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5th IRRIGATION PRACTICES SEMINAR

NESA REGION NEW DELHI, INDIA 1964

PN-AAE-285

FOREWORD

This volume reports the proceedings of the Fifth Near East-South Asia Irrigation Practices Seminar held in New Delhi, India from March 2—14, 1964, which was co-sponsored by the Government of India and the United States Department of State, Agency for International Development with eight nations of the region and the United States participating. Held biennially, this series of Seminars began in Izmir, Turkey in 1956 and was followed by meetings successively held in Tehran, Iran ; Lahore, Pakistan ; and Ankara, Turkey.

Delegates to the Seminar having major responsibility for the improvement of irrigated agriculture in the various countries are selected by their respective governments. The seminar forms a panel whereby common difficulties may be analyzed and experiences and ideas exchanged. All seminars have been dedicated to the idea that the results of irrigation effort are realized at only one place—on the farms and fields of the irrigator. The Fifth was no exception. Not only did the delegates exchange valuable information about irrigation science and technology, but much interest and discussion centered around problems of education, organization and service related to irrigation development and improvement.

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PROGRAMME

FIFTH NESA IRRIGATION PRACTICES SEMINAR

March 2 - 14, 1964

Vigyan Bhawan, New Delhi - India

Monday, March 2

10.00 Inauguration

Welcome Address, Shri G.R. Kamat, Secretary, Department of Agriculture, Chairman

Welcome Address, Mr. C. Tyler Wood, Director, US AID

Address, Dr. K.L. Rao, Minister for Irrigation and Power

Inauguration, Sardar Swaran Singh, Minister for Food and Agriculture

Vote of thanks, Shri Mahavir Prasad, Irrigation Adviser to the Government of India

INTERMISSION

11.15 Opening Address and Orientation. Dean F. Peterson

11.45 Meeting of Executive Committee

12.30 Adjourn

18.00 AT HOME—Minister for Food and Agriculture, Rashtrapati Bhavan

Tuesday, March 3

09.00 Chairman, Salahattin Kilic, Turkey

Country Progress Reports by Iran, India, United Arab Republic

14.30 Chairman, Mahavir Prasad, India

Country Progress Reports by Iraq, Jordan, Turkey

Wednesday, March 4

09.00 Chairman, G.M. Dissanayake, Ceylon

Technical Session—*Project Planning*

Ghasven Development Project—Iran. Presented by M.A.M. Rejali

Irrigation Conditions and Problems in Iraq. Presented by J. Al-Malaika

The Problem of Repayment—Turkey. Presented by Korkut Ozel

Irrigation Surveys and Investigations on Drainage, Salinity and Field Applications. India. Presented by T.S. Sidhu and R.V. Tamhane

Water Supply in Rural Areas. Turkey.

14.30 Chairman, A. Azarnia, Iran

Technical Session—*Operation and Management*

Operation and Maintenance in Irrigation Projects. Turkey Presented by Korkut Ozel

Rehabilitation of Shabankareh Project, Iran. Presented by M.A.M. Rejali

Rehabilitation of Old Irrigation Systems. Bogrami Project. Afghanistan. Presented by A. Mahbub

Planning Irrigation Works in India. Talk by Sardar B.S. Nag

Thursday, March 5

09.00 Chairman, M. El-Madany, United Arab Republic.

Technical Session—*Education and Training*

Country Report by Afghanistan.

TOPRAKSU Farmers Training Camps. Turkey. Presented by E. Oktenoglu.

Survey and Evaluation of Training Needs and Methods. India. Presented by S. Mohan.

Development of Agricultural School in Iran. Iran. Presented by A. Jenab.

11.30 Committee Meetings

12.30 Lunch at Vigyan Bhavan by Mr. Tyler Wood and Mr. Ray G. Johnson, U.S. A.I.D.

14.30 Visit to Agricultural Equipment Display at the Exhibition Grounds.

Friday, March 6

09.00 Chairman, N.A. Kadir, Iraq

Technical Session—*Drainage and Salinity*

Irrigation and Drainage Practices in Relation to Salinity Control in Soils of EDKO District. U.A.R. Presented by A.G. Mitkas.

Drainage Development and Problems in Iraq. Iraq. Presented by N.A. Kadir.

Drainage and Salinity in Iraq with Particular Reference to Dujailah Experimental Study. Iraq. Presented by A.M. El-Dujaili.

Measures Taken for Improving the Salinity and Drainage Conditions in the Lower Seyhan Project. Turkey. Presented by M. Kulen.

The Role of Tile Drainage in Land Development in U.A.R. U.A.R. Presented by M. El-Madany.

*For discussion only.

Marja Irrigation, Drainage and Settlement. Afghanistan. Presented by D.M. Noori

Standards for Reclamation of Saline and Alkali Soils. India. Presented by N. D. Rege and H. R. Uppal.

* Surface Drainage in Plains Area, by H. L. Uppal and S. R. Sehgal. India.
* Drainage and Salinity Problems in Gujarat State, by R.P. Talati and V.K. Shaligram. India.
* Field Drainage Project at Ranbirpura, District Patiala, Punjab State, by M. S. V. Rama Rao, India.

14.30 Chairman, A. Mahbub, Afghanistan.

Technical Session—*Farm Layout and Distribution Systems*

Cumra—Karkin Irrigation Development Project. Turkey. Presented by Ragip Boyaci

Determination of Command Area of Outlets based on Supply, Time Available and Development of Cropping Systems. India. Presented By B. Nath and S.S. Lamba.

* Waterproofing of Small Irrigation Channels, by H.L. Uppal. India.
* Improved Agricultural Implements for Preparing Lands for Irrigation Purposes by D.N. Khardekar, India.
* Delivery of Water to Government Canal Outlets, by Phool Prakash. India.
* Distribution and Management of Water Beyond Government Canal Outlets, by B.D. Rathi. India.

20.00 Dinner—Shri G. R. Kamat, Secretary (Agriculture) at Hyderabad House.

Saturday, March 7

06.30 Field trip to Ballabgarh, Agra and Achnera.

Sunday, March 8

14.30 Local Site Seeing

Monday, March 9

09.00 Chairman, S.M. Ghezawi, Jordan.

Technical Session—*Institutional Development*

Development of Institutions for Irrigation in Jordan. Jordan. Presented by U. Kakish.

An Analysis of Functional Services Required in Water Resource Development, Especially as Required for Irrigation Agriculture. U.S.A. Presented by A.W. Plummer.

An Analysis of Institutional Development Related to Irrigated Agriculture in Turkey. Turkey. Presented by Dursun Kesimoglu.

Institutional Base of Irrigated Agriculture in the United States. U.S.A. Presented by J.N. Spencer.

14.30 Panel Sessions

16.30 Visit to Engineering Museum, Central Water and Power Commission

17.30 At home. Secretary, Ministry of Power and Irrigation, Hyderabad House

Tuesday, March 10

09.00 Chairman. M.A. Raza, Afghanistan

Technical Session—*Field Research*

Determination of Evapo-transpiration Potential by the Thornthwaite Method by Mufit Kulen and Orhan Akyurek. Turkey

Assessment of Irrigation Requirements of Crops on a Climatological Basis, by N.G. Dastane and Mohindra Singh. India

Results of Research on Consumptive Use and Water Requirements of Cotton and Rice in Turkey, by Nevzat Ozalp, Nazim Durlu and Erdogan Omay. Turkey

Water Requirement of Crops on Soil Moisture Basis, by O.P. Gautam and S. Ray. India

Report upon Irrigation Water requirements in U.A.R., by M.B. Kalil, A.A. Samoloty, A.A. Gibali. U.A.R.

Summary of Research Findings and Applications of Water Requirements of Crops and Duties thereof in India, by S.N. Gupta and A.B. Bhattacharya. India

Manufacture of Simple Tensiometers and Gypsum Blocks and their use for Irrigation Purposes, by Sefak Yesiloy. Turkey.

Weed Control Problems of Irrigation Systems in Turkey, by Ismail Baykal. Turkey

14.30 Chairman, I.J. Naidu. India

Technical Session—*Field Research (Continued)*

Method for Scheduling and Determining Depth Employing Consumptive Use, by S.E. Roy. India

The Effect of Fertilizers on Wheat Production under Irrigated and Dry Farming Conditions in Turkey, by Needet Yurtsever. Turkey

Fertilizers in Relation to the Efficient Use of Irrigation Water, by Mukhtar Singh. India

16.15 Panel Sessions

21.00 Indian Classical Folk Dances, Ashoka Hotel

Wednesday, March 11

09.00 Chairman, Salahattin Kilic, Turkey

Technical Session—*Small Projects*

Development of Small Irrigation Projects in Turkey. Presented by Lutfi Dincer

Minor Irrigation Systems, India. Presented by J.K. Jain and K.V. Rao

*Flow of Groundwater towards Pumping Wells in the Vicinity of a Perennial Stream. India. Presented by R.S. Chaturvedi

14.00 Chairman, A.D. Pandit, Special Secretary, Department of Agriculture, India

Closing Technical Session.

A. Recommendations of the Panels

I. Education and Training, by Dr. Jamil Al-Malaika

II. Operation and Management of Irrigation and Drainage Systems, by Dr. Omar R. Gardi

III. Field Irrigation and Drainage Research, by Mohamed El-Madany

IV. Waterlogging, Salinity and Alkali Problems, by Dr. Ahmed L. Dujaili

V. Farm Irrigation and Drainage Systems, by G.M. Dissanayake

VI. Standards for Irrigation and Drainage Investigations, by Seref Ozgul

B. Recommendations of executive Committee, by Shri Mahavir Prasad

C. General Business

14.00 *Closing Session*

Seminar Report. Dr. D.F. Peterson, Seminar Advisor, US AID
Our Assessment. Mr. Salahattin Kilic, Turkey
US AID's Observations. Mr. Ray G. Johnson, Chief Agriculturist.
Closing Address. Shri A.M. Thomas, Minister for Food

17.30 Reception. International Commission on Irrigation and Drainage, Ashoka Hotel

Thursday, March 12

06.30 Leave New Delhi on field trip
Lunch, Roorkee

14.00 Leave Roorkee to visit Dhanauri Experimental Farm, Bhadrabad Hydraulic Research Station, Hardwar Dam, Bhimgoda Dam and Canal Headworks

21.00 Dinner, Roorkee

Friday, March 13

07.30 Visit Roorkee Irrigation Research Institute

08.30 Leave Roorkee to visit Dehra Dun, Dak Pathar Barrage and K.P. Canal

20.30 Dinner, Roorkee

Saturday, March 14

07.30 Leave Roorkee to visit state tubewell site near Muzzafarnagar

13.00 Lunch, Wheler Club, Meerut

15.30 Return to New Delhi
Departure of delegates

This report has been prepared from advance copies of papers accepted for presentation at the Seminar. Limited editing has been provided. In some cases material has been shortened or deleted to avoid repetition, or amended in order to improve clarity. Limited material which was ambiguous or contained errors that could not be clarified or corrected was omitted. It has been necessary to condense some material, but it is felt that the author's essential message has been preserved. Where material suitable for reproduction was not provided, certain figures were necessarily omitted ; on the other hand, only part of the excellent illustrative material furnished could be included.

The material was offered for publication by the Soil and Water Management Branch through the Communications Media Division of U.S. Agency for International Development, New Delhi, India. It was arranged and edited by Dr. Dean Peterson and printed under the supervision of Mr. Harold Rinnan.

CHAPTER I

OPENING SESSION

WELCOME ADDRESS

by

Shri G. R. Kamat

Secretary, Department of Agriculture, Government of India

Sardar Swaran Singh, Dr. Rao, Mr. Wood and friends :

It gives me great pleasure to extend a cordial welcome to the distinguished delegates and guests who have gathered here to participate in the 5th NESA Irrigation Practices Seminar. I am aware that several leading experts who have come from abroad have travelled long distances and at considerable personal inconvenience to participate in this Seminar. To them I wish to say that we are very pleased indeed to have them in our midst. May I also, on behalf of the gathering, thank Sardar Swaran Singh, our Minister for Food and Agriculture, for having very kindly agreed to inaugurate this Seminar and Dr. K.L. Rao, Minister for Irrigation and Power for agreeing to our request to address this Session. We are also grateful to the United States Agency for International Development, who have so readily extended all assistance and cooperation in organising this Seminar here in New Delhi.

This Seminar has a unique role to play in the matter of pooling of scientific information and exchange of technical knowledge. The countries participating in the Seminar commonly share a number of pressing agricultural problems. In nearly the entire Near East and South Asia region, the small land holdings, illiteracy among cultivators, subsistence farming, shortage of chemical fertilizers, etc., are some of the major impediments in the way of rapid agricultural development. The technical experts foregathered here will, I am sure, throw special light on how modern science and technology can help in rapidly raising agricultural production despite these handicaps.

Irrigation is undoubtedly the mainstay of agricultural development in most parts of the Region. There are large areas where rainfall is inadequate and erratic ; in most countries it is seasonal, fluctuating from year to year and often ill-distributed over the season. Therefore, our problem is one of bringing water either from

great distances or from under the earth, conserve it and distribute it to the fields. There are again large tracts, such as in India, where rainfall is adequate and assured but it drains off in a rush. There, the problem is one of storing the rain-water and conserving the moisture. Concerted efforts are being made in India and in other participating countries to step up the irrigation potential fast enough to increase agricultural production. But the utilisation of irrigation potential has now-here in this Region attained the optimum level yet owing to certain inherent difficulties of a fundamental nature to which I have already referred. A country could have found it possible to go easy on the development of irrigation use in the past when population had not began to press so hard as at present on limited food supplies. But we can no longer afford to place ourselves in this complacency, particularly when irrigation sources are being built up at great costs and available water resources are still inadequate to meet the wide-spread demand for irrigation. Formerly it was not unusual for an irrigation project to take a quarter of a century or more to reach the full limits of its potential. But now the needs are so urgent and of such magnitude that all the available resources of science must be pressed into service to yield the maximum returns in the shortest possible time.

Un-controlled use of irrigation water is known to aggravate or precipitate problems of water-logging, salinity and alkalinity in intensively irrigated tracts with comparatively flat slopes and inadequate drainage outlets. In India there is a total of about 6 million hectares of land which is so affected. In the major part of this affected land, over-irrigation for long periods with inadequate drainage has been mainly responsible. Investigations carried out in these areas have led us to the conclusion that controlled use of irrigation water is not only essential for bringing more area under irrigation from the same quantity of water but also for preserving the fertility of the land. We have also learnt the lesson that drainage is an essential counterpart of all irrigation projects to ensure effective and sustained agricultural benefits from the land.

The problem of water management and optimum use of irrigation water requires concentrated and coordinated efforts on the part of various agencies and disciplines ; not least of which are, the State Agriculture and Irrigation Departments, the Department of Community Development, extension organisations, research and training institutes. Although it is ultimately the cultivator, who has to bring about the optimum use of water for raising maximum yields, it is for us to ensure that he is equipped with the requisite know how and motivated with true purpose. Integrated activities in various fields are, therefore, necessary to provide the requisite financial, technical, material and organisational support to the farmer.

The main aim of this Seminar, I understand, is the advancement of irrigated agriculture throughout the Region by mutual exchange of knowledge and scientific informrtion and the stimulation of interest and activity in the right direction. This will provide ample field for detailed discussion on the basic problems of irrigation with due regard to the existing agro-economic conditions in the Region. I am sure the leading scientists and experts gathered here will be able to throw considerable light on these problems. I also trust that our own scientists and technicians will greatly benefit from the experience of their colleagues in other countries. I have no doubt that the recommendations of this Seminar will be carefully considered by the

Governments of participating countries and will go a long way toward developing irrigation on scientific lines.

Let me once again tell you how very gratifying it is to welcome such a distinguished gathering of experts from abroad. It is indeed a great privilege to welcome you all to this historic city of Delhi and I do hope you will find your stay in the city happy and comfortable. During and at the end of the Technical Sessions, you will be invited to field trips to see important irrigation works in the vicinity of Delhi. I hope you will find these visits interesting.

I thank you all once again for participating in this Seminar.

WELCOME ADDRESS

by

Mr. C. Tyler Wood

Director, US AID, New Delhi

Hon. Sardar Swaran Singh, Hon. Dr. Rao and friends :

On behalf of the United States Agency for International Development, co-sponsor with India of the Fifth Near East-South Asia Seminar on Irrigation, I join with Secretary Kamat to extend a most hearty welcome and best wishes from the country and agency which I represent. I think that it is most timely that the Fifth NESA Seminar is being held in India. India is now completing new and vast irrigation projects which will add materially to her agricultural resources. Furthermore, important steps are being taken to assist Indian farmers in their efforts to improve the practice of irrigation and the conservation of soil resources. Thus, I am happy that India decided to play the host and that US AID was invited to join with them in sponsoring this seminar.

I am impressed that India has such a large interest in irrigation. Except for China, there is more land under irrigation in India than in any other country. The number of farmers in India roughly equals the number of farmers on the continents of Europe and Americas and a large share of these farmers are irrigation farmers. India has made many important contributions to the sciences and arts of irrigation-contributions too numerous to summarize here. Her keen interest in the subject is exemplified, not only by her sponsorship of this seminar, but also by the presence this morning of both Hon. Sardar Swaran Singh, Minister for Agriculture and Hon. Dr. K.L. Rao, Minister of Irrigation and Power of Central Government of India. The personal interest of these two eminent and exceedingly busy gentlemen is most encouraging.

It is interesting to recall that human civilization began in the vast-desert lands extending through the Near East to Egypt and in the Indus and the Ganges valleys. In these lands man, for the first time, lived in communities ; he engaged, for the first time, in the organised arts and crafts of commerce, agriculture and industry ; he first learned to read and write ; and he first surveyed lands and recorded their ownership titles in the public records. It is interesting also that invariably these ancient communities engaged in the practice of irrigation ; so this is an ancient art.

The strength of the ancient communities was often measured by the effectiveness of their irrigational developments and by their means to command and to maintain physical works which provided them with water. When these works failed, or when the land became non-productive, the communities died.

Today, the desert-like lands of the Middle East and the Indian sub-continent are no less in need of irrigation than they were in past ages. They are still arid and in order to produce significant crops, they still must be irrigated. But there is a difference and an urgency today. A great many more people live on these lands than ever before. Populations are increasing! These people seek a new and better way of life; they want more freedom; and they want to increase their material benefits. The farmers of India, like the farmers of many other countries, are seeking to break the ancient bonds of low agricultural production and the consequent poverty and hardship of subsistence living. And they are seeking to do this by irrigation.

The ancients developed systems of irrigation which were so great in magnitude and so complex in design that they astound us even today. Nevertheless, in the last century, modern scientific and engineering technology has pointed in new directions. If we are sufficiently determined, we can build dams, canals and diversion works of almost any required size. Many works have already been built, others are under construction, on the drawing boards, or under investigation, and the means are at hand to continue to increase the useable water supply. Large investments have already been made and even greater expenditures are planned for the future.

But, of course, the building of the great dams, the canals and the reservoirs is not the whole story. It is only the first step! We are here today because we are concerned about the second step.

Increased agricultural production under irrigation results only as the overall total practice of agriculture improves. Good seeds, fertilizers, profitable markets, available capital and credit are extremely important elements of the total effort. The interrelationship of the numerous factors of increased agricultural production are like the links of a chain. Failure of one link can cause the entire effort to fail. Improved practice of irrigation is a vital and an important link in the chain and with irrigation, there must be adequate drainage so that water-logging, salinity and alkali do not occur. These are problems which not only reduce production but may totally ruin valuable and irreplaceable land resources for generations to come.

You who are here today have been given the responsibility by your governments to effect increased production through the proper practice of irrigation and drainage. You also have the task of helping the farmer obtain the other tools of production which he needs to complement his efforts in irrigation. These are difficult tasks. Not only must you obtain the sound scientific and technical knowledge required, which is difficult in itself, but you must also find the resources and develop the organizations which will serve and assist the farmer in getting his job done. This will be even more difficult.

Recognition of the problems facing the farmers who sought to improve their methods of irrigation encouraged leaders and their U.S. associates in this region to propose the first Near East-South Asia Irrigation Practices Seminar. This was held in Izmir, Turkey in 1956. Later seminars were held in Tehran in 1958, in Lahore in 1960, and in Ankara in 1962. Through the years most of the countries in the region have participated and reports of each seminar have been printed and widely circulated. The most recent report contains 318 pages. Technical subjects such as the water requirements for crops, the time and method of application of water, and the depth and spacing of drains have been covered ; but the seminar has been concerned also with such subjects as the education and training of farmers, extension personnel and technicians ; the development of organizations and institutions for improving irrigated farming ; the design of field and farm distribution systems ; the operation of irrigation and drainage systems ; and the research of irrigation and drainage practices. The delegates and their U.S. associates, have brought to the seminar from their own countries their experience in the various topics under discussion. The results of a seminar are difficult to measure but it is believed that previous seminars have helped to accelerate progress in the following ways : (1) The basic principles of scientific irrigational practices and of drainage have become widely known and disseminated throughout the area ; (2) More effective national and community level organizations for improving irrigation, and agriculture in general, have been developed in the various countries ; (3) Improved programmes for training farmers and technicians at all levels have been established ; and (4) Government officials at high levels have become more aware of the difficulties with which irrigation farming is faced and of the action necessary, with the result that increased national efforts are being made to improve the practice of irrigation.

We hope that this Fifth seminar may be as helpful as the previous ones. We think that an exchange of ideas, to learn where others have succeeded and where they have failed, is important. You have all had experiences which can assist someone else, whether he be your neighbour or a stranger with a similar task in a far away land. If your ideas are exchanged and freely discussed then the efforts of our host, India, to hold this seminar, the efforts made by your own country to send you here, and the efforts of the United States, will be amply rewarded.

