cropped and not on the basis of volume of water consumed, except in sugar

factory areas under Deccan canals, where a volumetric basis of supply is in use.

In lift irrigation from percolation wells, the discharge is much smaller and varies from 0.05 to 0.2 cusecs, depending on the depth to water in the well and the type of lift, etc. The well or wells may be the exclusive property of a single owner or may be shared by a number of small holders. The discharges from tube wells depend on the size of the well and are usually intermediate between supplies from percolation wells and canals.

The size of irrigation water courses or their number and the size of irrigation beds or basins are related to the discharge. Large-size basins (one-quarter to one-half acre) are employed in the case of water supplies from canals. In well irrigation, a large network of field channels is used, each about two to two and a half feet wide and the irrigation bed may be as small as six to twelve feet.

Topographic map

In fields with irregular topography or where the slopes are too steep for other methods, sprinkler irrigation is the only practical proposition. However, where the slopes are moderate and the soil is deep enough, land preparation can help by leveling and grading the surface of the soil to regular slopes.

The position of water courses, their number and size, and the direction and size of basins or border strips depend principally on the extent and direction of the slope. The farm water distribution system must naturally follow the slope, as much as possible with such adjustments as can be effected by leveling to ensure a good design which makes for uniformity in the spacing of water courses and the size of plots. A main water course is usually located along or near one of the farm boundaries, at the highest level. Parallel lateral ditches (water courses) arise from the main ditch more or less at right angles to the latter, as is illustrated in Fig.I. The slope should be such as not to cause erosion. Proper fall must be provided on the distribution system when the slope is too steep.

The plot or strip or furrows for irrigation can be laid out along the slope or across it. If the strips run along the slope, it should be regular and gentle. The extent of the slope should be related to the intake rate of the soil, the size of stream, and the length of run. In the U.S.A., standard schedules have been laid down based on the interrelation of these. In general slopes of 0.2 to 1% are permissible depending on other factors. With steeper slopes, disposal of runoff becomes necessary. Alternatively, where slopes are steep, strips or basins may be laid on contour across the slope so that irrigation can be done by the contour-check method. It will be desirable to have narrow strips so that the cross slope between the bunds is minimized if not eliminated.

The contour method of irrigation has been mechanically adopted on big farms in the Deccan Canal area in India, where topography is irregular and trained technical personnel is available.

In furrow irrigation of vegetable crops under conditions in India, two modifications are adopted where the field has a steep slope in one direction. In one of the adaptations (Fig.13), the furrows are laid across the slope, perpendicular to the lateral field ditches (water courses) which run along the slope. The number of furrows fed from a common spreading groove or furrow is adjusted according to the steepness of the slope. The steeper the slope, the fewer the number of furrows fed from the spreading groove. This method is workable, although on light sandy soil the rapid flow of water in the water course along the slope erodes the sides of the water course. The second adaptation consists of running the furrows in a zigzag or serpentive arrangement (Fig.14). Water is let in at one end moves slowly, and as the irrigation of the bed is near completion, the flow of water is checked at appropriate places by earth dams. A similar method is described by Brown (1951) in the irrigation of a walnut orchard in Los Angeles, even when the slope was as much as 3 to 4%.

When the land is sloping gradually in both directions under well irrigation, the beds are formed diagonally by intelligent farmers, so that the basin is more or less level within (Fig.15).

Field layout, land preparation and ditch layout

Land preparation is the essential prerequisite for proper layout for efficient irrigation by surface irrigation methods. The land must be leveled and a uniform grade of desired slope provided in one direction to facilitate uniform spread of water, if irrigation is done by the border strip method. With basin irrigation, the beds should be leveled as far as possible in both directions. In India, where check-basin irrigation is commonly adopted, the cultivator attempts to level the basins with a karah (scraper) and a sohaga (plank) in the Punjab. The karah is similar to the scraper, with the difference that the former is not provided with a trailer plank behind and instead of a laterally-placed handle, one is provided in the center. A large-sized karah with two handles, one on either side, is also used. The other implement, designated as sohaga, is merely a plank with a flat smooth surface below, which tends to smooth the soil surface. It does a certain amount of leveling in the hands of a skilled worker but in those of an unskilled worker merely follows the contour.

There is considerable scope for the introduction of a good leveling implement such as a float, which can be pulled by a pair of bullocks and planes the surface of the soil effectively.

Field layout and ditch layout are generally done by hand implements such as spade and jandra (hand scraper). Thus, these operations are

costly and laborious. Although some of the bullock-drawn implements, like the bund former and ridging plough, have been successfully used on Government farms for layout, they have not been extensively used as they are mostly made of iron parts and cannot be made by a village carpenter. There is scope for the use of bullock-drawn implements similar to those described in the pamphlet "Small Equipment Under Irrigation."

Water control equipment

After the water leaves the outlet into the farm water course and until it is let into the check-basins, the water is diverted by earth dams and cutting of the bund. Thus, a considerable amount of earth moves away, weakening the banks and spoiling the level of the adjoining fields from whence the earth is taken for repairs. Water control devices, such as head gates or diversion boxes, check dams, turn-out boxes, siphons, spile tubes, etc., both fixed and portable, such as are used in some other countries (e.g., USA), are not used under irrigated agriculture by farmers in India. The utility of inexpensive equipment for water control is worth investigation. This equipment can be made with cheap, locally-available material.

Sprinkler irrigation

Much work on the utility of sprinkler irrigation under Indian conditions has not been carried out. Preliminary studies show that the method results in saving of water but the irrigation cost is high. The I.C.A.R. has recently sanctioned a scheme for investigation of the economics of this system of irrigation as compared with the flat and furrow systems of irrigation.

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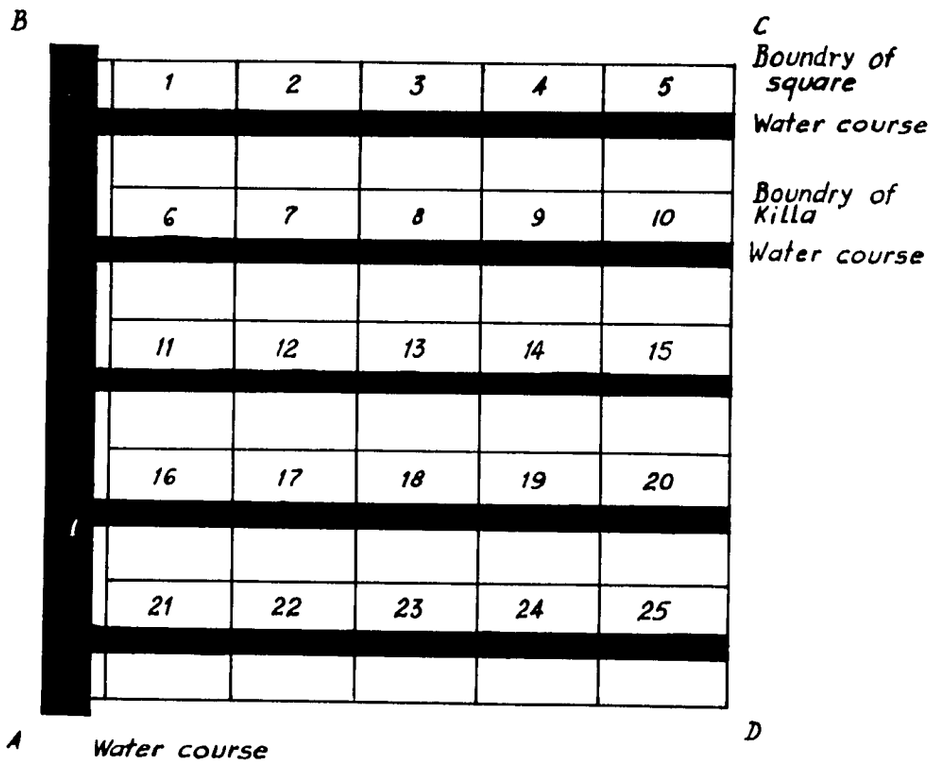

FIG. 1 - FARM IRRIGATION WATER DISTRIBUTION SYSTEM UNDER CANAL IRRIGATION

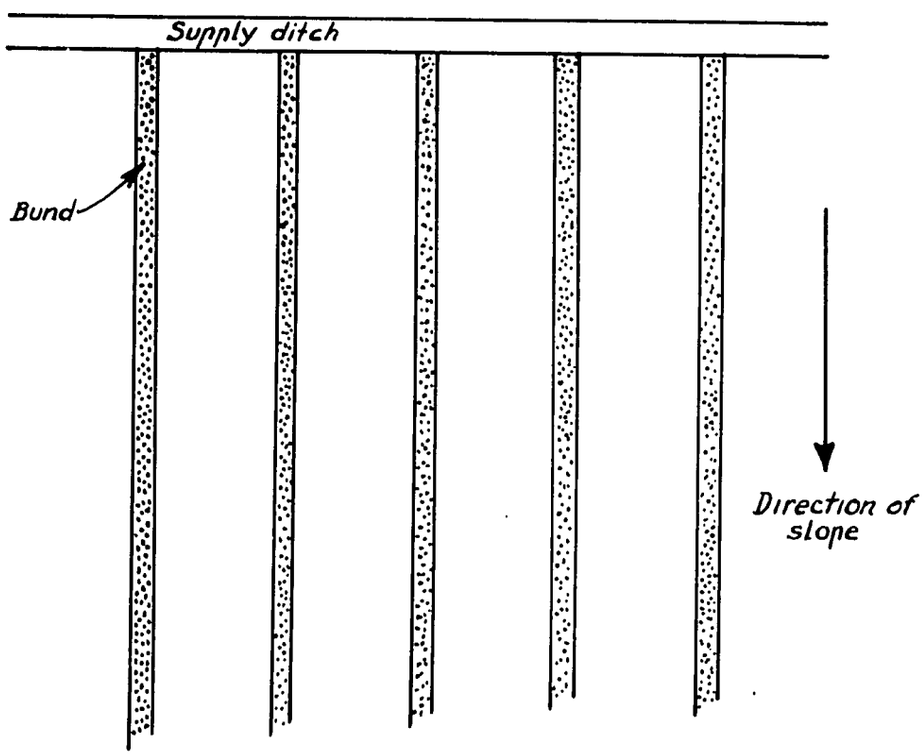

FIG. 2-BORDER STRIP METHOD

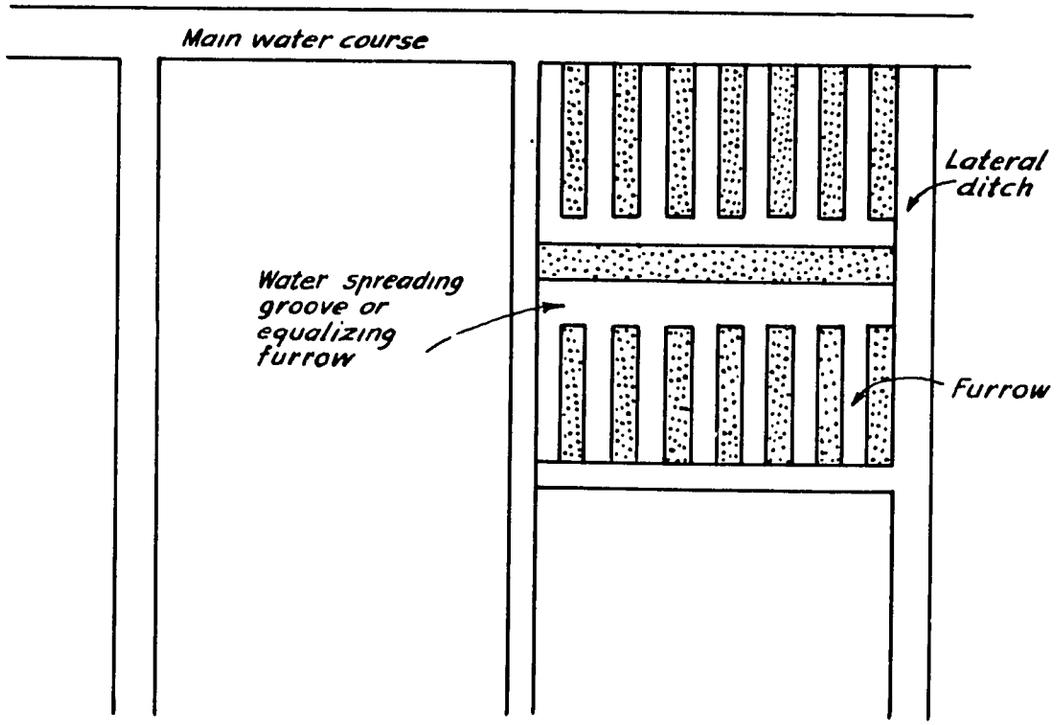

FIG. 3 – FURROW IRRIGATION

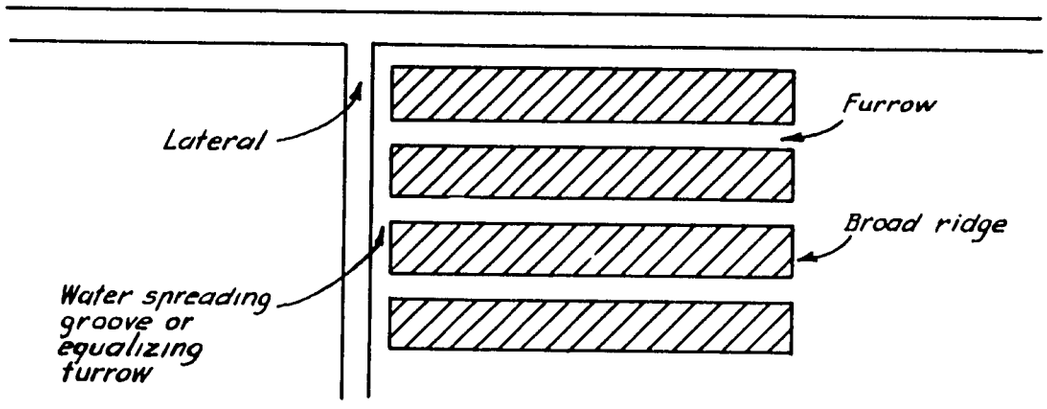

FIG. 4 - BROAD RIDGE AND FURROW METHOD

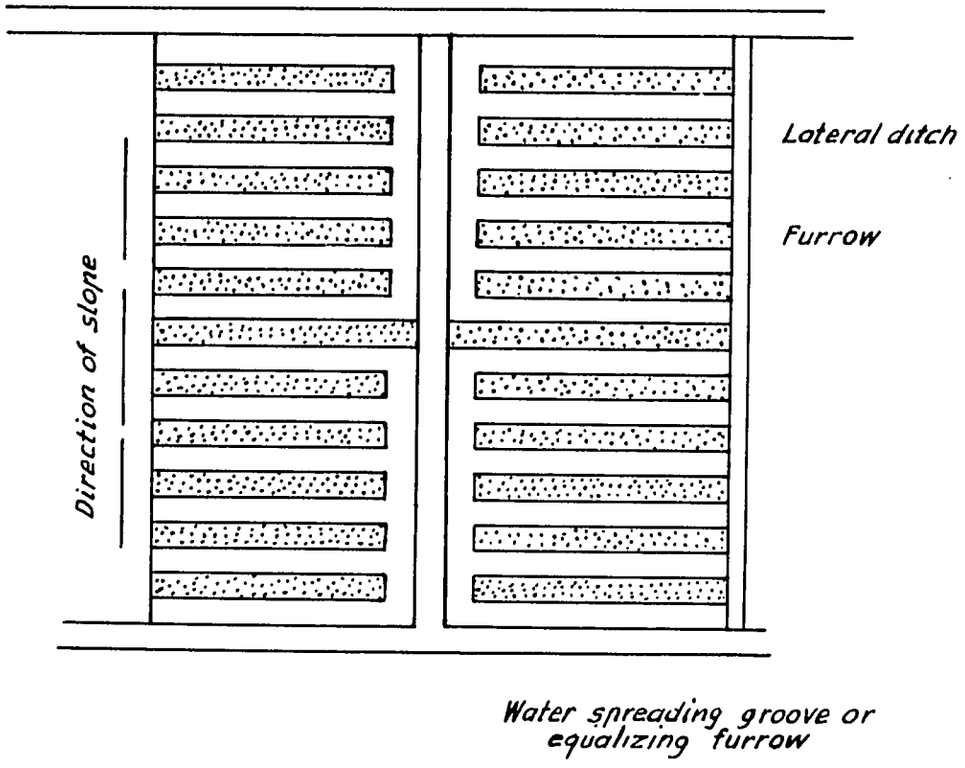

FIG. 5 – FURROW IRRIGATION
(FURROW ACROSS THE SLOPE)

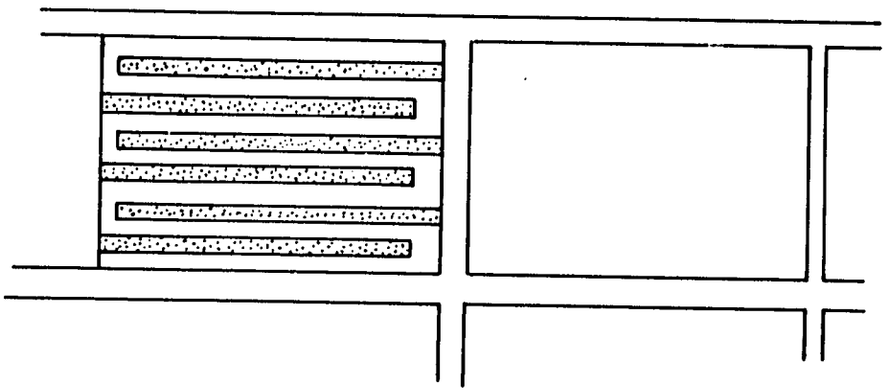

FIG. 6 - ZIGZAG FURROW IRRIGATION

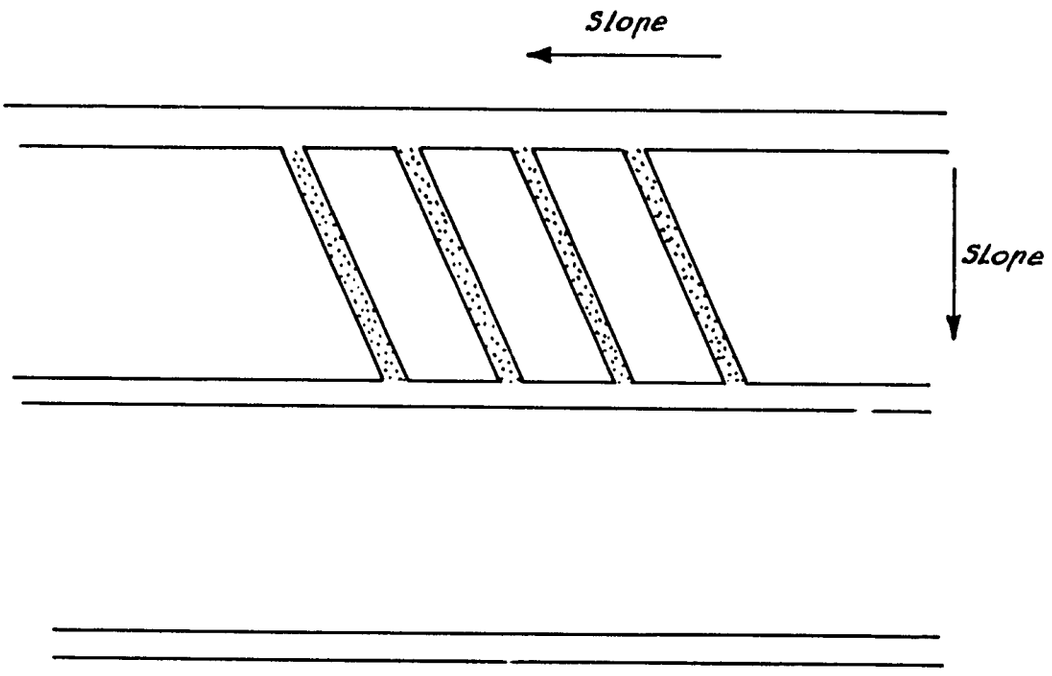

FIG. 7 – DIAGONAL LEVEL BASING

Promoting Better Farm Irrigation Practices in India

By

Dr. T. J. Mirchandani
Director, Agronomic Survey and Experimentation,
Indian Council of Agricultural Research, New Delhi

India has a total cropped area of 330 million acres, out of which 60 million acres are irrigated. About 40% of the irrigated area is under canal irrigation, 30% under tube-well and 20% under tank irrigation. The irrigation by tanks is mostly confined to the states of Mysore, Madras, Andhra Pradesh and Orissa. Factors such as topography, type of soil and rainfall have apparently contributed to the predominance of this source. In Punjab and Western U.P., canals and wells are the principal sources of irrigation. Canal irrigation is also particularly important in Andhra Pradesh and Madras. Under the second Five Year Plan, it is proposed to increase the irrigated area by 21 million acres by 1961, thus bringing the total irrigated area to 27% of the cropped area.

The introduction of irrigation is undoubtedly one of the most important factors in increasing production. In the rainfall tracts, it ensures protection against the failure or uneven distribution of the monsoon rains and, at the same time, promotes greater intensity of cropping by the introduction of new and additional crops in the rotation. In the arid and semi-arid zones, water is the limiting factor in crop production and the importance of irrigation in those areas cannot be overemphasized.

The Planning Commission has given high priority to irrigation in the second Five Year Plan and has allotted 480 crores of rupees for irrigation and flood control. It has been estimated that in India about 1356 million acre-feet of water are running into the sea annually, of which about 450 million acre-feet might be utilized. By the end of the second Plan, i.e., 1961, it is expected that 266 million acre-feet will be harnessed for utilization. Besides, there are the underground water resources which can be tapped by tube-wells, percolation wells, tanks, etc. It seems, therefore, that water is plentiful and it is the task of the engineer and agriculturist to make sufficient water available to the cultivator and help him to utilize it efficiently for farming.

At the end of the first Five Year Plan in 1956, the irrigation potential created was of the order of 16.5 million acres, distributed as follows:

Major and medium works	6.5 million acres
Minor works	10.0 million acres
Total	16.5 million acres

The estimated additional area brought under irrigation was:

Major and medium works	4.0 million acres
Minor works	9.5 million acres
Total	13.5 million acres

The figures indicate a short-fall of three million acres. It is further evident that while, from minor works, the utilization is 95% that from major and medium works, is only a little over 60%. The full utilization of irrigation water is of primary importance to our agriculture and every effort is directed to ensure this. The object of this paper is to indicate the steps that have been taken to promote better irrigation practices in India. The engineering aspect and also such other points as are covered by other subjects on the agenda have been purposely omitted from the scope of this paper.

Irrigation is, however, not an unmixed blessing. Its proper utilization leads to prosperity in agriculture, while injudicious use may lead to deterioration of soil fertility, development of salinity and alkalinity in the soil, waterlogging, etc. Instances are known in India and elsewhere where the introduction of irrigation has thrown out of cultivation thousands of acres of lands because techniques of water use have been faulty, provision for proper drainage has not been adequate, or some other factors have not been fully accounted for. It is, therefore, necessary not only to plan the increase of irrigation facilities but concurrently to evolve techniques for the proper utilization of every cusec of water available for crop production and transmit these techniques to the cultivator, who is the ultimate and the most important factor in increasing agricultural production.

The proper use of water resources for agricultural purposes is dependent upon the following factors:

I) the suitability of land, land management, mode of conveyance of water to farm lands and the preparation of land to receive water

II) knowledge of the water requirements of crops and cropping patterns

III) educational program to carry the results of research to the cultivator

IV) incentives

These factors are here examined to assess their individual and combined effect on the adoption of irrigation practices by the cultivator.

(I) The paper on "Land Classification as an Aid to Proper Irrigation Practices," by Greece, is being discussed separately at the Seminar. Similarly, a paper by Turkey on "Design and Layout of Farm Irrigation Systems" deals with the mode of conveyance of water to farm land and related problems. It is therefore not proposed to deal with Factor No. I - i.e., suitability of land, etc., except to say that it is vitally important that a pre-irrigation soil survey should be an essential part of the project study, prior to the final planning of any large-scale irrigation project. This will permit a proper assessment of water needs in different segments of the comanded area in relation to the quality of land in each segment, and delimitation of those areas which may be unsuitable to support irrigated agriculture. In fact, this has now become a regular feature with new river valley projects because the irrigation engineer needs this information when finding out the water duties on the canals.

It is equally important that there should be a pre-development of land, so that the water reaches conveniently all parts of the farm and the irrigation systems within the farms are designed to ensure the most efficient conveyance of water. In India, comparative study of farm irrigation systems has been done only to a very limited extent.

(II) Knowledge of the Water Requirements of Crops and Cropping Patterns.

Water requirements of crops: Determination of the water requirement of a crop under field conditions broadly consists of total water requirement during the growing season of the crop, quantity of water per irrigation and the frequency of irrigations. At different research stations in India, work has been going on over a long period and a considerable body of knowledge has accumulated on this subject. It is now possible to say what total quantity of irrigation water is required for major crops. This is shown in the following table, and is inclusive of the water used in transpiration and lost by evaporation and seepage.

Water requirements of some important crops under field conditions

Name of crop	Acre inches
Sugarcane	95.0
Cotton	42.2
Rice	41.7
Tobacco	39.2
Chillies	38.8
Ragi	29.8
Potato	26.7

(cont'd)

Name of crop	Acre inches
Groundnut	26.1
Jowar	25.7
Maize	17.8
Wheat	14.8
Oats	14.4
Barley	14.1
Linseed	12.7
Peas	12.0
Mustard	10.6

It is undoubtedly true that the water requirement of crops is dependent upon the nature of the soil, the position of subsoil water, climatic factors, etc. The above figures are broad averages, but the data also exist regionwise in many cases. In addition to total requirements, details have been worked out for quantity per irrigation, intervals between irrigations, interaction of irrigations with varieties and with manuring of some major crops. For instance, work on sugarcane in the Bombay Deccan area has shown that

a) 70% irrigation, including rainfall, falls short of the crop requirements under adverse climatic conditions

b) The optimum requirement for 150 pounds N is 95 inches.

c) A quantity above 120 inches results in significant fall in the yield.

d) The interaction of manure and irrigation indicated the necessity for higher irrigation with a high dose of manure

e) With 90 inches of irrigation, it is better to irrigate the sugarcane as follows:

   1. 8-day interval at yearly growth phase
   2. 10-day interval at tillering phase
   3. 12-day interval later on as against a uniform interval of 10 days

f) Maintenance of water at a depth of 4.5 feet is beneficial from the point of view of reducing irrigation water.

g) The straight-furrow method of irrigation was found to be more beneficial than the serpentine method

At Hyderabad, where two crops of paddy are raised - Abi (summer) and Tabi (winter) - during the year under irrigated conditions, the water requirements of Abi worked out to be 40 inches inclusive of

30 inches rainfall but excluding 7 to 10 inches of water requirement for puddling. During the Tabi season, the requirement was 40 to 45 inches including rainfall of four to six inches but exclusive of water for the preparation of the land.

At I.A.R.I., New Delhi, with wheat, two or three irrigations of three inches in depth gave significantly higher yields than one irrigati Three post-sowing irrigations gave the maximum yields in Punjab. In the black cotton soils of Andhra, wheat required ten to 14 inches of water made up of three to five irrigations, including a rainfall of about 3 inches.

The potato yield increased with close irrigation interval of six, 12, 18 and 24 days in Bihar, while at I.A.R.I., the maximum yield was obtained with 21 inches of irrigation applied in furrows 6 inches in depth. These are only a few illustrative examples to show the nature of the information that has been or is being obtained on important crops at the research centers in India.