Again, may I join my colleagues from the Government of India in extending a hearty welcome to you. May your discussions be profitable and helpful, and may you have a most enjoyable visit here.

ADDRESS

by

Dr. K. L. Rao

Minister for Irrigation and Power, Government of India

Mr. Chairman, Mr. Tyler Wood, Mr. Swaran Singh and Friends :

I am happy that the U.S. Agency for International Development accepted India's invitation and arranged the 5th Irrigation Practices Seminar in Delhi. It is a privilege to welcome the delegates from all the neighbouring countries who are engaged on problems of irrigation similar to that of ours in India. I am sure, we will be able to learn a great deal from their experience and the Seminar will provide the forum for exchange of views on the subject of irrigation practices in a cooperative effort to solve one of the major problems that mankind faces today.

Irrigation was never so important in human civilization as it is at present. Two-thirds of the world is underfed, that is, the basic sustenance of life is not being made available in adequate quantity to the major portion of humanity. While the possibilities for it are definitely there, in an effort to feed all the people, we have got to take various steps. Of these, irrigation is perhaps the primary one. It is a revealing fact while we irrigate only a tenth of the cultivated land in the world, the food produced from that fraction is able to supply enough for a fourth of the world population. That is, if we can provide more irrigation facilities, by doubling the irrigated area, the problem of food for the world can be solved. Irrigation facility is the best agricultural production multiplier. Even in U.S.A., the economic destiny of one in ten depends on irrigated areas, and large farms have sprung up on irrigation development nearby. We, in India, have realised the importance of this. Three-quarters of our population lives by agriculture, and nearly half the national income comes from agriculture. That is why, from about 50 million acres, or about 15 per cent of the cultivated land, we have gradually built up today nearly 80 million acres in the course of the last decade. This, as you can imagine, requires a major financial and engineering effort.

On the engineering side, we have to take steps for the conservation of the river waters by building dams and preventing wasteful flow of water in the rivers which flow full only in monsoon months. On an average, 3 to 7 crores of rupees are required in India for conserving one million acre feet. In tropical countries

like India, conservation of water is the most important method of utilising the river wealth of the country. Such conservation helps in meeting the deficit in foodgrains. Thus, in this country, out of the total of 323 million acres, in 280 million acres foodgrains are grown. Out of this, again, 80 million acres grow rice and 32 million acres grow wheat. India is deficit in wheat. Wheat to the extent of two million tons is being imported every year. Wheat is a crop that is grown in the months other than the monsoon, that is during July to September. Therefore, to meet the water requirement for wheat, water has to be conserved. If only another four million acres are irrigated from the conserved water, self-sufficiency in wheat can be achieved through improved irrigation practice only, that is by mere supply of water. Therefore, conservation of water by the construction of dams, tanks and other types of works, wherever it is possible, has to receive utmost attention.

Extensive irrigation is achievable through minor irrigation also. For, in India nearly 50 per cent of the irrigated area is fed from minor irrigation works.

Besides conservation of water, protection of crops against damages has to receive earnest attention. The major disease of irrigation is waterlogging and salinity and has to be combated. This problem is posed in Punjab. In many other parts of India, where there are good slopes and where the use of water is not too intense, no waterlogging occurs, in spite of irrigation for many years. Cauvery delta has never shown any signs of waterlogging or salinity, though irrigation has been practised for several centuries.

We have another factor in India leading to damage to agricultural production due to floods in States where the land is congested with water, and is not drained promptly, as in Bihar, eastern parts of Uttar Pradesh and Assam. This is now being tackled on a national scale.

In developing countries, there is an utmost need to bring about earliest utilisation of the newly created irrigation potential. In India, while on an average 80 per cent utilisation of the potential in the course of 3 years is achieved, there are some projects where, due to various prevailing practices, there occurs a lag. These are fortunately, very few, and the irrigation benefits are less than even 10 per cent of the irrigation potential created. Timely assistance to the farmers will help in early utilisation. A very good example is the Musi Project. Loan was advanced by the Reserve Bank to the Land Mortgage Bank, who, in turn, gave the loan to the farmers. The loans were of two types:—(1) 15-year loan to be repaid in 15 years at Rs. 300 per acre for levelling and farming bunds etc. ; and (2) 8-years loan at Rs. 50 to 100 per acre for agricultural operations i.e. purchase of seed, manure etc.

The Agricultural Department kept a fleet of twelve bull-dozers and two motor-graders and gave them on hire for land levelling. On account of use of machinery, the average cost of levelling with these bull-dozers was only about Rs. 70 to 80 per acre. The loan incentive enabled a quick development of the project, for out of 38,000 acres, 35,000 acres have been developed in 3 years. This indicates that assistance to the farmers should be given not only by providing them with water but also with other essential ancillaries, if intensive development is to take place.

In the modern age, scientific research in every walk of life has become inevitable. That is so in the field of agriculture production also. Research has given remarkable results in the development and use of improved seeds, fertilizers and other productive agricultural practices. Even in the field of irrigation, research is imperative with regard to the optimum requirements of water for crops. This research in irrigation engineering, as well as in agronomy, will lead to considerable economies in water use and enable extension of irrigation. It is found that the water requirement of crops is reduced when the crops are properly manured, and if water is supplied at the proper times. It has also been found that the frequency of irrigation is more important than the depth of irrigation.

All these benefits of research, fertilizers, better seeds and implements, however, can only be sparked off by adequate supplies of water to the land. Irrigation is, therefore, the essential starting point and, I venture to believe, is the real panacea for the food and raw material shortage that is haunting the expanding population of the NESA region today. But there is no denying that irrigation must go hand in hand with the best agronomical practices. Rightly paired and rightly yoked, irrigation and irrigation practices can take the economy of every country and of the whole region at a fast pace to self-sufficiency in agricultural production.

I wish you all, our distinguished guests, a happy stay in India and interesting and fruitful deliberations.

INAUGURAL ADDRESS

by

Sardar Swaran Singh

Minister for Food & Agriculture, Government of India

Dr. Rao, Mr. Wood and friends :

It is a matter of great pleasure for me to welcome you all to the Near East-South Asian Irrigation Practices Seminar, the fifth of the series to be held in this predominantly agricultural region. You are well aware of the benefits that accrue from the pooling of experience gained in different countries, the sharing of advances in scientific knowledge and the application of collective wisdom to the solution of common problems. In a world in which science and technology alone hold out the promise for bringing the widening gap between requirements and availabilities, technical cooperation and assistance is at once the right and obligation of human beings in all societies, developed or developing.

I have great pleasure in expressing my appreciation, at the outset, of the help and cooperation which the United States Agency for International Development has given in arranging this Seminar in India. It is with their initiative and enterprise, that it has been possible to arrange this assembly of top ranking scientists and technicians from 9 countries.

A very rapid growth of population and shortage of food is a problem common to all countries that are participating in this Seminar. Their land and water resources being limited, they are finding it a matter of vital necessity to make every effort to meet the needs of their growing population. Agriculture is the principal activity in all the countries of the region, but it suffers from some common basic handicaps, such as subsistence level of agriculture with outmoded techniques, fragmentation of holdings, general shortage of good seeds, chemical fertilizers, improved implements and lack of irrigation facilities—factors which ultimately lead to low crop yields. Shortage of trained personnel to educate, demonstrate and impart technical know-how to farmers under actual field conditions is also responsible for the slow adoption of scientific farming methods by the farmers. Frequently farmers fail to respond to new techniques due to lack of adequate finances.

All the developing countries taking part in the Seminar have been engaged in rapidly building up irrigation potential to meet the challenge of continuing shortage

of agricultural commodities. Little need be said as to the importance of irrigation to agricultural production. The supply of irrigation water makes the farmer less dependent on the gambles of fluctuating rainfall conditions. Secure in respect of this important input factor, the farmer feels more confident in undertaking intensive cultivation methods ; the cropping patterns change, transforming subsistence farming into scientifically managed business enterprise. There is, however, between the creation of irrigation facilities and their end use, *i.e.*, agricultural production, an important phase comprising water management and irrigation practices, which presents considerable scope for improvement in the NESA region. Irrigated agriculture will produce maximum and sustained results only when modern technology finds its due place in this phase of irrigation development.

The scientists and technicians who are gathered here will, I am sure, give their best consideration to the problems of this important phase in the light of their individual experience, and try to formulate their recommendations on measures which are best suited under the agro-economic conditions prevailing in the region. Although solutions to specific problems may vary from region to region, the exchange of information and pooling of knowledge will, I am sure, go a long way towards stimulating thought and action in the right direction.

The development of agriculture in India is of paramount importance, as it directly affects the fortunes of more than 70 per cent of its population entirely dependent on agriculture in one way or the other. Development of agriculture is basic to all industries. It is agricultural production which supplies raw materials to many of our industries. It is by raising agricultural production that we seek to supply the increasing demand for food from persons employed in other sectors of the economy. Increased production of exchange earning commodities like tea, coffee, oilseeds, etc., is also indirectly of great assistance to those sectors of development, which require considerable foreign exchange for their maintenance and growth. Besides, agriculture accounts for more than half of our country's national income. Therefore, judged in the over-all context, increased agricultural production can rightly be described as the pre-requisite of all development in India.

There are basically two approaches to achieve this objective of increased agricultural production—one is extensive cultivation and the other intensive cultivation. In India, unfortunately, not much scope is available for increasing area under cropped land. As a matter of fact, out of about 322 million hectares of the total area, as much as 132 million hectares have already been brought under cultivation. Our forests constitute only about 17 per cent of the total area which, I believe, is low as compared to many other countries. It is not desirable to allow any further denudation of this national wealth. Recognising this limitation, the future of Indian agriculture would appear to lie in concentrating more and more on the lands that are already under the plough with a view to maximising the yield without detriment to their long-term fertility. With this end in view, India has launched upon an Intensive Agricultural District Programme or what is commonly called the 'Package Programme' with the assistance of the Ford Foundation. Under this programme, all possible facilities are being provided to the cultivators, such as application of scientific know-how, the provision of fertilizers, pesticides, improved seeds, improved implements, liberal credit and composite scientific demonstrations in

selected districts all over India, having maximum irrigation facilities and minimum natural hazards, in order that the greatest potentialities for rapid food production can be realised in record time.

Driven by climatic conditions and forced by sheer necessity, man has developed the art of irrigation over the ages taking advantage of the mighty rivers that were otherwise flowing waste to the seas and of the groundwater storage which was available underneath. Thus sprang up intensive net-work of irrigation systems large and small and today the practice of irrigation is recognised as a *sine qua non* for agriculture under arid and semi-arid conditions. Under humid conditions also in many areas, irrigation plays a significant role. Starting with about 0·80 million hectares towards the beginning of the 19th Century, the irrigated area in India increased up to about 20 million hectares in 1947 when the country attained Independence. Since then this figure has registered a further increase of about 8 to 10 million hectares by now. Great emphasis is being laid on further development of irrigation from large multipurpose river valley projects as well as from small minor irrigation works, such as wells, tubewells and tanks. We hope to expand irrigation facilities to about 70 million hectares in another 20 years or so.

At the present stage of development in India when there is keen demand for irrigation in all parts of the country and irrigation facilities are being created at a fast pace, it has become imperative that the irrigation practices adopted by the farmers are of the highest standard practicable under the local conditions. Our customary and traditional methods of water distribution and application are based primarily on plentiful supply of irrigation water and free availability of cheap labour—conditions which are no more feasible in present circumstances. There is growing need now that modern technology and science be applied to this phase of irrigation development in an increasing measure. It is essential not only to attain economic and expeditious utilisation of the costly irrigation water made available but also to maintain fertility of the soil and avoid hazards such as water-logging, salinity and alkalinity.

The development of the water management phase presents many problems in India. In the first instance, the small holdings of the individual cultivators become a major obstacle in proper, timely and equitable distribution of water among the cultivators. It is not altogether easy to undertake measures for preparing the land for the optimum use of irrigation ; frequently these measures can be taken effectively only by means of collective action on the part of the landholders backed by technical and investment assistance from outside. They are not always able to combine their efforts sufficiently for timely construction and maintenance of field channels. Alignment of field channels frequently suffers and the construction is delayed because the small cultivators do not willingly part with the portion of their already small holdings. Local village institutions are now being increasingly charged with the responsibility of removing these difficulties through persuasive and cooperative efforts.

Quite a sizeable percentage of irrigation water is lost by seepage in the field channels. It is, therefore, desirable that field channels should be lined. On tubewells and some of the canal systems, the first mile or more of the field channels are

lined at Government cost. The financial position of the cultivator does not, however, permit him to line the field channels by conventional means, namely, cement concrete, and brick masonry. Concerted efforts are, therefore, being made to evolve economical methods of lining which might widely be adopted by the cultivators. Steps are also being taken to devise cheap water control equipment which may be used by the cultivators on the field channels to regulate the irrigation supplies with minimum loss of water.

Preparation of individual fields is an important aspect of water management as considerable amount of water is wasted if fields are not levelled and prepared properly. The Indian cultivator in the past had mainly dependent upon manual labour and man-operated implements to prepare the fields for application of irrigation water. Although the methods of irrigation adopted and the tools used displayed considerable ingenuity and were suited to the conditions then prevailing, they present considerable scope for improvement in the light of the technical developments that have taken place since. Efforts are, therefore, being made in India to evolve cheap bullock drawn implements which may help the cultivator to prepare his fields more efficiently and economically.

A major problem of water use arises in India when irrigation is introduced in areas where the crops were previously dependent on rainfall. Successful change from rain-served cultivation to irrigated farming requires orientation in the cropping pattern and also in the techniques of preparing fields and other agricultural practices. This necessitates the dissemination of knowledge among the farmers, arranging demonstrations of cropping patterns and irrigation practices and providing them with cheap implements for levelling and preparing of fields. A large number of specially trained personnel is required for handling this work. Extensive research becomes necessary in regard to irrigation methods, optimum depths, frequencies of irrigation, irrigation requirements of crops, improved implements and equipment for preparing fields, regulation and distribution of water. As the soil and climatic conditions vary widely from region to region, research is required to be planned on regional bases covering all the representative sections of the country. Steps have been initiated in the country in these directions.

Development of improved irrigation techniques, methods and practices in a developing country entails spade-work in many spheres including research, training, education, community development, extension and demonstration. This is necessary to evolve new techniques on a scientific basis and educate the cultivators in their use. The cultivator has a basic role to play in all irrigation and agricultural development. It is the cultivator on the land who has finally to produce crops. The task is to place in his hands the technical 'know-how' and the tools to do the job. In addition, the cultivator has to be provided with credit and capital ; assured supplies of improved seeds, fertilisers, implements and adequate marketing and storage facilities for his products. All activities of planning, construction, research, training, community development and extension have to be integrated and oriented in a way so as to provide the requisite financial, technical, material and organisational support to the farmer.

Involvement of many agencies is required in the endeavour. Starting with

individual farmers at the field level, the village communities (Panchayats), the district councils (Parishads), the State Government technicians and experts in the Departments of Irrigation, Agriculture and Community Development at the Blocks, the Districts and right up to the State headquarters—all have to be geared and oriented to a single objective : giving support to the farmer in his enterprise. To coordinate activities of the various Departments, the Government in the States have set up Working Groups, Committees and Boards at various levels. At the National level, the Ministries for Food and Agriculture, Irrigation and Power and Community Development and Cooperation and the Planning Commission are concerned with the problem of irrigation and water use. A high-powered Agricultural Production Board which includes representatives from all concerned Ministries has been set up with a view to ensuring an integrated approach in all matters and policies pertaining to irrigation and agricultural development.

Gentlemen, I have dealt in brief with some of the main problems that concern us today in the field of irrigated agriculture. I am sure you will deal with them and recommend solutions based on your own experience. The collective wisdom will, I have no doubt, help greatly in formulating policies and planning measures for future implementation and lead to overall development of irrigated agriculture in the NESA Region as a whole.

With these remarks, I have great pleasure in inaugurating this 5th Irrigation Practices Seminar and wishing its deliberations every success.

VOTE OF THANKS

by

Shri Mahavir Prasad

Irrigation Adviser, Government of India

Hon'ble Minister (F & A), distinguished guests and fellow delegates :

On behalf of this gathering, I have the rare privilege to respectfully thank you Sir, for having very kindly inaugurated this Seminar. I am sure that the deep interest you have in agricultural production and the expansion of irrigation will be a source of great encouragement to us in our deliberations. We are also grateful to the Hon'ble Minister (I & P) to have spared the time to address us. His observations born out of a varied experience of Irrigation Engineering, would be particularly helpful to us in our deliberations. We feel, Mr. Tyler Wood, honoured by your gracing us. We are also lucky in having our Secretary, Mr. G.R. Kamat to guide us in the development of irrigated agriculture.

2. The present Seminar is the 5th in the series that was started on the initiative of US AID some time in 1956 at Turkey. Assembled here are 35 distinguished delegates from 9 countries. In addition, several international associations have sent observers and we have here representatives from International Commission on Irrigation and Drainage, F.A.O., Ford Foundation, and the Rockefeller Foundation. Agricultural Research Service of the United States Department of Agriculture is also represented. Such a representative gathering affords a unique opportunity for discussion of problems of mutual interest and for exchange of ideas and experience.

3. You have rightly mentioned, Sir, in your speech that science and technology should replace traditional methods and ensure efficient water use. After a close study of local conditions and problems we, in India, are taking steps in this direction, particularly on the large number of surface reservoirs that we are completing and the extensive system of tubewell irrigation we are arranging from our groundwater resources. We eagerly look forward to the Seminar for a narration by other countries of their experiences in this direction. We expect the Seminar to set out :—

(*a*) the essential requirements of successful scientific irrigation under varying conditions ;

(*b*) the opportunities and also the limitations which exist in different countries for the application of scientific irrigation in field ; and

(*c*) the methods and procedures adopted in different countries for conveying results of research and on Extension work.

India, as you know, Sir, has quite a high irrigated area employing many

methods of exploitation of water resources. We would gladly share our experience with the visitors.

4. We have laid out two field trips for the participants of the Seminar. Due to limited time, the field trips have had to be arranged within 100 miles from Delhi. For this reason, it has not been possible to fix a visit to South India which specialises in interesting tank irrigation.

5. We have also tried to lay out a programme that would provide occasional rest and relief from the rather heavy discussions that are scheduled for the Seminar. We trust that the visitors would enjoy their stay in Delhi.

6. Friends in US AID and colleagues in the Ministry of Food and Agriculture have worked with great zeal in organising this Seminar. The willing hard work of Shri J.K. Jain, Deputy Irrigation Adviser, Mrs. Chatterji, under Secretary and Mr. Dave deserves special mention.

OPENING REMARKS AND ORIENTATION

by

Dean F. Peterson

Seminar Adviser, US AID

Mr. Chairman, Delegates and Friends :

I am both grateful and happy to again be with you in a NESA Irrigation Practices Seminar. By now many of you have become old friends and it is good to see you again. I look forward to working with you and with the new friends I hope to make at this time. May the next two weeks be profitable for us all.

PRESENT STATUS OF SEMINAR

I would like now to sum up the present status of our seminar effort. Where are we and what are we trying to accomplish ? To do this, I propose to draw on two sources of information : (1) the report of the Fourth Seminar held in Ankara in 1962 and (2) observations made as a result of my visits last summer to most of the countries participating in the present seminar.

I hope you have all had the opportunity to study the report of the Fourth Seminar. The Fifth Seminar should be particularly attentive to Chapter II. "Recommendations" of that report. One copy of the report has been provided to the head of each country delegation. There are some additional copies available from the secretariat of this seminar.

The Fourth Seminar considered desirable objectives for the present one. It recommended that future seminars should, if I may paraphrase :

1. Be concerned with the problems of water management on the farm as they relate to increased agricultural production and land conservation.

2. Recognise that such management depends on many resources which must be at the disposal of the farmer and that these must be integrated into irrigated farm production practice at the farm level.

3. Include planning, engineering and constructions related directly to on-the-farm production.

4. Give consideration to project water supply and drainage system planning, engineering, and construction insofar as these factors are related to the capability requirements for on-the-farm production.

May I suggest that you carefully study these four points. I believe that you will find that they relate directly to the practical tasks which you, as leaders in irrigation agriculture in your respective countries, need to accomplish if increased production is to occur, that is, the farmer must exercise good irrigation practice, both in order to produce optimum crops and to conserve the soil resource. He must do this in conjunction with other good agricultural practices. As a corollary, farms and farm irrigation systems must be properly designed and developed to achieve these objectives and the basic water supply works should be capable of meeting the optimum production requirements of the farm units.

The Fourth seminar also suggested desirable topics for consideration by this one. The list included: (1) Drainage and Salinity, (2) National Programmes to Improve Irrigated Agriculture, (3) Education and Training, (4) Farm Layout, (5) Small Projects, and (6) Research, particularly the results of application of research. These topics were described in considerable detail and you may wish to consult the Fourth Seminar report for further explanation. These topics have been listed for discussion by the Fifth Seminar.

I have tried briefly to restate our objectives. May this review be helpful to you during the next few days of deliberations.

FIELD VISITS

As many of you know, I spent approximately two months last summer visiting in most of the various participating countries for the purpose of reviewing progress and identifying topics which might profitably be discussed by this Seminar. Countries visited included United Arab Republic, Jordan, Lebanon, Turkey, Iran, Iraq, Afghanistan, Pakistan, and India. Perhaps some highlights of my general impressions and observations will be helpful to you.