In the coordinated agronomic experiments at a large number of centers scattered among the different soil-climatic regions all over India, irrigation cum manurial experiments on three important crops have been included:

(a) Wheat: No. of irrigations: Three, four and five. Three intensities of 2, 3 and 4 inches per irrigation. Nitrogen at 0, 30, 60 lb. as ammonium sulphate per acre, P_2O_5 at 0, 30, 60 lb. as superphosphate per acre.

(b) Cotton: No. of irrigations: Five, seven and nine. Three intensities of 2, 3 and 4 inches per irrigation. Nitrogen at 0, 50, 100 lb. as ammonium sulphate per acre, P_2O_5 at 0, 50, 100 lb. as superphosphate per acre.

(c) Paddy: Three intensities of 2, 3 and 4 inches. Three total amounts of water a_1, a_2, a_3, as follows, for varieties of different durations:

1. Short duration: a_1: 24", a_2: 36", a_3: 48"
2. Medium duration: a_1: 48", a_2: 60", a_3: 72"
3. Long duration: a_1: 72", a_2: 84", a_3: 96"

Nitrogen at 0, 30, 60 lb. as ammonium sulphate per acre, P_2O_5 at 0, 30, 60 lb. as superphosphate per acre.
Basal dressing: 5,000 lb. F.Y.M. per acre.

Design: Split-plot design with number of irrigations x amount of irrigation in main plots and levels of nitrogen x levels of phosphate in sub-plots in two replications.

Net plot size: 1/100 acre.

This work is proposed to be further extended to include all aspects of the problem. Special attention is being directed to moisture studies in the soil and subsoil while deciding upon the frequency of irrigation as well as the quantity of water to be applied per irrigation. Moisture studies now form an important part of research schemes on the water requirements of crops. While at the farms moisture studies can be done by taking soil samples for moisture determination in the laboratory or through tensiometers or plaster of Paris resistance blocks, a simpler method is required for cultivated fields. The I.C.A.R. sponsored a scheme for the development of a portable instrument for quick determination of moisture in a field and offered a prize of Rs. 2,000/- for designing the most efficient instrument for the purpose. Results are awaited.

The purpose of applying water to land on the basis of the moisture status of the soil would be to ensure that the irrigation is applied at the appropriate time and is just enough to keep the moisture content at field capacity up to the root zone of the crop. A cultivator can find out for himself when to irrigate. The method is to pick up a handful of soil from a required depth, squeeze it several times in the palm of the hand, and try to make a ball of it. The conditions under which irrigation should be applied are given below:

Sandy loam	Loam	Clay
Will not form a ball but will turn lighter in color on drying	Will form a ball that easily crumbles when tossed in the air one foot high and caught again	Will form a ball that cracks open when pressure is applied with the thumb

In order that the land not become over-irrigated, as soon as the water penetrates down to about three feet the irrigation should be stopped. This is to be ascertained by pushing in a rod, which will go down easily in wet soil but will not penetrate so easily in the dry zone. Two leaflets have been issued by the I.C.A.R. on these points. These tests are convenient for cultivators. They would, however, have to be inter-linked with the irrigation practices in the area. In the canal-commanded areas where irrigation water is supplied on a fixed rotational system, the cultivator has no voice in the timing of the water supply or the quantity, and he has to irrigate his lands when he is scheduled to get his turn and not when he needs it for any particular crop. The moisture test serves him as a guide for utilizing the water intelligently. For well or tank irrigation areas, or where water is available when and in the amounts he wants, this method would be valuable.

Cropping patterns:

The pattern of rainfall in India is as follow:

		% of rainfall
S. W. monsoon	June-Sept.	75
Post-monsoon	Oct.-Nov.	13
Winter or N.E. monsoon	Dec.-Feb.	2
Pre-monsoon	March-May	10
		100

The effect of the introduction of irrigation on the crop patterns in an area will be determined by the rainfall pattern, soil and climatic conditions, existing agricultural practices and whether the supply of water is perennial or seasonal. Different crops have different water requirements. The cropping systems have to be devised so that the maximum benefit accrues from irrigation. Where irrigation is the main source of water supply, as in the Punjab, cropping rotations have been worked out with cotton and wheat as the main crops in the rotation, with varying intensities such as:

I) Fallow - Wheat - Fallow - Fallow - Cotton - Cotton (66% intensity)

II) Fallow - Wheat - Fallow - Gram - Cotton - Cotton (100% intensity)

III) Green Manure - Wheat - Fallow - Toris (Oilseed) - Cotton - Cotton (133% intensity)

IV) Fallow - Wheat - Sorghum and Guar (fodder) - Gram - Cotton - Senji (fodder) (166% intensity)

In paddy areas in Madras and Andhra, irrigation ensures protection against failure of the monsoon and also enables the farmer to have a rabi (winter) crop after paddy. It may be a second crop of paddy or a crop like wheat, pulses or oilseeds. In the Bombay Deccan region, where sugarcane is the main crop under irrigated conditions, the rotation provides for two crops of sugarcane followed by a crop which requires less irrigation water in the three-year rotation. In U.P., the rotations found suitable under irrigated conditions are:
Sugarcane area: Sugarcane - Fallow - Wheat - Cotton - Fallow
Non-sugarcane area: Fallow - Wheat - Cotton - Fallow - Fodder - Gram

The Agricultural Research Stations have been working on different rotations with a view to recommending them to the cultivator. Much more work still needs to be done, especially in the new areas. In a new river valley project, e.g., D.V.C. and Hirakud, Orissa, new experimental farms have been established to carry on research on crop intensities, rotations and other problems of irrigated farming in the regions.

At the demonstration farm recently established in the D.V.C. area, where one million acres are to be irrigated, the program of the farm consists of the following:

Crops and treatments: 1. Paddy - Aman (July-December)
Aus (March-June)
Bors (December-March)
2. Jute 3. Sugarcane 4. Wheat
5. Potato 6. Cotton 7. Mustard

Crop				
	Intensity of water per irrigation	2"	3"	4"
	Total application for crop (Depth)			
Paddy	for Aman	60"	90"	120"
	for Aus & Boro	40"	60"	80"
Jute	Intensities	2"	3"	4"
	Depth	40"	60"	80"
Sugarcane	Intensity	3"	4"	5"
	Depth	60"	80"	100"
Wheat	Intensity	2"	3"	4"
	No. of irrigations	3	4	5
Potato	Intensity	2"	3"	4"
	Depth	20"	28"	36"
Cotton	Intensity	3"	4"	5"
	No. of irrigations	5	7	9
Mustard	Intensities	2"	3"	4"
	No. of irrigations	2	3	4

The total quantity of water will be adjusted for rainfall during the period of experiment. Interaction will also be worked out with sowing dates, seed rates and different manurial schedules. In the case of potatoes, furrow versus flood irrigation will be compared. Moisture determinations to measure the vertical and lateral movements of water and observation of the fluctuations in the sub-soil water table are being made. Prior to the introduction of irrigation, the area grew one crop of paddy, with an occasional second crop. With the advent of irrigation, intensity will be increased and the following are some of the rotations under study:

1. Paddy (early Aman) - Wheat	One year
2. Paddy (Aus) - Paddy (Aman) - Pulse	-do-
3. Green manure - Paddy (Aus) - Pulse	-do-
4. Paddy (Aus) - Green manure - Potato	-do-
5. Jute - Paddy (Aman)	-do-
6. Paddy (Aus) - Green manure - Sugarcane	Two years

A more complex set of experiments is in progress at the I.A.R.I. to obtain information on the following points:

I) To find out the optimum quantity of water required for important crops, viz., rice, maize, cotton, potato, onion, wheat and sugarcane; initial dose of soaking; frequency of irrigation; last date of stopping irrigation before ripening.

II) Cropping pattern to suit different irrigation systems. This would include studies of different intensities with different cropping systems and in relation to a given unit of irrigation water.

III) Interaction of irrigation to manurial schedule, tillage, sowing periods, seed rate treatments, varieties of crops, etc.

IV) Effect of different irrigation practices on the growth of the plant and on seed development. Along with the above work, it is very necessary to study the movement of moisture in the soil and its effect on salt and nitrate movement, and also the effect of water on the pH of the soil and other physical properties. These among other problems will involve investigations of:

a) Losses of water due to evaporation, percolation, and lateral movement.
b) Movement of moisture, salts, and nitrates.
c) Subsoil water level fluctuations with different intensities of irrigation.

New problems arise, such as the effect of intensive cropping on soil fertility, choice of new crops in the rotation, balanced manuring to prevent soil exhaustion, prevention of the rise of alkali salts and of waterlogging. Some of these are under study at different centers. An integrated study of such problems is necessary in all areas which are to receive irrigation. Irrigation facilities should also be coordinated with other improved techniques with the object of obtaining the maximum potential productivity of the region. The work so far done is a good starting point and the work so far planned needs to be greatly intensified - in particular, regional studies to meet the requirements of the differing soil and climatic zones in the country.

(III) Educational program to carry the results of research to the cultivator

As has been shown in the previous section, the technical aspect of the problems of irrigated agriculture is under active study by research workers in India. A great deal still needs to be done and schemes are under way to add to existing knowledge of the efficient

use of irrigation water. However, on the basis of data so far obtained, it is possible to advise the cultivator broadly on some of his problems, such as the quantity of water required for individual crops, the cropping systems that he may usefully follow, the interrelationship of manuring and irrigation and the precautions that he should take to prevent his land from salt infestation or becoming waterlogged. Information about the comparative values of different farm irrigation systems is rather limited. In some cases, the data may not be from the same region but from the nearest irrigated zone and modifications would be necessary to suit new areas or special problems of the individual cultivator.

The information is primarily collected at Government farms and from practices in vogue in the older irrigated areas. It is important that the results of research and experience be transmitted to the cultivator in an acceptable form. This can be done in three ways: (I) through demonstration farms situated in each distinct zone where the results are to be applied; (II) through trials on a cultivator's own fields; and (III) by means of a publicity campaign through posters, the cinema, etc. In India, all three methods are being used.

Demonstration farms: At present there are 483 research stations and farms in India. More are being established. On such farms, research findings can be demonstrated and cultivators may have easy access to the results. Special farmers' days are arranged where the work is fully explained to visitors. This work of demonstration has one limitation: the cultivator is a little hesitant to accept in full what is shown to him. He feels that the conditions on his own land are different from those on the Government farms and consequently he may not be able to make direct use of the results.

Trials on cultivators' fields: This method is likely to yield maximum results because what the cultivator sees on his own or a neighbor's land is of the greatest value to him. Our experience in India in the extension of fertilizer use has convinced us that there is no better method of publicity than trials on cultivators' fields. In these trials, the cultivator manages his land in the usual way with the recommended new practice included in his farming schedules.

In India we have a big program of community projects and NES blocks, through which rural development is envisaged. A NES block consists of about 100 villages in charge of a development officer to whom are allotted subject-matter specialists in agriculture, animal husbandry, education, health, etc. For every 10 villages there is one village-level worker whose duty is to work with the cultivators and help them in all spheres of rural development. Agriculture forms a dominant part of the program. The worker assists the farmer in adopting improved techniques such as manuring, irrigation, the use of improved seed, etc. The village-level worker has the help

and guidance of the subject-matter specialists attached to the headquarters in the block, who tour extensively to keep in touch with the worker and the cultivators. It has recently been suggested that either the number of villages assigned to each village-level worker should be reduced to five or there should be a separate extension irrigation service so that this aspect of the work, i.e., the proper use of irrigation water, may receive special attention. This is under consideration. Under this plan an Irrigation Assistant is proposed to be attached to each subdivision to work in collaboration with the Agricultural Assistant in the area. They will lay out trials on the cultivators' fields on the proper use of irrigation water and on cropping patterns to be adopted with the advent of irrigation. The number of such trials will be sufficiently large, and this will also enable the Irrigation Assistant to know the difficulties which prevent the cultivator from using irrigation water fully. Extension work is a two-way street, and it will be the duty of the Irrigation Assistant to bring the problems of the cultivator to the research farm for study and solution. A major portion of this work of carrying the results of research to the cultivator is done through the Extension Directorate and the Community Development Administration. It is expected that by 1963 the entire country will be covered by NES blocks.

Publicity: The publicity and information service has recently been strengthened in collaboration with T.C.M. This is becoming of great value in acquainting the farmer with the research results obtained, in easily understandable form. A film has been prepared on "Conservative Irrigation with Border Strips" and this provides a valuable medium of education. A portable exhibit case has been prepared and this is proposed to be given to each village-level worker. It will be convenient for him to show charts depiciting the different facets of his work. He can easily carry this with him. A large quantity of publicity material, such as posters, leaflets, etc., has been prepared and more will be made. Three leaflets have been published, on "How to Prepare Land for Border Strip Irrigation," "How to Know When to Irrigate and When to Stop" and "Earth-Moving Equipment for Border Strip Irrigation." These posters and pamphlets are being translated into regional languages and widely distributed. A flip book of about 20 sheets, depiciting various phases of farm irrigation and equipment problems, etc., has been prepared for use as publicity material for the cultivator.

A soil-cum-water conservation and irrigation workshop was organized in December 1957 at Betul, Madya Pradesh, where problems such as the preparation of farm land for irrigation, methods of irrigation, and when to irrigate, were discussed and demonstrated. Similar workshops are being organized on a regional basis.

(IV) Incentives

As the demonstrations, extension work and publicity gain momentum and technical knowledge is passed on to the cultivator, it is expected that fuller use will be made of irrigation resources by the cultivator. It is desirable to examine also the present difficulties which militate against his making use of existing facilities. These have been examined from time to time by different groups at the technical and administrative level. The position is summarized below. It seems essential that there should be pre-development of land in the irrigation systems so that the water reaches the whole of a commanded area. The people's participation in the construction of water courses may be encouraged, especially in NES blocks. Whenever such works are delayed, State Governments may construct them and recover the cost from the beneficiaries. The water courses should be lined and proper crossings constructed so that wastage and loss of water are minimized. Cultivators' holdings in India are small and scattered; this prevents full and proper development and utilization. In most States, work on consolidation of holdings is in progress.

The water rate is considered high by the cultivator. It has been suggested that water be supplied at a concessional rate, at least for the first few years until the cultivator gets to know its proper use and its value. Recently, the Government of West Bengal decided to forego the water rate completely for the first year in the area commanded by the Damodar Valley Irrigation System. It has been suggested that the power rate for lift irrigation should be lower than that for industrial purposes. Regarding motor pumps installed for irrigation purposes, the cultivator should be permitted to use the installed capacity for dehusking rice, crushing oil, grinding flour, etc., during the slack period when the motor is not required for irrigation purposes. Irrigation rates for old and new works may be pooled. These suggestions are under active consideration and some of them have been put into effect. There is no doubt that the cultivator knows the value of irrigation water, and if his problems and difficulties are appreciated and solved, he will utilize water resources fully and to the best advantage.

GENERAL:

In India the Government, the research worker and the cultivator are all of one mind that the irrigation potential should be increased and water utilized scientifically to ensure optimum crop returns, without any bad effects on the soil. The Central Board of Irrigation and the I.C.A.R. have kept this subject constantly before them for study and solution of problems as they arise. The Irrigation Commission in 1903 examined this question in some detail and made recommendations, one of which was on the desirability of introducing payment of the water rate on a volumetric basis. The Board of Agriculture, India, and later the Soils and Crops Wing of the I.C.A.R., have discussed

the question of the water requirements of crops and other related problems at their periodic meetings since 1905. An Inter-Ministerial Standing Committee was set up in 1949, on which the Ministries of Agriculture and Irrigation are represented by the senior technical officers, to review the work from time to time and make such recommendations as its members consider necessary. The I.C.A.R. has sanctioned schemes on all-India basis in this area, with special reference to new river valley projects. In the States, collaboration between the departments of agriculture and irrigation is gradually increasing, from the planning stage of irrigation works up to the efficient utilization of available water. During the last year or so, special attention has been given to this subject by the Study Group of the Planning Commission, by the Conference of State Ministers in charge of Agriculture and Irrigation, and by the National Development Council. The Ministry of Agriculture is sponsoring an all-India Seminar on Irrigation Water during 1958 at which the participants will be members of the Irrigation and Agricultural Departments, extension staff, teachers in agricultural colleges, and representatives of farmers. The agenda includes:

1. Land preparations for different methods of irrigation, the use of bullock-drawn implements in land preparation, the economics involved.

2. Methods of conveyance and distribution of water beyond the point of its delivery by the state engineering departments, methods of water measurement for application of the optimum quantity required for requisite moisture content in the root zone.

3. Cropping under irrigation, determination of the water requirements of various crops on different types of soils, the most productive cropping pattern undery varying conditions of irrigation and with different systems of fertilizer use.

4. Drainage, salinity and suitability of soil for irrigation, land classification.

Present knowledge on all aspects of the work will be reviewed, future lines of work laid down, and the machinery set up for its implementation. The participation of farmers will focus attention on their problems, and experience on their lands will be a valuable guide. Demonstration of irrigation practices will form a part of the seminar, and this has been arranged at the Indian Agricultural Research Institute.

In this paper, some of the steps that have been taken in India to make fuller use of irrigation water have been described. The problem is difficult and has many facets: the agronomist, soil physicist, irrigation engineer, economist-cum-statistician, extension man and cultivator all have to collaborate to solve the problem.

Much needs to be done still, but what has been done so far gives us hope that with concentrated effort all difficulties can be overcome and the proper utilization of irrigation water ensured.

IRRIGATION STAFF DEVELOPMENT

By

Salim W. Macksoud
Member, Lebanese Order of Civil Engineers
Associate Professor of Irrigation
Head, Division of Agricultural Engineering
Faculty of Agricultural Sciences
American University of Beirut, Lebanon

Introduction

Classically, irrigation and, more particularly, irrigation projects are approached, considered and studied at three different phases - an engineering phase, an agricultural phase and an institutional phase. The success of each project will be determined as much by the thoroughness with which each phase is studied and executed as by the degree of excellence exhibited by the staff responsible for each particular aspect of the work.

For the staff to be able to demonstrate such excellence, their previous training and experience should be as complete and as thorough as possible. Different training and experience is required by different members, but prominent among the fields in which such training and experience is essential for many staff members is the field of irrigation practices. The aim of this paper is to select, from among the vast number of workers in an irrigation project, such staff members as require this training and experience, outline in the specific aspects of irrigation practices this should cover and, finally attempt to draw up the lines along which such development might take place. To do this a brief background description of the phases of irrigation and their staff requirements is given, followed by a detailed description of the duties of those staff members requiring training and experience in irrigation practices together with the suggested steps to be taken for such development.

Phases of Irrigation Projects

Briefly outlined, the following are the various aspects of each phase of an irrigation project:

The Engineering Phase. The main aspects of this phase are the design, construction and continuous supervision and maintenance of the

structures required for making water available to the water user. The structures vary from one project to another but invariably consist of two main groups:

a) those required for procuring the water, a dam for storing it, a diversion or a pumping plant, and

b) those required for conveying it to the points where it is needed.

Accurate determination of the water needs of the areas served and reliable predictions of the approximate water yields, are two of the most perplexing responsibilities of the engineer responsible for this phase of the project. These constitute a much more difficult problem to solve than the actual design and construction of the structures once these two factors have been fixed.

The Agricultural Phase. The use of water on the land - how to apply it and how much of it each time - these are the main aspects of this phase. The answers to these questions are not fixed and definite but change with changing soil, climate, crop and economic conditions and, as such, represent a continuous challenge to those responsible for this phase of the project.

Land classification, so necessary for the success of any project, could be listed as a part of either the engineering or agricultural phases of irrigation or of both.

The Institutional Phase. Under this phase are grouped all the economic, social, legal and political factors that should be considered before a project is planned and executed, and after it is functioning.

a) Economically -

Is the project economically sound? Will it pay for itself in the coming years? Is the capital required available? Are there markets for the anticipated increased yields? Is there satisfactory provision for the increased credit facilities required by irrigated agriculture? Will prices remain at an economic level after the increased crop gets to the market? Will labor wages go up ?

These are some of the questions an economist should have the answers to before a scheme can be successfully carried out.

b) Socially -

Irrigated agriculture requires more workers per unit of land area than dry land farming. Is there a supply of labor ready to move into the area? Are the housing, schooling and civic accommodations adequate? Is there an extension system that could handle the educating of a dry land farmer or a city worker in the techniques of irrigated agriculture?

Water intake rate is an important feature that affects the design of a distribution system. Soils with very low water-intake rates can best be served with small heads of water delivered over long cintinuous periods, while soils with a very high intake rate require large heads of water - otherwise covering the fields would be impossible. Thus the size of the canal supplying water to various areas is a function, among others, of the water intake rate of the soil in the area it serves. The effects of management practices, irrigation water quality and time on the water intake rate should be anticipated and the planning engineer informed about them. Lands with irregular slopes, and with shallow soils, cannot be economically graded, and as such do not represent areas that can be economically irrigated by surface methods.

Generally a planning engineer and a land classifier should have had a general survey course on irrigation practices stressing the dependence of the success of their aspect of work on a project on the degree of its suitability and adaptability to the anticipated irrigation practices in the area. Their training is not simple and they cannot be produced overnight. Only through years of observation and experience following a vigorous basic training can we hope to have such competent workers.

So far, project planning (including land classification when carried out) in Lebanon and probably in most of the other Middle Eastern countries, has been carried out by foreign personnel. On the whole, these persons have been members of teams which have been doing this kind of work for many years in various countries and as such bring with them a rich experience. However, if they do not bring along also the attitude that local conditions and practices are of basic importance in molding local projects, then they will be attempting to build ivory towers that may never be used productively. I do not propose that new projects should be designed to perpetuate old, wasteful and uneconomic practices, but rather that existing practices in any locality are usually the result of many years of trial and error and, as such, are not completely without merit. Time alone does not give merit to existing practices, but it does make changing to better and more economical methods a slow process. All during the period of change farmers will be demanding the old and larger water flows, and the project should be able to supply them. When the farmers' application efficiency is improved, the water so economized could be used to bring additional land under irrigation. But to plan and design a project on the basis of the water needs of a community where very efficient methods are followed, and to supply only this quantity in an area still following wasteful methods, will result in dissatisfaction and reduced production. In areas where the community is by nature belligerent, or where the central government is weak, riots, demonstrations and acts of sabotage may result. These remarks are particularly applicable to a project which is being developed for an area where part of the land was previously receiving

water for irrigation. For projects in previously dry lands and where farmers have no previous fixed irrigation water demands, the general principle of stressing local conditions and practices would still hold but not this particular aspect of it.

Permanent Staff Duties and Training

Generally, either because projects have already been planned and executed or because this aspect of the work is being handled by imported foreign teams, local national workers in the irrigation field are likely to be directly connected with and responsible for the operation of irrigation projects and their extension work. The training each staff member requires is a reflection of his responsibilities in the operation of the project. Since different projects may be run on different patterns resulting from different policy decisions by those responsible for them, the following four policy problems in irrigation projects are given so that we may gain more insight into the required training of these administrative staff members. This training should be broad and flexible so that they can handle any possible policy decision among the following:

A. Water Delivery Patterns

Water may be delivered in one of three manners each with its peculiar advantages and disadvantages and thus suitable for different conditions, and each requiring a specific ability on the part of the staff responsible for its execution.

1. Distribution by rotation is the most common and generally successful method. It supplies a workable, flexible stream and has a concentrated labor requirement. Variations in stream flow can be easily absorbed by this method. Its drawbacks are limited to extreme cases, i.e., where crops must be kept continuously wet and land holdings are very small, where labor and facilities for handling large flows are not available, and where the ditches are of earth and require continuous wetting to reduce their conveyance loss and are on steep slopes when small heads are required.

2. Continuous delivery is useful on steep slopes and/or where frequent irrigations are required either due to slow water intake rate or because of irrigating crops up. Where holdings are large, it becomes similar to delivery by rotation. Its drawbacks are a continuous demand for labor, too small a stream on small holdings, and its inability to manage a reduction in water supply.

3. Delivery on demand, which is being followed on large diversified projects with success, usually requires a controlled water supply, a storage reservoir or pumping plant, and a well-constructed distribution system.

These are the social problems that should be tackled.

c) Legally-

International water rights, and sometimes even state or country rights, represent a serious legal aspect of many projects.

d) Politically -

Schemes that comprise areas from more than one country, or that plan to store the waters of one country in a storage lake situated in another, run into international political problems. Even projects in one country may still run into local politics as different pressure groups try to influence the choices between projects and dam sites.

Project Staff Requirements

From the above description of the phases of irrigation projects, it is apparent that in each phase, in fact in each aspect of each phase, specific staff requirements exist. Traditionally, such staff requirements have been divided into the following two groups:

1. Temporary Staff:
   A. Project Planners - Engineers, hydrologists, geologists, soil scientists, economists, agricultural economists, sociologists and lawyers

   B. Project Construction Engineers

2. Permanent Staff:
   A. Project Operators - Administrators, maintenance and operation staff.

   B. Project Extension Workers - Agricultural and social.

The responsibility of the first group ends when they hand over the completed project to the second group. These latter continue to be responsible for its success or failure as long as it is physically existing. Though mainly judged on the merits of their own achievement, they inherit a permanent and significant heritage from the planners and builders. Mistakes and errors committed by the members of this group are reflected in the performance of the latter. Sometimes it is possible to remedy or modify these shortcomings, while at other times it is not.

Staff requiring training and experience in irrigation practices

Presently, being specifically concerned with the subject of irrigation practices, let us select from among the vast number of

aspects of any irrigation project those that are related to irrigation practices; in other words, select those specific jobs which, for their proper execution, require a knowledge of water handling and use, and then later analyze the particular elements of components of water use knowledge required for each. From the temporary staff the following are of concern to us:

1. Project planning engineers
2. Land classifiers

And all the permanent staff:

3. Project administrator
4. Project maintenance staff
5. Project operations staff
6. Agricultural extension workers:
   a) Farm distribution system and land development staff
   b) Farm irrigation advisors

Temporary Staff Duties and Training

Both the project planning engineer and the land classifier should have had special training in the field of irrigation practices over and beyond the specific training in their own field of work.

The planning engineer should have a broad general knowledge of irrigation methods, water delivery practices and irrigation requirements for the crops that would be grown in the area considered. He should be familiar with soil classification charts and the moisture-holding capacities of various soils. For the engineer the important thing is not having specific detailed knowledge but having an awareness of the seriousness of the relation between these agricultural phase aspects and the design of the project. It is also important for the engineer to realize that these agricultural aspects change with changing climates, soils, and economic and social conditions.

An existing irrigation project in Syria was beautifully designed and executed except for one aspect - the irrigation requirement of the crops grown in the area. Figures for water use in France were taken as a basis for the design of the canals. The climate is a much drier and warmer one than that of France and the water requirement is much higher. Presently only half the land that could have been irrigated is getting water, because the canals are too small. Surplus water is running down the river without being used.

The land classifier, well trained in soil analysis and evaluation, should also be familiar with irrigation practices in general, but particularly with water movement on and into soils and with the operations and practices of land grading.

Generally, and particularly for small holdings, delivery by rotation is best, while a continuous supply can be used to advantage by large landowners. Delivery on demand is most conducive to water economy, as it is usually coupled with a system of charging for water on the basis of the actual volume used by each user.

The administrative and operational requirements of each delivery pattern are very different, both in numbers of personnel and in training.

B. Water Charges

Water is charged for either on a flat areas basis or on the basis of the volume used. The flat area basis is much easier to administer but is not conducive to water economy and is more likely to be abused by weak or corrupt officials. It is the system most commonly followed in existing projects in the area and its results substantiate the above remark. Favoritism is prevalent and influential landowners usually get more than their fair share. The responsibility of the administrative staff and the operational personnel is not an easy one and requires very wise and seasoned employees who are basically honest.

C. Water or Area Allocation

In most schemes, not all the land lying below the canals can be irrigated in any one year. That is, the available water is not enough to go around all the area that it is possible to irrigate. Therefore some policy of distributing the available water on the land should be followed. In some cases, a uniform percentage of all the land it is possible to irrigate is given water. This percentage is usually based on the ratio of the available water to the ideal flow. Thus, if 60% is taken as this percentage, then an owner of 100 acres would have 60 acres under irrigation and an owner of three acres would be able to irrigate one point eight.
Serious objections to this approach are raised by the small owners, who insist, and rightly so, that a minimum area is essential for their subsistence.

In other instances, available water is distributed on the basis of giving priorities to certain crops. A user with an orchard is given priority over an annual crop grower, since the orchard will suffer damages that will last more than one year, while damage to the annual crop is of shorter duration.

Generally this is a very difficult problem for the administrator to solve and for best results the basis of priorities should be incorporated in the constitution and by-laws of the project from the start.

D. Operational Funds

Different projects are financed from different sources. Some are government-supported and all staff members are paid by the government. Usually these are part of either the Ministry of Public Works or Agriculture, and their budget is fixed by the respective budget officer in the Ministry and approved by Parliament. In other cases the project is set up as a separate unit with its own budget, which is set up by the project administrator and approved by the board of directors of the project. And finally, in many cases in the Middle East, the project may be supported by the water users through flat charges on areas irrigated. The techniques of administration in each of the above cases are different and the successful financing of a project requires special and extraordinary skill on the part of the administrator, in most cases.

Project Administrator

These four general policy problems - water delivery, water charges, priorities and operation funds - together with the technical administration of the project, demand special training for the project administrator that should be along the following lines:

Basic Training. Usually a civil engineer is chosen as project administrator or manager of the irrigation department (in cases where the project includes power and flood control work). In some cases a lawyer or a businessman may be chosen, but an engineer, especially on smaller projects, is more suitable because he can be of more service and his training can be used to advantage as he serves as chief consultant to his maintenance staff and with reference to any further construction on the project.

Special Training. In addition to his engineering training, an administrator should have the following:

a) Detailed training in the operation of irrigation systems, including maintenance work and delivery methods and techniques. This he normally acquires thorough college courses in irrigation and a few years' experience as maintenance and then operation engineer.

b) A general background in irrigation methods and in the problems of irrigated agriculture, acquired mainly from experience.

c) An appreciation, based on a few college courses or on personal outside reading, of agricultural economics and rural sociology.

Thus it is apparent that a project administrator should, by preference, climb up from either the maintenance or operational

section of a project. It is possible to have a freshly educated college man handle the job, but an experienced staff member with less college specialization is more desirable.

The ultimate success of an administrator is influenced as much by the proper functioning of his clerical staff as by his ability. This department is attached to the administrator and is responsible for:

a) Farmers' water accounts or records of areas irrigated
b) Distribution records and efficiencies
c) Work orders, handling and accounting
d) Material and equipment purchases
e) Monthly and annual report preparation
f) Payroll preparation
g) General budget preparation

On larger projects an assistant administrator is assigned to be in charge of this non-irrigation phase.

Maintenance Staff

The maintenance staff is responsible for keeping the project in operation through continuous supervision, care and repair of existing features and usually the design and construction of minor additional features. This staff is usually headed by a civil engineer on large projects and by an experienced superintendent on smaller ones. The staff is broken up into smaller working units, each with its foreman. The normal work for any one year may include all or most of the following:

1. Canal cleaning: mossing, silt removal, bank trimming, gopher control, weed control
2. Structure maintenance and repair
3. Road repair and construction
4. Telephone line up-keep
5. Tool grinding and repair
6. Repair and maintenance of mechanical equipment
7. Additions to project: design, layout and execution of canals, gates and measuring structures

For the above, the staff should be selected and trained so that they can perform smoothly and with a minimum of delay; this is the most important element in a repair job on an irrigation canal in use. Generally, the chief maintenance man is again a civil engineer with a fair knowledgeof such work. His knowledge in the irrigation practices field is not important but if he has any hope of promotion to administrator, this is the time he can pick up rich experience.

Operations Staff

Here the main work is:
1. Water distribution
2. Water dispatching
3. Water measurement
4. Crop reports

A water-master, assisted by a number of ditch riders, usually handles the job of getting the water to the users, measuring it and reporting on the crops it is used on. Though mainly guided by the irrigation manager or administrator, a water-master, especially on smaller projects, is the key man for the success of the project. He should have a solid background in irrigation methods and crop water requirements. This is required for making decisions on distribution schedules and stream sizes and, in special cases, on priorities. He should be familiar with water flow and water measurement, for he is responsible for the distribution of water in the various canals and for measuring the amounts received and distributed in individual canals. Finally, he should be familiar with methods of weed control and the general care of canals so that he can minimize the work of the maintenance section.

Specifically, an operations engineer (or an administrator working through a foreman on small projects) should:

a) be well-trained in hydraulics-water flow and water measurement
b) have a strong background in irrigation practices - irrigation methods, crop requirements and delivery methods, and
c) have general training or experience in the care of irrigation structures, mainly in the control of weeds and silt

A good promotion system would employ a young graduate as a maintenance man and then, after a few years, send him to operations and, after several years, make him administrator.

Agricultural Extension Staff and Training

Generally, irrigation projects bring under irrigation lands that were previously dry-farmed or not farmed at all. The farmers in most cases come from farms where limited irrigation was practiced, but these practices are not suitable for large irrigated areas. The agricultural extension staff have the duty of helping these farmers make the best of this new situation. From the irrigation aspect, their work can be divided into two main categories:

1. Irrigation systems and land development work
2. Farm irrigation advisory work

Really this work corresponds to that of an irrigation and land development consulting office set up by private engineers, to which rich landowners usually come for help. In many sections of the Middle East this work is still done by private individuals or firms, who charge on the basis of the area studied. Many ministries of agriculture are still weak in staff of this caliber and owners have no alternative. It is hoped that such staff will be developed and put at the disposal of farmers to perform this badly-needed service.

1. Those responsible for the first category of work have general responsibility for setting up the environment for an efficient and prosperous water use situation. They have two problems:

   a) Land preparation

      They should be able to help the farmer divide his field for irrigation and determine whether any grading is required. Where grading is necessary, they should be able to survey the field, determine the most suitable grades and come out with the anticipated volume of cut and fill. They should also be familiar with the equipment that performs the grading -- scrapers and planes, large and small, and their unit costs.

   b) Water distribution

      A farmer, especially one newly moved to irrigated farm lands, requires help in planning his distribution system - the location of main and lateral ditches, their permissible slopes and sizes, pipe sizes, gate stands and other control features.

      Here again a thorough knowledge of irrigation methods is a basic requirement for the extension staff, together with elementary flow hydraulics. The staff member should be able to lay out distribution patterns that suit the land and to determine the size, slope and length of the various pipes or canals. He should be able to recommend length of run and flows required for each irrigation method. To be able to do this, he should be well-trained in elementary surveying, farm distribution patterns and layouts, the hydraulics of flow in pipe and canal, elementary soil physics, and elementary economic analysis. Generally an agricultural engineering education up to the Bachelor's level is recommended. But an agriculture college graduate, with a little extra training or some extra electives in college in the above fields, would be able to do the job well.

2. <u>Farm Irrigation Advisors</u>

   These staff members take over after the land is developed - graded or sub-divided - and the distribution system is laid out. In large areas they are special members of the extension system staff, while in small projects they are the same

people who work on land development and the distribution system. Their job is to advise the farmer on basic soil-water-plant relations. Primarily their work is to provide the answers to the questions:

a) How will I irrigate?
b) When will I irrigate?
c) How much water will I use?

and these answers are no easy goal.

a) There is more or less general agreement on the choice of method. It is a function of known factors and elements of production. Crop, slope of land, soil water-intake rate, and available water supply normally determine the method of irrigation. With little experience correct recommendations can be formulated by a well-trained irrigation advisor.

b) Basically this question is: how dry may I allow my soil to become before I apply water? The answer is not simple because it implies two things: 1) a relation between growth and soil moisture levels, and 2) an easy method for determining the available soil moisture at any one instant. Both implications are complicated and no final, straight and simple answer is known. However, a large wealth of experiments is available and many helpful correlations can be drawn.

c) "How much water should I use?" or "how much will I need?" is an easier question, and can be answered rather correctly in most cases. The irrigation advisor should be able to calculate the quantity of water required for irrigation from the soil characteristics - the apparent specific gravity of the soil, its field capacity, its moisture content prior to applying water, and the root zone depth of the crop grown. The total irrigation requirement of any crop is primarily a function of the climatic environment in which it is grown, together with modifications resulting from the irrigation and cultural practices followed. Here again, the advisor should be able to make use of the many available experimental results in formulating the answer to the farmer.

To be of help in answering the above questions, such an advisor should normally be a college graduate in agriculture or better still in irrigation science. A few colleges are offering such specialized training

from an agricultural standpoint. The stress is on soil-water-and-plant relations. A general background in agriculture is essential. Since, in many sitautions, both the irrigation advisory work and the distribution system and land development work are done by one person, each of the extension workers should possess the training required for both aspects of the work. Thus his ability to be of help will be greater and he will develop into an extension worker in whom the farmers believe and trust.

Concluding Remarks

Irrigation is the meeting ground for men from many fields of science. It is important that those meeting there feel that the irrigation engineer is not a stranger to them but rather the bond between them, and at the same time one of them.

Mr. M. R. Lewis once told me of the time when he gave two courses on irrigation, one in the School of Engineering and the other in Agriculture. Invariably the engineering students thought of irrigation as an agricultural science, rather strange to them, and took Mr. Lewis and irrigation as outsiders to engineering. This outlook is slowly changing and more and more individuals today accept irrigation as a science made by binding together not only engineering and agriculture but also fragments of economics, sociology and law. It is the ability to fuse together these various sciences and produce a homogeneous, self-possessed and self-assured individual that our hope for the future lies.

Aware of the need for an irrigation staff and realizing the problems of its development, what is the recommended approach? What steps could be taken, and by whom, that would give us an irrigation staff, well-developed and ready to take charge of our projects? The problem has three important aspects:

1) Who is to assume the responsibility of producing these staff members?
2) From where, with what background, and how will they be selected?
3) What training shall we give them and how should it be given?

1. Presently the stress in irrigation in many Middle Eastern countries is on the design and construction phase of new projects. The operational and extension work, still in the background, is administered by a section of either the Ministry of Agriculture or Public Works and sometimes of both. To my mind, an attachment to the Ministry of Agriculture is more desirable. A semi-independent division within this Ministry should be set up to

deal with irrigation. A section of this division should be responsible for the procurement of staff. Thus, this section will be able to lay equal stress on both the engineering and agricultura aspects of irrigation without prejudice and can employ graduates from both fields. Further they, will have the liberty to develop their own training program, stressing whatever aspects they deem necessary.

To better further its interests and its ability to be of service to the various communities, the section should set up local advisory boards in every district served by a project. This board, elected from the water users, should be gradually trained to handle all the problems of the area. For the first few years they will have advisory powers only, but later more and more of the responsibilities of water handling and extension work should be their own. The irrigation staff section, together with the local boards, should be responsible for outlining a program of staff development, selecting candidates and, finally, placing them in their respective jobs.

2. Preferably, project staff workers should be from the area being served. Granted that they may be subject to some local pressures due to their social, religious or family relations, still the benefit derived from their knowledge, love and attachment to the area, its people and its welfare far cutbalances the drawbacks.

   The minimum level of their education or previous training should be clearly set. The chiefs of units and those hoping to become chief operational or administrative officers should have a college background, preferably in general agriculture, engineering or irrigation science. The others should have had some agricultural training. Secondary agricultural education is common in many countries and such graduates would make good candidates for this type of work. The actual selection should be done by competition. Examinations on the various phases of their schooling, interests, character and physical fitness should be carried out and the most promising ones chosen.

3. The candidate so chosen should be given "on-the-job training." A six-month training period should be made part of every contract. The trainee would be sent to that section of the project where his field of activity is handled and would work under the person doing the work there. All candidates should be given a series of lectures, demonstrations and manuals on the general problems of irrigation. An examination should be passed after this training period.

   Throughout this training, those responsible for the work should not be satisfied with the development of only technical skills.

For a trainee to be really well-developed, he should have, apart from his technical skill, an optimistic faith in the success of his work and the project as a whole. He should develop a sense of fairness and impartiality and an awareness that water is a valuable and limited commodity. He should feel that upon his fair and intelligent care for and rationing of this necessary element the future of the project and of the whole country will depend.

Irrigation projects cannot rise above the level of the persons responsible for them. Let us strive to train and develop men who, with their ability and faith, will pull up their respective countries to the high level envisioned for them by those who had the knowledge and the power to realize these projects.

IRRIGATION STAFF DEVELOPMENT

Irrigation Department, Ceylon

Formal Discussion

by

A. E. C. de S. Gunasekera, M.I.C.E.
Director of Irrigation (Ceylon)

and

H. de S. Manamperi, A.M.I.C.E.
Divisional Irrigation Engineer

Prior to 1900, the investigation and construction of irrigation works formed part of the functions of the Department of Public Works. An irrigation officer of the P.W.D. was responsible for the inspection and formulation of schemes and for advising the provincial irrigation boards, which promoted irrigation schemes in their respective provinces. Toward the end of the century, provincial irrigation boards found that they were not able to get their schemes executed as fast as they desired. There was constant agitation for the formation of a department of Government to be solely responsible for irrigation works.

On the 15th of May 1900, the Irrigation Department was set up, with Mr. H. T. S. Ward as Director, Mr. Henry Parker as Irrigation Assistant, 16 engineers, 13 technical assistants (inspectors of works) and six clerks.

Today the Department of Irrigation has a cadre of one director, four deputy directors, four assistant directors, 160 engineers of various grades, and over 700 officers in sub-technical grades such as technical assistants and draughtsmen. The major sections of the Department are shown in the annexed table.

To understand this growth and development of staff, it is necessary to trace the historical and economic development of the Island for the last half century and more. Ceylon was ruled for over 2000 years, from 543 B.C., by her own kings. She lost her independence to the Portuguese (1505), then the Dutch (1658), and finally the British

took over the administration of the Maritime Provinces of the Island in 1796 and completed their conquest in 1815. The Sinhalese Kings had constructed large reservoirs for irrigation and vast networks of irrigation canals for transferring water from the well-watered central hills to the dry plains in the north of the Island. There, in the "dry zone," they had created an agricultural civilization in the shadow of the compassionate doctrine of the Master, Gautama Buddha.

For many years the people struggled against invasion, first from the neighboring Indian continent and then from the wealth-seeking countries of Europe. As a result of these invasions, their magnificent irrigation works fell into disrepair, throwing a once prosperous people into poverty, disease and despair.

The British rulers who took over the Island in 1796 were soon deeply impressed by the remains of the ancient irrigation works of the Sinhalese, and their current contrasting poverty. Successive governors of the Island realized the necessity of restoring the irrigation works to put the people back on their feet. Irrigation occupied a great deal of the thoughts of the Government. One of the most vigorous advocates of this policy was Sir William Gregory (Governor, 1872-77) who, during his six-year term of office, restored so many works in the North Central Province that he was called "the creator of the N.C.". It was the impatience of men such as this, who saw the wisdom and the necessity of restoring irrigation works, that gave rise to the setting up of the Irrigation Department in 1900.

From this date onwards the development of irrigation activity was in direct proportion to the development of the political independence of the people. During the period of British colonial rule, irrigation schemes were taken up for development only if the direct returns to the Government in the form of grain taxes, land sales and capital levies were favorable. As political independence was progressively achieved, the Government considered also the indirect benefits of land utilization, the setting of an impoverished peasantry on their feet, and the creating of a citizenry with self respect and independent judgment.

From 1900 to 1931 the country was ruled by a British governor with the limited of a Legislative Council (part elected) and an Executive Council nominated by the Governor. In 1931, a parliamentary form of government was introduced, which, however, reserved defense, finance and law under British control. In 1947 the Island achieved independence within the British Commonwealth.

Up to 1931, there was no significant change in the cadre of the Irrigation Department. There was an increase in the number of technical assistants from 13 to 88 and there were 15 draughtsmen in 1931. The total budget of the Department was Rs. 1,630,000, of which Rs. 500,000/- were for construction, Rs. 300,000/- for maintenance, and

Rs. 840,000/- for salaries and other charges. The budget for 1901 had been Rs. 800,000/-, approximately.

From 1931, when a measure of political independence was achieved by the people, until 1937, there was no special increase in irrigation activity. The ministers of the new Government were new to administration and were feeling their way, being hampered by a foreign bureaucracy which was unhappy in its changed status. However, the Minister for Agriculture, who was in charge of the Irrigation Department, began strengthening its cadre by ordering the creation of a training class for the recruitment of officers for the engineering and technical assistant (inspector of works) grades of the Department.

Irrigation works were in inaccessible unhealthy areas of the Island, and consequently it was difficult for the Department to obtain staff for service in these areas. By the creation of training classes for "engineering pupils" and "technical assistant learners", who were paid an allowance during their period of training, the Minister decided to attract young men into the service. This training program commenced in 1936 with four "engineering pupils" and 14 technical assistant learners. The training of engineering pupils has now been given up, but the technical assistant training program is still in force, the current number of learners being 80. These programs relieved the staff shortages considerably.

By 1937 the ministers of the Government, having gained sufficient self-confidence and knowledge of administration, were planning to improve the economy of the Island. One of their basic planks was the development of the dry zone, where many large abandoned reservoirs and the lands that they had once fed were hidden in the jungle. Fortunately for the country, the Minister in charge was Mr. D.S. Senanayake, later to become the Prime Minister of Independent Ceylon. Unfortunately, the Director and all the senior engineers of the Department were British, unused to taking orders from a Ceylonese.

Consequently, the years 1935 to 1938 were troublous times, and saw the departure of three directors of irrigation unwilling to work under the orders of a Ceylonese Minister. One of these directors was so uncooperative that he granted leave to five senior engineers at the same time, while complaining of a lack of staff to carry out the policy and program of the Minister. However, the clock could not be turned back, and the foundations of the Irrigation Department were being solidly laid.

A hydraulic laboratory was established in 1938. Engineers were obtained from abroad, from India, New Zealand, Russia (refugees) and other countries, to make up for the retirements of British engineers and to accelerate irrigation progress. A program for the training of Ceylonese in the sub-technical grades for engineering posts by granting them scholarships to universities in India was begun in 1941 and conti-

nued until recently, when the output of engineers from the University of Ceylon became adequate to supply the needs of the Department.

It often happens that great calamities bring forth also great benefits. So it was that the Second World War taught the people of Ceylon that they must produce an adequate proportion of their food, and gave the greatest fillip in history to irrigation activity. Before the war, Ceylon imported almost three-fourths of its food supplies, mainly from India, Burma, and Siam. The entry of the Japanese into the war in 1941 cut off regular supplies of rice from these sources, and Ceylon began a system of rationing which kept her just within the subsistence level.

The lessons of the Second World War have not been forgotten. Irrigation and agricultural activities have raised local production to meet about one-half of local food needs, there having also been a phenomenal increase in population. Much remains to be done, and there can be no relaxation of irrigation effort for many years to come.

Presently, the Irrigation Department has the following sections:

1. Planning
2. Investigations
3. Research
4. Designs
5. Construction, mechanized and manual
6. Maintenance

Construction:

Up to 1937, the Irrigation Department had undertaken only two jobs where mechanical aids to construction were employed. They were the Iranaimadu Tank (1910) and the Ridiyagama Tank (1925). In 1938, the restoration of Topawewa, an ancient abandoned tank, necessitated the closing of a breach 1000 feet long and 80 feet deep at the maximum. It was not possible to close this gap by manual labor, partly because of the volume of earthwork involved and partly because malaria, then prevalent in this area, made it impossible to maintain a large labor force. For this job, Diesel-powered crawler-type tractors, power shovels and dumpers and ancillary equipment such as lorries and dozers, were obtained. The foundations of the Mechanical Branch of the Department were thus laid.

The advantages of mechanized construction were soon realized and such construction was extended to all the major projects undertaken by the Department. Regional workshops were established and a central workshop was set up in Colombo for major repairs and for stocking spare parts.

Presently, the Mechanical Branch has the following staff:

Chief Mechanical Engineer	1
Deputy Mechanical Engineer	1

Mechanical Engineers and Assistant Mechanical Engineers	16
Electrical Engineer	1
Mechanical Stores Superintendent	2
Storekeepers, Clerks, Typists	55
Mechanical Foremen and Assistant Foremen	19
Works Foremen and Charge Hands	63
Lorry Drivers	150
Mechanics	530
Machine Operators	420

In several instances, large volumes of rock have had to be excavated in channels. To handle this work, a team of officers has been trained and functions under an Explosives Superintendent. A great deal of the construction work of the Department was done by direct labor. Consequently, as the works programs increased, the labor forces employed and the volume of stores handled became very large. In 1950, a Stores Liaison Officer was appointed for the selection, purchase and despatch of stores from Colombo to the different works. In the same year, a Welfare Officer was appointed to look after the welfare of the staff and workmen in the Department.

Investigations:

The restoration of large tanks such as Topawewa involved the construction of high embankments, and large volumes of fill. The design of these dam sections and the location of suitable borrow areas pointed to the need for a soil investigation organization. A Soil Laboratory was established and an investigation staff set up in 1940. The functions of this Laboratory have now been extended to the testing of construction materials, such as steel and cement, used for departmental works. It is also in charge of concrete and earthwork construction.

Closures of breaches and the design of large concrete structures such as spillways and aqueducts made it necessary to obtain data on foundation conditions. A drilling section was set up in 1946 for core drilling at various sites.

Research:

The Hydraulic Laboratory was established in 1938 to handle various problems that needed study in the course of designing flood control and irrigation schemes. One of its major fields of study is the functioning of river outfalls in connection with flood mitigation and land drainage problems.

Planning:

In the early years of itensified irrigation development, large abandoned ancient tanks were improved. However, there came a time

DEVELOPMENT OF IRRIGATION STAFF 1900 - 1958

	1900	31	42	52	1958
Director of Irrigation	1	1	1	1	1
Deputy Director of Irrigation	-	1	1	1	4
Assistant Director of Irrigation	1	-	-	2	3
Assistant Director (Administration)	-	-	-	1	1
Divisional Irrigation Engineers	-	7	7	10	13
Irrigation Engineers	16	16	10	42	75
Assistant Irrigation Engineers	-	9	23	25	50
Specialist Offices (Design and Engineering)	-	-	-	3	5
Accountants	-	-	1	8	7
Research Assistants	-	-	-	16	14
Drilling Superintendent	-	-	-	-	1
Drilling Foreman and Assistant Drilling Foremen	-	-	-	2	3
Technical Assistants	13	88	122	266	367
Clerks and Typists	6	-	80	242	376
Stenographers	-	-	-	6	6
Storekeepers	-	-	-	93	131
Drawing Office Assistants	-	-	-	2	5
Draughtsmen and Apprentice Draughtsmen	-	15	31	117	322
Computers	-	-	-	18	30
Laboratory Superintendent	-	-	1	1	1
Chief Engineer Mechanical Branch	-	-	-	1	1
Deputy Engineer	-	-	-	1	1
Mechanical Engineer	-	-	-	3	10
Assistant Mechanical Engineer	-	-	-	2	6
Accountant	-	-	-	1	2
Mechanical Stores Superintendent	-	-	-	1	1
Assistant Mechanical Stores Superintendent	-	-	-	2	6
Sectional Storekeepers	-	-	-	5	5
Storekeepers	-	-	-	14	30
Clerks and Typists	-	-	-	29	20
Mechanical Foremen	-	-	1	1	8
Assistant Mechanical Foremen	-	-	2	6	11
Works Foremen	-	-	-	20	33

when the irrigation map was getting uncomfortably crowded, and it appeared necessary to determine the optimum use of the water resources of the Island. The Department had for many years collected data on river flows and had established a river gaging and hydrology section in 1942. It was now necessary to collate these data and to utilize them for optimum development of the various river basins. A Planning Branch commenced in 1951 and now functions under a deputy director.

The development of water resources was at first treated as a matter purely of irrigation. The present trend is for the development of multi-purpose projects. The first step in this direction was taken in 1948 with the construction of the Gal Oya Reservoir (700,000 ac. ft.), which in addition to irrigating 125,000 acres for paddy, provides a measure of flood protection and has an installed hydro-power potential of 10,000 kilowatts.

The Planning Branch of the Department is interested in the water resources of the Island not only from the irrigation point of view, but also from that of power production.

IRRIGATION STAFF DEVELOPMENT

Formal Discussion

by

Adem Karaelmas

Director, Soil Conversation and Farm Irrigation Division

Ministry of Agriculture, Turkey

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I. Introduction

The government of the Middle Eastern countries are devoting very large amounts of local currency and foreign exchange to many large-scale irrigation development projects, and many more are in the planning stage for construction in the near future. While the major engineering planning of these projects is well advanced and of a high quality, in many instances the agricultural phases of these water development programs have not been fully recognized and frequently too little thought and effort have been devoted to the efficient use of the irrigation water on the farms. Since we believe that "the problems of irrigation come after the water gets to the land," * we must have well-planned agricultural programs in irrigation to apply water to our land with maximum efficiency for the continuous production of crops.

Successful irrigation projects involve not only the development of water recources but also the efficient and proper use of the water on the land after it has been made available. The planning of a successful irrigation enterprise must give full consideration to the agricultural factors of the soil, water requirements of crops, drainage and agricultural economics as well as engineering work. There are many defunct irrigation projects which bear mute evidence to the lack of adequate consideration of the agricultural factors, either in the initial planning or in the operational phase of the projects. Therefore, both the engineering and agricultural phases of the project must be given due emphasis if the maximum benefits are to be derived from the large investments being made in water and soil development.

The agricultural people working with or on water development projects must solve the problems, or prevent the problems from arising, of erosion, waterlogging, salt accumulation, loss of soil permeability and aeration and soil depletion. The agriculturist must also keep in mind

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* Dr. Frank Viehmeyer, University of California.

the necessity for achieving maximum production by the use of better irrigation practices. Since many of these practices involve considerable financial investment by the farmer, they must be "sold" to him on the basis of increased income as well as of doing a better job.

II. Particular Irrigation Problems in Middle East Countries

Our large scale irrigation projects have been primarily concerned with construction to develop water with little regard to the use of the developed water. Generally, our irrigation practices on presently irrigated land are inefficient. Irrigation distribution systems are crudely designed, no control structures are used and water application practices are often untimely and result in poor distribution of water. Irrigation as practiced by our farmers is still very inefficient; water is distributed (herded) over the fields in some cases by a great mass of handshovelled dikes and ditches. Water is allowed to flood across the fields with little control, resulting in over-irrigation in some places and no irrigation in others. Adequate surface drainage for surplus water is often lacking. We have financed engineering organizations for water development but have provided inadeqate support for the agricultural phase of irrigation.

As we all know very well, our farmers are uneducated and extremely conservative. It is very difficult for them to adopt new practices which change the farming methods which have been used on their land for centuries. It is easier to introduce or teach new irrigation methods in areas where there has been no irrigation. Under our conditions, very thorough demonstration and training are needed for proper irrigation. A high degree of skill is needed in providing technical assistance, to our farmers. We must be genuinely interested in the farmers' problems as well as being highly trained technically. We must train our farmers to become "irrigation farmers", to maintain the productivity of their land, to know their soils and the irrigation principles of soil-plant-water relations, and to apply irrigation water to the land at the proper time in the proper amounts to meet the requirements of the growing crops in the most economical manner.