CONSTRUCTION *VS.* AGRICULTURAL PRODUCTION

In most countries the resources allocated to construction of new water supply works for irrigation; that is, the money invested and the manpower allocated, continues in my opinion, to overshadow the efforts made to improve the other factors directly relating to production and conservation on irrigated farms. It will be difficult to bring these complementary efforts into balance. Constructed works are tangible results of engineering effort and the techniques which translate ideas into reality are clear cut and well understood. This is not the case with agricultural production, especially under irrigation, where success involves the efforts of large numbers of individual farmers.

It is encouraging, however, that most countries have increased the efforts devoted to improving irrigation production and conservation. Some are doing much more than others, but the trend is in the right direction. In spite of these efforts, in most countries agricultural production is not yet in a position to fully utilize the new water supplies being brought in and there is grave danger in many

places that misuse of these new waters may result in waterlogging and salinity problems, or that difficult social problems may arise in connection with settlement or re-settlement.

CO-ORDINATION OF PROJECT PLANNING WITH AGRICULTURAL NEEDS

I am happy to report also that in many of the countries visited, engineering organizations responsible for the development of irrigation water supplies are giving increased attention to requirements for agricultural production and conservation in their project investigation and planning activities. In all countries that I know of responsibility for agricultural production and conservation is assigned to authorities other than the one having responsibility for constructing and operating water supply works. Too frequently irrigation projects have been developed without adequate attention to such production and conservation factors as land capability, optimum water requirements, and drainage. These shortcomings can be remedied only by realistic evaluations of agricultural production factors, including settlement or resettlement at the planning stage. Close liaison must be maintained with those organizations responsible for agriculture and by providing capability for agricultural evaluation within the development organization itself. I note that in several countries, this liaison has improved and, in some instances, agricultural evaluation capability is being added to the planning branches of the developmental organizations. While these are gratifying steps, I personally feel that much more needs to be done. Too often dams and canals are designed to serve the water supply pattern of nature or for engineering convenience without much consideration being given to the needs of the farmers. This is fine if all that is desired is subsistence farming. Modern, high production irrigated agriculture cannot occur unless the works are made servants of the farmers. This condition can be remedied only by realistic consideration of agricultural production and conservation needs at the project planning stage.

EXTENSION AND FARMER ASSISTANCE PROGRAMMES

Generally more attention is being given to extension and farmer assistance programmes. More technical information is reaching the farmer and this is of improved quality. Many times, however, he does not have the resources at hand to take advantage of the new information. He may lack capital, or credit, or required improvements may be beyond his control, for example he may need new drainage or irrigation ditch rights-of-way, or the schedules for distribution of water to him may need to be revised. Sometimes required materials are not available on the market. I find that, generally speaking, conditions are gradually being improved. With increasing population, however, I fear the rate of improvement may not be fast enough. I have great faith in irrigation farmers. If they have profit incentive ; if soil conditions, water supply, and drainage are adequate ; if technical information and materials are available ; and if certain roadblocks beyond their control are removed they will go ahead.

EDUCATION AND TRAINING

While these findings are encouraging, some others are not quite so satisfying. The past two seminars have been concerned with education and manpower problems. The report of the Fourth Seminar outlined the task at hand very nicely and

considered the various categories of training needed: (1) Farmers, (2) Village Extension Workers, (3) Sub-professional and (4) Professionals. While I find qualified and reasonably adequate staff at the professional levels the lack of trained manpower in the other categories appears to me exceedingly critical. I feel that adequate and realistic steps are not being taken to close this manpower gap. There is the professional at one end and the farmers at the other, but the communication is bad because of the lack of middle manpower. A great many more people properly trained and willing to work in the field with the farmers are badly needed. Numbers must be increased and quality improved, both by training in schools and on-the-job. These efforts should be kept at the vocational level. They should stress "getting the job done" in the field, on the farms. This cannot be done in the office or in the laboratory.

ORGANIZATIONS AND INSTITUTIONS

I find also that my friends, in the government services are well informed on technical matters. They know what the farmers should be doing, but they do not know how to get them to do it. Here again there is a gap between theory and its application. The organizations, or the "institutions" if I may call them this, are not adequate to the task. Thus only frustration results. In the United States a large share of responsibility has been assumed directly by farmers themselves, often through farmer organizations. Many of the things which an individual farmer cannot do for himself are done by such organizations and institutions. Some of these institutions are entirely voluntary, others are government sponsored and some may have official status. These organizations and institutions are of special importance in irrigation and conservation; because, in utilizing a water resource, large numbers of people must work together, usually with governmental agencies, including states and communities. I think agricultural programmes are most successful when they involve the farmer in solving his own problems to the fullest possible extent. Effective Institutions are organizational devices, laws, and customs adopted in order to accomplish desirable objectives where action requires cooperative efforts of people. They bring the farmer into the picture, place greater responsibility on him, and shorten the path between him and his government. I do not know how to cause them to develop, and probably they should take different forms in the various countries. One point is clear, it is important that the farmers become full partners in the irrigation effort. They must be brought into the picture as early and as effectively as possible. With these objectives in mind; one session of the seminar has been allocated for discussion of this topic.

The Fourth Seminar urged that the United States increase its role as a technical participant in the seminar other than only as adviser. While it has not been possible to prepare a U.S. Country Report, two papers by U.S. authors are scheduled. To this end, US AID employed an experienced American conservationist Mr. John Spencer as a special consultant to prepare on "The Institutional Base for Irrigated Agriculture in the United States". Fortunately it has been possible to make arrangements so that Mr. Spencer will be in India to present this paper in person.

RESEARCH

Some good irrigation research programmes are developing. This is very

desirable and should be encouraged. There are some programmes which seem to be researching material for which adequate answers have already been found. As far as irrigation water management is concerned, I believe irrigation practice in the Near East — South Asia region could advance a long ways beyond its present state by simply placing in practice the basic scientific principles already known. Field studies and pilot studies to determine water and drainage requirements optimum cropping patterns and fertilizer practice at particular locations with the objective of reducing known basic principles to specific practice are badly needed and should receive priority over more abstract and generalized research.

There is much interest in research on water requirements and consumptive use. This is oriented to the needs of crops in relation to climate. Part of the task of irrigation practice, including drainage, is to reclaim and conserve the soil. Sometimes water requirements for this purpose are different than for immediate cropping objectives. This is especially true in arid, hot areas. I would like to see the problem of water requirements approached from the point of view of soil conservation as well as from that of crop requirements.

OPERATION OF THE SEMINAR

COMMITTEES

The Fourth Seminar formed six task committees. These committees made special studies and wrote recommendations on : (1) Education and on-the-job Training, (2) Agricultural Requirements for Irrigation Projects, (3) Service Programs for Irrigated Agriculture, (4) Operation and Management of Irrigation Projects, (5) Field Irrigation Research, and (6) Waterlogging, Salinity, and Alkali Problems. I believe that these recommendations were excellent. The Seminar will need to consider whether or not it wishes to add to or amend the previous recommendations. It may wish to consider other new topics as well as urge the delegates to give early study to this matter.

An important committee is the Executive Committee, which consists of the heads of each country delegations and myself as ex-officio member. This Committee will meet immediately following this address. One of the items of business will be to decide on committee business and membership.

ACKNOWLEDGEMENT

Before closing may I say something about the work that India has done in preparation for this seminar. Activities have been planned and arranged under the leadership of the Ministry of Food and Agriculture. The principal responsibilities have fallen upon a committee which includes also members from the Central Water and Power Commission and the Ministry of Community Development. Much affective work must be done to prepare for an International meeting like this one. I think you will find the arrangements and facilities superb.

Again I extend my greetings to you with best wishes and the sincere hope that the Seminar will be worthwhile and helpful.

CHAPTER II

RECOMMENDATIONS

Panel I

EDUCATION AND TRAINING

The Committee realises that one of the major causes of extremely low and inferior crop yields in most NESA countries is the lack of adequate training and education of personnel connected with agricultural development at various levels. It concurs with the recommendations of the Fourth Seminar. In addition, it wishes to make the following recommendations.

PROFESSIONALS.

1. Practical aspects of farm irrigation must be emphasized on training at this level.
2. Exchange of experienced post-graduate level personnels including those in teaching and technical supervision.
3. Encouragement of professionals to prepare manuals for use by lower-level personnel.
4. Encouragement of professional personnel in participating countries to exchange technical information.

SUB-PROFESSIONALS.

1. Orientation in irrigation training courses for a duration of two to twelve weeks (land levelling, farm layout, water use, drainage, etc.)
2. Making available a government training farm to facilitate the practical training of village level sub-professionals and farmers.
3. Training extension workers on irrigation practices.

VILLAGE EXTENSION WORKERS.

Training of village extension workers in two aspects :

a. Land and irrigation system development ;

b. Crop production including water use.

In order to accelerate programs, consideration might be given to training separate personnel for each task.

FARMERS.

1. Making available small model demonstration farms for training farmers on agricultural methods.
2. Actual field training of farmers in their own farms.
3. Organization of farmers field trips and demonstrations of improved agricultural practices on progressive farmers' farms.

IMPLEMENTATION.

1. Allocation of a minimum of one per cent of project budgets for training of government workers on land development and irrigation, one per cent for training and maintaining project extension agents and one per cent for cost of demonstrations and farmer's training. (At least 2 per cent of the project budgets should be allocated for technical services in designing and laying out farm irrigation systems).
2. The Committee cannot over-emphasize the importance of the formation of a standing committee whose function is to be the promotion of exchange of information between participating countries within periods between Seminars.

Panel II

OPERATION AND MANAGEMENT OF IRRIGATION PROJECTS

The panel agrees with the views expressed on the subject by a similar panel at the last Seminar. The following further suggestions are recommended :

1. The operation and management of irrigation and drainage products or portions of them should be gradually transferred to the beneficiaries through their own self organized associations if and when the state considers them qualified. Such organizations should be of a nature, size and pattern as will best fit the needs of the particular project or project entity. Operation and maintenance costs and collection responsibilities should also be transferred gradually to the beneficiaries.
2. The state should assume the responsibility for major operation and repairs on such projects as dams, reservoirs, hydroelectric plants, and multi-purpose structures, etc.
3. Hydrology sections for water supply forecasting should be set up as soon as possible to gather necessary information for proper water distribution and crop planning.
4. Ground water recharge programmes should be initiated in countries where such resources may be exploited.
5. There should be close liaison between operation and management and the planning and design of projects.

Panel III

FIELD IRRIGATION AND DRAINAGE RESEARCH

Part I.

It is recommended :

That the importance of field irrigation research be given special consideration by the countries represented in the NESA Irrigation Seminar.

That these countries realise that without research their prospects of progress along water and land used lines are very limited.

That, in the light of the above two recommendations, the Governments of the countries participating in the NESA Irrigation Seminar do their utmost to relieve irrigation research specialists from administrative duties and provide them with adequate remuneration so that they, in turn, may devote their full time and endeavour to greater productivity.

That in the future the NESA Seminar include as many participants as possible from among research workers for a better understanding of common problems and improved methods of solving them.

That immediate arrangements should be made to lay out common bases for each subject of research by specialists, and that the pertinent instruments and apparatuses should be available to all research workers in the participating countries. This procedure will help in the formulation of the results obtained in an international form and make their application more practicable.

Part II.

It is further recommended :

a. That the countries participating in

the NESA Irrigation Seminar be encouraged to establish research stations in their project areas.

That experimentation and research be carried out also on individual farms in these project areas as part of the project research program.

b. That project research programs be of a continuous nature and that simultaneous interpretation of data and implementation of results be carried out.

c. That research workers publish the results of their work in the form of technical bulletins to be made available to qualified personnel, and that extension departments carry responsibility for disseminating the information thus received by means of extension bulletins especially simplified and prepared for the benefit of farmers.

d. The need for the establishment of a technical cell or cells at the centre in each of the countries be considered for the planning and coordination of studies on irrigation practices, water requirements of crops and drainage investigations, to watch the progress of these studies, give technical guidance, and ensure the provision of necessary facilities and equipment.

Part III.

It is recommended and suggested by the Committee that major research work be carried out in the following fields :—

1. Irrigation
   - a. Timing of irrigation
   - b. Water requirements on the basis of consumptive use
   - c. Assessment and control of conveyance losses in field ditches
   - d. Sedimentation
   - e. Development of devices for the measurement of field irrigation water
   - f. Methods of irrigation, evaluation and standardisation
   - g. Standards of quality for irrigation water
2. Drainage
   - a. Evaluation of drainage water
   - b. Methods of measuring soil permeability in field, improvement and development
   - c. Effectiveness of covered drains *versus* open drains
   - d. Most Economical depth to water table for different crops under different soil and climatic conditions
   - e. Effect of irrigation water on salinity of drainage water
   - f. Effect of drainage on quality of irrigation water
3. Soil
   - a. Soil moisture measurement, development and devices
4. Crops
   - a. Cropping pattern
   - b. Crop rotation
   - c. Fertilizers
5. Weed control.

Part IV.

It is also recommended that more emphasis be placed on research on irrigation and drainage in future Seminars.

Panel IV

WATERLOGGING, SALINITY AND ALKALI PROBLEMS

The recommendations made by the 4th Seminar on Waterlogging, Salinity and Alkali problems were reviewed. Recommendation Nos. 1 and 2* were considered adequate and should continue to be implemented.

Regarding recommendation 3 ; *i.e.*

3. "More emphasis be placed on drainage, salinity and alkalinity problems in the curricula of engineering and agricultural colleges".

The committee was of the opinion that this required clarification.

Instead of including this subject in the undergraduate curricula of Engineering and Agriculture Colleges, consideration might be given to suitable study as a post-graduate course or on-the-job training. For reporting on data and research investigation a standard method and technique should be followed. The committee strongly recommends that in order to have effective implementation of the recommendations made at the Seminar each country should appoint a small committee to follow up recommendations made by them at the time of the Seminar. For this purpose one-year periodic reports on the progress of work should be submitted to the chairman of the committee by each member of the committee who will send a condensed report to the Co-ordinator of the Seminar with a copy to the individual member of the committee.

The broad out-lines for this report follow :—

I. Diagnosis of the problem of waterlogging, salinity and alkali.
   i. Surveys and collection of data.
      a. Soil survey.
      b. Hydrological survey.
      c. Collection of meteorological data.

II. Planning of waterlogging, salinity and alkali control projects.

III. Execution of waterlogging, salinity and alkali control projects.

IV. Special points and problems arising during planning and execution.

V. Progress of projects.

VI. Achievements.

The committee feels that there was lack of co-ordination between the various member countries and not enough exchange of notes and information. Each country should send to other countries, through their representative, all the literature available on the subject.

Recommended Research

1. Study of the effect of drainage water disposal on river water quality.
2. Salinity hazards and method of reclamation of saline soil.
3. Crop adaptation to saline, alkali and waterlogged environment.
4. Economic means of improving saline water from wells, drainage water, or river water for irrigation.

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* 1. It is highly stressed that adequate attention be given to the problems of waterlogging, salinity and alkali in :

(*a*) Project investigation, planning, and design

(*b*) Installation of facilities for successful project operation

(*c*) Operation and maintenance, including field scale research and extension work

"There should be close co-ordination among these three phases."

2. "Drainage investigations should also include the root zone and the hydro-geology that is pertinent to a project as well as soil drainage and waterlogging."

Panel V

FARM IRRIGATION AND DRAINAGE SYSTEMS

The majority of the countries are faced with difficulties of conservation of limited water resources. Properly planned and constructed farm irrigation and drainage systems play an important role in increasing production, conserving water and utilisation of farm labour. It is, therefore, recommended that each country give serious consideration to management and distribution of water through improvement of farm irrigation and drainage systems.

The Committee recommends that :

1. Farm irrigation and drainage systems be given priority in planning new projects and that such planning be done simultaneously with other phases of project development ;
2. in the future NESA Seminars, technical papers and discussions on improved methods of constructing and operating farm irrigation and drainage systems should be included in the programme ; and
3. farm irrigation and drainage systems should include the following items :—

A. Water distribution and Farm Drainage.

(i) Proper planning, designing, construction and maintenance of field (tertiary channels or field channels).

(ii) Lining of field laterals for saving seepage losses in transit.

(iii) Examination of the possibility of introducing the use of pre-cast irrigation channels for distribution of irrigation water.

(iv) A rational system of schedule for distribution of water among irrigators.

(v) Introducing improved water control equipment and structures including water measuring devices for regulation and diversion of supplies from the field laterals.

(vi) Proper planning, designing and lay-out of farm drainage channels in relation to the irrigation distribution system and as an integral part of the main drainage system of the tract.

(vii) Choice of the proper type of drainage system, *i.e.* whether open drains or tile drains, after taking into account local conditions of soils, topography, stratigraphy drainage requirements etc., and the relative advantages, disadvantages and economics of the two systems under these local conditions.

(viii) Entrusting the responsibility for construction and maintenance of field laterals and drainage channels to the cultivators/village institutions.

(ix) Supporting the cultivators by adequate finances and technical guidance in alignment, lay-out, placement, spacing etc., of field laterals and drainage channels.

(x) Introducing legislation enabling intervention by Government in case of default to construct or maintain field laterals drainage channels by the cultivators/village institutions.

(xi) National land consolidation programme for better farm irrigation and drainage systems.

B. Application of Irrigation Water.

(i) Adopting sound irrigation methods on a scientific basis in relation to crop soils, climate, stream water discharge, etc., and proper preparation of fields according to the methods adopted.

(ii) Introducing improved implements suited to the draft power available locally.

(iii) Advising cultivators on proper scheduling and depth of irrigation applications.

(iv) Evolving and popularising simple methods which the cultivators may conveniently adopt for knowing when to irrigate and how much to irrigate.

C. Cropping Patterns.

(i) Introducing intensive cropping pattern and scientific crop rotations, suited to irrigated agriculture.

(ii) Achieving best possible coordination between the irrigation demands of the cropping pattern and the supplies made available on the irrigation systems.

Panel VI

STANDARDS FOR IRRIGATION AND DRAINAGE INVESTIGATIONS

In the previous four Seminars the subject "Agricultural Requirements for Irrigation Projects" was widely discussed and detailed recommendations were made. The implementation of the various recommendations centres on the establishment of complete cooperation and coordination among the different organisational agencies, *i.e.*, Irrigation Agencies, Agricultural Experts Extentionists, Agronomists and Soil Scientists.

This panel feels that this cooperation and coordination at top levels only, as is the case in most of the countries, will not be the solution ; but should exist at all levels. Hence, the panel recommends that positive action be taken by all the countries to bring about such cooperation and coordination among the various organisations from the country level down to field officer levels.

The 4th Seminar recommended considering all the phases of development required to produce irrigation and drainage projects which will have the most beneficial impact upon the economic development of the nation concerned. After preliminary studies have been made, for projects where feasibility is indicated, the following considerations should be taken into account during the investigations of irrigation and drainage systems. These are considered essential for design purposes. (The list is not necessarily all inclusive) :

(1) Topography
(2) Hydrology
(3) Meteorology
(4) Soil and Land Classification
(5) Land Use and Development
(6) Drainage Requirement
(7) Agricultural Production
(8) Agricultural and Water Economy
(9) Communications
(10) Power and Industrial Needs
(11) Domestic Water Supply
(12) Water Planning
(13) Geology
(14) Groundwater Supply
(15) Sociological Survey
(16) Human resources
(17) Marketing

It is recommended that :

1. The degree and extent to which the investigations are carried out should be such that a reasonable estimate of the benefit-cost ratio can be determined. Allocation of water use should usually be made to those producing the greatest benefit in relation to the cost.

2. Due to the existence of inadequate or incomplete standards in NESA countries the standards to be adopted for these investigations should be similar to those developed by internationally known agencies to the fullest extent possible.
3. This panel has noted that each country has trained technicians in many of the fields and has utilized the services of foreign consulting engineering firms for many years. However, they have not developed specific standards for the respective countries. The panel feels that the several countries should develop their own standards. Each country should submit such standards for any one or all of the fields of activities for consideration and discussion at the next regional seminar.