In new irrigation projects, the training of the farmers in irrigation and land preparation should begin as soon as construction of the projects begins, to permit a high percentage of the farm land to be efficiency irrigated soon after the completion of the distribution system. Without this attention to farm development and water utilization, large projects frequently operate for many years at very low productivity. A good example can be observed in Turkey, where large government irrigation projects are already completed and operating at the present time . A field irrigation efficiency study has been made

on several of these completed projects. The average of field irrigation efficiency is not over 35%. This low efficiency is the result of inadequate "farm irrigation": farmers have not used proper irrigation methods, very few head ditches, little land leveling, few water control structures, poor field layout and no farm drainage. Under our conditions it is impossible to expect present farmers to do this type of work without a very large amount of technical assistance and adequate special irrigation equipment.

In contrast to this situation, the Ministry of Agriculture has been able to establish a field organization for farm irrigation in a small number of completed projects, to provide for the farmers adequate technical assistance and some assistance in special equipment for land preparation and irrigation. The study shows that with this assistance in the field our farmers were able to achieve an average field irrigation efficiency of 60 %. Continued work by this field organization in providing technical assistance in farm irrigation will increase this efficiency.

III. Development of a Technical Staff to Solve our Problems of Farm Irrigation

Our approach to the problem of organization for technical assistance for farm irrigation has been to provide for a separate organization to take care of farm irrigation. This organization, within the Ministry of Agriculture, is being developed on three organization levels: (1) a strong central national office, (2) regional offices, (3) technical groups for work areas, usually for a province. Our organization provides for a direct line of authority and responsibility and for very strong guidance through each organizational level to provide direct technical assistance in farm irrigation to the farmers of our country. The staffing and expansion of this organization have proceeded rather slowly for adequate study of our Particular problems and to provide well-trained personnel in each position.

The central or national organization has the responsibility of suppervising the national farm irrigation assistance program; it formulates the policies under which the field organization works, formulates general programs for farm irrigation, and provides technical standards under which the field organization works. The central office is also responsible for training, legislation, budgets and for the delegation authority to the field offices.

The field work is organized on two levels: (1) Regional offices to provide for programming of work, to provide technical guidance and supervision to the operational offices, to adjust technical standards to local conditions, and to provide general administrative support for field work; (2) technical groups in work areas to provide the actual technical assistance and training in improved farm irrigation practices to the land-owners. The personnel of this technical groups varies somewhat according to actual problem of the area, but normally they consist of trained irrigation engineers, trained irrigationists,

drainage specialists and soil conservation specialists, and soil survey specialists. Assistance and planning are normally based on a soil survey of the land area.

The specialized agency for farm irrigation improvement is supplemented by an agricultural extension program involving provincial irrigation specialists, county agents and village teachers. These extension personnel are normally trained in farm irrigation by the Farm Irrigation Division. Under our conditions the extension program in farm irrigation is responsible for creating interest in improved irrigation practices, for conducting irrigation practices demonstrations (with technical guidance and assistance from the Farm Irrigation Division for conducting an information program on farm irrigation, and for directing farm requests for technical assistance to the farm irrigation technical groups.

While the Farm Irrigation Division and the Extension Service are the primary sources of assistance to farmers on farm irrigation, it is also important that the local people participate in the program for the improvement of farm irrigation. Both of these government organizations cooperate in the formation of private and semi-governmental groups for the promotion of irrigation improvement. These groups consist primarily of cooperatives, districts and private contractors. The Farm Irrigation Division has taken primary responsibility for securing mechanical equipment for private contractors and cooperatives to be used for land preparation for irrigation. This function of supplying specialized mechanical equipment for land preparation has become increasingly important. We have supplied this equipment to private contractors in two of the important irrigation areas of Turkey and have developed sets of small animal-powered land preparation equipment which can be manufactured locally. One hundred sets of this equipment have been supplied by the Farm Irrigation Division to the Extension Service for demonstration purposes.

We have found that it is extremely important to coordinate the programs of the various government agencies concerned with irrigation development and to achieve a high degree of cooperation among these agencies. In Turkey these agencies are primarily the Hydraulic Works Department of the Ministry of Public Works and the Extension Service and Soil Conservation and Farm Irrigation Divisions of the Ministry of Agriculture. An important phase of the coordinated efforts is to avoid duplication of effort since most of our countries have limited financial resources. We have attained agreement between the Hydraulic Works Department and the Farm Irrigation Division in the assignment of functions performed by each agency during the planning, construction and operation phases of large-scale irrigation development projects. The Farm Irrigation Division has responsibility for the preparation of land classification for irrigability, participates in the economic feasibility studies and the drainage studies, and assists in the planning of major drainage facilities and in the preparation of charges

for water. The Hydraulic Works Department assists finacially in the maintenance of the Irrigation Research Stations operated by the Farm Irrigation Division.

Opportunities for coordination of the extention irrigation program and the Farm Irrigation Division programs are much more widespread. The Farm Irrigation Division has primary responsible for the training of extension personnel at each level of the organization. Regular organized training courses and short courses are conducted for the training of extention irrigation specialists, county agents and village teachers. This training is pointed toward the benefits to be obtained by the use of improved irrigation practices, methods of conducting demonstrations of improved irrigation practices, and the use of equipment adapted to irrigation farming. We have been quite successful in training county agents and village teachers in the use of locally - manufactured, small, animal-powered equipment for land preparation and water distribution.

Actual demonstrations of improved irrigation practices are normally conducted by personnel of both the Extention Service and the Farm Irrigation Division. The extention personnel normally plan the demonstration, while the personnel of the Farm Irrigation Division plan the technical phases of the irrigation demonstration. Personnel of both organizations are present at the demonstration to carry out the work and provide instruction in the improved methods. Usually requests for assistance by farmers for improving irrigation on their land are made to the extension organization and forwarded to the Farm Irrigation Division for planning, design and construction supervision. Training of the farmers in irrigation operations is carried out by personnel of both organizations.

IV. Development of the Irrigation Organization Within the Ministry of Agriculture of Turkey.

With respect to the actual development of the staff for a farm irrigation assistance program, I wish for your information to outline and discuss briefly our own experience. One of our fundamental objectives has been to provide well-trained personnel in farm irrigation at each level in both the Extension Service and the Farm Irrigation Division. Our next consideration was to grow and expand only as fast (or as slowly) as these trained personnel became available. These policies have resulted in our having at present a rather limited number of people throughout the country who are providing assistance to the farmers. It has had, we believe, a tremendous advantage in gaining the confidence of the farm population by providing high-quality work to demonstrate the effectiveness of improved irrigation practices; and we are now in a position rapidly to expand our force of technicians into a country-wide organization. "We have established a good reputation with the farming population."

Our coordinated irrigation program was initiated by the establishment of a Farm Irrigation Section within the Ministry of Agriculture in 1952. Irrigation research was also coordinated at this time to provide uniform information on farm irrigation and irrigation practices. At first our main effort was to train a small number of technicians in Turkey and in the U.S. After this program of training was well under way, and after a limited number of field demonstrations had been conducted it became apparent that it would be highly desirable to base our field work on soil survey and land classification information. With this in mind, a small staff of soil surveys was trained and a Soils Institute started to provide the necessary land and soil information for the best possible farm irrigation planning.

Our first organization privided for a small central office consisting of personnel selected from our first training courses and several "technical groups" of irrigation engineers and irrigation specialists. The central office provided facilities for training additinal personnel, for formulating policies and general programs, for establishing design standard and operating procedures, and for general administration support of the field workers. The "technical group" were thus able to devote practically their entire time to field work, with a very minimum of administrative effort. The field work at first was largely devoted to planning and conducting demonstrations of different improved irrigation cooperation of the extension organization, and also served as a means of training selected farm people, extension irrigation specialists, county agents and village teachers.

The number and size of these technical groups were expanded as more trained personnel became available, and their work was also expanded to provide technical assistance in improved irrigation practices to farmers on a large scale. A limited amount of specialized mechanical land preparation equipment was made available to the technical groups, both for demonstration purposes and for a construction program on land where the use of large equipment was practical. A very considerable amount of the time of these technical groups was devoted to actual on-the-land training of farmers in the use of water and in improved irrigation practices.

During this period the Farm Irrigation Section trained a number of provincial irrigation specialists for the Provincial Extension Service. Each specialst attended an organized training course in irrigation methods and practices and was also provided with on-the-job training in farm irrigation. At the present time, 40 extension irrigation specialists have been trained and are assigned to the staffs of of the Provincial Extension Service. These specialists have been very important in promoting interest in improved farm irrigation and are a continuing source of requests for technical assistance in designing and constructing improved farm irrigation systems.

Within the last two years our staff in farm irrigation had reached a size where an adjustment in organization became necessary. On January 1, 1957, our organization was changed to form the Soil Conservation and Farm Irrigation Division within the Ministry of Agriculture. The principal change, other than the addition of responsibilities in soil conservation, was to incorporate a regional organization to provide better supervision, control and administrative support. In this new organization we expect to include, usually, eight provinces, or work units, in each region. Two regions have been organized to date; others will be organized and staffed as soon as personnel become available. We expect to be able to provide better service to the agricultural population with this organization, particularly by having available in the regional offices a staff of technical specialists who will be available for on-the-job training and for planning and designing working connection with more complicated problems.

This regional organization will enable us to do a much better and more extensive job of training county agents and village teachers in farm irrigation. Such training in practical irrigation has been provided for the county agents and teachers during the irrigation season.

Short courses have been given them during the irrigation season since 1956; 50 county agents and 150 village teachers have received this training. The expansion of our regional organization will permit larger numbers to receive this training in the future. These short courses now include instruction on the use of locally-manufactured irrigation equipment; sets of this equipemnt are provided for demonstration purposes in the working areas of the county agents and village teachers. The regional organization will thus enable us to do a much better and more extensive job of training both extension people and farmers in practical farm irrigation.

Our training and organization have given emphasis to a very large number of irrigation demonstrations to show the advantages of improved irrigation practices. These demonstrations have shown the farmers why, how, when and what work should be done to increase crop production by improved farm irrigation, and how these methods reduce the labor requirements of irrigation. In these demonstrations we feel that it is extremely important for the farmers to participate, with the help and technical advice of the irrigation specialist, county agent, village teacher or irrigation technician.

Most recently, our organization has given encouragement, advice and assistance to private contractors in connection with land leveling and land preparation for irrigation. Contractors have also been given assistance in obtaining heavy equipment for earth-moving work.

LOW-COST SIMPLE EQUIPMENT TO IMPROVE TILLAGE PRACTICES AND SOIL AND WATER CONSERVATION ON NEAR EAST FARMS

by

James D. Metzger
Irrigation Advisor, USOM/Turkey

Introduction

In the first records of history, all crops for the sustenance of mankind were produced and prepared by the power of human muscles. Many centuries passed before the power of animals was used to relieve human beings. With the discovery of iron, tools were fashioned that further relieved the labor of human muscles, but the transition from hand-farming to modern power-farming came slowly. The changes which have taken place in some parts of the world during the past decade have affected human values so significantly that one wonders what effect farm machinery will have on our welfare. In fact, there has been more farming progress in the last 100 years than in all the previous history of the world.1/

In 1856 nearly 80% of the population of the United States lived on farms, while in 1958 more than 85% lived in towns and cities. In 1856, farm tools were so crude that each worker could produce only enough food for himself and four or five others. But, by 1920, with improved horse-drawn equipment, the farm worker could support himself and nine others; and in 1958, with modern power equipment, he can support himself and nearly 17 others.2/

Farm Management

The farm manager has many things to consider in planning a profitable farming operation and one of his foremost considerations is farm equipment. There is no rule to be followed in determining the type or amount of equipment needed. Every situation is different, and the problem is as important to the operation of a small farm where the farmer may use only a few simple pieces of equipment with animal power as in the operation of a large unit where the highest degree of mechanization is employed. The farmer who owns and uses equipment which has been made at the local blacksmith shop need look no further than that same shop for repairs and maintenance; whereas the man who owns and uses complicated mechanical equipment designed to do a specific piece of work, may have to depend upon a national network of specialized sales and service.

1/ Farm Machinery and Equipment, H.P. Smith.
2/ U.S. Department of Agriculture Miscellaneous Publication No. 630.

Farming Operations In the Near East

Reliable figures are not available as to the size of farms or the percentage of people engaged in agriculture for all the countries represented here. In Turkey, 80% of the population are engaged in farming, 90% or more of whom use hand tools, small equipment, and animal power. The average size of farms is less than 15 acres, or about six Ha., and this is often divided among several small tracts located some distance apart. While conditions vary somewhat in different countries, many of the problems are similar. Small farms, limited operating capital, and inadequate power are among the most common handicaps. Cooperative efforts among the farmers of a community can help in some of the larger operations, but it is not always easy to obtain the necessary cooperation or to maintain facilities for economical operation of equipment held in common.

Most of the farmers in Turkey have some animal power available, and improvement in the care and handling of these animals, coupled with better types of small animal-drawn equipment, could do a great deal to ease the human workload. If the same amount of improvement could be made in animal-drawn equipment here as was made in the United States during its early development, a great deal of labor could be released for productive work in other occupations. It seems evident that a more rapid and far more economical increase in the production of food and fiber can be obtained by improving methods now in use along with the introduction of the new and complicated methods of mechanized farming which are so difficult to absorb into the social and economic patterns of a community.

It is not my intent to discredit the use of mechanized farm power in this area, but until some of the basic requirements of sales, services, operation and maintenance are better established, it is virtually impossible to make economical use of mechanized farm equipment, to say nothing of the difficulties involved in mechanizing power on small farms.

In a report by the European Productivity Agency of the Organization for European Economic Cooperation, by arrangement with the United States Foreign Operations Administration, the following statements appear: "PORTUGAL--Mechanization of small farms is difficult cheifly because of economic reasons. Because of varying soil conditions tractors in many cases do not support the cost of a machine capable of working. DENMARK, on the other hand, finds that, by and large, mechanization of all farms from five to six ha. can be economical if intelligence is used in obtain-maximum output. Two-wheel tractors are not advisable. The tractor must be capable of replacing at least two average horses."3/ On our farms in Turkey it will be difficult to replace animal power with tractors which can operate economically on small farms. Most farms cannot support both a tractor and animal power, and the power needed is so varied that it is difficult to do without some animals.

3/ The Mechanization of Small Farms. European Productivity Agency of the Organization for European Economic Cooperation, by arrangement with United States Foreign Operations Administration.

Because of the vast improvement which can be made in the methods now being used, the remainder of my remarks will be confined to suggestions for such improvement. Much of the equipment needed in Turkey can be made in Turkey, while better methods of feeding and of hitching farm animals would greatly increase their efficiency.

Mr. Virgil Petit, Farm Equipment Specialist with ICA in Washington, prepared an airgram under date of October 23, 1956, on the subject of GUIDE-LINES ON HAND AND ANIMAL-POWER AGRICULTURAL TOOLS AND EQUIPMENT OF ICA. He has so ably stated his point on the subject we are discussing that I am taking the opportunity to read a part of the airgram to you (ICATO CIRC A-89):

"In many cases where ICA operates, the improvement of hand and animal-power agricultural tools and equipment offers an opportunity to improve the lot of the farm people. The use of improved tools will ease tasks and permit greater production with less danger of displacing labor than a sudden conversion to mechanization with large capacity mechanical power-operated equipment.

"In any program for the improvement of hand- or animal-power tools and equipment, the objectives should be to create a true desire for such tools and equipment available; to train farmers in the use and care of such tools and equipment, and assure that the farmers will continue to benefit from the change. There must be issurance that the supply of improved tools will continue to be available and that instruction in their use will continue after ICA has eased out of the program.

"Major emphasis should be on introduction of tools and equipment found to be suitable elsewhere under similar conditions which have proved more efficient than those now used. Tools and equipment which will be accepted rather than wholesale introduction of tools and equipment from the United States and other countries of different economic status is essential. Research on existing tools and equipment of the country requiring a long period of minor improvements is to be avoided. In some cases, improvement of tools and equipment presently used may be advisable along with testing of foreign tools and equipment.

"Improved hand- or animal-powered tools and equipment selected for introduction should not be radically different from those now in use. Farmers have learned to use, and have become accustomed to handling, the tools now employed. A hand tool of different characteristics and especially one involving a radical change in position of operation or employing different muscles is very likely to be discarded before the operator becomes experienced enough to appreciate its advantages. If testing has shown the improved or new tool to have advantages, long and

persistent training in its use will be needed to secure its acceptance. It will require a "selling" campaign to induce farmers to buy improved tools and equipment. Farmers will wish to continue to use what they have until worn out even though better tools are developed and available.

"Improved hand- and animal-powered farm tools and equipment must be readily available before introduction is attempted. Many demonstrations have been futile because the tool or equipment was not available in the locality at a price the farmer could afford to pay even though they had been convinced of the advantages. In other cases, the lack of credit facilities has prevented obtaining the improved tool or equipment.

"Animals are a highly mobile source of power especially suitable for movable equipment and at the same time are a readily available source of power for seasonal or temporary stationary work. Many operations performed by hand can be done better by animal power wherever feasible.

"Equipment developed in the more progressive parts of the world should be suitable if properly selected. Minor changes can be made on production types of tools to accommodate local usage, but the important features should be retained. For example, with the many types of animal-drawn plows now manufactured, it is better to test the ones appearing more suitable, then substitute local preferences, such as a single handle if desired, and possibly a longer tongue, rather than trying to develop a new plow. Such a plow could be adapted to local production by buying only the parts which are difficult to make locally.

"In selecting foreign equipment the pulling power and speed of the animals of the country should be considered, as equipment of some countries may be heavy or require too much speed for the local animals.

"Animal power is generally employed for (1) transportation; (2) movable equipment; and (3) stationary equipment.

"In transportation (aside from direct carrying) the force is used in pulling various carriers ranging from poles to multi-wheeled wagons, and at times becomes the major portion of the work load of various kinds of movable equipment. In both of these conditions, the methods of harnessing the animals could usually be greatly improved; but if the improvement of harnessing is radical, it will mean training new animals. Attempts to change methods of hitching old animals usually fail. The neck yoke for oxen gives better results than the head yoke, but it cannot be used on carts in hilly country unless brakes

are provided on the carts. Likewise, the padded collar for horses and mules is an improvement, but requires training.

"In movable equipment the work done by different means from the simple wedge and cutting action of a plow to the more complicated use of drive wheels, gears, etc., as in a mowing machine. The usual items of this type include plows, harrows, seeders, fertilizer applicators, mowing machines, rakes, tedders, loaders and binders. The plow should, in most cases, be first in an improvement program. A second item should be a seeder not only to sow and bury the seed properly, but to get the crops in rows so a cultivator can be used to control weeds, thereby decreasing labor and increasing output of many crops. Where hay-making is practiced or can be profitably introduced, the mowing-machine, rake, tedder, etc., are worthwhile. Likewise, the animal-drawn binder is good where grain is grown. The harnessing problems of movable equipment are the same but greater than in transportation equipment.

"Stationary animal-powered equipment in most cases used the animal for pulling a sweep for transforming the linear motion to rotary power, which can be greatly amplified or reduced by belts and pulleys or gears to suit needs. The use of treadmill devices and the direct use of hooves to thresh grain, etc., are very inefficient methods.

"Some of the more common usages of animal power for stationary equipment include pumping, grinding, or crushing grain or canes, pressing cane. A great deal of improvement is possible in most of these devices. The harnessing problems are the same as for other categories of animal-powered equipment. The sweep for changing motion is usually very crude and inefficient. Where available, old auto, truck or tractor differentials and transmissions can be utilized to make improved sweep devices. Most equipment operated by such power is likewise very crude and can be profitably replaced by better devices used in other parts of the world."

Introduction of Locally-made Equipment

In the past few years we have introduced several items of equipment which can be made in Turkey and powered either by small tractors or animals that the farmers already own. Some of these items have been introduced to do a type of work that was completely new to the farmers, and the results may not be the same as if a new piece of equipment were introduced to do a type of work that the farmers have been doing. Other items of equipment have been introduced to do work which has been done previously.

New equipment for a new type of work. Terracing for soil conservation and the construction of farm irrigation systems are new to the Turkish farmer. Introduced for this purpose were:

1. Slip scoop, or scraper
2. Fresno
3. V-drag
4. Buck scraper
5. Float

The Ministry of Agriculture in Turkey made 100 sets of these items, and county agents and village teachers were given instructions in their use. At this time only two of the itmes have received enough attention from the farmers for them to take the initiative in building them for use on their own farms. These were the "slip scoop" and the "fresno," used in the construction of terraces and powered by two animals.

Many farmers in Turkey recognize the need for land preparation in irrigation but, previous to the introduction of small equipment, the only available method of getting this work done was with large earth-moving machinery imported from America and owned and operated by the Turkish Government. This equipment served very well in demonstrating what could be done on farms where a proper irrigation system was installed, but the difficulty of obtaining enough of this type of equipment and the problems of transportation from one job to the next made its use difficult on the small farm.

From all outward appearances, the demand from farmers for land preparation for irrigation was enough to encourage county agents and village teachers to use locally-made equipment for that purpose. At this time, however, very little of the equipment used in preparing land for irrigation has been accepted.

In the last few weeks I have made a special effort to study the situation in an attempt to find the reasons for non-use of some of the items. It appears that the equipment needed for some of the heavier work is being powered by small farm tractors, but that virtually none is in use where more than two animals are required. Although animal power is used extensively in Turkey, most of it is of a type where only one or two animals are needed. The type of multiple hitches required to use the large fresno, float, and V-drag successfully is new and has not been accepted. The Turkish technician is not trained in the use of animal power, and is not in a position to introduce the idea to the farmers.

New equipment for current farm operations. Hay sweeps and hay-stackers were introduced on the state farms and haras this past season and it is too early to know what the acceptance will be, but after discussing the problems of introduction with Mr. Wenburg, who has carried on this development, I find that he has found it difficult to obtain proper use of animal power.

CHAPTER 2.

FIELD TRIPS

Field trip to Veramin Vally and Mamazon

On May 5, the seminar group visited the experimental farms of the Ministry of Agriculture at Veramin. Important work in plant breeding, particularly with cereals, was discussed. Experiments to determine the best time and amount of irrigation for cotton, and methods of determining soil moisture, including sampling and drying, and the use of tensiometers and plaster of paris blocks, were inspected.

After lunch at the Mamazon Station of the Near East Foundation, the agricultural schools and its attached gardens were visited. Mr. White of the Foundation gave a very interesting account of its program in Iran which includes, besides schools for rural teacher training, for sanitation aides and for girls' vocational training, rural sanitation work, rural credit and cooperatives, and community development and farm demonstrations. A report on one demonstration follows.

Later the group visited rural cooperatives and two of the villages where H.I.M. the Shah has distributed the land to former tenants. Housing, streets and the general appearance of these villages since the residents became owners rather than tenants show marked improvements.

Soil moisture sampling at Varamin irrigation experimental plots.

IRRIGATION - COTTON DEMONSTRATION REPORT

by

Delmer J. Dooley
Agricultural Engineering Specialist

During the 1957 crop year, a project was set up to investigate methods of planting and irrigating cotton. The fourth and last picking of the crop was done in February, 1958, so yields can also be determined.

Each plot contained approximately 7000 sq. ft., or about one-sixth of an acre. Measurements were 17 ft. by 410 ft.; in meters, this would be five meters 20 c. by 125 meters. The cotton was picked and weighed separately from the row crop planting, kusband planting and bedding planting. Water measurements on the above plots revealed that kusband planting used 828,128 liters of water; row-planted cotton used 793,701 liters of water; and bedding-planted cotton used 550,264 liters of water. In percentages, this indicates there is a 5% advantage in water saved by row-crop planting over kusband planting; bedding planting has a 33% advantage in water saved over the kusband method. All plots were irrigated at the same time and were given nine irrigations each.

The yields from the three methods of planting were as follows:

Row-crop planting of cotton yielded 96 kilograms from four pickings.

Kusband planting of cotton yielded 156.5 kilograms from four pickings.

The bedding method of planting yielded 165 kilograms of cotton from four pickings.

The row crop plantings required 120 cm. of irrigation water.

The kusband planting required 127 cm. of irrigation water.

The bedding planted cotton required 83 cm. of irrigation water.

Expressing yields in relation to the amount of water used would indicate these results:

Row-crop planting yields 800 grams of cotton for each centimeter of water applied.

Kusband crop planting yielded 1283 grams of cotton for each centimeter of water applied.

Bedding crop planting yieled 1987 grams of cotton for each centimeter of water applied.

These tests did not measure man hours of labor spent on each type of planting. Observations made during the year would indicate that the greatest number of man hours would need be assigned to kusband planting, fewer to bedding planting, and still fewer to row-crop plantings.

In view of the results over the past two years, it appears most practical at this time to promote the bedding method of planting for crops adapted to that type of planting.

Field Trip to Karaj Dam and Karaj College

On May 7 the morning was spent in a trip to the dam under construction by Morrison-Knudson on the Karaj River. Access roads, a diversion tunnel and some site excavation have been completed. A model of the dam and site was seen and explained at the camp headquarters, after which the group visited the actual site to see the work under way. The dam is a multiple-purpose project to furnish storage for the Tehran city water supply and irrigation and hydro-electric power; probable flood control benefits are incidental.

The members of the party were guests at a luncheon given by Karaj Agricultural College. After lunch the laboratories and a part of the experimental and teaching farm areas were inspected. The extensive building program and the fine quality of the physical plant were admired.

The seminar group at Karaj College.

WELCOME TO KARAJ COLLEGE

by
Ruhollah Farzaneh
Assistant Dean, Karaj College

On behalf of the Karaj Agricultural College I welcome you to this campus and take this opportunity to express our gratitude for the honor of this visit. Before we start the tour of the campus, I would like to give you a few words on the status of the College, its organization, and its curriculum.

Thirty-eight years ago, in 1920, an agricultural school was transferred from Teheran to Karaj. The school was established in this garden and in the palace of Fathali Shah, the Ghajarieh Dynasty. This was the birth of Karaj College, and later, by the orders of the great Reza Shah, the initial steps for a new and improved College were taken. The College was under the jurisdiction of the Ministry of Agriculture until the year 1943 and in that year Karaj College became the Agricultural College of the University of Teheran. The student enrollment in 1945 was 60 and in the current year is 291 in general agricultural courses and 60 specializing in some major fields. This is probably the largest agricultural college in the Middle East and compares in enrollment with many of the American land-grant colleges. According to plans for expansion of the College, it is hoped that student enrollment will reach 500 in the coming year. Through expansion of College facilities and the aid given us through the United States Operations Mission in Iran for improving and developing the College, it is estimated that within five years student enrollment will reach 1000 and within ten years 3500.

The curriculum of the College formerly consisted of a three-year program in general agriculture, but three years ago one more year was added for majoring in any of the 11 established fields. The program has been established on the basis of studies and experience in American and European universities, with specific attention to its compatibility with the agricultural needs of the country.

In the first three years, the College presently offers basic courses and courses in general agriculture, and the fourth year is especially designed for majoring in different fields. The major fields are: agronomy, animal husbandry, irrigation and drainage, farm machinery and agricultural engineering, horticulture, forestry, entomology and pest control, rural economics, agricultural extension, plant improvement and breeding and, finally, agricultural industries.

At present the College does not offer any courses leading to the Master's or Doctor's degree, but provisions are being made for establishing a graduate school in the College. Another success of the College in increasing student enrollment has been the admittance of coeds to the

College, and since last year several girls have enrolled. Entrance to the College is by competitive examination and in the past year, out of the 1650 who participated in the entrance examination, only 100 were accepted.

The present campus area is about 270,000 square meters. In addition to this, 80,000 square meters located outside the campus provide space for the Animal Husbandry Department. The Horticulture Station consists about two hectars, and one hectar is designed for a training farm. The Ministry of Agriculture has contributed 200 hectares of land located about five kilometers away from the campus to be utilized for establishing a demonstration experimental farm.

At present, all the faculty members except those who teach foreign languages are Iranians who have received their education in either European or American universities. In addition to College faculty members, various visiting lecturers from the Ministry of Agriculture and foreign specialists are invited to teach classes which are pertinent to the major fields. The College, in order to expand the number of faculty members and to increase their professional competence, plans to send some of its graduate students abroad in order that they may receive training leading to the Doctor's degree.