MEMBERSHIP OF THE PANELS

Panel I -- Education and Training

Dr. Jamil Al-Malaika, Iraq, Chairman
Shri S.V. Patil, Mysore, India, Secretary
Dr. M.T. Eid, U.A.R.
Mr. M. El-Madany, U.A.R.
Mr. Said M. Ghezawi, US AID, Jordan
Mr. Emory M. Howard, Jordan
Mr. Abdollah Jenab, Iran
Mr. Dursun Kesimoglu, Turkey
Shri J.P. Mital, Uttar Pradesh, India
Mr. Irfan Okienoglu, Turkey
Mr. Albert W. Plummer, US AID, Iran
Shri N. Sankaran Narayana Reddy, Madras, India
Shri R. Srivastava, Madhya Pradesh, India
Mr. Abdul Sattar Zia, Afghanistan

Panel II — Operation and Maintenance

Dr. Omar Rashid Gardi, Iraq, Chairman
Mr. Abdul Mahboob Tarrar, Afghanistan, Secretary
Mr. Korkut Alaettin, Turkey
Mr. Ismail Baykal, Turkey
Shri K. Bharathan, Kerala, India
Mr. Ezadin Dagistani, Jordan
Mr. Lufti Dincer, Turkey
Mr. G.M. Dissanayake, Ceylon
Dr. Mohammad Teha Eid, U.A.R.
Shri K.V. Ekambaram, Madras, India
Mr. Dost Mohd. Noori, Afghanistan
Shri R.K. Pandita, Jammu and Kashmir, India
Shri M.S. Purandare, Maharashtra, India
Shri Mahavir Prasad, India
Mr. F. Raji, Iran
Mr. Thomas R. Ramsay, US AID, Turkey
Shri S.N. Roy, Bihar, India
Shri D.S. Sinha, Madhya Pradesh, India
Mr. Carroll F. Wilcomb, US AID, Afghanistan

Panel III — Field Irrigation and Drainage Research

Mr. Mohamed El-Madany, U.A.R., Chairman
Dr. Naji A. Kadir, Iraq, Secretary
Shri V.P. Avadhoot, Madhya Pradesh, India
Dr. Alvin D. Ayers, U.S. Agricultural Research Service
Shri K.L. Bhatia, India
Mr. Ragip Boyaci, Turkey
Mr. Elwood Dull, US AID, Afghanistan
Dr. M.T. Eid, U.A.R.
Mr. Abdollah Jenab, Iran
Mr. Usama Kakish, Jordan
Dr. O.N. Mehrotra, Uttar Pradesh, India
Dr. A. Gani Mitkas, U.A.R.
Mr. Mohammad Hakim Parwana, Afghanistan
Dr. Mukhtar Singh, India

Panel IV — Waterlogging, Salinity and Alkali Problems

Dr. Ahmed M. El-Dujaili, Iraq, Chairman
Mr. Albert W. Marsh, FAO, Secretary
Mr. Ragip Boyaci, Turkey
Shri V.M. Dave, Gujarat, India
Mr. M. Formali, Afghanistan
Shri D.G. Kulkarni, Maharashtra, India
Dr. A. Gani Mitkas, U.A.R.
Mr. Passam Said Nimry, Jordan
Mr. Korkut Ozal, Turkey
Mr. Seref Ozgul, Turkey
Mr. Mohd. Ali M. Rejali, Iran
Mr. Harold Rinnan, US AID, India
Dr. R.V. Tamhane, India
Dr. H.L. Uppal, Punjab, India

Panel V — Farm Irrigation and Drainage Systems

Mr. G.M. Dissanayake, Ceylon, Chairman
Mr. Abdul Majeed Tarrar, Afghanistan, Secretary
Mr. Asghar Azarnia, Iran
Mr. Mohamed El-Madany, U.A.R.
Mr. Mohd. Darwish Hani, Jordan
Shri T.K. Jain, India
Shri N.V. Khursale, Maharashtra, India
Mr. Mufit Kulen, Turkey
Shri S.S. Lamba, India
Mr. James D. Metzger, US AID, Jordan
Mr. Irfan Okienoglu, Turkey
Shri S. Pani, Orissa, India
Shri B.D. Rathi, Uttar Pradesh, India
Shri P.S. Yog, Uttar Pradesh, India

Panel VI — Standards for Irrigation and Drainage Investigations

Mr. Seref Ozgul, Turkey, Chairman
Dr. R.V. Tamhane, India, Secretary
Mr. Rodger Collons, US AID, Turkey
Shri J.K. Jain, India
Mr. George C. Knierim, US AID, India
Mr. Mufit Kulen, Turkey
Shri J.P. Mital, Uttar Pradesh, India
Shri V.T. Motwani, Gujarat, India
Shri G.A. Narasimha Rao, Andhra Pradesh, India
Mr. Haider Ali Noordi, Afghanistan
Shri R.C. Patro, Orissa, India
Mr. Mohamed Ali M. Rejali, Iran

CHAPTER III

CLOSING SESSION

CLOSING TECHNICAL SESSION

Chairman

Shri A. D. Pandit

Special Secretary to the Government of India

The recommendations of the six panels were read and approved. These recommendations are published in full in Chapter III.

REPORT OF EXECUTIVE COMMITTEE

The report of the Executive Committee was presented by Mahavir Prasad and endorsed by the Seminar. This report follows :

1. CONTINUATION OF SEMINARS.

It is recommended that the NESA Seminars continue, since they have proved to be highly beneficial.

2. SCOPE AND OBJECTIVES OF FUTURE SEMINARS.

The Fourth Seminar outlined the scope and objectives of the seminar adequately. These are accordingly restated with minor modifications, agreed upon by the committee. It is recommended that the seminars shall be concerned with the problems of *soil* and *water* management on the farm, especially, as they relate to irrigated agricultural production, drainage and land conservation, recognizing that such management depends on many resources which must be at the disposal of the farmer and whose integration into irrigated farm production practice should receive due consideration. Planning, engineering and construction activities related directly to on-the-farm production shall be included ; and consideration shall be given to basic project water supply and drainage system planning, engineering and construction, insofar as these factors are related to the capability requirements for on the farm production.

The following points are recommended as continuing objectives for the future :

a. Drainage and salinity problems
   (1) Surveys, standards for investigation, evaluation and design
   (2) Actual project experience

b. National programmes for improvement of irrigated agriculture
   (1) How to deal with problems
   (2) How to link with the farmers' resources
   (3) Development of effective institutions

c. Education and on-the job-training
   (1) New training methods programmes and techniques
   (2) Problems encountered and how they are solved
   (3) Interchange on available schools
   (4) Programmes for training farmers
   (5) Demonstration farms and irrigation farming camps in newly developed areas
   (6) Special emphasis on training middle-level technicians

d. Farm layout for an irrigated agriculture
   (1) An acceptable size and configuration
   (2) An acceptable arrangement relative to topography
   (3) An acceptable arrangement relative to irrigation distribution systems and an effective distribution system
   (4) An acceptable arrangement relative to transportation and drainage

e. Small projects
   (1) Organizations, evaluation, development techniques
   (2) Advantages
   (3) Actual examples

f. Technical factors in irrigation practice
   (1) Application techniques
   (2) Soil, water, crop relations
   (3) Salinity control

g. Research
   (1) Directly related to irrigation and drainage
   (2) Application of research

The committee recognizes that irrigation developments are often closely related to village water supply and to health and disease control problems. While these are not considered matters of primary interest of the seminar, consideration may be given to them where appropriate.

It is recommended that information be exchanged on standards and requirements for loan applications for various lending agencies.

3. MODIFICATIONS AND IMPROVEMENTS IN THE PROGRAMME AND PROCEDURES.

It is recommended that the following modifications and improvements be introduced in the programme and procedures of future seminars :

A. The duration of the seminar shall be approximately 2 weeks.

B. To increase the benefits of the seminar, all papers and reports should be prepared and circulated among the participating countries three months before the seminar so that they are available to and read by the delegates before the seminar. If papers are studied by the delegates in advance, more time can be made available for discussions which are of great value.

C. Each paper should have a summary of up to 500 words.

D. The "Country Progress Report" shall report progress since the previous seminar in the fields of irrigation and agriculture and include the problems of the country concerned. It should be prepared according to the outline given below as a guide :

a. Very brief orientation and description of the country and present status of irrigation development. This is intended primarily to refresh the memories of the delegates.

b. Report accomplishments since last seminar, especially as they relate to past recommendations.

c. May briefly mention plans for new water supply developments in order to give meaning to later discussion.

d. Development of institutions and procedures for improving irrigation and drainage at the farm level.

e. Experience and evaluation of such institutional actions.

E. Each country may designate a representative, who with the US AID representative if available and possibly in connection with a Committee shall provide liaison in seminar matters and in the dissemination of information between countries. Agencies in various countries should exchange information directly with similar agencies in other countries. Exchange of personnel of appropriate agencies between countries for inspection, consultation, and training is recommended. Consideration should be given to involving appropriate university personnel to the fullest practical extent.

F. Generally additional time should be provided for discussions. This may require further limitations on the number of papers and possibly on topics covered. Some specialized sessions should be held simultaneously. These should form the basis for reports and recommendations of future seminars.

4. GENERAL TECHNICAL SESSION.

It is recommended that a general technical session be included in the programme to round off those matters discussed in the seminar which are inter-related to some extent.

5. RESPONSIBILITY FOR ORGANIZING AND CONDUCTING FUTURE SEMINARS.

It is recommended that :

A. The U.S.A. should continue to take leadership responsibility for organizing and conducting future seminars.

B. On the other hand, the advisory rôle of the U.S.A. in organizing, programming and conducting the seminars should decrease.

C. A NESA country where a seminar has been held should help the others where future seminars will take place.

D. The aim of B. and C. is to make NESA countries capable of organizing, programming and conducting seminars themselves.

E. The Committee feels that the U.S.A. should take its place in future seminars as a member, as a NESA country does.

Salahattin Kilic, Turkey, Chm.
Mir Akbar Raza, Afghanistan
G.M. Dissanayake, Ceylon
Mahavir Prasad, India
Asghar Azarnia, Iran
Naji A. Kadir, Iraq
Said M. Ghezawi, Jordan
Mohamed El-Madany, U.A.R.
D.F. Peterson, U.S.A.

INVITATION FOR 1966 SEMINAR

On behalf of the Government of Jordan Mr. Said M. Ghezawi extended an invitation to hold the Sixth Irrigation Practices Seminar in Jordan.

RESOLUTION

The following resolution was read by Asghar Azarnia, Iran, and endorsed by the Seminar :

Mr. Chairman and Gentlemen :

The real technical value, usefulness and importance of this Seminar is apparent from the wonderful progressive reports and contribution submitted by the respected delegates from different member-countries.

The Seminar has contributed extensively to the improvement of irrigation and agricultural practices of the Near East — South Asia countries and has been helpful in developing their natural resources.

Arrangement of such seminars requires advance planning and by all means is a very difficult task. The Indian Government has shown the greatest interest in this Seminar and has provided the greatest assistance and hospitality in every possible manner to guarantee the success of the Seminar.

Keeping this in mind, be it resolved that hearty thanks and appreciation be extended to the Indian Government and other cooperating concerns for this wonderful service.

SEMINAR REPORT

by

Dean F. Peterson

Seminar Adviser, US AID

Mr. Chairman, Your Excellencies,
Fellow Delegates :

My task today is to briefly summarize the work of the Fifth Near East-South Asia Irrigation Practices Seminar. In this task I will begin by taking a short look backwards and then I will attempt to summarize what has been accomplished here in the Fifth Seminar.

There is no need to restate, except briefly, the importance of irrigated agriculture to the arid and semiarid lands encompassed within the boundaries of the nations here represented. I think there are four important facts, however, to be considered and I would like to list these here even at the risk of some repetition. These facts are :

1. Irrigated agriculture is either the foundation, or an exceedingly important part of the economy of the Near East-South Asia countries. It is inconceivable to believe that great economic gains can be achieved in any of these countries without very significant increases in irrigated agriculture production.

2. Production gains in agriculture can only be made on the farm, by the farmer. Support efforts such as engineering works, governmental organisations for agriculture, and the work of the private sector in furnishing materials and markets are all of no avail unless they contribute significantly to this end.

3. If a good and timely water supply is available ; use of good irrigation methods, properly co-ordinated with other good farming practices, provides means by which agricultural production can be multiplied, as much as several times in some instances.

4. Irrigation farming, besides having a responsibility for increased production, has the further responsibility of soil conservation and soil improvement. Fortunately techniques for increasing permanent agricultural production and for soil conservation are not in conflict.

I turn now to the past accomplishments of the seminars. These have been covered, not only by the seminar reports, but also during the opening session, so I will make only a brief review here.

A decade ago national leaders in Irrigation Agriculture in the Near East-South Asia region, along with their friends in U.S. Agency for International Development, became aware that knowledge of modern scientific irrigation practice on the farm needed much wider dissemination and application in their countries than was then being achieved. Even though rapid improvement in other agricultural production factors such as seeds, pest control and fertilizer usage were moving apace, poor irrigation and drainage practice threatened to place serious ceilings on production levels might be achieved, and furthermore, to ruin at least semi-permanently, large areas of irreplaceable land. Thus, as one of several steps, a leadership seminar in irrigation practices was held in Izmir Turkey in 1956. Similar seminars have been held successively each two years since in Iran, Pakistan and Turkey. Most of the countries in the region participated in these seminars. Delegates exchanged ideas and developed recommendations for action in several specific areas of endeavour.

Many of these recommendations have been given top-level consideration by the various nations and placed under some degree of implementation. The concern of the delegates quickly expanded to include not only dissemination of technical and scientific information, but the problems of implementation became matters of primary concern. Frequently, desirable steps were easily identified. More often, the means whereby these could be implemented could not easily be found. The delegates soon became aware that irrigation practice was somehow inter-woven with the whole fabric of rural social life and frequently with high level national policy as well. Thus exchange of experience was not restricted to technical subjects alone; but information about programmes, organizations, legislation and institutional development became topics of great interest. All of these past seminars were, I believe, quite successful. Recommendations, agreed upon by all of the delegates from all of the countries, bore sufficient weight so that they could not be passed over lightly by authorities in the various countries.

The 1962 seminar strongly recommended that the respective countries place increased emphasis on farm level programmes to increase agricultural production on irrigated lands. Further, increased attention at the project planning stage to agricultural production and conservation factors such as drainage, land capability, water distribution, and settlement was strongly urged. Increased attention to education and training at all levels was deemed important and special attention was given to drainage requirements.

The 1964 Seminar, which we are closing in New Delhi to-day drew upon the efforts of delegates from Afghanistan, Ceylon, Iran, Iraq, India, Jordan, Turkey and United Arab Republic, as well as US AID. The work of this seminar has been closely tied to the experiences and recommendations of past seminars. Some evaluation of the extent of implementation of these recommendations was possible by my personal visit to most of the countries last summer and a summary of my observations was laid before the delegates on the opening day of this sminar.

During the early sessions of the seminar, progress in each country was noted by Country Progress Reports. In brief summary, good results are being obtained,

sometimes under rather difficult conditions. Subjects on which progress is lagging have been identified and, in some instances, suggestions which would lead to improvement have already been made by this seminar.

One session of the seminar has been concerned with "Project Planning". Techniques used by the various countries for evaluating land capability and for establishing drainage and irrigation requirements enjoyed considerable discussion. Problems of land tenure, fragmented holdings and providing for farm drains and irrigation distribution systems were discussed as was the matter of repayment of capital and operating costs.

Under "Operation and Management of Irrigation and Drainage Systems" information regarding organizational practices and rehabilitation of old systems has been exchanged. The delegates are concerned that the farmers themselves share the responsibility for this function to the fullest possible extent. A panel was formed on this subject and its recommendations have been endorsed by the seminar.

Information which included such diverse topics as farmers work training camps in Turkey and the development of agricultural colleges in Iran brought out new ideas in educating and training. The delegates are especially concerned about training of middle-level technicians for actual work in the field. Likewise this topic was studied by a panel which developed a report of recommendations, concurred in by the seminar.

As might be expected, there was great interest in prevention of waterlogging and salinity. Much information was exchanged on technical details, not only with regard to design of drainage systems, but also regarding early appreciation and evaluation of the possible hazards of poor drainage, both surface and sub-surface. One difficult problem is the establishment of field drains in areas already heavily settled by farmers. A panel continued study of the general problem of waterlogging and salinity ; however, an additional panel was formed and given the special responsibility to study standards to be used for investigation of project drainage requirements. Both of these panels have made specific recommendations which have been passed by the entire seminar.

Field distribution systems for irrigation and drainage was a topic given attention. Such systems should be capable of meeting the farmers' needs more exactly and deliveries should be measured. Serious problems are encountered, however, especially where land parcels are small and access to individual fields is difficult. The delegates felt that much responsibility should be given to the farmer; however, adequate technical assistance must be available to him. Attention should be given to right-of-way problems and to improved field access. Some limited experiences in land redistribution were presented to the seminar. These have occurred both on a voluntary basis with assistance of a government agency and by expropriation, purchase and resale on new projects in settled areas. Another panel considered these problems, and, with concurrence of the seminar, has presented recommendations.

Special consideration has been given to small project development. Several countries have turned to comprehensive programmes to develop minor water resources. Usually these projects may be developed faster, require less complicated engineering and construction organization and provide for more balanced developmental programmes among the various regions of the country than do major projects. Nevertheless standards for engineering and construction on such projects must not be relaxed to the point where inadequate service is rendered to the farmer. This type of development has led to rather different patterns of authorization, organization and techniques in the various countries and many beneficial ideas have been exchanged on the subject by the delegates.

A topic of vital importance was "Research". Eleven research papers were presented. The delegates felt that exchange of research results as rapidly as possible by the various countries would be economical of manpower resources and accelerate progress. Comprehensive study of research in irrigation and drainage was made the subject of a panel study and this panel has presented recommendations, agreed upon by the delegates.

On Saturday March 7, irrigation practices were inspected in the field under the Agra Canal. An additional field trip to inspect irrigation works and practices under the Ganga Canal in the vicinity of Roorkee will be made in the next three days.

Besides exchanging ideas and discussing their work in detail with their international colleagues, the delegates have found a strong bond of friendship, accentuated by common tasks and common problems and a determination that the efforts in which they are engaged shall not fail.

In summary, over the past eight years, good progress has been made. As more well-trained and dedicated technicians are drawn into the effort, the rate of progress can be expected to accelerate, and indeed we hope this will be the case. There will continue to be a need for exchanging information and experience not only by written communication, but by discussions face to face, and I look forward to the day when international exchange of information about irrigation practices will be advanced even further.

OUR ASSESSMENT

by

Mr. Salahattin Kilic, Turkey

Mr. Chairman, Excellency A.M. Thomas, Fellow Delegates, Ladies and Gentlemen :

On behalf of all delegates from NESA countries, it is a great pleasure for me to extend our heartiest thanks and gratefulness to the Government of India for hosting us here. We have received a very warm welcome and observed a very well organized seminar. Every one who has spent his effort and her effort, to make this seminar the most beneficial, and our visit the most pleasant, deserves our gratitude.

Because of the increase in population and the desire for a better life, it is necessary for the governments to continue large investment programmes ; accordingly the technicians must determine the most effective means and methods to exploit water, soil and other natural resources. This task is more difficult in our part of the world. Near East and South Asia, due to unfavourable distribution of rainfall, traditional overuse of land for several thousand years and a high annual rate of increase of population.

We can not achieve our goals, which are to increase agricultural production, and at the same time to maintain the fertility of soil by simply applying water to land. A successful irrigation project is composed of five major components ; land water, seeds, fertilizers and farmers. Possibly, the human element plays the most important role in the success and/or failure of irrigation projects. You may plan and determine the effect and the results of the proper application of water and fertilizers on certain soils, however to teach every farmer is a special case requiring methods which will induce him to change his traditional way of farming.

We are fortunate that modern techniques enable us to solve most of the technical problems. Again we are fortunate to live in a world in which the inhabitants, despite the difference in boundries, nationalities, and belief may come together to exchange knowledge and experience. Our gathering here, in India, is one of the best examples for that common understanding.

I give you a comparison to show how these seminars have been useful. The organization committee had difficulty due to a shortage of papers to carry out a one week seminar in 1956 in Turkey, while we are given limited time for presentation and discussion in this Fifth Seminar in Delhi. The size of a medium report

in this seminar is almost the same as the size of the complete report of the first seminar.

I believe a large number of people agree on the efforts of impartial and straight minded technicians in promoting cooperation between countries and in increasing prosperity and happiness of human beings.

I believe that providing water for people, their lands, plants and animals is a very exciting and sacred job for any one to carry out.

To see and to learn the experience of India in irrigation and drainage will be as beneficial as the technical sessions in the seminar.

Finally, I would repeat our expression of gratitude to the Government of India and the Agency for International Development for making this seminar possible.

Thank you.

U.S. A.I.D.'S OBSERVATIONS

by

Ray G. Johnson

Chief Agriculturist, US AID, New Delhi

Mr. Chairman — Excellencies — It pleases me greatly to be able to say a few words today. This Irrigation Practices Seminar has been a working meeting. The delegates have worked — and worked hard Today's schedule has been heavy. My remarks are to be very brief.

This is the fifth in a series of such seminars or regional meetings. My first contact with members goes back to 1955 in Tehran. Although it was not my pleasure to attend the first meeting held in Izmir, Turkey in 1956, I am familiar with what went on. I've been able to maintain direct or indirect contacts ever since. May I make some observations ?

This year's papers reflect a growth in breadth of approach by irrigationists to irrigation planning, development, administration and operation. This is as it should be. Irrigation development is not for the purpose of building of structures. It is for the economic and productive utilization of a water and land resource by a cultivator. Water development is more multiple purpose — irrigation, power, recreation, flood control, and human resource development are all components of water development and each pays its fair share of cost in today's planning and financing. However, structures are not the end point — merely means to an end. Productive, economic, sustained human benefits must be the end point.

Two things have impressed me at this conference. I've mentioned the growth of the breadth of thinking — as well as the high quality of papers and follow-up discussions. My second observation has been that your delegations are made up of relatively younger men. You know the development going on not only in your own country, but what has been done and is now being done within the region. You have been asking good and searching questions. You have shown a desire to acquire and then evaluate the experience of others.

I congratulate you — everyone of you — and your countries are to be congratulated for seeking out young, energetic, knowledgeable human resources for this field and giving them responsibility.

I congratulate India — both the technicians and the administrative services — for the exceptional and outstanding manner in which this seminar has been hosted and operated. The definite and exhibited support of the Ministers concerned, the follow through by the secretaries and the closely coordinated working group efforts are the results of long hours by real professionals as well as diplomats.

The US AID of India (and I know I can speak for the US AID's of the region) are pleased to have had a small part in this working meeting of the irrigation professionals and associates of this part of the world.

Thank you.

CLOSING ADDRESS

by

Shri A. M. Thomas

Minister for Food, Government of India

I regret I was prevented because of my preoccupations in Parliament to be present at the inauguration of the 5th NESA Irrigation Practices Seminar. I may assure you, however, that having regard to the vital importance of the subject matter of the Seminar and my special responsibilities in the matter of utilising irrigation potential, I have kept myself fully posted with your deliberations from day to day and am particularly pleased to have the opportunity of being with you this afternoon.

I consider it highly opportune that the 5th NESA Irrigation Practices Seminar should have been held in India. The need for application of modern technology and scientific methods in the field of irrigated agriculture has never been greater in India than today when, because of food shortage and rising population, and all-out effort is being made to build up the irrigation potential. Irrigation, however, is only a means to an end and not an end in itself. What needs to be ensured is that the available supplies of irrigation water are put to the most efficient use in the interests of increasing agricultural production within the shortest possible time. Our experience shows that the problem of water management is much more complex and complicated and is fraught with many more difficulties than that of creating irrigation potential. The introduction of new skills and techniques in water management necessitates considerable spade work in many spheres including research, training, community development, extension and demonstration. As the role played by the cultivator in water management is of fundamental importance, it is vitally necessary to equip him with the requisite know-how and motivate him in the right direction. Integrated activities in various fields are, therefore, necessary to provide the requisite financial, technical, material and organisational support to the farmer. Concerted and coordinated efforts on the part of the various agencies, such as State Agriculture and Irrigation Departments, the Department of Community Development, Extension Organisations, Research and Training Institute, etc. are required.

It is heartening to know that during this Seminar, you, the distinguished representatives from nine participating countries, have pooled your experience and given detailed consideration to these basic problems of irrigated agriculture. As the essential background conditions of agriculture are very similar in the NESA Region, the recommendations made by you will be of material assistance to us in solving these problems.

I understand that after giving full deliberations to various problems and difficulties, the Seminar has emphasised, among other things, the need for providing a properly-planned institutional base to support the activities of the farmer in the matter of developing irrigated agriculture. As agro-economic conditions and other factors vary from country to country, the irrigation methods, practices and institutional set ups found effective in one country could obviously not be equally effective in another unless adapted to meet local requirements. Nonetheless they can, and undoubtedly do, provide a useful guide. The other important recommendations of this Seminar, I am given to understand, are that more extensive training programmes should be organised for imparting specialised training to different categories of personnel as well as the farmers who are concerned with direct utilisation of irrigation water for the raising of crops. More attention and thought should be given to proper lay-out of farm irrigation and drainage systems and to other practices which not only economise the use of irrigation water but also assist in preventing the hazards of water-logging, salinity and alkalinity. Provision of proper drainage facilities, as an integral part of irrigation projects right from the very beginning is highly essential in order to obtain sustained benefit of irrigation without deterioration of land. It is not only convenient but also far more economical that drainage is attended to when the project is executed. If this is overlooked initially and the tract becomes water-logged and salt infested, our experience shows that its subsequent reclamation is a complicated and expensive process.

The recommendations made by the Seminar are the quintessence of the long and diverse experience of a galaxy of leading experts in different fields under different conditions and will undoubtedly go a long way in improving the status of irrigated agriculture in the NESA Region. I have no doubt that the participating countries will take full advantage of their collective wisdom. The present session may be the closing session of the 5th NESA Irrigation Practices Seminar, but it is also the commencement for each delegate and each country of a new responsibility, *viz.*, that of effective follow-up action, as without such follow-up action, little will have been gained from your present labours.

We are deeply indebted to the US AID for conceiving the idea and for assisting in the organisation of this series of Irrigation Practices Seminars, and thus making available the benefit of pooled experience and knowledge to all the developing countries of the NESA Region. Our thanks are particularly due in this respect to Dr. Dean F. Peterson, who has very ably and competently helped in organising the Seminars and in conducting, from day-to-day, the proceedings of the Technical Sessions and other activities of the Seminar.

Our grateful thanks are also due to Dr. K.L. Rao, Minister for Irrigation & Power and the officers of the Ministry of Irrigation & Power and the Centre

Water & Power Commission for their wholehearted cooperation in making the Seminar a success. The delegates to this Seminar have travelled long distances at considerable personal inconvenience, to be here. We are honoured to have them in our midst and trust that their stay in this country has been pleasant and fruitful. We have tried as best as we could to take care of their comfort and convenience, but if for any reason our performance has not been equal to their expectations, we hope that they will remember only our intentions and not our deeds. You will agree that besides the gain in terms of knowledge and experience there is also a gain in terms of mutual goodwill at such international gatherings and I am sure that many a friendship cultivated during this brief period will be lasting and will serve to cement the bonds of friendship that already exist among the participating countries.

CHAPTER IV

COUNTRY PROGRESS REPORTS

AFGHANISTAN

Generally, throughout the country precipitation was below average during 1962 and 1963 water years, and the relative total annual runoff of the rivers was below that of an average year. Comparatively, run off in the Southern and Western parts of the country was lower than that of the Northern and Eastern regions. Nevertheless, some periodic floods of short duration occurred in some basins. Indications exist that runoff will be higher during the 1964 water year.

Irrigation development has been continuous in the Helmand and Arghandab Valley project in order to bring more land under cultivation, increase productivity through supply of dependable water and make efficient use of the regulated river flow. During 1962 and 1963, 10 kilometers of main irrigation canal was completed (10 cms. capacity), 9 kilometers of main canals was lined and 9 kilometers of sublaterals (0·3 to 0·4 cms. capacity), 15 kilometers of farm ditches (0·1 to 0·2 cms. capacity), 70 kilometers of deep outlet drains (3 meters deep), 86 kilometers of open farm drains (1·3 to 1·9 meters deep) with 44 major irrigation structures (check drops, bridges, chute drops, checks, etc.), 64 smaller structures with some land leveling and smoothing were completed.

In the Nangarhar irrigation project where the area to be irrigated is 31,500 hectares, a rock earthfill diversion dam on Kabul River, 22 meters high, with diversion tunnels, main canal intake of 130 cms. capacity and the two sub-dividing structures on the main canal, *i.e.* the intake for irrigation canal of 50 cms. capacity and power intake of 80 cms. capacity, are completed. The excavation of the irrigation main canal, 70 kilometers long and 34 main outlet structure on the canal, is about 90 per cent complete. From the two tunnel sections along the line of the main irrigation canal (total length of 8·85 km.) the first section 1·4 km. long is complete, and 70 per cent of the construction work of syphons on the main canal (17 in total) is accomplished. Work on the lateral and sublaterals is about 10 per cent complete so far. In the powerhouse at the diversion site three sets of turbines and generators of total capacity 11,000 kw. are already installed. It is planned that out of the total 31,500 hectares, 6,500 hectares of high lands will be irrigated by lifting the water from the main canal by electric pumps at two pumping stations. A part of the generated power will be used by the pumps and the remaining part will be used for domestic purposes of the nearby towns and villages.

Work is underway to solve the inadequacy of the diversion structures (brush dams) at the headworks of the Adjmir Canal in Kataghan province. After completion, the required amount of water will be supplied by extending the tail race canal of the existing powerhouse (at 40 cms. capacity) by 82 meters and then excavating a branch canal with 15 cms. capacity and a length of 2·5 kilometers up to the point where it joins the existing old canal.

Twenty shallow wells (25 to 30 meters deep) have been dug and installation of pumps is underway in Katawaz area for irrigation purposes.

Note : This progress report was prepared by Mir M.A. Roa, Deputy Minister of Agriculture, Afghanistan.

Other rehabilitation surveys and minor reconstruction works have been performed in various parts of the country.

Construction of Sardeh Dam in Ghazni, 26 meters high, rock-earth fill type, is continuing and the work is about 70 per cent complete. The total capacity of the reservoir is 125 million cubic meters which will be used mainly for irrigation purposes.

Considering the importance of collection and analysis of basic data, and technical recommendations needed for basic planning for development of the water and soils resources of the country, a new organization "Afghan Water and Soil Survey Authority" was established in 1963. This resulted in the centralization of activities in the field of soil and water resources investigations, where before various agencies were engaged in performance of similar activities with duplication of efforts and lack of coordination. The authority is responsible for the survey and evaluation of water and soil resources of the country including hydrological and hydrogeological investigations, soil-survey and analysis ; topography and preliminary designs for irrigation, power development, and flood control purposes. In the various technical fields of activities of the Authority, assistance is received from the United Nations Special Fund, US AID, and the Federal Government of Germany.

Towards the completion of the network of Hydrology stations, key posts are installed on most of the major rivers of the country, and in some of the stations records have been obtained up to fourteen years. Approximately 90 per cent of the stations are equipped with automatic recorders.

Reconnaissance soil survey is completed for a total area of 1,682,360 hectares since the last seminar, and soil maps, land classification and land use maps are prepared at the scale of 1 : 100,000. A brief summary of soil survey work is given below :

Location	Total area surveyed (Hectares)	Land suitable for irrigation		Land that can be used as pasture or developed with high cost
		Class II and III (Hectares)	Class IV and V (Hectares)	
Hari Rud valley	410,770	139,430	84,930	186,410
Ghazni Katawaz valley	878,290	350,130	89,450	438,710
Kabul valley	238,300	172,400	26,900 10,650 (v)	28,350
Upper Adraskand valley	155,000	29,700	5,300	120,000

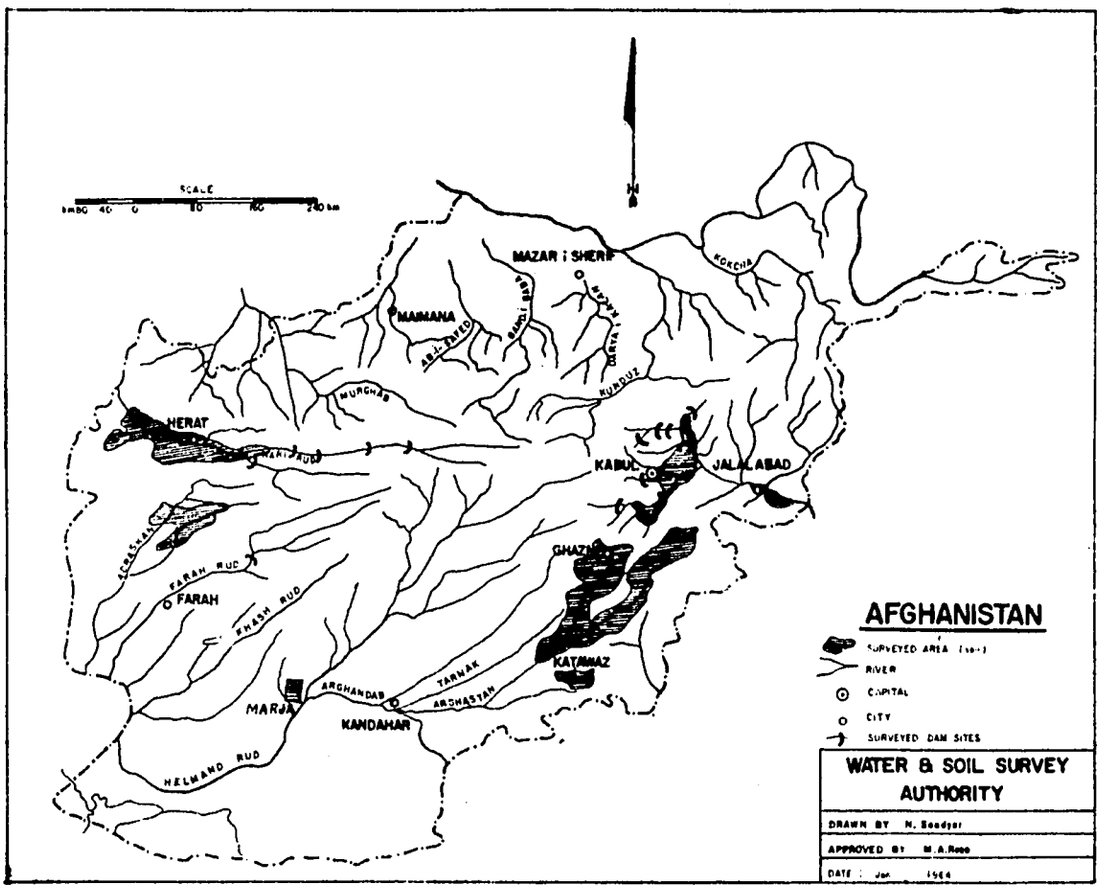
Geological and topographical investigations have been performed on thirteen dam sites ; one on the Farsh River (plus the three dam sites surveyed in 1960-61), five sites on the Hari Rud and its tributaries, seven sites on Kabul River and its tributaries. The topography maps on dam sites are of 1 : 2,000 scale with 5 to 10 meter contour intervals. Reservoir contours are made up to the maximum economic dam heights. General possibilities of control and use of water with respect to irrigation, power supply and flood control are studied in the basins of Hari Rud, Kabul and Farah.

Due to the great difficulty with regard to water shortages for irrigation use and power production, emphasis has been placed on Hari Rud valley survey. The Government has had plans for the development of the valley for many years. With the controlled

flow of the Hari Rud, it is found that all of the class II and III lands will be irrigated, and with efficient use of water it is possible even to irrigate some of the class IV land.

In Kabul valley studies with regard to furnishing more and firm flow of water for purposes of increasing the cultivable area, and generating more electric power is continuing.

Since the surface water potential alone, can not satisfy the expansion requirements of the valleys, use of the ground water resources is a must in many of the valleys. Ground water investigation programme are at the starting stages now.



INDIA

INTRODUCTION

Introductory material describing physiographical, soil and climatic features and crops was included in the report of the Fourth Seminar. It is repeated herein only where significant charges have occurred.

LAND RESOURCES

The geographical area of the country is 806 million acres of which land utilisation statistics are available for about 739 million acres for 1960-61 :

		Million acres
(i)	Total geographical area ...	806·30
(ii)	Area under cultivation ...	328·00
(iii)	Cultivable land not yet cultivated	96·00
(iv)	Fallow lands	56·30
(v)	Forests	138·50
(vi)	Land put to non-agricultural use	34·70
(vii)	Unculturable lands ...	85·30
	Total reported area ...	738·80

WATER RESOURCES

No new information on surface supplies beyond that included in the Fourth Seminar Report is presented. A complete assessment of the country's underground water resources has not been possible so far but there is evidence that they are of considerable magnitude. They are particularly prominent in the Indo-Gangetic alluvial plains.

AGRICULTURE

The areas of major foodgrain crops during the five years ending 1962-63 are given below.

IRRIGATION DEVELOPMENT

A brief history of irrigation development in India was included in the Fourth Seminar report. This may be brought up-to-date by the following statement. The generation of hydro-electric power and its use on large scale ground water pumping through tubewells (deep wells) is comparatively a recent development. Deep tubewells were constructed for the first time in the thirties of this century, mostly in Uttar Pradesh and since then their number has been increasing.

TABLE I. AREAS OF MAJOR CROPS IN INDIA

Million acres

Crop	1958-59	1959-60	1960-61	1961-62	1962-63
Rice	81	83	83	85	86
Jowar	43	42	42	44	44
Bajra	28	27	28	27	26
Ragi	6	6	6	6	6
Maize	10	11	11	11	11
Small millets	12	12	12	12	12
Wheat	31	33	32	33	33
Barley	8	8	8	8	7
Gram	25	25	23	24	23
Tur	6	6	6	6	6
Other pulses	29	29	28	29	29
Total Foodgrains	279	282	279	285	283

With the country's attaining freedom in 1947, a number of big irrigation projects on an hitherto unprecedented scale were taken up. To mention a few, Bhakra-Nangal in Punjab, Hirakud in Orissa, Damodar Valley system in Bihar and West Bengal, Tungabhadra in Mysore and Andhra Pradesh and some of the Chambal Valley works in Madhya Pradesh and Rajasthan are the major projects recently completed. A countrywide programme for taking up small irrigation projects was also launched and this programme has been reinforced considerably in the course of the three Five Year Plans.

RELATIVE MERITS OF MAJOR-MEDIUM AND MINOR SCHEMES

India has extensive programmes involving major (more than Rs. 50,000,000), medium (Rs. 1,000,000 to Rs. 5,000,000), and minor (less than Rs. 1,000,000) and, as reported previously, has found it profitable to engage in programmes of all sizes. In regions of low rainfall such as part of Rajasthan and certain areas in Andhra Pradesh, major irrigation schemes are the only satisfactory means of providing irrigation. On the other hand there are territories like Himachal Pradesh, Tripura Pondicherry etc., and undulating regions covered by the Aravali, the Satpura and the Vindhayan ranges, the Deccan Trap and some tracts in the Western and Eastern Ghats, where topographic and other considerations permit only minor irrigation works. Likewise there are many areas where surface water irrigation is inadequate and dug-wells or tubewells, utilizing groundwater are the only available means for extending irrigation. Yet there is a third category of areas where major-medium and minor irrigation schemes may have a complementary role to perform and only through integrated development of the resources may it be possible to obtain maximum utilisation of available resources.

IRRIGATION IN PRE-PLAN PERIOD

At the beginning of the Third Five-Year Plan, *i.e.*, in 1950-51 gross area irrigated in the country was 55·76 million acres. The net irrigated area was 51·5 million acres and the sourceswise break-up of this figure was :

		Million acres
Government canals	...	17·9
Private canals	...	2·8
Tanks	...	8·8
Open wells	...	14·7
Other sources	...	7·3
Total	...	51·5

ACHIEVEMENTS DURING THE PLAN PERIOD

Major and Medium Schemes : During the first two Five Year Plans more than 400 new Major-Medium Irrigation schemes were taken up. About 100 schemes have been included in the Third Five Year Plan. As a result additional irrigation potential of 12·1 million acres was created by the end of the Second Five Year Plan. Actual utilisation of the irrigation potential created was about 8·6 million acres. It is expected that a total new potential of about 23·20 million acres will have been created by the end of the Third Five Year Plan, with total utilisation of about 18·6 million acres expected.

Minor Schemes : Achievement under the First and Second Five Year Plans comprised sinking about 300,000 new open wells (dug wells), boring and deepening about 50,000 existing open wells, installation of about 283,000 pump sets, construction of about 20,000 tubewells of various sizes, and construction and repair of about 25,000 tanks. In addition, a large number of small diversion, drainage and embankment schemes were constructed. Great emphasis is being given to the development of minor irrigation sources and it is expected that comparatively much better progress will be recorded during the Third Five Year Plan. Schemes taken up

during the first two Plan Periods resulted in creating an additional irrigation potential of 9·7 million acres. A further additional potential of about 9 million acres is expected to be created during the Third Five Year Plan.

FINANCIAL OUTLAYS

An aggregate estimated cost of major and medium irrigation schemes included in the First, Second and Third Plans is of the order of Rs. 17,500,000,000. By the end of the First Plan, an outlay of Rs. 3,800,000,000 had been incurred. The outlay in the Second Plan is estimated at Rs. 3,700,000,000. The provision made for irrigation during the Third Plan period is Rs. 6,000,000,000. The expenditure incurred on minor irrigation during the First and Second Five Year Plans was of the order of Rs. 600,000,000 and Rs. 1,400,000,000. During the Third Plan, it is expected the outlay would be in the neighbourhood of Rs. 3,500,000,000.

IRRIGATION ORGANISATION

Irrigation is a State responsibility. In most States, there is a separate Irrigation Department to handle major-medium as well as minor irrigation schemes. Small schemes irrigating below 100 — 200 acres are dealt with by the State Revenue, Agriculture of the Community Development Departments. Loans advanced to the cultivators for execution of individually owned minor irrigation schemes, like open wells (dug wells), tubewell (deep wells) or pump-sets are also handled by these Departments. The Departments are equipped with engineering staff to plan and implement these schemes on technically sound lines. Coordination between the activities of the various Departments at the district level is carried out by the various committees set up for the purpose. At the State level, the coordinating authority is the Development Commissioner or the Agricultural Production Commissioner. There are also some committees and working groups at the State level for coordination. At the level of the Central Government, the minor irrigation is looked after by the Ministry of Food and Agriculture. The major-medium irrigation schemes are dealt with by the Ministry of Irrigation and Power. This Ministry is technically assisted by the Central Water and Power Commission. An Agricultural Production Board has been set up at the Centre to coordinate the activities of the various Central Ministries and the Planning Commission concerned with Irrigation and Agricultural Development.

Assessment and realisation of revenue from irrigation are generally handled by the Revenue Department in the southern States, while in Northern India assessment is made by the Irrigation Department and realisation by the Revenue Department. The Irrigation Department consults the Agricultural Department on fixing the intensity of irrigation, duty crop pattern, etc. for adoption in new projects.

SURVEYS AND INVESTIGATIONS

River Valley Projects require elaborate investigations. For integrated development of water and land resources of the country on a planned basis, and to ensure continuity in the development of water resources, adequate information regarding technological possibilities, namely, suitable project sites, hydrological data, irrigable areas etc., for all feasible projects in a river basin should be available in advance, so that projects can be selected properly and given appropriate priority.

States have been advised to prepare master plans for long term development of irrigation to bring out clearly the ultimate potentialities of various irrigation and multi-purpose schemes. Special investigation units have already been set up in almost all of the States and these are being further strengthened. On request from some of the States, investigation units of the Central Water and Power Commission also undertake surveys and investigations of certain important projects.

Many States have set up separate units for surveys and investigations on minor irrigation schemes. These units have recently been strengthened. Some States have also been carrying out surveys for establishing ground water potentialities with a view to delineating fresh ground-water-worthy areas and to regulate the construction of new wells in already proven areas so that over-draft and the failure of wells is avoided.