All subjects are taught in Farsi; however, foreign languages (English and French) are taught on a level that makes the students competent to utilize various foreign periodicals and books.

The research programs in the various departments of the College have had a recent start. However, with the technical and financial aid given by the United States Operations Mission, these programs are being greatly expanded. I would like to take this opportunity to express our thanks to the United States Operations Mission in Iran for their assistance in our teaching, research and expansion programs. Recently, with the aid of USOM/I, Karaj College has entered into a contract with Utah State University and under the provisions of this contract eight American advisors will cooperate with different departments of the College.

In closing, I would like to thank the delegates of the various countries participating in the Seminar. I hope that the results of the Seminar will aid all the countries involved and, guided by such hope, we take special pleasure in being your hosts today.

Field trip to the Garmsar Land Reclamation Project

On May 11 the group travelled by train to Garmsar and from there visited the drainage and reclamation project just getting under way. The laboratories, field officers and the lands themselves were all visited and the work inspected and discussed. Mr. A. Memarbishi described the project and the investigations under way.

Boring test hole at Garmsar drainage project.

DRAINAGE AND RECLAMATION INVESTIGATION, GARMSAR AREA

by
A. Memarbashi
Soil and Water Department
Ministry of Agriculture, Iran

Geographical Situation

Garmsar is situated at a distance of 114 kilometers southeast of Tehran. There are altogether 101 villages, privately owned or belonging to the public domain, in this region, which extends on the north to Firouz-Kuh, on the east to Semnan, on the south to Kavir (salt desert) and on the west to Veramin. The Iran State Railway connecting Tehran with Bandar-Shah and Tehran with Meshed crosses the northwest and north of this region, respectively.

Water Source

The Garmsar plain is irrigated by Hableh-Rud, which starts west of Firouz-Kuh. This river at the start is named Namrud and when it is joined by Goursefid, it is then called Hableh-rud. Another tributary stream then enters it. Then the river crosses the Bonkuh area and is distributed to the Garmsar area for irrigation purposes. The total water used for irrigation in the different villages amounts to 4,845 cu. m./sec. (323 Sanghe).

The Crops Raised

The region of Garmsar is one of the important agricultural areas of Iran. The main crops are wheat, barley, cotton, castor beans, hemp seed, melon and fruits, such as figs, grapes and pomegranates. Hableh-rud irrigates about 35,000 hectares of land. The land of this region as it approaches the salt desert (Kavir) becomes more saline. The interesting point in cultivating this area is that the land is very susceptible to new agricultural methods.

The Salt Deserts of Garmsar

In the southern part of Garmsar there is a large area of salt desert which includes thousands of square kilometers of saline land and marshy areas. Every year some of the farmers and landowners here try try to cultivate a small patch of their lands, but this work is very limited and they lack technical knowledge and means.

To cultivate the lands of Garmsar without drainage and leaching of the fields is useless, and often the work done produces no results.

It has been decided by the Ministry of Agriculture to conduct research on about 1000 hectares of Garmsar desert land through the Agricultural Engineering Department. This work is under way now in the southern part of Nouraldin village.

The Shape and Boundary of Land

The land is rectangular in shape, 1700 meters long and 6000 meters wide. It is bounded on the north by the cultivated land of Nouraldin, on the south by Kavir, and on the west by the village of Deh-Neguesh. The land slopes downward from north to south with a grade of 3.5:5000 on the average.

The Necessity of Drainage

Since in this area water could easily be provided through ghanats (underground tunnels), and the area is close to an agricultural center, it is advisable and worthwhile to undertake land reclamation. Furthermore, to reclaim this 1,000 hectares of land will furnish a suitable sampling station as a means of guidance and introductory tryout. So this will pave the road for others, as well as starting the reclamation of the area.

As in this area the underground water level is too high, concentration of salts, either dissolved or undissolved, makes the place a salt desert. As a result, drainage work and leaching are a necessity and without these cultivation is impossible.

Work Planned for Drainage Operation

1. Mapping. A topographic map is to be made of the area of 1,100 hectares with a scale of 1:3000, and then from that drawing another map will be made with a scale of 1:5000 for soil surveying.

2. Cross-section of soil on research lines. On the land on which the study is going to be conducted, seven lines of study to a length of six kilometers are indicated. The profiles of the soil to a depth of three meters are to be determined.

3. Measuring the underground water level and its fluctuation. In the grid of research lines, piezometers to a depth of four meters are to be set up, and the depth and fluctuation of underground water will be measured systematically.

4. Soil survey mapping. The map of the soil survey of the area of 1100 hectares, the section under study, with a scale of 1:5000 is being made by Iranian and foreign engineers. For this operation 300 samples are taken from 150

cross-section grids which are under study. Then these samples are tested at the laboratory.

5. Furnishing water. To provide water for the area, a proper study was made and it was determined to dig three ghanats, with the arrangement that the water available will flow from the high spot of the land. As the high spots get under way and become cultivated, then the rest of the area can be irrigated by other ghanats.

6. Sampling of soil, surface and underground. Samples are taken from different soils and waters and are sent to the laboratory for testing.

7. Meteorological station development. A meterorologic station has been developed and equipped for work, and data are being recorded.

Future Work Plan

1. Completion of survey map.

2. Measuring the permeability of the soil.

3. Geological survey of Garmsar for saline and lime formation on nearby mountains, and to find out the water pressure for artesian wells.

4. Precipitation studies on the runoff of rain.

5. Drainage plans and projects indicating the distances and depth of drains; execution of drainage work; land reclamation studies; indicating the kind and quantity of soil to be reclaimed; land levelling and preparation of land for leaching; alfalfa cultivation for the improvement of soil and increasing permeability; starting the cultivation of ordinary crops.

Field trip to Agricultural Engineering Demonstration Farm and Ghezelhasar Drainage Project

On May 13 the group visited the Agricultural Engineering Demonstration Farm operated by the Ministry of Agriculture with advisory aid by the Utah State University Contract Group. This trip was very informative. The farm has two principal units: one operated with tractor-drawn machines and a smaller unit using animal-drawn equipment. Both types were in operation but, in view of the general prevalence of farm units too small for tractor operation in the countries represented by the group, particular interest was displayed in the animal-drawn operations.

Similarly, one of the most interesting demonstrations was the furrow irrigation of one of the larger fields. The locally-trained irrigators were controlling the flow in the furrows by means of small bundles of grass placed in the heading of each furrow. The result was probably nearer perfect control than would have been possible with spiles or syphons.

In the afternoon the Ghezelhesar Drainage Project was inspected. The ghanat under construction was something new to practically all of the visiting delegates and, therefore, particularly interesting. The effect of the ghanat in drawing down the water table ahead of the digging of the gallery was of special interest. Several wells in the line of the ghanat had been dug as far below the water table as was convenient. Then, as the gallery advanced, it was possible to lower each one in sequence until the one immediately at the head of the gallery was dug down to the grade of the tunnel.

The program at the Agricultural Engineering Demonstration Farm is explained to seminar participants.

Horse-drawn ridger and float at the Demonstration Farm.

Furrow irrigation at the Demonstration Farm.

A trip to the Ghezelhessar Drainage Project.

DRAINAGE AND LAND RECLAMATION IN THE GHEZELHESAR AREA

by
M. Ayazi
Agricultural Engineering Department

Location of the Area

Ghezelhesar is a public domain village of 750 hectares situated five kilometers south of the Tehran-Ghazvin road, 15 kilometers beyond Karaj. The Alborz mountains are to the north and the Shoor range to the south. The low-line of the area between the two mountain ranges passes very close to the Ghezelhesar area. The runoff from both mountain ranges and waste water from Kamal Abad, Houssein-Abad, Chahar Dangeh, Malak Abad and Mehdi-Abad villages comes into Ghezelhesar.

Introduction

A large section of the area has had a high water table for a long time. About 25 years ago an open drain called the Siah Jube was dug, but it is not deep enough and has no laterals. About 15 years ago, a tube-well ten centimeters in diameter and about 55 meters deep was dug about one and one-half kilometers from this area. The free-flowing discharge is about one liter per second. The need for drainage in this area is obvious. Recently the Livestock Bongah, interested in setting up a sheep-breeding station, wanted to establish pastures on the area. But the high water table and the concentration of white and black alkali in the root zone prevented execution of the project.

In 1955 the Bongah requested the Agricultural Engineering Department and ICA to assist in developing the area, and drainage investigations were begun October 5. Drainage and land reclamation on a large scale and using modern techniques are rather new in Iran. This area, since it is close to Tehran, is a good place to undertake such a project for demonstration and training purposes. Students who are taking the agricultural engineering training course can work there and have practical experience in applying what they learn.

Work Done by Livestock Department

At times open Siah Jube has an adverse action; when the surface runoff increases and the drain runs full, it affects the water table of the surrounding area. Also, weeds and the sloughing off of the sides reduce the capacity of the ditch. Some other drains have been dug in different parts of the area without lowering the water table. Also, three and a half years ago, three open drains were dug two meters deep with no laterals, but the locations of these were not well-chosen and the side slopes were not properly designed. Maintenance on these ditches will be necessary every year.

New Project Work

Weather Data. Temperature and rainfall data recorded by Karaj Agricultural College, about 15 kilometers away, are presented in Table I.

Topographic Map. A topographic map on a scale of 1/4,000 was prepared by the Plan Organization. Later a map on a scale of 1/3000 was prepared by the students of the agricultural engineering course, for training as well as for more detailed information.

Soil Investigation

Auger holes. Along six investigation lines and with the alignment of three suggested main open drains, 120 auger holes were dug to determine the soil and subsoil texture. In most of the area the soil is heavy with a low infiltration rate. A detailed soil survey and land classification is under way.

Permeability. The permeability of the soil, as measured by disturbed soil samples in the laboratory and by the piezometer method in the field, is moderately low to low (Table II).

Soil analysis. There are non-saline-alkaline and saline-alkaline soils besides the saline soil in the Ghezelhesar area, and reclamation is necessary. See Table III.

Water Quality

Analyses show that the surface water (from ghanats) is first-class, but the soil water is second- and third-class and contains high and very high soluble salts. See Table IV.

Water Source Survey

1. Precipitation. Rainfall from the upland drains into the Ghezelhesar area, because of the low infiltration, stands on the surface for a long period, making surface drainage essential.

2. Excess irrigation water. Faulty irrigation practices cause drainage problems. Surface runoff and percolating water contribute to the rise of the water table.

3. The following steps have been taken to detect upward flow, if any, in the area:

   a. Measurements of the water level in a tube well 33 meters deep and ten centimeters in diameter in the northern part of the Ghezelhesar area show that

there is no underground water pressure. The fluctuation of the water table in the well is similar to that in the piezometers.

b. Some piezometer clusters have been established with two, four, six and eight meter depths, and show that there is no upward flow in the area.

Water Table Observation

Piezometers have been set to a depth of two meters, at intervals of 100 meters, along six lines of investigation. Auger holes have been dug beside each piezometer. The log of the auger holes, water table measurements and the permeability classes of the soils show that the area has a high water table, at least during six months of the year, and the soil can be considered waterlogged.

In 1956 Dr. O. W. Israelsen, Professor at Utah State University and well-known expert in the drainage field, was invited by ICA to come to Iran and has seen the area and given his advice and guidance.

Feasibility of Project From Economic Viewpoint

From past experience and on the basis of investigation, it was obvious that to grow improved pastures and other crops it would be necessary to drain the area and reclaim the soil. The first step was to determine whether the project was economically feasible or not; of course with consideration of public benefits. The value of the land, which is near the Tehran-Ghazvin road, is increasing year by year. The Karaj dam, now under construction, will make more water available for irrigation. For these reasons, it is feasible to reclaim this area. If we were to invest approximately $50.00 per hectare to establish a third-class drainage system, and later about $40-45 per hectare to establish a first-class system, the cost would not exceed the benefits.

Drainage Classes

In planning a drainage system, it is necessary to know for what purpose the land will be used. Third-class drainage which will dispose of surface runoff is usually sufficient for improved pastures. It is seldom necessary to establish underground drainage systems except for growing high-value cash crops. Third-class drainage systems can be established and then gradually improved until they become second- and first-class. Because the Ghezelhesar area is a sheep breeding station, a third-class drainage system will be sufficient for the time being. There will be no difficulty in the future in establishing a first-class drainage system.

Drainage Class 3. The third-class drainage system in the Ghezelhesar area consists of three main drains with laterals and one

outlet (Siah Jube). Drain #1 is 1,700 meters long, #2 is 400 meters long and #3 is 1,900 meters long.

Outlet. The Siah Jube, the major part of which is situated in the low-line, has been chosen as the outlet of the drainage system. Some parts of this outlet need to be straightened, deepened and cleaned of silt and weeds. A section of the outlet has been chosen as follows: bottom width 1.2 m., depth 2.5 m. and side slopes $1\frac{1}{2}$ to 1 m. The slope is 0.0012 and the velocity of flow will be about one meter per second (roughness coefficient, n = 0.04). The outlet will collect the water from three main drains and their laterals, and at the same time act as the outlet of the underground drainage system.

Surface runoff. The surface runoff from about 1,000 hectares will run into Siah June, and its capacity must be large enough to collect this runoff and take it away. Because of the lack of rainfall intensity data, it wasn't possible to compute the volume of water which will run into the outlet, but by comparison with a similar area and using existing data, it is figured that the rainfall intensity will be about 12 millimeters per hour. Therefore, using the rational formula or soil conservation service method, the runoff is computed as eight cubic meters per second, and with its large section Siah Jube will carry this runoff. The following section has been chosen for the three main drains: bottom width 1.2 m., average depth 2.5 m. and side slope $1\frac{1}{2}$ to 1 m. The slope is 0.0012 in some parts and 0.0015 in others, according to the topography. The velocity of the flow will be about one meter per second (the roughness coefficient, n = 0.04). Some drops of about 0.75 m. are needed along the drains. It is presumed that there will be an underground drainage system in the future.

Bottom width. The bottom width has been chosen as 1.2 m. to permit cleaning the drain by mechanical equipment in the future.

Side slopes. According to the type of soil, the side slope of the drain has been chosen as $1\frac{1}{2}$ to 1.m.

Water development. There is a ghanat system in the Ghezelhesar area which delivers 45 liters per second of water, but this is not enough for irrigation. Water may be developed by digging a deep well and using a motor pump or by establishing a ghanat system. Because a part of the Kamalabad area, which is adjacent and above the Ghezelhesar area, needs to be drained, it is much better

to establish a ghanat system in the Kamalabad area. This will serve to drain the upland and to irrigate the lowland. According to the prepared plan, a ghanat system three kilometers long is now under execution.

Project Accomplishments

The execution of the project was started last fall by hand labor and mechanical equipment (bulldozer and Brisco ditcher). The excavation of the main drains was accomplished with mechanical equipment to a one-half meter depth, and the lower part was done by hand labor. One kilometer of ghanat has been dug, and about 17 liters per second of water have been gained. Of course, this will increase when the ghanat system is finished. Work on drain #1 has not as yet been started.

TABLE I

Data On Rainfall and Temperature
Station of Karaj Agriculture College

Month	1330 Temperature Min.	1330 Temperature Max.	1330 Rainfall rain	1330 Rainfall snow	1331 Temperature Min.	1331 Temperature Max.	1331 Rainfall rain	1331 Rainfall snow	1332 Temperature Min.	1332 Temperature Max.	1332 Rainfall rain	1332 Rainfall snow	Remarks
Farvardin	0.4	25.8	23.1		0.4	28.	31.30		-5.6	24.5	24.52	5	
Ordibehesht	5.4	30.3	15.1		-0.8	30	118.25		3	27.6	45.5		
Khordad	10	33			8.8	33			6.3	33	1.0		
Tir	10	37.4			11.5	37.17	6.75		12.5	36.5	36.5		
Mordad	13.9	37.9	6.25		12.2	34.2	+		12.2	35.5	2.3		
Shahrivar	10.2	34.6			10	32.9	2.50		8.8	34.6			
Mehr	3.2	30.5	34.75		7	30.9			7	29.6	19		
Aban	0.9	20.5			-7.3	23.4		21.1	-2	22.4	64.25		
Azar	-3.1	15.6	5.5	6.6	-4.4	16.5	8.87	7.15	-8.5	13		37.81	
Dey	-8.6	9.5		12.0	-5.5	13.9	22.5	18.25	-9.8	113.7	14.75	19.0	
Bahman	-5.4	15.9	20.2	3.66	-5.5	15.2	7.75		6.5	13	24.40	10.35	
Esfand	-6	20	39.74		-6	16.5	13.95		10.1	18	43.57	13.68	
Total			150.35	22.26			211.87	55.5			269.29	85.84	
Grand total			172.61				267.37				355.13		

Month	1333 Temperature Min.	1333 Temperature Max.	1333 Rainfall rain	1333 Rainfall snow	1334 Temperature Min.	1334 Temperature Max.	1334 Rainfall rain	1334 Rainfall snow	1335 Temperature Min.	1335 Temperature Max.	1335 Rainfall rain	1335 Rainfall snow	Remarks
Farvardin	-3	23	78.5		-2.7	26.5	47		-7.5	18.4	76.5		
Ordibehesht	3.5	27	8.25		2.2	28.5	28.5		1.5	29.4	2.5		
Khordad	10	32	3.75		5.4	32.5	9		6.4	30.5			
Tir	10.6	35.9	15.5		9	37.6			13	35.6	6.25		
Mordad	12	35.5	5.75		12	37.9			13.5	36			
Shahrivar	10	33			11.2	33	+		10	34			
Mehr	4.5	28.5			5	30.6	22.1		37	27.5			
Aban	1	25	1.25		1.5	24.5			-2.8	22.5			
Azar	-3.4	13.5	4.5	49.25	-7.5	18.5	19.35	20	-9	19.5	1.5	5.75	This quantity of pre-
Dey	-4.5	14.5	19.5		-9.5	11.5	3.65	29.5	-9	7.5		16.25	cipitation up to the
Bahman	-3.7	18	2.25	13.5	-5.5	15.6	24.35						morning of the date
Esfand	-5.5	21	35.75		-6	18.6	70.82						Dey 16, 1335
Total			175.0	62.75			263.77	49.5					
Grand total			237.75				213.27						

TABLE II

Soil Analysis, Ghezelhesar Reclamation Project

Lab. No.	Collector No.	pH of saturated extract	Saturation percentage	Ecx10³	Soluble Cation and Anion						Exchangeable					
					Na m.e/l	Ca+Mg m.e/l	Total Cation	CO_3 m.e/l	HCO_3 m.e/l	Cl m.e/l	CEC m.e/100 gr.	ESP	ES m.e 100 gr.	Gypsum m.e/100 gr.	Alkalin earth carbonate M.e/100 gr.	S.A.R.
3409	I	8.4	79.3	3.05	24.8	6.5	31.3	1.0	16.0	5.0	33.3	28.9	9.63	3.78	30.75	13.76
3410	II	8.0	60.0	12.6	109.3	36.0	145.3	-	3.0	19.0	23.0	22.1	5.10	0.04	18.60	25.76
3411	III	8.5	54.7	25.6	439.6	6.0	445.6	1.5	24.5	86.5	26.7	91.9	24.55	2.96	25.90	253.78
3412	IV	9.2	76.7	3.05	61.6	-	61.6	1.5	8.0	7.0	18.5	89.2	16.50	-	27.85	-
3413	V	8.7	76.9	4.8	43.5	5.5	49.0	-	6.0	8.5	19.1	28.4	5.44	0.96	28.57	26.23
3414	VI	8.4	50.7	302.4		77.5		2.5	6.0	159.0	18.54	-	-	31.87	25.12	-
3415	VII	8.0	58.2	138.6	1'42.4	29.9	1472.3	-	4.0	83.0	19.95	84.7	16.90	30.40	17.37	29.5
3416	VIII	8.7	89.4	15.1	29.4	8.0	137.4	1.0	5.0	20.0	24.30	62.2	15.13	-	20.75	64.20
3417	IX	8.1	60.1	15.1	179.5	69	248.5	-	2.0	52.0	15.87	38.3	6.08	0.96	46.35	30.5
3418	X	8.5	91.3	25.2	408.3	21.0	429.3	-	3.5	92.0	25.90	68.3	17.70	-	37.45	126.0

TABLE III

Water Quality, Ghezelhesar Reclamation Project

In milli-equivalents per liter

Coll. No.	Sources	T.S.S. p.p.m.	$EC \times 10^6$	pH	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	Sum Cation	S. A. R.	Residual Na_2CO_3	Class
I	Grd. Water at hole C5	1244	2000	-	x	9.10	2.75	7.96	0.85	5.15	15.40	21.40	8.6	3.10me/l	C3S2
II	Siah Joui water	1908	2685	-	x	12.102	0.75	15.76	2.15	10.55	19.10	31.80	7.6	-	C4S2
III	G.W. at the end of drain outlet No. 2	46714	45291	-	x	20.75	134.85	532.7	65	90	613.4	688.30	120.	-	Over C4S4
IV	G. water at hole C9	18654	19680	-	x	14.90	46.25	205.0	7.10	64.0	195.0	266.10	32.7	-	C4S4
V	Ganat water No. 1	860	1392	-	0.90	3.60	1.15	2.38	3.65	3.10	1.28	8.03	0.70	-	C3S1
VI	Ganat Water No. 2	570	845	-	1.05	4.05	0.80	2.41	2.60	3.70	2.01	8.31	1.13	-	C3S1
VII	G. water at hole A 4	578	867	-	x	12.45	3.30	5.74	1.05	2.15	19.10	22.30	15.50	9.25"	C3S3
VIII	Well water 33 m. deep	1302	2006	-	x	16.70	4.25	9.42	0.80	1.40	22.20	24.49	21.10	14.5 "	C3S4

CHAPTER 3.

DISCUSSION GROUPS

REPORT OF DISCUSSION GROUP I

Operation and Maintenance of Projects

The diverse and broad general background of the group participating in the discussion indicated the desirability of devoting the work of the group to two general areas that related to organizational requirements and responsibilities and that related to operational needs. While many specific problems were discussed and points of value to the interested countries were presented, it was thought appropriate to limit the report of the group to recommendations of general application and acceptance.

A general statement regarding the character of the organization which should operate and maintain irrigation projects is quite difficult, due to the different types of governmental organizations, customs, and people in the area. However, it appears that the most desirable objective is operation and maintenance of project works by an organization selected or formed by water users and/or landowners for the specific purpose of operating and maintaining the project, with powers to assess charges or work requirements for the necessary services. On new projects, it is recommended that the construction agency build and operate all laterals to the individual farm. Operation and maintenance by this agency should continue for a short period to permit the formation and training of a proper, responsible water-users' organization. Following transfer of responsibility, the organization should continue to receive help, technical assistance, and inspection from the constructing agency on matters of operation and maintenance. Where a financial obligation exists, the constructing agency should continue to exert control over maintenance until the obligation is removed. The farm ditches on individual properties should be maintained and operated by the respective operators of the land. A single agency operating with the constructing agency should be responsible for the proper dissemination of information and advice, including demonstration programs, designed to establish good irrigation practices and the efficient carrying out of recommended farm operations.

For planning, designing, constructing, operating and maintaining new irrigation projects, it is recommended that all of the phases stated above be the responsibility of a single agency - utilizing and promoting, however, the specialized services of other agencies

developed for the benefit of the farmer in general -- and that these phases not be divided between two or more separate and distinct government agencies operating independently. This appears to be necessary so that all facets of these projects may be coordinated and developed to a maximum degree of efficiency. This may include the construction of roads, communications, and buildings as well as recreation and conservation features.

In view of the fact that the proper and beneficial use of water is the ultimate aim of an irrigation project, it is recommended that in the original concept of a project and in the planning and preliminary design stages of project development, maximum consideration be given to proper agriculture practices, advice, and experience by including in the planning groups the agriculturists, agronomists, soil scientists, economists, etc., required. Further, it is essential that the services of agricultural personnel be utilized to the maximum in the operation and maintenance phase.

The successful culmination of an irrigation project in our various democratic countries makes it mandatory that the policies, methods and procedures adopted to plan, construct, and operate such projects be shaped to the desires, requirements, and pleasures of the most important person on the project the landowner or renter-irrigator. This means that we cannot force the individual farmer to make the project a success by government fiat. He must be part of the project, assisting in all its elements and wholeheartedly in favor of its scope and concept; and he must be willing to work hard, take financial risks, and gamble with his future to make his project a success. To encourage this participation, certain elements of assurance are desirable. Some of these elements may be listed as: (1) assurance of a dependable supply of required water, (2) assurance of delivery of water when and in amounts the farmer desires, (3) assurance that the farmer will have a market for his product, (4) assurance that the farmer will receive sufficient profit for his efforts, (5) assurance that proper agricultural advice and assistance will be available, (6) assurance that equipment, seeds, fertilizer, credit, etc., will be available, (7) assurance that programs for education and information on a project basis, designed to take full advantage of the increased economic status of the project farmers, will be present.

Regarding the matter of repayment of capital costs of the project, the concensus of the group was that, whenever possible:

(1) Some portion of capital, operation and maintenance costs should be borne by the landowners and water-users to stimulate interest and participation in the project; and

(2) a binding agreement should be arranged with project beneficiaries, prior to construction, setting forth the operational and financial responsibilities of the parties involved and the remedies available in the event of failure to perform these responsibilities.

In the area of physical operation and maintenance, the following recommendations were made by the group relating to specific problems presented in connection with construction, operation and maintenance staff and methods:

(1) Small structures, including checks, drops, turnouts, etc. should be of a permanent type providing for water control by the operating agency, using locally-available materials to the greatest possible extent.

(2) Canals and laterals should be lined where water losses may be high or where it is impossible to retain essentially the designed section. Unlined sections should have adequate side slope.

(3) All physical facilities required for successful and beneficial project operation and maintenance should be provided as a part of the construction phase, eliminating, to the greatest possible degree, reliance on operation and maintenance activities and funds for major capital investments. Particular emphasis should be placed on provision of drainage works and provision of turnouts based on relationship of farm units to topography.

(4) As long as financial obligations exist, the financing agency should, either itself or through its agents, exert control of the maintenance of project works. An essential element of such control is inspection at regular intervals (probably not exceeding one year) and provision of facilities and labor to carry out recommendations resulting from inspection.

(5) While size of maintenance staff will vary with the size and intricacy of a project, specific and separate responsibility for equipment maintenance and for project construction and maintenance operations should be provided. The water-user should be responsible for farm maintenance. Further crews for emergency repairs, maintenance of canal bank roads, weed cleaning, silt removal, and canal erosion repairs should exist.

(6) The maintenance equipment normally required includes tractor-dozers, weed drags, small drag lines, graders, chemical spray equipment, hand tools and specialized equipment dictated by maintenance needs. However, use of hand labor should be

carefully considered, particularly in under-developed areas, if time of completion is not a critical element.

(7) Ditchriders or water tenders should be provided in sufficient numbers to maintain water control to the farm headgate.

Group Participants:

A. Azarnia, Iran	Saifuldin Wahbi, Iraq
E. Chaya, Lebanon	Moini Zandi, Iran
A. E. C. de S. Gunasekra, Ceylon	O. H. Folsom, United States
Andy Meimaris, Greece	L. J. Snyder, United States
N. Uner, Turkey	T. R. Thompson, United States

Robert Johnson, Observer, Near East Foundation, United States

REPORT OF DISCUSSION GROUP II

Drainage Investigations

The subjects of drainage and the experience with it of various countries were discussed. Many serious problems of waterlogging and soil deterioration have been created by constructing irrigation projects without making suitable provision for general and farm drainage. These problems have further been aggravated by the absence of flood control measures in many countries.