At the Centre, since 1955, systematic exploration and assessments for ground water potentialities have been undertaken on a nationwide scale by the "Exploratory Tubewells Organisation", in 13 States of the Indian Union. Five hundred fifty-six exploratory boreholes were drilled, of these 258 were successful and converted into production wells opening 84 areas of future development. This has created a potential for about 8,000 additional tubewells with an average output of 1½ cusecs in the proven areas.

OPERATION AND MANAGEMENT OF COMPLETED WORKS

Operation and management of all State-owned completed works, whether major-medium or minor, is invariably handled by the State Irrigation Department. Adequate finances for the purpose are earmarked in the annual budget of the State Government. Operation and maintenance of minor irrigation works irrigating below 100-200 acres has increasingly been entrusted to the local institutions known as the *Panchayats*. Necessary legislative measures to ensure proper maintenance of works by these agencies have been taken in most of the States. The *Panchayats* are equipped with technical staff to look after the work properly and have also been authorised in many States to levy a suitable cess or water rate on the beneficiaries for defraying maintenance cost. Individually owned minor irrigation works, like wells, pump-sets etc. are invariably maintained by the cultivators themselves. Proper workshop facilities including mobile units are being arranged by the State Governments for the repair and upkeep of the pumping sets and other water lifting appliances. The officers at district level are expected to keep an eye on proper maintenance and proper utilisation of these works.

UTILISATION OF IRRIGATION FACILITIES

The States have constituted working groups at various levels, starting from the State right upto the Block to ensure the full use of irrigation facilities for each project completed or initiated during the Five-Year Plans and to review carefully at regular intervals the progress of irrigation on such projects. The working group at the State level is generally composed of the Development Commissioner and officers of the Agriculture, Cooperation, Irrigation and Community Development Departments. Working groups consisting of officers directly concerned with the implementation and the development of the projects have also been set up for each major project. The Agriculture Department is expected to undertake advance measures for the development of the commanded areas so that the fields are in a fit condition to receive irrigation water as soon as it is available. These consist of (*a*) tractorisation and levelling of fields ; (*b*) pre-irrigation soil surveys ; (*c*) construction of field channels ; (*d*) setting up experimental farms for determining and evolving new cropping patterns ; (*e*) setting up of demonstration farms/plots to propagate scientific irrigation practices particularly economic use of water ; (*f*) supply of improved seeds, fertilizers and development of local manurial resources ; and (*g*) credit and marketing facilities — establishment of warehouses and godowns.

WATER-LOGGING PROBLEMS AND DRAINAGE MEASURES

The problem of water-logging is fairly acute in some irrigation tracts in India. It is roughly estimated that the transit losses in a canal system average about 45 per cent. Inadequate drainage, particularly in the flat alluvial plains of Uttar Pradesh and Punjab results

in rain-water standing over the countryside for long periods and percolating into the ground water table.

No regular statistics have been maintained regarding the extent of water-logged areas and their rate of increase. The problem exists in many States in varying degrees, but it is more acute in the irrigated tracts of the Indo-Gangetic plains which have flat slopes and poor outfalls. In the Deccan where drainage conditions are generally good, the problem is not so acute except in some intensely irrigated tracts. As per figures available, the areas where water table is within 5 feet of the ground, total to 4·7 million acres in October. This affects winter sowings. In June, however, this area reduces to only 0·479 million acres. In addition to this, in an area of 3·31 million acres, the water table is reported to vary between 5 to 10 feet of the ground in October while in June it increases to 3·79 million acres. The State of Punjab is the worst affected.

Although the importance of water-logging was realised long ago, no concerted measures were undertaken prior to independence. Since 1947, however, efforts have been intensified to check this menace. In Punjab, six pilot projects are at present in progress to determine the best method of tackling the problem in areas where the water table is between 0′ to 5′ deep. On the basis of the results to date, it is proposed to launch an anti-water-logging programme estimated to cost Rs. 20,000,000 for improvements to both surface and as sub-surface drainage.

Some drainage schemes have been undertaken to reclaim water-logged and salt affected areas in the State of Maharashtra. Similarly in West Bengal, a few drainage schemes have been completed while some more are under contemplation. Shallow tubewells have been installed in various parts of Delhi to lower the ground water table in addition to improvements to surface drainage.

The problem of water-logging was again recently gone into by a Study Group on Wastelands of the Committee on Natural Resources of the Planning Commission. It has now been decided that apart from the reclamation of already water-logged lands the future programme in this field should also comprise :

a. Prevention of flooding of the land from river spill ;

b. Improvement of surface drainage ;

c. Installation of shallow tubewells for depressing the water table and use of such water for irrigation where possible ;

d. Lining of irrigation canals where possible, and

e. Construction of seepage drains along irrigation channels.

The above measures will substantially reduce the rate of increase in the extent of water-logged areas in future. Punjab has already started work on these lines while other States are preparing plans to do so.

SOIL CONSERVATION AND LAND RECLAMATION

Soil erosion is a serious problem in India as in all tropical and sub-tropical countries. It is one of the main reasons for low crop yields. Deterioration of soil also occurs due to water-logging, salinity and destruction of soil structure. Already, large areas have been rendered unfit for cultivation and in many more, production has gone down considerably. Soil erosion is evidenced by gullies deepening in the agricultural land, deep ravines, enormous silt load brought down by various river systems from their catchments, deteriorating pastures and diminishing land returns, recurrent floods and marching desert. Besides, there are vast stretches of lands that have been thrown out of cultivation due to water-logging, soil salinity and alkali conditions. Factors which have largely contributed to the erosion and deterioration problems are:

(i) Extension of cultivation to steep hills at the cost of forests ;

(ii) Over-grazing of pastures ;

(iii) Poor farming practices characterised by lack of conservation farming, absence of legume in rotation, mono-culture farming and cultivating the land along the slopes ;

(iv) Uncontrolled use of irrigation water ; and

(v) Economic and social factors such as subsistence farming, insecurity of tenancy, small fragmented holdings, etc. which are in fact at the root of many of the above causes.

The problem area needing immediate attention is estimated to be about 200 million acres. Out of these, 100 million acres are agricultural land spread over Peninsular India (Deccan and Central India Plateau), the Himalayan and sub-Himalayan area and the red and laterite soils. There are about 50 million acres comprising the hilly region and wastelands, etc. and another 50 million acres of arid Rajasthan desert where wind erosion is a serious problem.

During the First Five Year Plan, about 0·7 million acres were protected. In the Second Plan, the total area covered was about 2·5 million acres of agricultural land and about 0·5 million acres of non-agricultural land. The important targets set for the Third Plan include :

a. Anti-erosion and soil conservation measures.	About 11 million acres
b. Conservation farming (dry farming)	,, 25 ,, ,,
c. Reclamation of ravines	,, 0·03 ,, ,,
d. Reclamation of saline, alkali and water-logged land	,, 0·2 ,, ,,
e. Afforestation and pasture development in desert and hilly areas, water-shed and denuded forests	,, 0·8 ,, ,,
f. Soil conservation measures in the river valley projects for the protection of dams and reservoirs	,, 0·8 ,, ,,

IRRIGATION RESEARCH

The Central Board of Irrigation and Power is the coordinating authority for research work in hydraulic and hydro-electric engineering. In addition to specific problems, they have sponsored a scheme of Fundamental and Basic Research on 21 problems of irrigation. The Board has exchange relations with over 260 Research Organisations throughout the world. Twenty-three research stations are maintained at various sites in India.

To encourage new ideas and invigorate technical thinking, applied research aiming at improvement of design and construction practices in vogue on minor irrigation works has been recently initiated.

Research work on water requirements and irrigation practices is also being conducted at some research stations. Among these, mention may be made of the Indian Agricultural Research Institute, New Delhi ; Irrigation Research Station. Bikramganj, Bihar and associated centres ; Indian Institute of Technology, Kharagpur ; Irrigation Research Institute, Roorkee ; and selected centres under the scheme of model agronomic experiments.

AGRICULTURAL RESEARCH

See description in Fourth Seminar Report.

EDUCATION AND TRAINING

Facilities for training irrigation and agriculture exist in all States. Steps have been taken to establish new institutions and to expand existing institutions in order to provide sufficient trained personnel for the agricultural development programmes.

For disseminating the results of research, the Indian Council of Agricultural Research

has continued to expand facilities for training the agricultural and veterinary personnel required for the production, distribution and use of various types of extension teaching aids and mass communication methods. Good progress has been made in distributing literature pertaining to improved techniques of agriculture, animal husbandry, etc. Arrangements have also been made for producing agricultural films.

In addition to the activities of the Agricultural Departments, the Community Development Programme, initiated in 1952, aims at the individual and collective welfare of the rural population on an aided self-help basis. The entire country has been brought under this programme with 5,223 Blocks comprising 567,000 villages serving a population of 335 million. Agriculture receives the highest priority in the programme which includes other activities, such as communications, health and sanitation, housing, education, etc. In order to provide trained personnel for the Community Development Blocks, a structure of extension training sufficient to train nearly 50,000 '*Gram Sevaks*' and 12,000 'Gram Sevikas' (male and female village level workers) was initiated. One hundred Extension Training Centres have been established and are engaged in 2-year integrated training programmes for village level workers. In addition, 44 *Gramsevika* Training Centres have been established to provide suitable education and field training to women village level workers who work for the welfare of women in the Development Blocks. Having met the initial requirement of trained *Gramsevaks* and *Gramsevikas* these training centres will be continued partly for providing pre-service training to village level workers (both men and women) required for replacements and partly for imparting short-term in-service training to those workers who have been in the field for 3 to 4 years in order to bring them up-to-date in their subject-matter. The '*Gramsevak*' has been accepted as a multi-purpose extension worker. Accordingly, he is provided adequate opportunities for practical training in agricultural engineering, irrigation methods leading to soil and water conservation, horticulture, plant protection, animal husbandry, *Panchayat* and cooperation, extension and social education, public health, minor engineering programmes and rural industries.

Considering the important role of agricultural implements, 31 Workshop Wings have also been set up at the campuses of Extension Training Centres to provide suitable training to '*Gramsevaks*' and village artisans. These Wings will gradually be extended to all the 100 Extension Training Centres. Trial-cum-demonstration farms have been set up under various irrigation projects to evolve proper use of water, manure and fertilizers, and cropping patterns best suited to the area. In addition, demonstrations on the cultivators' own fields, are also organised by the State Agriculture and Community Development Agencies.

Another scheme provides training on Minor Irrigation and Water Use to the district level technicians and the sub-district level staff engaged in the Departments of Irrigation, Agriculture and Community Development. District-level technicians are trained directly by the Government of India. The syllabus for these technicians covers subjects such as wells, tanks, water lifting appliances, surveying, operation and maintenance of irrigation works, soil-plant-water relationships, irrigation methods, water control equipment and farm irrigation structures ; drainage, etc. The sub-district level staff are trained by various States. In general, there is one training centre in each State and specialists on Engineering and Agronomy are provided. Three sessions of about 3 months each are planned for each Centre every year. Theoretical as well as practical training is imparted with emphasis on the practical part. This programme has been initiated in 13 States. Experts from various State Governments, the Government of India and foreign countries are also invited from time to time to deliver lectures and arrange demonstrations.

INTENSIVE AGRICULTURAL DISTRICT PROGRAMME

The Intensive Agricultural District Programme (popularly known as the "Package Programme") which is being implemented in one district of each State seeks to demonstrate the potentialities of increasing food production through a multi-pronged, concentrated and coordinated approach to agricultural development in areas which can quickly respond to such production efforts. In the long run, it aims at a continuing, self-generating "break-through" in productivity and raising the production potential by stimulating human and physical processes of change. The programme not only involves adoption by cultivators "package of improved practices" such as improved seeds, fertilizers, pesticides, improved implements, proper soil and water management etc., but also involves a "package of services" consisting of competent technical staff, availability of credit and production supplies, land and water improvement, adequate research information for basing extension recommendations, storage, and marketing and price assurance.

One of the basic considerations in formulating the programme is its repeatability in other areas. The details of the programme have been worked out on the assumption that the experience gained in the selected districts would be repeatable in other areas.

The I.A.D.P. was initially introduced in the year 1960-61 in 7 districts of 7 States, *viz.* Tanjore (Madras), W. Godavari (Andhra Pradesh), Shahabad (Bihar), Raipur (Madhya Pradesh), Aligarh (Uttar Pradesh), Ludhiana (Punjab) and Pali (Rajasthan). Thus, in these districts, the programme has already completed about 3 years of operation. It was subsequently extended to one district in each of the remaining States as well, *viz.*, Mandya (Mysore), Surat (Gujarat), Sambalpur (Orissa), Palghat and Alleppey (Kerala) Burdwan (West Bengal) Cachar (Assam), Bhandara (Maharashtra) and 6 Blocks in Jammu and Kashmir. Six were started in 1962-63 and two in 1963-64. The selected districts together account for a cultivated area of about 19 million acres on a little over 5 per cent of the total cultivated area of the country. During the short period that the programme has been in operation, farm planning has been useful, on the whole, in making a substantial number of cultivators aware of the gains to be made from the adoption of improved practices of a simple kind, such as, improved seeds, fertilizers, plant protection measures, etc. The number of farm plans actually prepared increased from 0·055 millions in 1960-61 to 0·38 millions during 1962-63.

Increased use of fertilizers ranged from about 45 per cent to 200 per cent during 1962-63. Attention is being paid to prophylectic treatment of seeds and crops on an area-wide basis. Specific control measures, new pesticides, and new equipment are being popularised through demonstrations. An implement workshop is being established in each district in order to give a fillip to production, popularisation and demonstration of improved implements suited to the region.

Although one of the important considerations for selection of I.A.D.P. districts was availability of adequate irrigation facilities, the intensity of irrigation differs greatly from district. In almost all the districts, there is considerable opportunity for intensification of minor irrigation programmes. With this in view, State Governments have been making funds available to these districts every year out of the allocations made in the State Plan. Steps are also being taken to ensure efficient and timely use of the available water in accordance with the soil characteristics and crop requirements. The districts are implementing a scheme designed to demonstrate sound and practical methods of solving farm irrigation and drainage problems and provide on-the-ground training and experience in water management to extension staff. The scheme envisages laying out a few pilot demonstrations on proper farm irrigation and drainage practices in each district. It includes

the appointment of a Water Use Specialist in each district and procurement of a few small earth-moving implements for land levelling, etc.

Close coordination between the various Departments, like, Irrigation, Agriculture, Community Development, Revenue, etc. must be ensured. The State Governments are setting up a small committee in each district, headed by the District Collector, and consisting of the district level officers of the concerned Departments.

COOPERATIVES AND CREDIT FACILITIES

In India, coorperation has been recognised as an instrument of national policy for inceasing prodution and improving the economic conditions of the rural population. A National Cooperative Development Corporation has been set up consisting of representative cooperation opinion and Government agencies concerned. The functions of this body are schemes of cooperative development, principally in the field of agriculture.

The cooperative credit sector in India consists of the primary agricultural credit societies (service cooperatives) at the base, the Central Cooperative Banks at the district-level and the State Cooperative Banks at the State level. Agricultural credit is provided to the cultivators primary Credit Societies which get the necessary resources from the Central Cooperative Banks which in turn obtain the facilities from the State Cooperative Bank and the Federal Bank of India, *viz.* the Reserve Bank. At the end of the Second Plan, there were about 200,000 primary agricultural credit societies in the country with a membership of 17 million. Some of these societies were strong enough to undertake the various service and supply functions expected of them. But roughly fifty per cent were weak and efforts were made to reorganise and strengthen them by a programme of revitalisation launched in the Second Plan. As a result, the short and medium-term credit advanced by the primary agricultural credit societies has gone up from Rs. 229 million in 1950-51 to Rs. 2,280 million in 1961-62 and to about Rs. 2,500 million in 1962-63. This is expected to go upto about Rs. 4,000 million in 1965-66. Cooperatives accounted for about 3 per cent of the credit requirements of the agriculturists in the country in 1950-51. Now they are covering about 20 to 25 per cent and this percentage is expected to gradually increase. All the villages in the country will be covered with primary agriculture credit societies by the end of the Third Plan, i.e. 1965-66. The membership of the Societies by then will be about 30 million covering about 45 to 50 per cent of the agricultural population.

The loaning policy of the cooperatives has been reoriented for production. Short-term loans are issued against personal sureties for seasonal agricultural operations. For construction of small channels or *bunds* or for irrigation facilities, purchase of bullocks, etc., medium-term loans are provided. Such loans up to Rs. 500 are advanced on the basis of personal security and from Rs. 501 to Rs. 1,000 on the basis of a charge created on land. Larger, medium-term loans are given only on the basis of a mortgage of land as security. To the extent possible loans are based on production plans, especially in areas in which the intensive agricultural district programme (package programme) is in operation. The results of these programmes have thrown some light on the methods to be adopted for tailoring credit to production. In the past, the cooperatives provided credit mainly on the basis of land as security. Thus a large proportion of the members either obtained inadequate credit or no credit at all and there was considerable delay in securing loans. If agricultural production is to increase, all the cultivators including marginal and submarginal cultivators who are many in number in this country, should be provided sufficient credit. The Government have decided to provide out-right grants for special bad debt reserves of primary agricultural credit societies and Central Cooperative Banks in

order that such grants may cover the additional risks involved in providing credit to the weaker sections.

In addition to short and medium term loans, long-term loans for improvement of land, digging of wells, installation of pump sets, construction of large irrigation channels, etc. are being provided by the Cooperative Land Mortage Banks. All the States in the country have now set up Central Land Mortgage Banks. Share capital participation in the land mortgage banks by the Government, provision of managerial subsidy and subsidy for appointment of land valuation officers, etc. have been provided in the Five Year Plans. It is expected, that by the end of the Third Plan, long-term cooperative credit (outstandings) from the cooperative land mortgage banking structure would be of the order of Rs. 150 millions. A decision has been taken to route all Government loans for land improvement and production purposes through cooperatives thereby recognising cooperatives as the sole institutional agency for provision of agricultural credit. The State Governments are taking action to implement this policy in a phased manner so that in a period of 3 to 5 years, direct loans by Government for production and land improvement to the cultivators will cease in most areas.

For providing finance to cultivators for production of plantation crops such as rubber, cocoanuts, arecanuts, etc., and for large scale reclamation of land in areas where major irrigation projects are coming into existence, special schemes are being prepared by the State Government. These will be implemented through the cooperative land mortgage banking structure with the assistance of an Agricultural Refinance Corporation set up in the country in 1963. The Corporation will help the Land Mortgage Banks to get reimbursement facilities for advancing loans to cultivators. To ensure effective recovery of loans by sale of produce, marketing cooperatives have been organised. There were about 2,300 marketing societies by the end of the Second Plan and about 200 more expected under the Third Plan. These are expected to cover the important market centres in the country. Primary agricultural credit societies are being affiliated to these marketing societies. Action is being taken to see that the marketing societies recover the loans issued by the primary societies by the sale of agricultural produce of its members. Provision of storage facilities for selected agricultural credit societies and for marketing societies is also being undertaken.

PROGRESS MADE ON THE RECOMMENDATION OF THE PREVIOUS SEMINAR.

I. EDUCATION AND ON-THE-JOB TRAINING

Professionals

The Central Government arranged an Orientation Training Course on minor irrigation and water use in South India during 1962. Nineteen technicians participated. About 20 experts from all over the country were invited to deliver lectures and arrange demonstrations. During the training period of two months, 10 days were exclusively spent on field practicals. Many of the trained hands have been appointed instructors for regular training of sub-professionals. Two to three such orientation training sessions are planned for every year in different parts of the country. It is envisaged that in due course a Central Training Institute will be set up.

Sub-Professionals

A training programme for the sub-professionals on minor irrigation and water use has been initiated in the 13 States in the country as already mentioned. The programme has made considerable head-way in 5 States where about 100 sub-professionals have already been trained. Preliminaries are also over at the other training centres and training sessions will start in full swing shortly.

Village Level Extension Workers

During the 2-year integrated course at the 100 *Gramsevak* Training Centres established in the country, village level workers were trained in extension methods, agronomy and water use. For the village level workers who have put in 3 to 4 years of service, in-service training courses of 2 months' duration are being organised at the selected *Gramsevak* Training Centres. During these courses training is imparted on various topics including different aspects of irrigation and water use depending on the requirements. Periodical visits and field trips to experimental stations are regularly organised for the village level workers both during the pre-service and in-service training courses. The Farm Advisory Unit of the Ministry of Food and Agriculture is regularly bringing out leaflets in simple languages for the use of village level workers and farmers.

Farmers

The Directorate of Extension in the Ministry of Food and Agriculture has formulated a scheme for the training of 120,000 progressive farmers during the Third Plan period in improved agricultural practices and allied fields. This training will be completely practical through demonstrations and will be organised at selected *Gramsevak* Training Centres, progressive farms and agricultural colleges. Farmers will also visit progressive farms, research stations and other agricultural institutions. A programme for the exchange of young Indian farmers with those of the U.S.A. has already been taken up on a restricted scale.

II. AGRICULTURAL REQUIREMENTS FOR IRRIGATION PROJECTS

When new irrigation projects are formulated, the irrigation Department in the States invariably consults the Agriculture Department in regard to the agricultural aspects of the projects, such as the cropping pattern proposed intensity of irrigation, soil conditions and irrigation requirements, etc. All proejcts costing over Rs. 50 million are referred by the Central Water and Power Commission in the Ministry of Irrigation and Power to the Ministry of Food and Agriculture for advice on agricultural aspects. Also a joint working group of the Ministries of Food and Agriculture and Irrigation and Power has recently been constituted, and is making a study of the irrigation potential and water management beyond Government outlets and of measures for optimum utilisation of water.

The cost of drainage works in irrigated areas in the case of continuing and new schemes has to be included in the project cost. This procedure is now normally followed by States in preparing initial estimates of the project. As and when necessary, drainage schemes are also formulated and executed for old projects.

Sufficiently detailed soil surveys are now usually made while planning a project. If this is not done on a particular project, the Central Water and Power Commission, while scrutinising, advises the project authorities to carry out such soil surveys.

Every effort is made to intensify agricultural development in areas brought under irrigation. In fact, the availability of irrigation facilities constitutes an important criterion for the selection of districts under the Intensive Agricultural District Programme (IADP) and the Agricultural Production Programmes of individual crops, such as cotton, oilseeds and paddy. The measures for intensive agriculture include (a) fertilizer use, (b) adoption of plant protection measures, (c) use of improved seed, etc.

The importance establishing research stations in project areas to investigate and study problems of irrigated agriculture has been fully appreciated. Five irrigation research centres have been sanctioned by the Ministry of Food and Agriculture, for operation in 5 major projects, namely Bhakra-Nangal, Chambal, Tungabhadra, Hirakud and Gandak.

Provision has been made under each centre for setting up one main station and four sub-stations. The main stations are being established by the State Governments concerned. A few research stations were started by the State Governments earlier in some of the new irrigation project areas. Research schemes for work on agricultural aspects of irrigation have also been sanctioned by the. Indian Council of Agricultural Research and by the Ministry of Food and Agriculture for operation at some of the old research stations under the State and the Central Governments.

In addition to the normal extension service available in irrigated areas, centrally sponsored pilot projects and demonstrations have been sanctioned for operation in ten irrigation project areas. Of these, pilot demonstration centres have already been established in four projects. A few more projects for irrigated areas are also being formulated. To ensure maximum economical land development, it is proposed to set up a few pilot projects in different representative regions of the country, with a view to collecting data on the extent to which agricultural production can be profitably increased if all steps required for proper development of land and promoting economic utilisation of irrigation are provided simultaneously. These projects are expected consequently to pave the way for setting up a land Development Corporation in the country.

III. SERVICE PROGRAMMES FOR IRRIGATED AGRICULTURE

As the majority of farmers in India have uneconomic holdings, a programme for consolidation of holdings is considered essential and is making headway in many States. A scheme of organisation of cooperative joint farming societies has also been taken up on a pilot basis. Three hundred eighteen pilot projects, each consisting of 10 such societies, are to be organised during the Third Plan. The purpose is to demonstrate to the farmers that by pooling lands, man-power, and other resources they can increase agricultural production, employment opportunities and standards of living. By the end of December 1962, 296 cooperative farming societies had been organised. Besides these, organisation of cooperative farming societies in on-pilot areas is encouraged. In all there were about 2,700 cooperative societies at the end of 1962. A National Cooperative Farming Board has been set up. In the States, Advisory Boards have been constituted for planning and promoting the programme of cooperative farming. All these measures are expected to pave the way for a cooperative form of organisation for better use of machinery and irrigation facilities to increase agricultural production.

Agriculture Irrigation Department in the States have been required to provide necessary technical aid and other facilities to the farmers for levelling and preparing their fields and constructing the field channels. Separate funds have been earmaked specifically for this purpose in the Annual State Plans. The project authorities provide the alignment for the field channels. On-the-job training has also been provided to the farmers in some areas.

In areas, where canal systems are not found adequate to meet irrigation requirements, efforts are being made to provide storage facilities in the higher catchments so that all-the-year-round supplies are available. A number of important canal systems in the country have been re-modelled to carry higher discharges for meeting the increased requirements of irrigation. Efforts are made to supplement the canal supplies by taking up works for groundwater utilisation such as dug wells, deep wells, etc.

Grading of agricultural commodities in India has been carried out since 1937 under the provisions of the Agricultural Produce (Grading and Marking) Act and Rules framed thereunder. Grading under this Act is voluntary. Certain important essential commodities such as ghee, vegetable oils, butter, eggs, rice, etc., are being graded and packed in

standard containers or pads for use by consumers according to standard specifications prescribed under the above-mentioned act. The graded produce is sold under 'AGMARK' seal, a national mark that guarantees purity and quality. Further steps have been taken during the Third Plan to intensify the work relating to grading. For introducing grading at the producers' level, the Third Plan provides for organisation of grading services in various States and setting up 500 grading units in the regulated markets and marketing cooperatives. Grade standards have also been prescribed for all foodgrains and other important commercial crops. A special cell has also been set up in the Directorate of Marketing and Inspection, Ministry of Food and Agriculture to carry out intensive publicity for educating both the producers and consumers in this regard. Agmark emporia are also being organised in the important cities for popularising Agmark products.

As regards standardisation of weights, with the introduction of metric system in the country diversity in the use of weights and measures that existed before has disappeared. Metric weights are now commonly used.

Every effort is being made to provide adequate credit for agricultural production. The Government has accepted cooperatives as the main institutional agency for provision of agricultural credit. Detailed information on this subject has been covered in an earlier paragraph entitled "Cooperatives and Credit Facilities". The measures taken are expected to go a long way in providing larger and larger quantum of credit for increasing agricultural production.

There is a planned programme for organisation of marketing societies to cover all important market centres. Adequate storage facilities, subsidies for managerial staff, state participation in share capital etc., is being undertaken.

A systematic programme has been taken up for construction of godowns by cooperative marketing and village societies. By the end of June, 1962, 3,000 rural godowns with a capacity of about 100 tons each and about 1,100 godowns at *Mandi* (centralised market) level with a capacity of 250 tons each were constructed with Government assistance. Besides these, 1,500 rural godowns and 1,000 godowns at the *Mandi* level were constructed by the cooperatives from their own resources. The total capacity of godowns owned by cooperatives is estimated at nearly one million tons. Cooperatives are also being encouraged to have a large number of godowns on hire for storing production requisites, agricultural produce, etc. There is a planned programme for construction of godowns both at the village level and at the *Mandi* level implemented in the Third Plan.

In the processing sector also there is increased interest in cooperatives. There were 57 cooperative sugar factories in the country of which 34 were in production during the 1961-62 season. By the end of March, 1963, the total number of factories in production increased to about 43. They accounted for a little over 20 per cent of the total national production of sugar. Up to June 1962, about 251 other processing units were set up in the cooperative sector which included cotton, paddy, oilseeds and groundnut processing units. The value of agricultural produce processed by cooperative processing units including cooperative sugar factories during the year ending June 1962 was approximately Rs. 520 millions. Next to sugar, the main crops processed by cooperatives were cotton and oilseeds.

Primary agricultural credit societies and marketing societies are increasingly being recognised as the agencies for distribution of fertilizers, insecticides, certified seeds, etc. Cooperatives have been entrusted with monopoly distribution of nitrogenous fertilizers in almost all the States.

IV. OPERATION AND MANAGEMENT OF IRRIGATION PROJECT INCLUDING THOSE USING GROUND WATER

In most States there is a separate Irrigation Department for operation and maintenance

of irrigation systems. The Department is directly responsible for all the necessary repairs and proper regulation of supplies. Regulation of the canals and rostering of channels are carried out after carefully ascertaining the anticipated demands for the crops in the area.

For such minor works, irrigating below 100 to 200 acres, the responsibility for operation and maintenance is being increasingly entrusted to the *Panchayats*. These bodies are being equipped with technical staff and necessary statutory powers for carrying out their work efficiently. *Panchayats* are empowered to levy a suitable cess or irrigation rate on the beneficiaries for meeting the cost of maintenance. In addition, financial grants are also made by the State Governments to these bodies for defraying maintenance and operation expenditures.

State Departments in charge of well construction are taking adequate measures to safeguard against over-draft of supplies and failure of wells. While encouraging well construction in a region, due attention is paid to the location, spacing, etc., so that there is no interference and depletion of supplies in the existing wells. The Departments are equipped with technical staff for this purpose. Efforts are being made to link up the construction of wells as far as possible with soil conservation schemes, like contour bunding, gully plugging, etc., so that good supplies are ensured in the wells.

The first 1-2 miles of the channels on deep wells are invariably lined to reduce the seepage losses. On dug wells also, the cultivators frequently apply mud plaster to their field channels to reduce the losses. Attempts are being made to evolve a suitable cheep lining which may be widely adopted. For repair of pumpsets and other lifting appliances, workshops are being established at the District and Block headquarters and mobile units have also been provided in many areas.

V. FIELD IRRIGATION RESEARCH

Irrigation research specialists in India are not loaded with heavy administrative responsibilities.

As already mentioned in the report, five irrigation research centres have been set up by the Ministry of Food and Agriculture in five project areas. Work on irrigation investigations is also in progress at the research stations attached to some of the Central agricultural institutes and at some of the State agricultural research stations. Schemes on water use research have also been sanctioned by the Indian Council of Agricultural Research and by the Ministry of Food and Agriculture. Results are published in scientific journals. Extension literature is also produced but more stress is placed at present on demonstrations on farmers' fields, this being the best method of convincing the farmers as most of them are not literate.

Research work on such items as timing of irrigation, irrigation methods, cropping patterns, and farm irrigation systems is underway at selected research stations in the country. The programme has recently been strengthened by an additional scheme of research on minor irrigation and water use introduced during the Third Plan. On farm drainage, some work has been carried out in the States of Gujarat and in the Punjab. With the establishment of research centres in the river valley projects, work on all these items will be intensified. These are also proposals to strengthen the research stations for carrying out studies on irrigation and drainage at the existing centres where some progress has been made in these fields of investigations.

VI. WATER LOGGING, SALINITY AND ALKALI PROBLEMS

All investigations for major irrigation projects include pre-irrigation soil survey of command area bringing out clearly the chances of development of salinity and alkalinity conditions in the post-irrigation period.

Drainage is provided in the project estimates to ensure maintenance of water table at a safe level in the project areas. Provision for extra water is also made for reclaiming existing saline and alkaline soils coming under new irrigation projects. The Committee on Natural Resources, under the Planning Commission, has prepared a comprehensive report on wastelands including saline, and water-logged soils and their reclamation. Implementation of the recommendations of this Committee is being taken in hand and when completed, will be helpful in bringing large areas of such soils back into production.

A land reclamation organisation has been set up in the State of Punjab where the problem of water-logging, salinity and alkalinity is most acute. A Land Reclamation Act has been passed by the State Legislature. Already much progress has been achieved and now crops are being raised successfully on many lands which were barren before. It is hoped that 100 thousand acres of land will be under reclamation at an early date. Already about 1,000 cusecs of water is being used for reclamation purposes and this quantity is likely to be doubled in the next year.

Drainage investigations form an important item on the schedule of pre-irrigation soil surveys. So far, over 67 million acres of land have been thus surveyed for the country's major irrigation projects. The investigations include study of sub-soil water table fluctuations and profile studies to a depth of 6 to 10 feet.

IRAN

INTRODUCTION

Iran has a total area of 1,640,000 square kilometers and is located between 25 and 39 degrees latitude. It is a semi-arid region. Overall average annual rainfall is about 300 millimeters with total river runoff of about 100 billion cubic meters per year. Considering the average water requirements of different crops at different latitudes as 6,000 cubic meters per hectare there is sufficient supply to irrigate 17·6 million hectares of land. However, because of the lack of proper management and river control, low irrigation efficiency, and small investment in irrigation system structures, there are only about 2·6 million hectares presently under irrigation. There is sufficient good irrigable land to utilize all of the total water supply that can be developed economically.

The population of Iran is increasing at a rate of 2·5 to 3·0 per cent per year. The pressure of the population for increased food required that Iran utilize all available means to increase its food supply, including the expansion of irrigated areas and the improvement of crop yields on these areas. Over half the value of crop production comes from irrigated lands even though the irrigated area constitutes only about 40 per cent of the annually cropped area. Recognizing the importance of irrigation in producing food supplies for Iran, the Government has placed great importance on the development of irrigation ; a total budget of 28 billion rials has been allocated for water development. In order to carry out such developments rapidly, Iran is utilizing the services of the Plan Organization, the Irrigation Department, the Ministry of Agriculture, and special regional authorities such as Khusetan Power and Water Authority, Sefid Rud Water and Power Authority, Karaj Water and Power Authority and Azarbajan Water and Power Authority. The services available from foreign agencies such as the United Nations, United States Agency for International Development, Economic Commission for Asia and the Far East are also utilized to the fullest possible extent.

PLANNING AND INVESTIGATION

Prior to 1952 water resource investigations were only done on a small scale as a part of the design for some small irrigation schemes. In 1952 FAO experts began assisting and training engineers of the Irrigation Bongah to undertake specialized investigations for collecting basic data for hydrography, soils, agricultural statistics, topography, water economics, and small project designs. Capability has now been developed to undertake these types of investigations. Most of the results of this basic data collection were used by contract groups of consulting engineering firms which worked out the project development plans. During the past year the task of planning for small and medium sized projects has been taken over by the Irrigation Bongah, but large project plans and designs are still undertaken by foreign engineering firms.

Hydrology : The number of river flow observation stations has increased from less than 50 of questionable accuracy in 1950 to about 260 stations (60 stations since 1961) manned by an experienced staff of 200 engineers and technicians specially trained by

US AID and FAO advisers. This staff, and that to the Metrological Service of Iran, have established about 100 metrological stations and 4 sediment sampling laboratories. During the past year, the hydrological work has been expanded and a special group has been established to work on hydrology analysis as related to water resource planning requirements.

Groundwater : Iran is rich in groundwater resources as demonstrated by the development of 40 thousand ghanats (horizontal wells) during the past few hundred years. These ghanats have already developed most of the groundwater that can be obtained by that means, but hydrogeologic experts are aware that much more groundwater can be developed by using modern drilled wells to capture and regulate flows that escape capture by the shallow ghanats. Realizing that the groundwater development in Iran will be an extremely complex undertaking by reason of the existing ghanats, a special groundwater division was established in the Irrigation Bongah in 1959 to train Iranians in groundwater investigation and development with the assistance of FAO specialists. This division now has a staff of about 80 professional employees in addition to lower grade assistants.

Since 1959 the groundwater division has carried out investigations in 11 areas covering about 7,000,000 hectares. This is shown in Table 1 along with the number of ghanats, wells, and other information. In addition to the area studies, special technical assistance has been provided to individual water users drilling new wells and in making reconnaissance planning studies.

Soils : A soils division of the Irrigation Bongah was established in 1954 with the assistance of US AID and later FAO. Since that time the staff has expanded to 11 professional soil scientists and chemists. This staff has completed a reconnaissance soil classification of 165 million hectares and a semi-detailed classification of 2,500,000 hectares.

Developments Plans : Feasibility studies have been made for nine large irrigation and multipurpose projects involving large dams. Of these, five of the dams are completed and one is under construction, and the irrigation systems are being expanded. In addition to these eight other comprehensive planning reports have been prepared for medium sized projects. In addition many special reports have been prepared on special problems of various areas and projects in Iran.

Water economy investigations : In 1954 investigations of water use, agricultural development and statistics on irrigated areas was commenced with the assistance of an FAO advisor. Since then reports have been made on 19 different areas in Iran in addition to short reconnaissance observations of numerous other areas, covering hundred thousands of hectares.

IRRIGATION DEVELOPMENT

Prior to 1953 nearly all irrigation development in Iran was by local groups using ghanats for groundwater development and temporary brush and rock diversion dams to supply crude earth ditches lacking adequate control structures. The government had constructed only six small diversion dams and small irrigation projects.

Since 1953 the government has completed 11 diversion and storage dams and had been constructing irrigation networks to serve 475,000 hectares. In addition rehabilitation work has been progressing on 20 old irrigation systems. About 1955 many private groups and farmers began installing small river pumping plants to divert from the rivers onto the higher unirrigated adjacent lands. About this time farmers began installing large numbers of small centrifugal diesel pumping plants in hand dug shallow wells to irrigate small areas of high priced crops. In about 1958 the farmers interest in utilizing deep wells increased and several private well drilling companies have since been formed. There

are now about 100 well drilling machines operating in Iran which are capable of drilling about 1,000 deep wells per year. The Irrigation Bongah is now equipped with drilling equipment and technical staff to do exploratory work in groundwater to assist in increasing the development and efficient utilization of Iran's groundwater resources.

FLOOD CONTROL

Prior to the contruction of large government projects, very little investment was made in flood control projects as the local people were more concerned with utilizing their limited resources in developing irrigation water supplies. Only minor low levees were occasionally constructed to give partial flood protection. The large dams that have been constructed in recent years are generally multipurpose projects which are designed to provide alar ge measure of flood control on the major rivers. A start has been made in developing the hydrologic foundation upon which to base future flood control projects and flood control activity is expected to increase in the future as agricultural and hydrologic development increase. Attention is now being given to spreading flood waters for groundwater replenishment.

TABLE 1. GROUND WATER INVESTIGATION PROJECTS IN IRAN TO 1963

No.	Name of Project	Total area (Km^2)	Ghanats		Exploration wells		Water Balance (M^3/yr.)		
			No.	Total out-put (M^3/yr.)	Shallow	Deep	Entering	Leaving	Remainder
1.	Ghazvin	600	880	370×10^6	8	10	640×10^6	450×10^6	190×10^6
2.	Varamin	3276	329	255×10^6	8	2	185	205	—
3.	Tabriz	Apro. 4000	405	103×10^6	4	—	U.I.	U.I.	U.I.
4.	Rezayeh	Apro. 3500	40	U.I.	—	—	U.I.	U.I.	U.I.
5.	Maraghen	Apro. 3500		U.I.	—	—	U.I.	U.I.	U.I.
6.	Karaj	3400	U.I.	U.I.	2	—	U.I.	U.I.	U.I.
7.	Meshed	Apro. 5000	325	U.I.	—	—	U.I.	U.I.	U.I.
8.	Esfahan	Apro. 29000	U.I.	U.I.	—	—	U.I.	U.I.	U.I.
9.	Jahrum	Apro. 3000	U.I.	U.I.	—	—	U.I.	U.I.	U.I.
10.	Borazjan	2000	U.I.	U.I.	—	1	U.I.	U.I.	U.I.
11.	Arak	5060	498	120×10^6	—	—	320×10^6	190×10^6	128×10^6

U.I. = under investigation

IRAQ

SUMMARY

The importance of irrigation and drainage in the economic life of Iraq since the earliest times needs no stressing. Irrigation has passed through many stages and was undoubtedly very extensive during various periods in the past. In the last four decades it has developed extensively and made considerable progress towards more scientific management and control.

The land suitable for cultivation is practically valueless without water. The delta of the Tigris and Euphrates rivers lies in a belt of low rainfall which is quite insufficient for any cultivation, therefore, it is almost completely depend on irrigation for its development.

Since the average yearly runoff in the twin rivers is in excess of that required for year-round irrigation of the total land suitable for cultivation, it is clear that the greatest need of Iraq is for storage projects. This does not mean the construction of dams and reservoirs only, it means also the distribution of stored water when and where it is needed.

An important point is flood control. Unless full control of the Tigris and Euphrates and their tributaries is secured, important projects costing millions of Iraqi Dinars* will be threatened by flood-water destruction. The flood of 1954 is still vividly recalled; it caused tremendous losses when it flooded farms and villages and threatened the capital. This tragic event has been repeated many times, thus there is duty to pay more attention to exploiting and utilizing this boon rather than neglecting it to become a source of destruction.

The Directorate General of Irrigation established in 1918, has done its best for development of Irrigation and drainage projects. When all the projects adopted by the Directorate are executed, irrigation purposes will be served along the most modern lines now in practice all over the World. All the cultivable lands in the delta of the two rivers can be cultivated on a permanent basis instead of under the present fallow system.

INTRODUCTION

Iraq has an area of 453,500 squares kilometers (112 million acres) and a population of about seven million. It is blessed with two comparatively large rivers running from the northest to the southest. The discharge of the two rivers and their tributaries is ample and the quality is good.

The land is fertile in the river valley and there is a year-round sunny climate. These treasures are seldom found in such favourable proportions as in the Mesopotamia Valley. Here there is the foundation for an agricultural economy based on inexhaustible resources which can support its people indefinitely at a high standard of living. Unfortunately, with these favourable conditions, Iraq is suffering from a low standard of living due to improper use of these treasures.

* One Iraqi Dinar = One English Pound = 2·8 U.S. Dollars.

Note. This report was prepared and presented by Dr. Omar R. Gardi, Irrigation Engineer, Directorate General of Irrigation. Ministry of Agrarain Reform, Government of Iraq.

The country is doing its utmost to utilize these resources properly and irrigation has progressed considerably through the last three or four decades, but it still has a long way to go. In order to visualize the progress of irrigation in Iraq it is worth while to take a look at what the ancients did.

ANCIENT IRRIGATION

Iraq, the historic cradle of civilization, was for centuries a centre of culture and world power, founded upon the effective utilization of the abundant soil and water resources of the valleys of the Tigris and Euphrates Rivers which provided a high standard of living for its inhabitants.

For thousands of years civilization in the valleys of the twin rivers, flourished side by side with irrigation. Assyrians in the North, and Summarians and Babylonians in the South were the pioneers of irrigation in Mesopotamia. Persians, Greeks and Cassanians followed the Babylonians. Great works were undertaken during the periods extending to the Arab conquest in the year 637. The Nahrwan Canal extended for hundreds of kilometers east of the Tigris from above Sammarah to near Kut. On the west bank of the river, the Ishaki canal runs from Sammarah to Baghdad. From the Euphrates, old canals : the Issa, the Sarsar, the Melcha, the Kutha and many others were provided. These developments, brought fertility to vast areas between the two rivers extending as far south as the tail of the present Gharraf Canal.