It has been observed that addition of water to subsoil may take place from:

1. Seepage from irrigation system,
2. floods, rainfall runoff, collections from submerged borrow pits, etc.,
3. excessive application of irrigation water, and
4. artesian pressure under certain conditions.

It is therefore recommended that:

1. Drainage investigations should be conducted concurrently with land classification as a part of project planning and, where conditions indicate that waterlogging may occur, main drains should be excavated at the time canals and distributaries are constructed. Before undertaking any development project, it is essential to investigate drainage requirements and the causes leading to such problems. Drainage should form an essential part of any irrigation and land development project.

2. Drainage facilities may be provided through the following, depending upon local and economic considerations:

   1. Open drains for surface waters
   2. Open drains for subsurface waters
   3. Subsurface-tile drains
   4. Drainage through wells

3. All road and railroad projects should invariably be required to include in their development programs drainage works, and to avoid impediments to surface or subsurface drainage.

4. In order to reduce addition of water to the subsoil, proper irrigation practices should be adopted.

5. The subject of drainage being very important, and the majority of countries being in the process of undertaking new projects, experience should be interchanged which would be of mutual help.

6. It is strongly recommended that soil scientists and agronomists, along with farmers, should collaborate with drainage engineers for planning and execution of drainage and reclamation projects.

Group Participants:

A. G. Asghar, Pakistan

Abid Awn, Iraq

M. Ayazi, Iran

Geo. Koumbarakis, Greece

H. de S. Manamperi, Ceylon

B. R. Shori, India

Tom Clark, United States

Donald Dobson, United States

Stanley Phillipi, United States

REPORT OF DISCUSSION GROUP III

Field and Farm Demonstrations for Applying Improved Irrigation Practices

In view of the importance of introducing improved irrigation practices to cultivators' fields, it is essential to set up farm and field demonstrations. There are at least eight steps in getting a new, improved practice into common use by cultivators. The basis must be first the research station. Second comes the experimental farm, where the research is tested on a somewhat larger scale. At first it is difficult to obtain the permission of private cultivators to use their land for demonstrating a new practice. Therefore the third step is often the government demonstration farm.

As the new practice is demonstrated to be practical, field demonstrations can be held on the farms of certain progressive cultivators. This is the fourth step. Fifth is the use of entire private farms for demonstrating the improved practice, but a considerable degree of subsidy is usually required, possibly enough to cover at first the entire cost of installation of the new practice. The demonstration steps lead into the sixth step, which is an operations program available to all interested cultivators within the area. At first, a considerable degree of subsidy is required in the form of technical assistance, equipment use, and possibly also materials. As this phase of the operations program proceeds successfully, it is followed by the seventh step, wherein all subsidies except technical assistance are withdrawn. The eighth and final step is reached when the majority of remaining cultivators become ready, willing, and able to apply and maintain the new practice without any form of assistance. Because new practices are continually being discovered and developed, there is continual need for all of these steps. Only the third, fourth and fifth steps, comprising government demonstration farms, field demonstrations, and private demonstration farms, are covered in this report.

The main objective of demonstration fields and farms is to teach cultivators the most practical and efficient ways to apply irrigation water on farms in the vicinity and to induce them to adopt the improved practices. A second objective is to provide training to extension workers, both in land preparation and water

application, as well as in how to utilize demonstrations in disseminating this information to cultivators. To be most effective , the demonstration should extend through at least one complete cropping cycle. It is recognized, however, that shorter and more local demonstrations of land preparation and water application practices are also required, in order to reach as large a number of cultivators as possible. A demonstration farm should be located in an area which is representative of the characteristics of the region and is easily accessible to the cultivators of the area.

The program and procedure of a field demonstration will follow the general lines set out below:

1. The securing of physical data relating to the program, such as the soil map, topographical maps, etc.

2. Planning the lay-out.

3. The laying-out of the irrigation distribution system.

4. Land preparation.

5. The setting up of water-control structures.

Other important factors to be taken into account are:

(a) Pre-demonstration arrangements, including publicity, invitations to prominent leaders to participate, etc.,
(b) Facilities for the invitees, such as a P.A. system, tea, etc.,
(c) The issue of illustrated material and the showing of films, etc.

A field demonstration should be followed up by visits to cultivators' fields and by publicity on the methods demonstrated, using leaflets, films, etc.

A program of field demonstrations and demonstration farms should be accompanied by the maintenance of data pertaining to:

(a) The proportion of cultivators adopting the measures advocated.
(b) The increase of yield and saving of labor and water.

The achievements of the program of demonstrations must be periodically evaluated.

Recommendations

The following recommendations are made by the group to the Governments of the participating countries:

1. That each Government acknowledge the importance of demonstrations to the introduction of improved irrigation practices.

2. That there be establishment of an extension type of organization to provide technical assistance to implement such a program.

3. That every effort be made to train extension workers and village leaders in the improved practices and the methods of demonstrating them.

4. That there be a wide distribution of the results of research by audio-visual methods.

5. That the program of demonstration be gradually extended to include operations programs where government help, technical and otherwise, could be progressively withdrawn.

It cannot be stressed too strongly that demonstration farms must be backed by a comprehensive program of field demonstrations, publicity and follow-up. These, and the periodic evaluation of results, will prevent the aims and objects of the demonstration farm being subordinated. (These farms should not be allowed to deteriorate into production farms.)

Group Participants:

Adem Karaelmas, Turkey	T. F. Ramsay, United States
Paris Oikonomides, Greece	John Steele, United States
H. L. Uppal, India	Victor Surface, United States
V. E. A. Wikramanayake, Ceylon	Harold Weiland, United States
F. D. Bertelson, Pakistan	Marshall Young, United States

REPORT OF DISCUSSION GROUP IV

Research Needs in Irrigation

The chairman, Dr. T.J. Mirchandani, initiated the discussion by reading the report on irrigation research submitted to members of the last session of this Seminar held in 1956. It was felt that more specific recommendations should be made at this session.

After considerable discussion, the following recommendations are put forward for consideration by members of this Seminar:

1. (a) That additional work be done on determining the consumptive use of water for various crops under different soil conditions. That values obtained by use of the atomometer method (Halkias) be compared with the Lowry Johnson and Blaney Criddle methods. (Consumptive use as herein used is defined by the U.S. Salinity Laboratory).

   (b) That studies be carried on further to determine farm water requirements under the same local conditions.

2. That the whole subject of water use in rice cultivation be evaluated, to determine the minimum needs of the crop. Is ponding actually necessary?

3. That water requirements for leaching be determined in relation to different types of soils and (a) salts usually contributing to salinity and alkalinity and (b) toxic concentrations of special elements, if any, such as baron, which has been found to limit yields in Iraq.

4. That investigations be undertaken on formulating simple inexpensive techniques for determining (a) infiltration rates and (b) permeability.

5. That research studies be made on fertilizer-irrigation interactions.

6. That the proper sequence of tillage operations be determined for irrigated lands that would result in minimum compacting and crust formation.

7. That investigations on the comparative advantages of different irrigation methods for particular crops in specific areas should be initiated.

8. That research studies should be made on the physico-chemical properties of irrigated soils to determine changes which might result from either irrigation or leaching.

9. That research be undertaken to determine ways and means to minimize seepage losses from all farm water courses, utilizing locally-available material.

10. That local experimental work be initiated to ascertain the proper spacing of open drains in areas of varying soil characteristics.

11. It is recommended that the research projects endorsed by this Seminar be conveyed to the various Governments represented, as projects needing immediate and serious consideration. At the same time, it is also urged that adequate funds and research facilities be provided by the respective Governments for setting up effective organizations in their countries for dealing with the research needs of irrigation, if such organizations do not already exist.

Group Participants:

Muzaffer Alap, Turkey

R. Farzanieh, Iran

Nurhan Gurel, Turkey

N. Halkias, Greece

S. Macksoud, Lebanon

T. J. Mirchandani, India

S. T. Senewiratne, Ceylon

A. N. Renshaw, United States

J. S. Reger, United States

CHAPTER 4.

COUNTRY REPORTS

Country Report: GREECE

I. Introduction

1. Greece is a fundamentally agricultural country in which agricultural production contributes approximately 35% of the total national income and 80% and more of the total value of exports.

The cultivated area is 3,515,000 ha. distributed among one million agricultural entreprises; i.e., the average holding amounts to 3.5 ha. The consequence of the small size of the holdings is that there is an intense underemployment of the rural population and this, in conjunction with other factors, constitutes one of the most serious reasons for the low income of the Greek farmer.

2. Serious efforts have been and are continually being made on the part of the Ministry of Agriculture to increase agricultural production and improve the standard of living of the Greek farmer. Irrigation constitutes an essential factor. This becomes more obvious if we take into consideration the climatic conditions of Greece, which, as regards temperature and light, are favourable for the development of crops, while they are rather unfavourable as regards humidity owing to the insufficient volume of rainfall and, chiefly, to the fact that is distribution during the year is not uniform.

3. According to observations during a number of years, it is estimated that by irrigation the volume of production is in general tripled.

For the above reasons, the extension of irrigation is considered of the greatest importance and the state services, both by planning and carrying out large irrigation works and by giving assistance to the execution of smaller ones (individual or collective), try to increase the irrigated area.

II. Existing Irrigation in the Country

1. Presently irrigated area

The area presently irrigated is estimated at 364,000 ha. or 10.3% of the total cultivated land of the country, and of this, 236,000 ha. (64.8%) are irrigated by gravity and 128,000 ha. (35.2%) by pumping. The above data refer to spring and summer irrigations and not to winter irrigation, which is also practiced in Greece on 10,000 ha. approximately.

The most important irrigation works are thoseexecuted or still under construction by the state services. The greatest proportion of these works have been carried out during the post-war period and, in particular, from 1949 onwards; they are usually of a medium (more than 1000 ha. and up to 10,000 ha.) or large (more than 10,000 ha.) order and they are either connected with projects of general public importance concerning the development of extensive areas, or they are exclusively irrigation works, usually serving a more or less considerable area.

Comparison of the presently irrigated area with that irrigated prewar, as shown in the following table, indicates that great progress has been accomplished in the extension of irrigation:

Year	Irrigated area
1939	177.000 ha.
1950	242,000 ha.
1958	364,000 ha.

From the above table it may be seen that, since 1950, an additional area of 122,000 ha. has been irrigated.

The major part of the irrigated lands is in the plains and the proportion of irrigated, hilly and mountainous lands does not presently exceed 10% of the total irrigated area.

The irrigation period in Greece covers in general the months from May to October. In addition to the spring and summer irrigations (to which the above date refer), it must also be mentioned that, in certain areas of the country and for certain cultivations (especially olive trees and vineyards), river waters are used during the winter season for the flooding of the fields and, thereby, for the storage of water in the deeper layers of the soil, together with the enrichment of the soil with the silt contained in these waters.

As regards the source of supply of irrigation water:

34.3% of the lands are irrigated from rivers
36.0% of the lands are irrigated from natural resources
18.4% " " " " " " common wells
8.5% " " " " " " artesian or deep wells
2.8% " " " " " " lakes or artificial ponds

Of the total irrigated area of the country, 83% is occupied by annual cultivations and vegetables and 17% by tree plantations and vineyards.

In detail, irrigated cultivations in Greece are the following (year, 1958):

Cultivation	Percentage of total irrigated area
Cotton	20%
Corn	9%
Corn in inter-cropping with beans	7%
Beans	3%
Potatoes	7%
Various vegetables	10%
Tomatoes	3%
Melons and water-melons	2%
Rice	4%
Legumes	1%
Various annual crops (flax, tobacco, etc.)	9%
Alfalfa and clover	7%
Meadows	1%
Citrus trees	5%
Olive trees	4%
Various fruit trees	7%
Vineyards	1%

2. Irrigation projects under construction

Presently, there are in Greece four large irrigation projects under construction by the state services, through which it is estimated that a new area of 175,850 ha. will be irrigated, and 15 medium irrigation projects, which will bring under irrigation a new area of 30,210 ha. It is expected that through the same projects an improvement of irrigation on 42,660 ha., approximately, at present non-satisfactorily irrigated, will also be effected.

In addition to the above-mentioned large and medium-sized irrigation projects, there are also under construction a large number of small ones, which concern mainly the construction of lined small canals and of intercepting structures in water-springs, the digging or drilling of wells, etc. Almost all of these projects, through which a new area of 5,000-6,000 ha. will be irrigated, will be completed within this year.

3. Proposed irrigation projects

In view of the major importance of irrigation, the Greek Government inaugurated some years ago an extensive study of land reclamation possibilities in all the country.

According to this study, future prospects on irrigation are that, finally, 32% of the cultivated land of the country, i.e., 1,100,000 ha.,

will be irrigated within a period of 20 years. Taking into consideration that 364,000 ha. are already irrigated, there remains an area of 740,000 ha. to be irrigated in the future. The projects under construction, under planning or under reconnaissance by the state services cover an area of 890,000 ha., out of which 540,000 ha. are new land to be irrigated and 110,000 ha. are land already irrigated which will be improved.

Beside the above-mentioned figures, it is estimated that an additional area of 200,000 ha. will be irrigated in the next 20 years through smaller independent works and installations (common and deep wells, mostly).

It is estimated that within the next five-year period an area of 136,000 ha. will be irrigated through large and medium projects carried out by the state services, and another 50,000 ha. through the smaller independent works.

4. Private and collective irrigations

(a) The independent (individual) irrigation works comprise the total area irrigated through common wells (67,000 ha.) and the largest proportion of that irrigated through artesian or deep wells (20,000 ha.) and, furthermore, lands irrigated from surface or source waters through more or less simple installations and works. The proportion of independent irrigation installations of the total irrigated area of Greece can be estimated as 36%, approximately.

(b) The case of small irrigation works carried out by small groups of farmers for the irrigation of their fields is not so frequent in Greece. On the contrary, quite frequent is the case of collective works for irrigation, as, for instance those laid out by communities or farmers' organizations.

(c) Community irrigation installations comprise deep wells and, also, irrigation works for the utilization of river or source waters. Community deep wells usually serve both for water supply and irrigation, and it is estimated that a total area of 10,000 ha., approximately, is irrigated through them. The whole program of deep-well drilling is in the hands of the Ministry of Agriculture, which carries out the drilling operations on behalf of the communities or individual farmers. A subsidy of 50% is given by the State and the rest is payable through a loan from the Agricultural Bank.

Community irrigation projects, through which surface or source waters are utilized for the irrigation of a more or less large number of fields in the community area, are very often studied and supervised by the state services, and many times they have even been constructed

with the mechanical equipment of the Mechanical Cultivation Service of the Ministry of Agriculture. The necessary expenditure is covered either from community funds, or from contributions of the beneficiaries, or from loans given by the Agricultural Bank, or from public investment funds given in the form of a loan, repayable within five years at an interest rate of 2% (program of small works of public benefit). In many cases, the State shares in the cost of these works, by way of a subsidy, at a proportion of 30-40%, average, of the total cost of the work.

(d) Another type of collective irrigation works is that carried out by the irrigation districts. The "irrigation districts" are self-administrated organizations which have as an objective the maintenance, operation and construction of land reclamation works. They are laid out on cooperative principles and are established through the decision of a majority of the people who will benefit from certain land reclamation works within a given area, but with obligatory participation by members of the minority. These organizations are supervised and controlled by the Ministry of Agriculture.

The irrigation districts have been carrying out supplementary operations and works within existing irrigation projects under their jurisdiction, with a view to their full development; but, in addition to these, they have also carried out irrigation works of local importance, usually through loans from the Agricultural Bank or through other funds, and with a contribution of personal labor on the part of the beneficiaries. The total irrigation works under the jurisdiction of the irrigation districts cover an area of 28,000 ha., approximately, of which an area of 13,000 ha. is irrigated through works executed by the initiative of these organizations.

(e) As far as the use of ground water for irrigation is concerned, great progress has been made during the last decade.

After the Second World War, according to a program of development of natural water resources, irrigation by ground water developed rapidly, and with improvement of pumping equipment made in Greece, water for irrigation is being pumped economically from various depths all over the country.

To accomplish this program, the Agricultural Bank of Greece gives mid-term loans (five-year loans) to farmers to construct their wells and buy the necessary pumping equipment.

The Agricultural Bank of Greece is a public utility organization under the supervision of the Ministry of Agriculture and, among its other tasks, gives loans to farmers or to communities and cooperatives to carry out small irrigation and drainage projects. This Bank, in the years 1956 and 1957, gave loans for irrigation amounting to $6,000,000, in which loans for well construction and pumping equipment supplies are included.

Most of the wells in Greece are dug wells of a depth varying from seven to 12 meters; the depth of the ground water varies from four to eight meters. There is also a considerable number of driven wells, as well as of drilled wells for agricultural use of water supplies, but most of the ground water is pumped from shallow wells to a total lift of up to 15 meters. Drilled wells are always constructed after geological investigation and under the supervision of the Ministry of Agriculture. Most of the wells drilled have an average depth of 100 meters and the depth of the static water level varies from 15 to 30 meters.

For irrigation from wells, the pumping plants needed are not usually bigger than five to ten HP. Therefore the Agricultural Bank of Greece, with the approval of the Ministry of Agriculture, adopted a program for supplying farmers with such small Diesel pumping plants.

In recent years all pumping equipment, i.e., Diesel engines, pumps, pipes, etc., are made by Greek factories under the supervision of technicians employed in the Ministry of Agriculture and in the Agricultural Bank. However, since electric power is now available in many parts of the country, electric motors have started replacing Diesel engines in many cases.

This special program of the Agricultural Bank, referred to above, has been applied since 1948 and the results obtained by the end of 1957 are as follows:

(aa) 16,000 pumping plants of a total horsepower of 107,000 HP were installed in an almost equal number of agricultural holdings.

(bb) 32,000 hectares of arable land were irrigated, most in newly-irrigated areas.

(cc) $6,500,000 were given by the Agricultural Bank of Greece as mid-term loans to farmers for well constructions as well as for procurement and installation of pumping equipment. The farmers participated in the expense either through their personal labor or through cash investment, estimated at $2,500,000.

(dd) The economy of a considerable number of agricultural developments has been stabilized and unemployed people have been used efficiently.

(ee) The farmers have become more familiar with pumping equipment and they do not confront any difficulty now in operating their pumping plants.

III. Problems of Irrigation Practices

1. The use of irrigation in agriculture presents a great number of problems, specially in Greece, where the application of irrigation on a large scale is rather recent and the construction of the most important irrigation works started only in the period after the Second World War.

2. The most serious technical problems presently faced are related to the technical works of the irrigation projects, the lining of the irrigation canals and the closely connected irrigation drainage problems.

3. Another difficulty of a technical nature in the application of irrigation is the leveling of the irrigated fields. Leveling is a difficult operation requiring technical knowledge and experience and, in addition, a costly one, which cannot be undertaken by the farmers themselves, especially during the first periods of their installation of newly irrigated lands when they have to face increased cultivation and other expenses. Taking into account these facts, the Ministry of Agriculture considers it necessary that in the large irrigation projects under construction the leveling expenditure should be covered by public investment funds and, in addition, that a subsidy on the total cost of the operation should be granted for the leveling of fields within existing irrigation projects. In this context, the Mechanical Cultivation Service has given in the past considerable assistance, as it has carried out leveling operations on irrigated lands on behalf of the farmers.

4. Another difficulty in the practice of irrigation is that the standard of technical knowledge of the agricultural population as regards irrigation, in certain departments of the country, is rather low. This situation is continuously ameliorated through the constant education, control and technical guidance of the farmers by the services of the Ministry of Agriculture. Lack of adequate experience and technical knowledge is also the cause for the cases of unsatisfactory handling of the questions related to the operation, maintenance and administration of irrigation projects by the organizations of the beneficiary-farmers. At any rate, these organizations are under the control of the Ministry of Agriculture and better efficiency and a general improvement in their way of operation are gradually being observed.

5. The size and shape of farm property in Greece constitute another difficulty in the application of irrigation. Farm properties of an average size of about 3.5 ha. are divided into small pieces which are scattered among three, four or more different places within the irrigable area. The shape of these small pieces of land is mostly

irregular. For these reasons it is even more difficult to plan and locate distribution systems along property lines, and it is therefore necessary to substitute for all these pieces of land, that usually belong to different classes, with a larger farm of a regular shape and of equivalent land value.

IV. Irrigation Organization

1. Up to the present, the various reclamation works were not carried out by one single service but by different ministries and even different services within the same ministry.

This participation of many services in the planning and execution of the works had, as a result, the lack of a unified and long-term program, a confusion of competencies and frequently a non-rational solution of the different problems.

2. In order to remedy these inevitable disadvantages and to establish firm and unified bases for the handling of reclamation works, the "land reclamation law" was voted in October 1958, which provides for the following:

(a) The consolidation of all services of the Ministry of Agriculture dealing with land reclamation works into one Land Reclamation Service. This new Service will comprise a central and a district office. The Central Service will deal with subjects related to organization, planning, technical guidance, financial assistance, inspection and control and, in general, with staff work. The District Service will carry out the main work.

(b) The competencies of the Ministry of Public Works and the Ministry of Agriculture have been definitely determined and separated. Thus, from now on, the Ministry of Agricultur will be responsible for reconnaissance, the drawing up of preliminary reports, general planning and agricultural development, as well as the operation, maintenance, administration and, in general, the management of all the projects except the flood control works.

As for construction, the Ministry of Agriculture will construct only independent irrigation and drainage projects for areas smaller than 2,000 ha., and all the tertiary irrigation canals and drainage ditches.

The Ministry of Public Works will be responsible for master plans and final plans and for the construction of projects covering an area larger than 2,000 ha. In addition, it will be responsible for the construction and maintenance of dams on large rivers and torrents, as well as for the related diversions and main delivery canals.

(c) The Agricultural Bank will deal only with the financing through loans of land reclamation projects; the Ministry of Interior will carry out, through the municipalities and communities and at their own expense, reclamation projects of small or medium order on condition that the relative plan is approved by the Land Reclamation Service.

(d) Provision is made for an extensive research program on irrigation and drainage problems at different irrigation projects all over the country.

(e) Self-governed organizations will be formed by the farmers benefited by these works in the different areas where land reclamation works have been completed or are now under construction or to be constructed. These organizations will operate under the supervision of the Ministry of Agriculture and will deal with the administration, operation and maintenance of the works.

(f) In the law "on land reclamation works," definite rules and principles have been set up as regards the financing of such works by the State and the contribution and obligations of the beneficiaries. Thus, the expenditure for construction of land reclamation works is, on principle, charged to the beneficiaries, but the State can share in this expenditure in various proportions, depending on the importance of the works and the ability to repay of the interested farmers. On these bases the financing of irrigation works will be handled as follows:

(aa) Major works concerning the irrigation of extensive areas, such as dams, main canals and main technical works, can be subsidized up to 70% of their cost, or even up to 100%.

(bb) Irrigation and drainage works of a medium order an of local importance can be subsidized up to 50% of their cost, including the cost of the relative road network.

(cc) Smaller works, concerning independent properties or small groups of these, such as deep-well drilling or leveling, can be subsidized up to 40% of their cost.

The expenditure, in addition to the above subsidies, will be covered either by the beneficiaries, through their own funds, or by loan, or by State funds which will be granted in the form of a loan against repayment. The repayment of these funds will be effected, in the case of large projects, through the payment of regular contributions by the farmers, and in the case of medium or small projects, through the contracting of loans by the Agricultural Bank. The repayment of these loans will be made without payment of interest and within a maximum period of 20 years, starting after the elapse of a "period of development," which is determined to be a maximum of six

years in the case of irrigation works, starting after the works can be put into operation and lasting, within the above limits, until the realization of regular returns.

The new Reclamation Service, through the uniform control and handling of the works and the enacting of basic principles, will accomplish better development of the works under construction and, in general, a better use of the soil and water resources of Greece.

V. Accomplishments on Farm Irrigation

1. Training demonstrations

(a) The Agricultural Extension Service of the Ministry of Agriculture has included in its program the technical guidance of farmers as regards the application of irrigation.

This Service has 377 agriculturists, graduates of Athens and Salonica Universities, and 75 graduates of agricultural mid-colleges. In addition to these, there are 20 specialists who work at the different inspectorates and ten more specialists who work at headquarters in Athens.

Since 1958, this Service has established 25 demonstration fields of two to five ha. each, in five different areas of Greece, i.e., five demonstration fields in each area, which are concerned with surface and sprinkler irrigation. A great number of farmers have already visited them and it is hoped that a considerable number will apply the demonstrated improved methods of irrigation.

(b) In the northern part of Greece, where irrigation is applied to a greater extent, the local Service of Productive Works of Macedonia (YPEM) executes different irrigation projects, takes care of improvement of the nets and the leveling and, at the same time, gives instructions to farmers as regards the application of improved methods of irrigation.

(c) The Mechanical Cultivation Service, which is a state service and belongs to the Ministry of Agriculture, with its mechanical equipment, which amounts to 650 tractors and 110 excavators, executes land reclamation works in all the country.

This service has two directorates, ten branches and 13 sectors all over Greece.

As far as irrigation is concerned, this Service carries out earthmoving work, including land leveling for irrigation, on medium and small irrigation projects on behalf of farmers, cooperatives or communities, and on medium or large irrigation projects included in the state pro-

grams; furthermore, it carries out maintenance operations on projects of all kinds.

The plans for medium and small projects are prepared by the district or central services of the Ministry of Agriculture as well as by other Ministries and, in some cases, by the Mechanical Cultivation Service itself, while plans for large projects are carried out by the competent services of the Ministry of Agriculture or by those of the Ministry of Public Works.

Therefore, the above service contributes considerably in the extension of irrigation and in its proper application. It is provided that, in future, the efficiency of the Mechanical Cultivation Service as regards land leveling operations will be greatly increased.

(d) Besides the bulletins which the Ministry of Agriculture and the Bank of Agriculture publish for familiarization with irrigation practices, training courses are organized annually which are attended regularly by the agronomists engaged in irrigation practices. These courses include lectures given by specialists as well as practical training in the field.

In the past, these courses included hydrology, surveying, soil conservation, land leveling, irrigation application, sprinkler irrigation, drainage, machinery suitable for leveling, etc. These courses will continue in the future and an effort will be made to have as many participants as possible, and special attention will be given to their better training, especially in the field.

2. Land preparation work

Up to now the arrangements applied on irrigated lands have consisted of the leveling of the land with a slight gradient in one direction. Lately we have applied, in an experimental way, the double-aisle arrangement (amenagement a double aile), which according to programs under consideration, will be applied extensively in areas with heavy soils and with a high volume of rainfall.

In the irrigation projects recently constructed, as well as in the ones under construction, drainage has always been taken into consideration; drainage networks are presently constructed or are to be constructed in the areas of older projects.

3. Irrigation methods

(a) Surface irrigation

Furrow irrigation for cotton and, in general, row crops has been practised in Greece for many years. Flooding in checks has also been used for irrigating alfalfa, corn, legumes, orchards and rice.

During the last two years an effort has been made to use the border method of irrigation for alfalfa, but to a small extent.

In some new irrigation projects which are under construction, it is planned to apply level irrigation.

In general, the program of the Ministry of Agriculture is turned toward the application of all the modern methods of surface irrigation, according to the conditions prevailing in Greece.

It is estimated that during the past years surface irrigation has covered a total area of 337,000 ha.

(b) Sub-irrigation

Sub-irrigation practices have been developed in some areas, mainly as a trial, and have covered an area of 7,000 ha. all over Greece.

This method of irrigation has been applied only on very perme able soils (peat soils or burned peat soils).

According to a program of the Ministry of Agriculture, it is planned that this type of soils should be irrigated by sprinkling.

(c) Sprinkler irrigation

The system of sprinkler irrigation is not yet widely applied in Greece; there is, however, a serious tendency for its expansion, which is encouraged on the part of the Ministry of Agriculture in view of the advantages of the system under Greek conditions, especially as regards the economic utilization of irrigation water and the possibility of irrigating areas of irregular topography. It is estimated that, during the past year, sprinkler irrigation has covered a total area of 20,000 ha.

The main cultivation which is irrigated by sprinkling in Greece is cotton, but, in addition, sprinkling is also applied to all the cultivations which are in general irrigated in the country, (potatoes, maize, vegetables, tree plantations, etc).

As regards the conditions under which sprinkler irrigation is applied, it is observed that the system has chiefly been applied in the fertile plain areas, where the high yields of the cultivations can meet the considerable cost which the system entails. As regards soils, sprinkler irrigation has been mainly applied on very permeable soils and on permeable ones.

The sprinkler irrigation plants used by Greek farmers are mostly of small capacity, i.e., the average water discharge of each plant is estimated as 50 m3/h.

All sprinkler irrigation plants now in use are portable and the pipes are made from galvanized steel with spherical couplings, for the most part.

Frost protection by sprinkling is not applied in Greece. Yet the competent service of the Ministry of Agriculture believes that the application of this method, in certain areas, for frost protection of citrus tree plantations will have beneficient results and, for this reason, intends to apply the method on an experimental scale.

In order to obtain better results in the application of sprinkler irrigation, the Ministry of Agriculture in collaboration with the Agricultural Bank decided that, beginning next year, every farmer who wants to buy sprinkler irrigation equipment through Agricultural Bank loans should submit a special report which will have to be approved by irrigation specialists.

4. Land classification and soil survey for irrigation projects

Land classification is not only useful but necessary for establishing irrigation projects.

The total area surveyed in Greece for the purpose of estimating the extent of the suitability of the land for irrigation is about 600,000 ha.

Land classification showed that about 5% of this area is unfit for irrigation. Irrigable lands in the surveyed area comprise about 80%, while 15% are lands that require special agronomic, economic or engineering studies in order to decide whether they could be changed into proper irrigable lands or must remain non-arable waste lands.

VI. Irrigation Research

1. Up to the present, there has been no extensive research on irrigation and drainage questions, However, many observations on proper length of run, size of furrow stream and depth of applied water have been made some experiments carried out by the Productive Works of Macedonia (YPEM) showed a high correlation between the average monthly water use by cotton as measured by soil moisture sampling and as calculated by the method of "atmometers." The departure of the calculated value from the measured one for the most critical month (July) in 1957 was found equal to approximately 3%. In general, the atmometers method (Halkias) gave five times less departure from the measured values than the Blaney - Griddle method.

2. Now the new Land Reclamation Service of the Ministry of Agriculture provides a Central Experiment Station on irrigation and drainage problems, with three to five local experiment stations at different locations in the country. According to the program of the new Service, all possible means are provided for systematic and complete research on irrigation and drainage problems under the conditions prevailing in this country.

INDIA

I. Existing Irrigation in the Country

The total area irrigated at the commencement of the first Five Year Plan, i.e., before April 1951 was 51.5 million acres, of which 17.9 million acres were irrigated by private canals, 8.8 million acres by tanks, 14.7 million acres by wells and 7.3 million acres by other sources. Due to major, medium and minor irrigation schemes taken up in the First Five Year Plan, an additional area of about five million acres from major and medium schemes and ten million acres from minor schemes was to be brought under irrigation by March, 1956, thus raising the total irrigated area in India from 51.5 million acres to 66.5 million acres up to March, 1956.

A. Areas Under Government Irrigation Projects

During the period under review, i.e., September 1956 to May 1958, 18 major and medium irrigation projects which were taken up during first Five Year Plan have been completed and the remaining are in progress.

Up to the end of March 1956, an irrigation potential of 4.42 million acres was created by schemes in the major and medium irrigation projects taken up in the first Plan, which was increased to 5.31 million acres up to March 1957, thus giving an annual increase in irrigation potential of 0.89 million acres. Data for the increase in irrigation potential during the year 1957-58 have not been collected so far, but it is expected that an irrigation potential of about one million acres may have been created during this year, thus giving a total increase of 1.89 million acres as the irrigation potential during the period under review.

Detailed project reports for most of the schemes from which irrigation potential has been created during the period under consideration are not yet available, hence it is not possible to say exactly the land which cannot be irrigated. Generally, out of the total commanded area within the command of the canal system, 60-80% is irrigated. The balance is left out due to roads, buildings, wells, villages, etc. There has not been any instance in the major irrigation projects where the commanded area has been left out of irrigation due to other reasons, such as saline soil, etc., as so far the irrigation projects have been taken up in areas where the land is suitable for irrigation.

To give an idea for the whole of India, out of a gross commanded area of 811 million acres, 467 million acres are culturable area, leaving out forests, uncommanded area as and fallows, etc. It has been roughly estimated that about 75 million acres may eventually be irrigated by multi-purpose large and medium irrigation projects. An equal area could be irrigated under other categories of irrigation sources, thus making a total of about 150 million acres under irrigation from all sources, against a culturable area of 467 million acres.

The land utilization statistics for the country, as reported for 1956-57, are given below:

CLASSIFICATION OF AREA, 1956-57
(Provisional)

1	Area (in thousand acres) 2	Percentage of total reporting area 3
Area under forests	125,485	17.4
Area not available for cultivation	117,855	16.4
Other uncultivated land excluding fallow land	96,965	13.5
Fallow land	58,670	8.1
Net area sown	320,763	44.6
Total reporting area	719,738	100.0
Area for which no returns exist	86,532 (10.7)	----
Total area	806,270	----

Note: Figure in bracket indicates percentage of total area.

India can be divided into four zones with respect to the crop patterns adopted in irrigation projects. These are:

1. Northern Zone: i.e., Punjab, Uttar Pradesh, Rajasthan and Madhya Pradesh.

   In this zone during the Rabi period, which is in winter, the main crops grown are wheat and oilseeds, and during Kharif, which is in summer, cotton, rice, pulses, sugarcane and maize are grown. The total intensity of irrigation in this zone is about 75%.

2. Eastern Zone: i.e., Bihar, Orissa, Assam and West Bengal.

In this zone, the intensity of Rabi is 25% as compared to 80-100% for Kharif. The main Rabi crops are wheat, pulses, etc., and during Kharif mainly rice, jute and sugarcane are grown.

3. Western Zone: i.e., Bombay.

The intensity of irrigation is about 70-80% and the main crops grown are rice, cotton, wheat and sugarcane.

4. Southern Zone: i.e., Andhra, Madras, Mysore and Kerala.

In this zone, the intensity of irrigation is about 60-70% and the main crops grown are rice, sugarcane and garden crops, which are known as wet crops, and cotton, jowar, pulses, oilseeds, maize and ragi, which are known as dry crops.

B & C. Irrigation Projects Under Construction and Proposed, and the Land to be Irrigated by Them

Nearly 300 schemes were taken up in the first Five Year Plan in the major and medium irrigation sector to irrigate ultimately an area of nearly 22 million acres. Of these, 109 schemes have been completed to the end of March 1958 to irrigate ultimately nearly four million acres. The remaining schemes are in progress and are expected to be completed within a period of another seven years.

In the second Plan, 200 schemes have been included to irrigate, on full development, 16 million acres. Of these, 52 schemes are under construction, with an irrigation potential of 4.9 million acres. The remaining schemes will be taken up during the course of the second Plan.

In addition to the above, minor irrigation works with a potential of ten million acres were taken up under the First Plan. In the second Plan, minor irrigation works with a potential of nine million acres are expected to be completed.

II. Problems of Irrigation Practices

A. As per present practice, water courses are generally to be constructed by cultivators and, due to this, sometimes there is some time-lag between the availability of supplies and their actual use. In order to accelerate the use of irrigation waters,

steps have now been taken to have the construction of water courses carried out by project authorities at the cost of the cultivators, which may be recovered in easy instalments in the form of land revenue. The extra expenditure of interest on the capital cost will be more than compensate for by the earlier development of irrigation.

B. Cultivators quite often are unable to level the land, as it is not within their means to undergo this expenditure; therefore, it is essential that some aid in the form of long-term loans be advanced to the cultivators for this purpose.

C. According to old practices in some areas, water was being wasted by cultivators in irrigating their fields by their making large compartments and flowing the water from field to field. This loss was much more in areas where rice is the main crop and irrigation is done from field to field.

To utilize economically the water from the newly-constructed storage reservoirs, water courses and field channels are now being properly aligned and constructed. Cultivators are also being educated to adopt proper field practices for the economical use of this water.

D. The main problem which arises due to irrigation in areas where irrigation has been going on for a number of years is water-logging. At present, this is in acute form in certain parts of the Punjab and Uttar Pradesh. Various methods have been employed for keeping subsoil water much below the root zone of the plants. Broadly, these are:

1. Provision of surface drains
2. Seepage drains along canals
3. Transfer of areas to tube-well irrigation from canals
4. Lining of canals; and
5. Running the canals in rotation.

E. Irrigation in arid and semi-arid regions results in the rise of injurious salts to the surface, which make the land go out of cultivation and the output becomes very low. Adoption of controlled irrigation and drainage is being recommended in these areas.

III. Irrigation Organizations in the Country

In India, irrigation is a state subject. The organization in the state is headed by a chief engineer. In some states, there are additional chief engineers, depending upon the extent of irrigation or development in the state. Execution and maintenance of irrigation projects are carried out by irrigation departments. Assessment and realization of revenue from irrigation is generally done by the Revenue Department in South India, while in North India assessment is done by the Irrigation Department and realization of revenue by the Revenue Department. The Agriculture Department is consulted by the irrigation departments with respect to the intensity of irrigation, duty, crop pattern, etc., for adoption in new projects.

At the Centre, there is a specialized technial body, coordinating matters concerning irrigation and power in the states, known as the Central Water and Power Commission, which is composed of a water wing and a power wing. This organization is under the Ministry of Irrigation and Power. Problems connected with the irrigation matters of the various states are scrutinized and coordinated by the water wing.

IV. Accomplishment in Farm Irrigation

A. Training

There is an extensive program of training for agricultural workers at different levels. Training is of a composite type, covering all aspects of agriculture including irrigation practices. This is imparted to field workers at the village level in agricultural schools, to agricultural supervisors at the training centres at the state level, and to more senior people such as block development officers at the regional training centres located in different parts of the country. This is part of the rural development program of the Community Project and National Extension Service. By 1962, it is expected that the whole country will be covered by National Extension Service blocks. The districts which are included in the National Extension blocks have each an agricultural school for training purposes and most of the states have training centres for senior members. Facilities are given to farmers to obtain training or to take refresher courses at the farm attached to the school. A beginning has also been made in some states in organizing soil-cum-water conservation and irrigation workshops to demonstrate and train workers, including farmers, in problems such as the preparation of farm land for irrigation, methods of irrigation, when to irrigate, etc.

B. Demonstration

There are about 400 demonstration farms in India where the results of research are being demonstrated. Cultivators have easy access to results at these farms and farmers' days are organized when the work is fully explained to visitors. These farmers' days are a usual feature at the demonstration farms, and the farmers from the neighbourhood come in large numbers. The value of these demonstrations is being increasingly realized and more and more farmers are adopting improved techniques.

C. Land Preparation

The lands being put under irrigation are generally very flat plains, and hardly any levelling is required. Hence, no large-scale levelling operations are undertaken.

In hilly and semi-hilly regions, terracing is done; levelling is being done only where rice is grown. Lack of financing is one of the biggest hurdles in carrying out the levelling of land as it is carried out by the peasants themselves and does not generally form part of a project.

For irrigation purposes, the land to be irrigated is divided into plots, known as "chaks" in the Northern regions. Generally, a chak is an area which can be irrigated from an outlet. The size of a chak will depend upon:

1. The discharge which can be handled efficiently by the cultivator

2. The nature and slope of the country, and

3. Village boundaries and village holdings.

It has been found that the discharge which can be handled efficiently is about two cusecs; hence, for irrigation purposes it is so taken that it is not less than one cusec nor more than three cusecs. The chak is treated as a miniature irrigation scheme. The local watershed is used for the main water course and the boundaries form local drainage. The branch drains are made to follow the minor ridges.

In areas where marked ridges and depressions are not present, the layout is based generally on the requirements of village boundaries. Before an area is divided into chaks, an accurate map having close contours is first prepared; these are generally to a scale four inches equals one mile, with one-foot contour intervals on these plans the layout of chaks is marked.

On established areas generally the chak boundaries are irregular, due to village and individual holdings. In a new project the areas, somewhat larger than those occupied by drainage channels, are reserved with a view to improvment later on.

In the southern regions distributaries are generally provided for field blocks of below 200 acres. Detail levelling for these areas is taken up. Field channels are taken up to 25-acre sub-blocks. No sluices in these field channels commanding less than 150 acres are generally provided, as irrigation is mostly by open cuts. Generally, the Government Irrigation Department constructs the distributaries up to 150-acre blocks and below this the work is carried out by the cultivators who own the fields. However, the alignment of the field channels and land acquisition for these channels down to the 25-acre limit are done by the Government department.

Irrigation methods. The most widely-used methods of irrigation are the border method and the check basin method, the latter being a modification of the former.

In the south and on the hill slopes the field-to-field system of irrigation is in use.

For raising vegetables and some other cash crops, furrow or corrugation irrigation methods are also used.

D. Classification of Lands

Schemes for soil survey and land classification have been in progress in different states over a period of years, and the Central Government has also been assisting in these projects. Special surveys have also been undertaken from time to time, such as for saline and alkaline soils. In order to coordinate with the soil survey work and to extend the work, the Government of India has sanctioned an all-India scheme of soil and land use surveys to cover the entire country. Priority in this survey is being given to the catchment area of river valley projects, and it is expected that 15 lakhs acres will be done every year in the three projects which have been taken up. The scheme is linked up with a soil survey of four major groups of soils in India--these being alluvial, black cotton, laterite and red soils.

The Central Water and Power Commission has also carried on an up-to-date soil survey on the projects investigated by them, to the tune of 22 million acres. Besides this, the states have also carried out extensive soil surveys on the projects investigated by them.

At present water control equipment is confined to some research stations and some large agricultural holdings, such as those attached to sugar factories. The individual cultivator whose holding is very small has his water delivered to him on the rotation system. The control of the water is at the water course head by means of modulus, semi-modulus, etc.

V. Irrigation Research

There are irrigation and power research institutions in the country which carry out research on hydraulics and irrigation problems. These are:

1. Central Water and Power Research Station, Poona
2. Hirakud Research Station
3. Irrigation Research Station, Poondi, Madras
4. Irrigation and Power Research Institute, Punjab, Amritsar
5. Irrigation Development Division, Poona
6. Mysore Engineering Research Station, Krishnarajasagar
7. River Research Institute, West Bengal
8. Uttar Pradesh Irrigation Research, Roorkee
9. Hyderabad Engineering Research Laboratories, Hyderabad
10. Bihar Institute of Hydraulic and Allied Research, Patna
11. Civil and Hydraulic Engineering Laboratories, Indian Institute of Science, Bangalore

These institutions do research on hydraulic structures, embankments, flood control devices and various allied works. Research as regards the application of water to land is being conducted by the agriculture research institute and agricultural colleges. These are scattered all over the country and each state has at least one research station, several sub-stations, and one agricultural college (some have more than two) where research on irrigation and crop relationships is carried out. Besides, the Indian Council of Agricultural Research of the Ministry of Food and Agriculture has subsidized several schemes with relation to irrigation farming and has also established model agronomic centres at 34 places in different soil-climatic zones in the country. These centres, especially those in the river valley projects, have in their programs a fuller study of all problems relating to the application of irrigation water to land, such as the water requirements of crops, the time and interval of watering, the effect of irrigation on the physico-chemical properites of soil, the interaction of manuring with irrigation, etc. The activities of the various agricultural research centres are coordinated by the Indian Council of Agricultural Research.

In some of the National Extension Service and Community Development Project areas, farmers have readily accepted the results of research which have been communicated to them and have asked for

more; in others the farmers are gradually being educated to adopt the recommended practices and their response is encouraging. During the Second Five Year Plan, it is proposed to give close attention to problems which link research with development, and also to continue work on fundamental problems. These are tasks to be carried out by cooperation among the central and state governments and the Indian Council of Agricultural Research and other agricultural colleges and institutions in the states.

IRAQ

The following brief report has been prepared to give a general description of existing irrigation developments in Iraq, the problems associated therewith, accomplishments during the period September 1956 to May 1958 on farm irrigation practices, research along these lines and plans for future development.

Irrigation Development

Existing developments

In general, existing irrigation developments in Iraq are confined to the broad valleys of the Tigris and Euphrates Rivers, extending from the Arabian Gulf on the south to the vicinity of Baghdad, where the two valleys diverge. Above Baghdad, the major developments are located in the valleys of the principal tributaries. It has been estimated that the total area of irrigable land in Iraq (within the valleys of the Tigris and Euphrates Rivers) amounts to approximately 22,000,000 meshares, of which approximately 11,650,000 mesharas were irrigated during 1957. An additional 1,350,000 mesharas of cropped lands were held fallow that year, indicating an additional 9,000,000 mesharas suitable for development. Distribution of the irrigated areas by Liwas is shown in the following table (Agricultural Census 1952-53, Ministry of Economics, Government of Iraq):

Liwa	No. of Farm Holdings	Area Irrigated (1,000 Mesharas) Fallow System	Water Supply
Baghdad	1,555	1,339	Tigris and Euphrates
Mosul	4,026	61	Tigris
Basra	448	401	Tigris
Diwaniyah	2,029	1,845	Euphrates
Muntafiq	1,773	1,409	Tigris and Euphrates
Amarah	3,325	1,537	Tigris
Kirkuk	3,425	543	Tigris
Kerbala	261	223	Euphrates
Diyala	2,100	1,096	Diyala (Tigris)
Hilla	1,363	1,099	Euphrates
Arbil	1,998	63	Tigris
Sulaimaniya	1,047	153	Tigris
Kut	1,665	1,438	Tigris
Dulaim	496	433	Euphrates
Total	25,511	11,640	

The total irrigated area was estimated by Mr. F. Haigh in 1948, in his report on control of the rivers of Iraq, at 13 million mesharas. Since then at least one million additional mesharas have come under lift and gravity irrigation.

These areas have been developed by both governmental and private enterprise. Major structures have been constructed primarily through the efforts of the Government. Minor structures, to a large extent, have been constructed by individual farmers.

Moving downstream from Ramadi, the first major canal diverting from the left bank of the Euphrates is the Saklawiyah Canal, irrigating some 167,000 mesharas of land. Next is the Abu Ghraib Canal west of Baghdad, which irrigates about 280,000 mesharas. Next comes the Youssifiyah Canal, irrigating some 270,000 mesharas. Latifiyah irrigates 98,000 mesharas. The old Mussayib Canal supplies 60,000 mesharas with water. The Nasiriyah Canal irrigates a small area of 27,000 mesharas and, immediately below it, the first diversion from the right bank is the Hussainiyah Canal irrigating some 141,000 mesharas in the vicinity of Kerbala. The Hindiyah Barrage elevates the water for the Beni Hassan Canal, a right-bank diversion irrigating some 162,000 mesharas. On the left bank, the Kifl Canal and the Hilla Canal with their Babil, Horriyah, Dagharah and Diwaniyah branches, irrigate some 2,632,000 mesharas. Below the Hindiyah Barrage, downstream from Kifl, the Shamiyah Canal makes a left-bank diversion, irrigating 373,000 mesharas of rice land. The Bahr-El-Najaf irrigates 80,000 mesharas, the Meshkhab 93,000 and, from Shinafiyah to Samawah to Nassiriyah, approximately 437,000 mesharas are irrigated, chiefly by river pumps. This totals 4,912,000 mesharas of gross area in existing projects, of which about one-half is irrigated annually.

The Tigris River in Iraq obtains its water from a number of tributaries, namely, the Greater Zab, the Lesser Zab, the Adhaim and the Diyala. On the Tigris and its tributaries, together with the Shatt-al-Arab, in 1957 there were 3,219 pumps with a total rated 129,517 horsepower. Most of these were located in the Baghdad, Kut and Amarah Liwas. The area irrigated by these pumps totals about 3,391,000 mesharas. Of the gross area served by the Tigris and its tributaries, 8,127,000 mesharas, 3,767,000 mesharas are irrigated below Kut, where there are three distinct divisions -- the Gharraf Canal serving 2,350,000 mesharas; the Dujaila Canal serving 513,000 mesharas, and the Amarah Canals serving 710,000 mesharas. The Amarah Canal system includes the Buteira, the Tabar, the Mujar, the Musharrah, the Chahalah and the Mujarriyah Canals.

Upstream from the Wadi Tharthar Barrage, there is the Fatha-Samarrah and the Upstream Fatha, each irrigating 75,000 mesharas. A total of 690,000 mesharas are served by pumps along the river terraces from Samarrah to Baghdad. The river terraces from Baghdad to Kut, totaling some 1,940,000 mesharas, are irrigated chiefly by pumps. A weir on the Diyala River near the crossing of Jebel Hamrin divides the waters into the right-bank Khalis Canal and, on the left bank, to the Ruz,

Harouniyah, Shahraban, Mahrut and Khorqssan Canals. The area served on the right bank totals 560,000 mesharas and on the left bank a gross area of 980,000 mesharas is irrigated.

Within Iraq, there are no major streams feeding into the Euphrates River; likewise there are no irrigation developments except by direct diversion by pumps or canals from this stream. From Hit to Nassiriyah, nearly all of the river terraces immediately adjoining the Euphrates are irrigated with pumps. A survey in 1957 revealed 2,045 pumps with a total horsepower of 69,762. Many more homemade water lifts, using draft animals, are in existence, each of which may provide a two- to four-meter lift to irrigate four or five mesharas. Some 425,000 mesharas in the Euphrates system above Hindiyah are probably irrigated in this manner.

Crops

Accurate data on crop production and the total areas devoted to individual crops are apparently not available. From the data which are available, however, it appears that more than 70%, or roughly eight million mesharas of the total cropped area, is devoted to the raising of grain as a winter crop and 20% is used for summer crops, including mostly foodstuffs. Approximately 400,000 mesharas are used for rice production, of which 165,000 mesharas are in the Amarah Liwa. Some 20,000 mesharas of rice are grown in the Sulaimaniya Liwa. Four hundred thousand mesharas are used in the production of dates. The Date Association of Iraq reports there are about 22,900,000 date palms. Other major crops include cotton, corn, millet, sesame, vegetables, green gram, vetch, flax and deciduous fruits and nuts.

It is estimated that in the future, with full project development, the cropping pattern will change and that there will be a very large increase in the production of alfalfa and an increase in corn, dates and beans, while a decrease will probably occur in rice production.

Projects under construction

At the present time, there are ten projects under construction. Not all of these projects, however, are being constructed for the development of new irrigated areas. Some are being built for the alleviation of drainage conditions on presently-irrigated areas, others are being built to provide a supplemental water supply for presently-irrigated lands, and a few are being constructed to provide an irrigation water supply for new areas. A brief description of all projects under construction is given below:

Dujaila Drainage Project. When completed, this project will provide adequate drainage for all lands presently irrigated by the Dujaila Canal, located approximately 200 kilometers south-

east of Baghdad. Approximately 600,000 mesharas are in the project area, of which 150,000 are located on the east side of the canal and 450,000 on the west side. The main outfall drain and several branch drains have been completed for the eastern area, and construction on drains for the western area will be under way in the near future.

Derbendi Khan Project. The Derbendi Khan Dam will be a rockfill structure with an impervious compacted earth core. The dam site is located on the Diyala River approximately 250 kilometers northeast of Baghdad. It is being constructed for flood control and irrigation purposes, and is also designed for the ultimate production of hydro-electric power. The dam will be 135 meters in height and will have a base width of approximately 500 meters and a crest length of 450 meters. Maximum capacity of the reservoir will be approximately three milliards. The prime contract was awarded in November 1955 and the expected date of completion is June 1960. Total cost of the dam is presently estimated at ID. 17,650,000. The diversion tunnel, awarded as a separate contract, cost ID. 457,000. This contract was completed in November 1957.

Dokan Dam Project. This will be a concrete arch structure located on the Lesser Zab River about 55 kilometers northwest of Sulaimaniyah. It will have a maximum height of 115 meters and a crest length of 360 meters. Reservoir capacity will be 6.1 milliards. The project is designed for irrigation, flood control and hydro-electric power purposes. Capacity of the power plant will be 200,000 kw. This project is expected to be completed in June 1959 at a total cost of ID. 12,900,000.

Sungasar Project. The Sungasar Project is designed to provide an irrigation water supply on new lands to be settled by approximately 1,000 Kurdish families whose present lands and homes are located in the Dokan reservoir area. The project is located adjacent to the north boundary of the Dokan reservoir area, along the right bank of the Lesser Zab River. The gross area will contain about 42,000 mesharas, of which 20,000 will be irrigated. Irrigation water will be supplied by direct diversion from the Garafin and Zharawa Rivers. Construction began in August 1956. Total estimated cost of the project is ID. 930,000.

Habbaniyah Project. The Habbaniyah Project consists chiefly of flood control works designed to divert excess flood flows from the Euphrates River into desert depressions at Hor Abu Dibbis and Lake Habbaniyah. The principal works consist of the Ramadi Barrage, designed to divert excess flood flows from the Euphrates into Lake Habbaniyah; the Majarrah Discharge Canal and Regulator, designed to carry water southward from

Lake Habbaniyah to the Abu Dibbis Depression; and the Habbaniyah Outlet Regulator, which controls the flow of water from the lake back into the Euphrates. Although these works have been completed, it is possible that additional storage on the Euphrates River, above Ramadi, may be necessary to afford a greater degree of flood protection. Plans are also being made to enlarge the Mujarrah Canal and regulator to provide for greater discharges into the Abu Dibbis.

Habbaniyah Drainage Project. This project is designed to provide adequate drainage for an area of about 9,000 mesharas, located east of Lake Habbaniyah. Seepage water from the Lake has seriously affected the area, which extends from Ramadi on the right bank of the Euphrates downstream for a distance of about 15 kilometers. Principal works will include a small pumping plant, the out-fall channels, 24 kilometers of main branch drains and related structures. Total cost of the project is to be ID. 60,000.

Saklawiyah Project. This project involves the construction of main and branch drains to serve an area of 200,000 mesharas, located immediately northwest of Baghdad. These lands are served by the Saklawiyah and Abu Ghraib Canals. Total estimated cost of the project, including that of the pumping station which will discharge drainage water into the Tigris, is ID. 609,000.

Mussayib Project. The Mussayib Project is located in the Euphrates Valley, approximately 80 kilometers southeast of Baghdad. It is designed to provide irrigation and drainage facilities for 232,000 mesharas of new land and also to provide drainage facilities and rehabilitation to irrigation facilities on 110,000 mesharas of presently-irrigated land. The principal irrigation works consist of a diversion regulator, 19 head regulators, 179 kilometers of main canal and branches, and two irrigation pumping stations. A complete drainage system, including main, branch and collector drains, is being provided. Disposal of drainage water will be by pumping.

Faisaliyah Regulator (Shatt-Al-Mishkab Project). This project, designed primarily for river control and irrigation purposes, is located on the Euphrates River approximately 200 kilometers south of Baghdad. The principal structure is a cross regulator equipped with seven 12-meter gates, an eight-meter navigation lock and a fishway. The contract also includes three head regulators for diversion canals. Construction on this project started in 1957 and is expected to be completed by 1960. Total estimated cost is ID. 1,200,000.

Hilla Project - Twairij Drainage. The Twairij Drainage System will serve an area of about 32,000 mesharas, located west of Hilla. In addition to providing drainage for this particular area, it will also serve as a pilot project for all lands located between the Hilla and Kifl Canals. In addition to the main drain, there will be a system of branch drains having a maximum spacing of 1,000 meters. The drainage waters will be pumped into a high-level channel and discharged into the Euphrates River.

Proposed and potential projects

At the present time Iraq is undertaking a program of complete resource development. In addition to the projects now under construction, there are many which are either in the design stage or under consideration for potential development. Similar to those now under construction, these projects will serve varied purposes. A total of eleven projects are now in the design stage and 29 are in the planning stage. All work in connection with these projects is being carried out by Iraqi engineers, with technical assistance being provided by professional engineers of foreign nationalities.

Three of the 11 projects now in the design stage will provide irrigation water to approximately 1,400,000 mesharas of new lands. The remaining projects in this category will provide drainage, water control and supplemental water supply benefits to presently-irrigated lands.

Irrigation Problems

Drainage and salinity

Sixty to 80% of all irrigated and potentially irrigable lands in Iraq are saline to a lessor or greater degree, with the prospect, because of an arid climate, of becoming more saline as time and irrigation go on. Although the quality of water used for irrigation from both the Tigris and Euphrates Rivers is considered to be very good, it must be realized that these waters do carry from 200 to 400 parts per million of dissolved salt, which over the centuries has been left behind. The largest portion of the dissolved salt is calcium carbonate, which readily precipitates out of solution in a soil with a relatively high pH. Other salts carried in the irrigation waters are the chlorides and sulphates of calcium, magnesium and sodium. Seldom does the sodium percentage run above 20 in the river waters.

In the areas north of Baghdad, drainage is not at the present time considered a serious problem. The problem begins in and about Baghdad and becomes progressively more severe to the south. Here, the water

table is closer to the surface, and correlated with this is the excess salt problem. The fallow system of farming, whereby a piece of land "rests" every other year, is followed rather extensively in the large Mesopotamian Plain. The farmers do not fertilize their lands, except small vegetable areas, with either commercial fertilizer or farm manure. The planting of legumes or cover crops to be plowed under is not practiced. The land, therefore, has to "rest" a year in order that the slow chemical breakdown of insoluble plant food into available plant food becomes great enough to produce another crop. Another advantage of the fallow system is that time permits a drop in the water table, and perhaps more important is that the total yearly supply of water for any given area is not more than one-half what it would be under intensive farming. This results in a water table low enough to prevent the drowning out of crops from a saturated soil, and alleviates to some extent the salt problem. A small but insignificant amount of drainage and leaching takes place in this fashion.

In providing drainage, of which quite a bit of work is now under way, large outfall systems will have to be constructed, and in places where gravity discharge back into stream channels is not possible, pumping plants will have to be installed to lift the drain waters into the rivers. This will effect the quality of the water for use further downstream. Through wise planning and operation much of this water can be pumped out and re-used when the river is at its low concentration of dissolved solids. Considerable gypsum and lime are expected to be present in drainage waters, which will be much more desirable for re-use than if the soluble salts were of a sodium or alkaline nature. This problem likewise needs careful study as time goes on. Similarly, the type and spacing of farm drains needed with the peculiar soils of Iraq have not been well-established -- correlation of laboratory data with field operation of drainage systems is as yet in the preliminary stages.

Silt

Silt is another problem affecting the construction, operation, and maintenance of irrigation works. During 1953 a rather detailed study of the movement of river sediments in the Tigris River at Baghdad was made by the Irrigation Directorate. It was found that the sediment load is somewhat higher with a rising river than with a falling river. Likewise, the silt and clay load is higher than the sand load in terms of percent by volume. During the late summer and early fall, months when the river discharge was steady and running from 200 to 360 cubic meters per second, the total sediment discharge varied from 0.046 to 0.081 cubic meters per second. During the month of May the river flow gradually decreased from 3,142 to 2,350 cubic meters per second and the total sediment discharge dropped from 3.63 to 2.02 cumecs. The sand discharge during this period dropped from 1.35 to 0.46 cumecs. On March 3, 1953, a high flow of 7,229 cumecs of water passed Baghdad, carrying with it 15 cumecs of sand and 86.55 cumecs of

silt plus clay. The slope of the Tigris River runs about 56 to 50 centimeters per kilometer from Mosul to Balad, and from Balad through Baghdad to Kut it is about 7cm/km. The slope on the Euphrates runs in much the same pattern, but is flatter -- Ana to Hit, 30 cm/km, Hit to Shinafiya, about 10, 3 cm/km on south to Nasiriyah. Much data are still lacking as to where and how much and how fast silt deposition is taking place on farm land. The foregoing gives some idea of the complexity of the silt problem. Since river sediments are relatively fertile in comparison with land that has been farmed for generations in the manner practiced in Iraq, the farmers want their canals to carry silt to their lands, particularly in the rice lands in the southern part of Iraq. The old lands there tend to be more saline than those further north.

Inadequacy of basic technical data

Similar to other Middle Eastern countries, Iraq is still lacking in the basic data which are essential to the proper development and utilization of water and land resources. This is especially true in regard to streamflow and climatological data; information regarding the quantity, quality and availability of groundwater resources; infiltration and permeability rates for soils in different parts of the country; and more reliable information pertaining to the consumptive requirements of the various crops produced.

Irrigation Organization

The Directorate General of Irrigation is the official agency in Iraq which handles all matters pertaining to the irrigation of lands in the country. This agency is established as an integral part of the Ministry of Agriculture. It is headed by the Director General of Irrigation, who is assisted by four chief engineers and various other specialists in the broad field of reclamation. Headquarters for the Directorate are maintained in Baghdad. The Directorate maintains nine field divisions, each headed by a division engineer, responsible for all operations in his area and also responsible to the Director General. In addition to the Baghdad headquarters, there is also maintained in Baghdad a large workshop and a laboratory for general reclamation purposes.

Investigations

Drainage investigations

At the present time there are approximately 13,000,000 mesharas of land under irrigation in Iraq. It is estimated that approximately 60% of this total area is affected seriously by high water tables and the presence of injurious salts in the soils. Drainage is no doubt the

most serious problem associated with irrigation in Iraq. Drainage investigations are now in progress in a number of areas, all of which are presently irrigated. The Irrigation Directorate is investigating the Rumaitha and Shattra areas, which total about 600,000 mesharas. Investigations in the Diwaniyah area, which includes some 1,500,000 mesharas, are being conducted by the Nedeco Company. The East Gharraf area, comprising 1,000,000 mesharas, is being studied by the Cotha Company. Development Board engineers (First Technical Section) have conducted both major and minor drainage investigations in a number of areas. In the Dujaila area, they have established an experimental drainage project which is providing much useful data relative to drain spacing and salt removal. All of the above-mentioned drainage investigations are being made on a detailed basis. They include the collection and analysis of all data necessary for the design and construction of main drains and farm drains. The studies will also provide data and methods for salt removal or leaching, which will be required on most of the lands. In view of the seriousness of the drainage problem, the Development Board is planning to provide drainage facilities for all irrigated lands in Iraq.

Soil and land classification surveys

This work is currently being performed within the Government of Iraq by the Irrigation Directorate, the Miri Sirf Committee and the Abu Ghraib Agricultural Experiment Station. It is also being performed through contracts with the Development Board by a number of consulting firms, including Hunting Surveys, Tippetts-Abbett-McCarthy-Stratton, NEDECO and the Kuljian Corporation. Soil surveys of a semi-detailed nature have covered approximately 1,500,000 mesharas in the Euphrates Basin and 800,000 mesharas in the Tigris Basin. Land classification surveys, chiefly of a reconnaissance nature, have covered about 1,800,000 mesharas in the Euphrates Basin and 6,200,000 mesharas in the Tigris Basin. During the interim period between the two Seminars, the Irrigation Directorate continued a semi-detailed land classification of two areas totalling about 600,000 mesharas. Approximately 50% of the field work has been completed. Lack of trained personnel has handicapped these investigations. The Miri Sirf Committee, during the same period, completed similar classifications on two project areas totalling about 40,000 mesharas.

Training

Formal training was limited to attendance at the three-week training course in Izmir, Turkey. This course was conducted from April 2 to April 20, 1958. It consisted of training in irrigation practices and methods, terracing and the use of animal power for farming, and the using of simple shop-made equipment. Three Iraqi agricultural agents and three Miri Sirf technicians were sent to Turkey for this training.

Demonstrations

On the Hawija Miri Sirf Irrigation Project, irrigation methods and practices have been demonstrated. These included water control; land preparation, involving light levelling and smoothing and border dike construction for irrigation of close-growing crops; and orchard interplantings. A total of 285 settlers on the project have access to this demonstration farm. The demonstration, plus a policy of non-delivery of water to wasteful users, has resulted in careful water use by settlers.

Research Program

One of the greatest problems to be solved in the development of better irrigation in Iraq has to do with the reclamation of lands which have become increasingly saline and non-productive under continued irrigation and increasingly high groundwater tables. The major problem is to determine if this land can be reclaimed so that it can be farmed intensively rather than by the fallow system, wherein the land is only planted and cropped every other year. In order to solve this problem, the Development Board, the Irrigation Directorate and an American consulting firm of engineers have been conducting leaching experiments with test plots throughout selected areas. In addition to the above research, various other studies have been conducted by governmental agencies in regard to farm irrigation practices. The Abu Ghraib Agriculture College, for example, has conducted some preliminary research on irrigation methods best adapted to Iraq, determinations of farm irrigation water requirements, improved methods for measurement of permeability and infiltration rates and, to some extent, studies of irrigation efficiencies.

As a result of the leaching and drainage experiments, it has been decided that large areas of saline lands now being farmed by the fallow system with inadequate production can be reclaimed and cultivated intensively, with a tremendous improvement to the agricultural economy of Iraq.

TURKEY

I. Existing Irrigation in Turkey

A. Areas in Government Irrigation Projects

We now have 19 completed irrigation projects in Turkey. These projects were planned to supply irrigation water for 209,000 hectares; however, at the present time 77,752 hectares of land are actually being irrigated. The remainder, or 132,148 hectares, are not yet under irrigation.

One of the main reasons that the entire project area has not been served with water is that the irrigation system has not been completed for 73,270 hectares. Another factor in the situation is the low irrigation efficiency which results from the following:

(a) Insufficient land levelling
(b) Farm irrigation systems inadequately developed
(c) Inadequate or no provisions for main and farm drainage
(d) Poor methods of irrigation
(e) A large water loss from the primary and secondary distribution systems
(f) The tertiary or farm irrigation systems do not have sufficient control structures, and proper rotation systems for water application have not been developed

The distribution of crops in the existing 77,752 hectares of irrigated land is as follows:

30.6% cotton
26.2% grain
6.9% pasture and forage crops
4.3% orchard
4.4% vegetables
2.8% melons
3.9% sugar beets
13.3% rice
8.5% unclassified

B. Number of Irrigation Projects under Construction

There are 36 projects under construction. Nine will be completed in 1959, 18 are scheduled for completion in 1959, and seven in 1960. Two will be opened for operation in 1961. The projects under construction will provide irrigation for 190,350 hectares of land in 1961.

C. Proposed Irrigation Projects

Thirty-eight additional irrigation projects have been proposed, to provide 508,000 hectares of land with irrigation water.

D. Private Irrigated Area

Although the exact figure is not available, more than one million hectares of land are estimated to be privately irrigated.

II. The Problems of Irrigation Practices

The problems of applying irrigation water to the fields are as follows:

(a) Uncontrolled irrigation

1. Improper irrigation methods. The farmers are usually conservative and it will take time to instruct them in the use of proper irrigation methods instead of the wild flooding system which they are accustomed to using. Continued efforts are being made to influence them to adopt modern irrigation methods on their farms.

2. Insufficient land leveling

3. Inadequate farm irrigation systems

4. Poor timing of irrigations and over- or under-irrigation

(b) Drainage and Salinity Problems

1. The lack of adequate main and farm drainage systems

2. Poor topographic location and consequent high water tables and salt accumulation. Inexperience farmers were unable to anticipate this problem.

3. Application of irrigation water of poor quality

III. Explanations of Irrigation Organizations in Turkey

Responsibilities for irrigation in Turkey are divided between the State Hydraulic Works Department within the Ministry of Public Works and the Soil Conservation and Farm Irrigation Division of the Ministry of Agriculture. The Hydraulic Works Department is responsible for the planning, construction, and operation of large-scale irrigation works, and the Ministry of Agriculture is responsible for irrigation extension research on soil moisture, plan relations, crop rotations, fertilization, drainage of farm lands, and efficient use of water on farms.

In 1952 an Irrigation Section was set up in the Department of General Agriculture in the Ministry of Agriculture. In 1957 it became the Soil Conservation and Farm Irrigation Division of the Ministry of Agriculture. This organization is being developed on three organizational levels: (1) a strong, central or national office; (2) regional offices; and (3) technical groups for work areas, usually for a province.

The central or national organization has the responsibility of supervising the national farm irrigation assistance program; it formulates the policies under which the field organization works, formulates general programs for farm irrigation, and provides technical standards under which the field organization works. The central office is also responsible for training, legislation, budgets, and for the delegation of authority to the field offices.

The field work is organized on two levels (1) regional offices to provide for programming of work, provide technical guidance and supervision to the operational offices, adjust technical standards to local conditions, and provide general administrative support for field work; and (2) technical groups or work areas to provide the actual technical assistance and training for improved farm irrigation practices to the landowners. The personnel of these technical groups varies somewhat according to the actual problems of the area, but normally consists of trained irrigation engineers, trained irrigationists, drainage specialists and soil conservation specialists, and soil survey specialists. Assistance and planning are normally based on a soil survey of the land area.

The central or national office has six sections, as follows:

a. Small Water Resources Development
b. Soil Conservation
c. Soil Conservation and Farm Irrigation Machinery and Equipment
d. Soil Survey, Land Classification and Drainage
e. Farm Irrigation
f. Irrigation and Soil Research

At present there are two regional offices located in the western and southern parts of Turkey and ten work unit offices attached to the regional offices. In addition, there are seven independent work unit offices directly responsible to the central office.

Forty irrigation specialists of the Extension Service of the Ministry of Agriculture are located in 40 provinces. Their responsibility is to establish close cooperation among the Extension Service, the Soil Conservation and Farm Irrigation Division and the farmers.

There are four irrigation experiment stations and a Soil and Fertilizer Research Institute, which has three sub-laboratories. These sections are working on the research aspects of land and water use.

IV. Accomplishments on Farm Irrigation

A. Training

Thirty technical people from the Soil Conservation and Farm Irrigation Division and the Extension Service have been trained for 60 days in the practical and theoretical aspects of soil conservation and irrigation practices.

Fifty county agents and 180 agricultural village teachers have received practical training in the use of locally-made equipment for irrigation and soil conservation practices. Each of these agencies and teachers was provided with locally-made equipment for demonstrations in his work area. Forty agricultural workers have taken part in short courses on improved irrigation practices.

B. Demonstrations

1. Land-leveling demonstrations

From September 1956 to May 1958 40 land-leveling demonstrations were held on 625 hectares of land in central Anatolia and southern and western Turkey.

2. Modern irrigation methods demonstrations

Irrigation methods demonstrations have been set up in 38 locations on 570 hectares of land. Furrow irrigation methods have been demonstrated on cotton, peanuts, sugar beets, citrus orchards and vegetables. Border methods have been demonstrated on alfalfa and other forage crops. The basin method has been used with rice production.

3. Farm irrigation system demonstrations

Attempts have been made to include farm irrigation system demonstrations wherever irrigation methods demonstrations have been held. Approximately 2500 farmers have attended these demonstrations. As a result of this work, 245 farmers have applied modern irrigation methods on their farms.

C. Land Preparation Work

Following is a summary of the types and amounts of land preparation which has been carried out:

Land leveling	1858	hectares
Layout system	1300	"
Farm drainage	2800	"
Irrigation methods	1262	"
Farm Planning	1030	"
Total	8250	

D. Land Classification and Soil Survey for Irrigation Projects

Semi-detained land classifications for irrigation suitability have been carried out on 150,000 hectares of land in two main areas where the State Hydrolic Works Directorate has irrigation projects planned.

E. Farm Irrigation Equipment

1. Land preparation

The following kinds of equipment are being used in Turkey for land preparation:

Scrapers
Land planes
Eversman land levelers

In addition to the above equipment, some locally-made types are being used, such as floats, fresnos and buck scrapers.

2. Water Control

Several kinds of equipment have been used for establishing efficient water control systems on the farms. These include:

(1) Ditchers
(2) Locally made V-drag
(3) Locally made border maker
(4) Spiles
(5) Siphons
(6) Flumes

V. Irrigation Research

A. Research Program

Four irrigation research stations or institutes are engaged in carrying out research activities on the relationships of soils, crops, moisture and climate. Two main objectives are being stressed by these organizations: one is cooperative work with the Ministry of Public Works for the purpose of providing the required data for sound irrigation project development. The other is gathering the necessary research information to help farmers use their land to the best advantage. The main phases of the irrigation research being investigated are:

1. Soil-water relationships
2. Soil-water-crop relationships
3. Climate-soil-moisture relationships

B. <u>What has been done with the results of irrigation research.</u>

When dependable, useful data have been obtained, the Soil Conservation and Farm Irrigation Division and its regional and work unit offices and the Extension Service have been carrying the data to the farmers by extension and demonstration methods, by publishing the experimental results, and by providing direct technical assistance on the land to farmers in planning and applying improved irrigation practices.

(All figures in part I on irrigation projects have been taken from Ministry of Public Works, General Directorate of State Hydraulic Works, publications.)

CHAPTER 5.

RESOLUTIONS

PROGRAM

AND

LIST OF DELEGATES

RESOLUTIONS

RESOLUTION NUMBER I

The delegates to the Second Regional Irrigation Practices Seminar extend heartfelt thanks to the Government of Iran, represented by the Ministry of Agriculture and the Irrigation Bongah, and to the University of Tehran for their great hospitality and excellent facilities, which have greatly furthered the success of the Seminar and the pleasure of the delegates.

RESOLUTION NUMBER II

The delegates to the Second Regional Irrigation Practices Seminar extend heartfelt thanks to the International Cooperation Administration and the United States Operations Mission to Iran for organizing and arranging this Seminar.

RESOLUTION NUMBER III

The members of the Second Regional Irrigation Practices Seminar extend heartfelt thanks to the Governments and United States Operations Missions participating in the Seminar for their cooperation, without which no Seminar could have been held.

RESOLUTION NUMBER IV

The delegates to the Second Regional Irrigation Practices Seminar believe that the improvement of irrigation practices in Middle East and South Asian countries is of paramount importance and presents similar problems, and recommend for each of these countries increased effort on the part of both irrigation construction and agricultural farm advisory agencies, either public or private, in securing such improvement.

RESOLUTION NUMBER V

The delegates to the Second Regional Irrigation Practices Seminar recommend that the third of a continuing series of Seminars concerned with the promulgation of better irrigation practices be held during 1960.

RESOLUTION NUMBER VI

The Second Regional Irrigation Practices Seminar recommends that each country develop a national training program for agricultural irrigation at least two levels:

1. Local workers whose duties would be to teach the farmer better irrigation practices by field demonstrations, by working with the individual farmer on his own fields, and in many other ways; and

2. Specialists to be available to help train the local workers and assist on special problems.

RESOLUTION NUMBER VII

The delegates to the Second Regional Irrigation Practices Seminar endorse and appreciate the offer by Professor Macksoud of American University of Beirut to act as an informal and unpaid corresponding secretary for the group, until such time as a permanent secretariat may be organized.

COMMITTEE MEMBERS

A. G. Asghar, Pakistan
Abid Awn, Iraq
M. Ayazi, Iran
E. Chaya, Lebanon
A. Karaelmas, Turkey
M. R. Lowis, United States
Andy Memaris, Greece
H. L. Uppal, India
T. Senewirathe, Ceylon

PROGRAM

SATURDAY, MAY 3, 1958

Morning

Registration: Tehran University Club

Opening Session - Ibne-Sina Hall

Welcome by Dr. Feylessoufi, Managing Director, Irrigation Bongah
Opening of Seminar by H.E. General Hassan Akhavi, Minister of Agriculture, Government of Iran
Address by Mr. Harry A. Brenn, Director, United States Operations Mission to Iran
Lunch given by the Irrigation Bongah: Tehran University Club

Afternoon

Reports by Country delegations
Address on Ghanats and Deep Wells, Dr. Feylessoufi

Evening

Visit to the tomb of Shah Reza

SUNDAY, MAY 4, 1958

Morning

Assembly and Announcements: Tehran University Club
Causes of and Remedies for Excess Salinity and Alkalinity in Irrigated Soils, Mr. Abid Awn, Drainage Engineer, Irrigation Directorate, Iraq

Afternoon

Use of Limited Water Supply, Mr. G. A. Asghar, Director of Land Reclamation, West Pakistan

Evening

Cocktail-Buffet by invitation, Mr. Ray G. Johnson's home

MONDAY, MAY 5, 1958

Assembly at Tehran University Club
Travel by bus to Varamin Experimental Farms and Mamazon Valley
Lunch at Near East Foundation Station
Visit to Mamazon Village and
Villages divided by H.I.M. the Shah among the former tenants

Evening

Dinner given by Dr. Feylessoufi, Hotel Darband

TUESDAY, MAY 6, 1958

Morning

Assembly and Announcements: Tehran University Club
Relation between Farm Irrigation Practices and Project Design and Management, Mr. Asghar Azarnia

Afternoon

Land Classification as an Aid to Proper Irrigation Practices, N.A. Halkias, Irrigation Specialist, Land Amelioration Works, Macedonia, Greece

Evening

Visit to Golestan Palace

WEDNESDAY, MAY 7, 1958

Assembly at Tehran University Club
Travel by bus to Karaj Dam
Lunch given by Karaj Agricultural College
Visit the laboratories and farms of the College

THURSDAY, MAY 8, 1958

Morning

Assembly and Announcements
Development and Use of Ground Water, George C. Koumbarakis, Technical Advisor to the Agricultural Bank of Greece

Afternoon

Design and Layout of Farm Irrigation Systems, Naki Uner, Director, Soil Conservation and Farm Irrigation Division, Ege Region, Turkey

Evening

Visit to Ethnological Museum

FRIDAY, MAY 9, 1958

Moslem Sabbath

SATURDAY, MAY 10, 1958

Morning

Assembly and Announcements
Indian Experience in Promoting Better Farm Irrigation Practices, T. J. Mirchandani, Director, Agronomic Survey Experimentation, India

Afternoon

Irrigation Staff Development, Dr. Salim W. Macksoud, Head, Department of Agricultural Engineering, American University of Beirut, Lebanon

Evening

Visit to Old Stadium

SUNDAY, MAY 11, 1958

Assembly at Tehran Railway Station
Travel by train to visit Garmsar
Box Lunch
Comparison of ghanats and open drains

MONDAY, MAY 12, 1958

Morning

Assembly and Announcements: Tehran University Club
Group discussions

Afternoon

Group discussions

Evening

Visit Parliment Buildings

TUESDAY, MAY 13, 1958

Assembly at Tehran University Club
Travel by bus to Agricultural Engineering Demonstration Farm at Karaj
Box lunch at farm
Visit Ghezelhasar drainage and land improvement area

WEDNESDAY, MAY 14, 1958

Morning

Assembly and Announcements
Reports of discussion groups
Discussion of group reports

Afternoon

Reports of committees and discussion groups
Conclusions and recommendations

Evening

Farewell dinner by the Government of Iran

THURSDAY, MAY 15, 1958

Assembly at Mehrabad Airport
Travel by plane to Isfahan
Inspection of centuries-old irrigated gardens and water distribution systems

FRIDAY, MAY 16, 1958

Visit historic buildings and other sights in and near Isfahan
Return to Tehran and disband

DELEGATES

CEYLON

GUNASEKERA, A.E.C. de Silva, Director, Irrigation Department
MANAMPERI, Henry de Silva, Divisional Irrigation Engineer
SENEWIRATNE, Terence, Rice Cultivation and Water Use Specialist, University of Ceylon
WIKRAMANYAKE, Vivian E.A., Lecturer in Agricultural Engineering, University of Ceylon
PHILLIPPI, Stanley I., United States Operations Mission to Ceylon

GREECE

ECONOMIDES, Paris, Agriculturist, Ministry of Agriculture
HALKIAS, Nicolas, Head, Agricultural Engineering Studies, Reclamation, Macedonia
KOUMBARAKIS, George C., Technical Advisor to Agricultural Bank of Greece.
MEIMARIS, Andres, Director, Hydraulic Constructing Office, Larisa

INDIA

MIRCHANDI, Tahilram, Director, Agronomic Survey Experimentation, Council of Agricultural Research
SHORI, Bal Ram, Superintending Engineer, Central Water Power Commission
UPPAL, Harbanslal L., Director, Irrigation and Power Inspection, Amritsar
CLARK, Tom A., Water Resources Advisor, United States Technical Cooperation Mission
FOLSOM, Oliver H., River Valley Development Advisor, United States Technical Cooperation Mission
RENSHAW, Anderson N., Agricultural Extension Advisor, United States Technical Cooperation Mission
SURFACE, Victor C., Information Advisor, Agriculture, United States Technical Cooperation Mission

IRAN

ARFAA, Heydar-Ali, Director General, Ministry of Agriculture
AYAZI, Manoutcher, Assistant to Head, Agricultural Engineering Department, Ministry of Agriculture
AZARNIA, Asghar, Assistant to Director, Kuhrang Water Society, Isfahan
FARDAD, Abdulhassan, Head, Agricultural Engineering Department, Ministry of Agriculture
FARZANEH, Ruhollah, Assistant Dean, Karaj Agricultural College
FEYLESSOUFI, E., Managing Director, Irrigation Bongah
GHOLIZADI, Mohammad, Assistant Manager, Irrigation Bongah
MEMERBASHI, Aziz, Head, Soil and Water Branch, Engineering Department, Ministry of Agriculture

MOGHADAM, Rahmatollah, Head of Project 105, Special Activities Account, Irrigation Bongah
MOINIZAND, Esmail, Planning Officer, Irrigation Bongah
ANDERSON, Bruce, Agricultural Engineer, Utah State University Contract, United States Operations Mission
REYNOLDS, Tom, Extension Advisor, United States Operations Mission, Meshed
THOMPSON, Theodore, Head, Water Resources and Watershed Management Branch, United States Operations Mission

IRAQ

AWN, Hussain Abid, Drainage Engineer, Directorate General of Irrigation, Ministry of Agriculture
WAHBI, Saifuldin, Chief Engineer, Ministry of Agriculture
DAVIS, Ray E., Chief Agriculture Division, United States Operations Mission
RAMSAY, Thomas, Irrigation Engineer, United States Operations Mission
REGER, James S., Drainage Engineer, United States Operations Mission
SNYDER, Le Roy J., Civil Engineer, United States Operations Mission
YOUNG, Marshall, Civil Engineer, United States Operations Mission

LEBANON

BIZRI, Ibrahim, Director General, National Litani Commission
CHAYA, Elie, Chief Engineer, National Litani Commission
MACKSOUD, Salim W., Head, Division of Agricultural Engineering, American University of Beirut
WEILAND, Harold, Chief, Public Works Division, United States Operations Mission

PAKISTAN

ASGHAR, Abdul Ghani, Director of Land Reclamation, West Pakistan
BERTELSON, Dwight, Soil Scientist, United States Operations Mission

TURKEY

ALAP, Muzaffer, Director, Irrigation Research Institute, Tarsus
GUREL, Nurhan, Sectional Director, Farm Irrigation Operations, Ministry of Agriculture
KARAELMAS, Adem, Director, Soil Conservation and Farm Irrigation Division, Ministry of Agriculture
UNDER, Naki, Director, Soil Conservation and Farm Irrigation Division Ege Region
DOBSON, Donald D., Head, Land and Water Use Branch, United States Operations Mission
STEELE, John C., Irrigation Specialist, Nebraska University Contract Group, United States Operations Mission