The period of Arab rennaissance in art and science, lasting centuries, proceeded side by side with advanced irrigation, particularly on the Diyala, Gharraf, Kufa and Basra. Agricultural districts were raised to higher levels of prosperity while old canals were improved and maintained. The country supported a population of more than twenty five million.

These prosperous periods were followed by desolation to the country and destruction of its irrigation system with the Mongol invasions in 1256. First by Hulagu, and over a century later, by Tamarlane in 1393. Desolation continued during the successive periods of weak rulers until the Turkish conquest in 1534.

Four centuries of Turkish rule slowly revived some of the old irrigation systems in scattered areas of the country. It was not until the early years of the present century that the Ottoman Empire decided to expand irrigation in Mesopotamia with a vast programme of reconstruction and development prepared by Sir William Willcocks. The first important work, the Hindiyah Barrage, on the Euphrates, was completed a short time before the first world war, whereas works on Habbaniyah flood relief scheme for the Euphrates, though started, had to be abandoned on account of the war.

The advance of the British Armies in 1914-1918 resulted in improvement to and remodelling of the derelict irrigation systems throughout the country. New canals were dug and great expanses of arid lands were brought under cultivation. An important factor was the extension of mechanical irrigation which brought fertility to wide strips of lands along the banks of the streams.

PRESENT IRRIGATION

Understanding the historical reasons for the deterioration of irrigation in Iraq and following establishment of the national Government in 1921, the Irrigation Department, created in 1918 by the occupation authorities, was recognized. Since then, the Government has been trying to reclaim the culturable lands in the country by reconstructing the old irrigation systems. While improvement and extension to these systems was achieved surveying and projecting were also actively pursued by various agencies and these covered great areas for further irrigation development together with flood control, hydro-electric power, navigation and recreation.

The total culturable area is about 48 million mesharas* (120,000 sq. kilometers). Sixteen million mesharas situated in the northern part of the country is fed by rainfall supplemented by perennial streams arising in the mountains and is called the "Rainfall Zone". The other 32 million mesharas is situated in the middle and southern part of the country where precipitation is very low and is completely dependent on irrigation for its development. Of this 32 million mesharas, 22 millions are good cultivable land falling in the delta of the two rivers. Presently only 13 million mesharas are cultivated on a so-called "fallow" system basis whereby the land is allowed to rest in alternate years. The theory is that during the rest period the productivity of the land will be restored. This theory has not worked in practice as is demonstrated by the low crop yield in comparison with other countries where modern improved practices including crop rotation, drainage and proper methods of applying water to the land have been followed. The fallow system is one of the reasons why it is impossible for a family to retain use of a particular parcel of land from year to year so that little interest in improvement of the land can be maintained. Another reason for the fallow system is the deficiency of water when it is needed.

Almost half of the 13 million mesharas cultivated under irrigation each year are supplied with water by pumping from rivers and canals rather than by gravity. There are more than 7,000 pumps installed with about 250,000 horsepower. These irrigate about 5 million mesharas. It seems uneconomical to use pumping equipment where the lift is low and where large areas are served when low diversion dams could be built that would provide gravity supply. Several factors have led to the present excessive use of pumping. These include :

1. The desire to limit irrigation to high well-drained bankland rather than to low back-bottom poorly drained lands.
2. The independent action of individual landowners whose required capital investment for a pumping installation is much less than that required for a diversion dam serving a much larger area.
3. The supposition that, in-as-much-as pumping must bear the cost of fuel consumed, less water is used with pumping than with gravity irrigation.
4. The rapid rate of which many irrigation canals have become filled with silt brought in by the turbid river waters.
5. The extensive system of credit operations arising from the dependence on pumps which has become a salient feature of the local economy.

Where gravity irrigation is practiced, little actual control of the flow of the rivers and canals is provided. Thus full advantage cannot be taken of topographic conditions to obtain a maximum extent of gravity irrigation. Furthermore, primitive flooding is generally practiced so that some crops get insufficient water where others are over-irrigated, thus, in general, much wastage of water takes place.

WATER REQUIREMENT AND RESOURCES

It was pointed out previously that there are 13 million mesharas irrigated on the fallow system due to lack of water at the time when it is required. In order to supply this land with year-round irrigation water, the flow in the Tigris and Euphrates rivers must be controlled. If controlled these two rivers and their tributaries would supply the remaining 9 million mesharas not irrigated now with sufficient water for year-round cultivation as well as provide a full supply for the 13 million mesharas now partially irrigated. In order to cultivate this 22 million mesharas on a permanent system for maximum yields it is estimated that the annual water requirement will be 26·1 milliard cubic meters for the Tigris basin

* One meshara = 0·0025 sq. kilometers = 0·618 acres.

and 12·1 milliard cubic meters for the Euphrates basin.

Nature has provided Iraq with an ample supply of water but has not chosen to regulate it so as to furnish the water in the desired amounts when and where required. Drouths used to follow destructive floods that caused great damage to crops and threatened urban centres such as Baghdad. To accomplish the regulation not provided by Nature, great efforts and sums of money have been expanded in the past. Much greater expenditures will be required in the future to realize the full potential of available resources. There are many aspects to this complex problem. These include the storage and later distribution of waters, selecting crops suitable to the soils, settling and working the land, and the related social and economic questions to be resolved. To coordinate this great effort a long range plan is essential. To be successful this must be based on sound engineering investigations and designed to utilize the best modern practices.

The annual water requirements of 38·2 milliards of cubic meters for the existing and proposed new areas represents a very large volume of water. Fortunately, the discharge characteristics of the Euphrates and Tigris rivers and their tributaries have been measured and studied for many years. Records of flow of the Tigris at Baghdad extend back to 1906. Records of the Tigris at other places, of the Euphrates, and of the main tributaries of the Tigris are available for shorter period of time. In recent years the Iraq Government has expanded the programme of streamflow measurements. The flow of the Tigris river at Baghdad since 1906 has averaged 38·8 milliard cubic meters a year. Flow for some individual years, however, has been much lower ; 1930 was the lowest with only 15·7 milliards cubic meters. With storage reservoirs the flow during a single year is not necessarily critical as it is possible to store water during a wet year and use it during a succeeding dry year ; therefore, the flows during a succession of dry years is the critical feature that affects the design of storage reservoirs, determines the amount of available water, and hence the area that can be irrigated. In the Tigris basin, such a succession of dry years occurred from 1930 to 1934. During this critical period, the total flow of the upper Tigris and of the tributaries was 162 milliard cubic meters of 32·4 milliard cubic meters a year. As the requirement is only 26·1 milliard cubic meters, it would appear that ample supply is assured.

On the Euphrates River, flow measurements at Hit since 1924 show the average flow to be 26·4 milliard cubic meters a year ; 1930 was the lowest with only 12·0 milliard cubic meters. The lowest succession of dry years was 1930 to 1934, as on the Tigris ; the total flow was 86 milliard cubic meters or an average of 17·2 milliard cubic meters a year. Thus it appears that ample supply is assured, as for the Tigris. The records showed that not only do the peak demands not coincide with the peak flows but also the monthly distribution of the flows varies considerably among the tributaries. The second factor appears to conflict with the first as reservoir storage space must be kept empty for flood control and full to meet water demand. For so complicated a matter, repeated trial solutions are necessary to determine the best recommended storage capacity for irrigation flood control and sediment (dead storage) outlet and spillway capacities and the operation rules for each reservoir.

MAJOR PROJECTS EXECUTED

Since its establishment the Directorate General of Irrigation has been responsible directly or indirectly for the execution of many storage, flood control, irrigation and drainage projects. These projects have cost more than 150 million Iraqi Dinars. Listed are a few of the major projects completed or in the completion stage :

Habbaniyah Project

The principal purposes of this project are flood control, storage and recreation. If

consists of a Barrage on the Euphrates near Ramadi city to assist in the control of floods by raising the water level upstream of the Barrage and diverting the excess quantities through the Warrar Regulator and inlet channel into Habbaniyah Lake. The maximum discharge of the inlet channel is 2,500 cumecs, and the maximum capacity of the lake is 3·2 milliard cubic meters. Any excess to the capacity of the lake can be diverted through Majarrah escape into the Abu Dibbis Depression. The stored water can be fed back into the Euphrates through Thibban Regulator and outlet channel during the low water season and will serve all the areas on the delta of the river. The total cost of the project was about 7 million Iraqi Dinars.

Tharthar Project

The principal purposes of this project are flood control, hydroelectric power and the supply of irrigation water to Ishaqi project. It consists of a barrage and regulator on the Tigris river opposite Samarra City to divert the flood water through an artificial channel to Tharthar netural depression. The total length of the channel is about 65 kilometers with a maximum capacity of 9000 cumecs. The capacity of the depression is about 70 milliard cubic meters. The total cost of the project was about 20 million Iraqi Dinars excluding the power plant which is not yet constructed except for its foundations.

Dokan Project

The project consists of a dam and reservoir located on the Lesser Zab about 65 kilometers northeast of Sulaimaniyah. The principal purposes are flood control, irrigation, hydro-electric power and recreation.

The dam is a heavy concrete arch type, 110 meters high, about 25 meters thick at the base and 360 meters crest length. The maximum capacity of the reservoir is 8·1 milliard cubic meters and the stored water will irrigate an area of land covering about two million mesharas on the right and left banks of the river and in Adhaim area. The total cost of the project was about 16 millions Iraqi Dinars excluding the power plant which has not been constructed except for its foundation and outlets.

Derbendi-Khan Project

The project consists of a dam and reservoir located on the Diyala River about 55 kilometers southeast of Sulaimaniyah. The principal purposes of the project are also flood control, irrigation, hydro electric power and recreation.

The dam is a massive rockfill with earth core about 135 meters high above stream bed, maximum base thickness of 510 meters and crest length of 450 meters which includes 75 meter length concrete spillway opening. The maximum capacity of the reservoir is about 3 milliard cubic meters and the stored water will be used to irrigate an area of about 1·6 million mesharas in the Diyala River basin. Since most of the area in the Diyala basin is developed at present and depends entirely on irrigation, stored water must be carried from year to year and special attention must be paid to storing the maximum amount each year. This kind of operation is disadvantageous for flood control operations since the reservoir must be emptied to take the floods.

The total cost of the project was about 26 million Iraqi Dinars excluding the power plant which has not been constructed except for its foundation, outlets and two small turbines to supply enough power for the operation of the spillway gates.

Upper Euphrates Project

These projects are situated the west of Baghdad and irrigate an area of about one million mesharas including the gardens of Baghdad. They consist of a number of small projects including Abu-Ghuraib, Saklawiyah and Yusufiya.

These projects have been completed in various stages during the last three decades and each consists of a head cross regulators, main and branch canals. About

60 per cent of the drainage system for the whole area is completed and the other 40 per cent is under construction or under design.

The total cost of these 15 projects is about 10 million Iraqi Dinars.

The Greater Mussaib Project

The project covers an area of about 250,000 mesharas distributed into small holdings. It consists of a main regulator on the Euphrates River about 65 kilometers south of Baghdad, main and branch canals, cross regulators and a complete drainage system. The total cast of the project was about 7 million Iraqi Dinars.

Hillah Canal Project

Hillah canal is the original water course of the Euphrates River, but due to a change in the course of the river it was necessary to build Hindiyah Barrage across it to divert enough water into Hillah canal (180 cumecs) for irrigation. The canal serves an area of about two and a quarter million mesharas. It consists of a head regulator, a main canal (remodelled in 1958), three main distribution systems namely Diwaniyah, Khan Al-Jadwal and Rumaitha, cross regulators, branch drains, and pumping stations. About 20 per cent of the drainage system for the area is completed.

The total cost of the project when all the drainage system is completed will be about 10 million Iraqi Dinars.

Gharraf Project

Gharraf Canal is the old Tigris River Channel and due to the change in the course of the river it was necessary to build Kut Barrage in 1939 to regulate the flow into the Gharraf and Dujailah canals and the new course of the river

The area covered by the project is about 4 million mesharas, half of which is under cultivation at present during the flood season by gravity and pumping. Only a small percentage of the area is cultivated during the low water season by pumping due to the low water level in the canal.

In order to irrigate the existing cultivated land all year round by gravity and to extend irrigation to the other parts of the area, it was necessary to build cross regulators and remodel the whole system. The project consists mainly of the following :

a. Head Regulator completed in 1939 and its included in Dalmaje Project to be remodelled.

b. Main Canal with a maximum discharge of 450 cumecs. Completed.

c. Five cross regulators to raise the water level in the canal. Completed in 1963.

d. Levees along both sides of the main canal are under construction at present.

e. About 400 branch canals completed and will be remodelled in the near future.

f. A complete drainage system about 20 per cent completed.

The project has cost about 10 million Iraqi Dinars to date and will require another 20 million Iraqi Dinars to complete.

MAJOR PROJECTS UNDER CONSTRUCTION OR TO BE EXECUTED IN THE NEAR FUTURE

The Directorate General of Irrigation recently have asked the Planning Board of the Government of Iraq for the allocation of about 150 million Iraqi Dinars for the investigation, design and execution of the projects adopted by the Directorate in the next five-year plan starting on April 1st, 1964. The major projects included in this plan are the following :

Eski Mosul Project

The project consists of a dam and reservoir and will serve as a water storage scheme

for irrigation, flood control and power generation. The proposed site for the dam is on the Tigris River about 50 kilometers northwest of the city of Mosul.

Preliminary investigations of the dam site have been completed and in a few weeks a consultant firm will be selected to design and prepare the tender documents for the dam. It will be a massive rockfill or earthfill dam about 100 meters high and 4,000 meters over all crest length with maximum reservoir capacity of about 13 milliard cubic meters. The dam and its appurtenant structures will cost about 70 million Iraqi Dinars excluding the power plant which will cost another 25 million.

Bekhem Project

The project consists of a dam and reservoir. The proposed site for the dam is on the Greater Zab, about 40 kilometers east of Aqra. The principal purposes served will be flood control, irrigation, hydro-electric energy and recreation. Perhaps its most important function will be flood control because the peaks of all the highest recorded floods on the Tigris have been established by the peak flows of the Greater Zab.

The dam site has been investigated and the dam designed. Tender documents are ready for advertisement. The dam is of concrete of massive buttress type more than 200 meters high, about 125 meters in width at the base of the highest buttress, and 840 meters crest length. The reservoir capacity is 8.3 milliard cubic meters. The total cost of the project is about 50 million Iraqi Dinars excluding the power plant.

Upper Euphrates Project

It appears that Habbaniyah Lake alone is not capable of storing enough water for the exploitation of lands along the Euphrates and for complete flood control. The flow in the river depends on the extent of consumption by Syrian farmers. It was the possibility of sites for storing water downstream of the Iraqi border for use throughout the year was studied.

Preliminary investigations have already been completed and show that there are two possible dam sites at Rawa and Haditha and that the required quantities of water can be provided either by :

a. constructing two small dams, one at Rawa and one at Haditha. The total capacity of the two reservoirs will be about 4 milliard cubic meters which will irrigate about 3 million mesharas. The total cost of both dams will be about 37 million Iraqi Dinars or by,

b. constructing one high rockfill dam at Haditha which will cost about 54 million Iraqi Dinars. The capacity of the reservoir will be about 10 milliard cubic meters and water will be available to irrigate about 4.5 million mesharas.

The consulting engineers have recommended one high dam at Haditha and in the very near future a decision will be taken to proceed with either one of the above alternatives.

Kirkuk Irrigation Project

This project is the complementary part of the Dokan project on the Lesser Zab. Its purpose is to use stored flood water for all year round irrigation.

It will provide water for 1,250,000 mesharas of land which is today either desert or dependant on rain. Especially important is the fact that 700,000 mesharas are of high quality land, suitable for all kinds of crops and heavy irrigation. It will serve the existing Hawijah Irrigation Project (172,000 mesharas) and its extension (30,000 mesharas), the Adhaim Project (482,000 mesharas) and Kirkuk Project (764,000 mesharas).

The project consists of a dam at Dibbis to raise the water level in the river by 15 meters and divert the flow into the feeder canal which will serve for the irrigation of the

lands between Kirkuk and the Jabil Hamrin, together with the lands on either side of the Adhaim river. It also includes minor canalization and a pumping station to supply water to about 100,000 mesharas of high lands around Kirkuk.

The construction of the dam will be finished in 1965 and the main feeder canal will be advertized in the very near future. The whole project is expected to be finished in 1975 with a total cost of about 60 million Iraqi Dinars.

Ishaqi Project

The area of this project lies on the right bank of the Tigris river north of Baghdad. The total area of the project is about 640,000 mesharas of which about 300,000 mesharas are suitable for agriculture. Part of this area is under cultivation at present by pumping.

The project headworks have been included in the construction of the works at Sammarah for the Wadi Tharthar diversion. In addition the work consists mainly of two main drains, branch drains, main canal, branch canals and pumping station. One of the main drains (65 kilometers) and the pumping station have already been completed and the other parts are planned to be executed in the very near future. The total cost of the project is about 10 million Iraqi Dinars.

Diyala Project

This project is the completion of work related to the Derbendi-Khan Dam and Reservoir on the Diyala River in order to use the stored flood water for year-round irrigation. The project area is situated on the Diyala basin and consists of two main parts :

Middle Diyala : This will cover an area of about 250,000 mesharas which are partly under cultivation at the time being either by rain or by small canals taking off directly from the Diyala River without any control. The work consists of constructing three weirs on the Diyala River to divert the flow into three main canals, a fourth main canal taking off without a weir, and the branch canals. The total cost will be about 4·5 million Iraqi Dinars.

b. Lower Diyala : This will cover an area of about 1,150,000 mesharas which are partly under cultivation at present under six independant canals taking off at the upstream of Diyala weir. The work consists of remodelling the weir, constructing a combined intake structure for five canals which takes off from the left side of the river about 10 kilometers upstream from the weir, remodelling the canals and branches and the construction of the minor canalization. The total cost will be about 15 million Iraqi Dinars. The project is presently under design and construction will start in the very near future.

There is a complete drainage system presently under construction for the Lower Diyala part of the Diyala Project which will be completed in a year's time and which will cost about 12 million Iraqi Dinars.

Dalmaj Project

The project includes that part of the Middle Tigris Right Bank area which can be irrigated either by gravity flow or low lift pumps from the Tigris Upstream Barrage. It will cover the remodelling and extension of the existing project which consists of two free flow canals and a third canal served by a pumping station. The three canals presently serve about 180,000 mesharas.

The work consist of raising the retention level at Kut Barrage and Gharraf Head regulator by 1·2 meters, remodelling the head regulators for the two free flow canals and constructing a new pumping station for the third canal, remodelling the existing canals or constructing new canals where the existing ones cannot be remodelled and constructing a complete drainage system for the whole

project. The work also includes minor canalization and few small pumping stations.

The project will serve about 400,000 masharas of good cultivable land which is divided into about 6,500 farms. It has been divided into 15 contracts to enable small Iraqi contractors to contribute to the construction and not to reduce interference with existing irrigation. All contract documents are ready for advertisement and the first contract (raising the retention level at Kut Barrage) has been advertized. The whole project is expected to be finished in about 1970 at a total cost of about 10 million Iraqi Dinars.

EDUCATION AND TRAINING

Although about 70 per cent of the Iraqi people depend on agriculture for their livelihood, farmers in many places still use primitive farming methods due to their ignorance of existence and handling mechanical equipment used for farming and due to their low standard of living.

There is about 48 million mesharas of cultivable land in Iraq and there is enough water for irrigation which should be more than ample to supply the seven million inhabitants of Iraq with farm products. Unfortunately this has not been realized and the Government of Iraq has established in the recent years several offices through the Ministries of Agriculture and Agrarian Reform to aid farmers technically and financially so that they can get better use of their land. Some of these offices are :

a. **College of Agriculture.** Students take a four year course after high school. These include agronomy, soils, plantation, irrigation and drainage, surveying, etc. After completing their courses they become assistant technical advisors to the farmer organizations. It is intended to establish an Agricultural Engineering Department at this College.

b. **Agricultural Schools.** There are about 10 of these schools in the major cities of Iraq where the students, after graduating from junior high schools, take a three year training course in scientific farming methods. After graduating they are placed in agricultural offices to aid and advise the farmers in the use of modern methods of farming.

c. **Directorate General of land Confiscating and Division.** Since most of the agricultural land was owned by big landowners and fuedalities up to 1958 and most of the product went to the owner leaving the farmer with very little to live on, this office was established to confiscate land and divide it between farmers according to the Agrarian Reform Laws.

d. **Directorate General of Agricultural Cooperative Department.** The responsibility of this office is to organize, supervise and direct the cooperative organizations of farmers according to the rules and regulations. After the farmer gets a piece of land from the Directorate of Land Confiscation (40 to 60 mesharas), this department sees that the farmer joins one of the cooprative organizations so that he will use his land in the best possible way.

e. **Cooperative Farmers Organization.** These organizations are formed by the farmers themselves and each farmer shares in the stock of the organization. They provide needy farmers with seed and financial aid and technical advice and they meet regularly to study the best ways for the improvement of their land and production. Another responsibility of the organization is finding markets for their products.

f. **Directorate General of Agricultural Machinery.** This office takes the responsibility of renting modern agricultural machines and equipments

to the farmers. It is a non-profit office and has established several training centres to train drivers and mechanics for driving and maintaining their and other private owned machines.

g. **Agricultural Bank.** This bank provides the farmers organizations and sometimes the farmers themselves directly with cash advances.

CONCLUSION

The Iraqi Government has realized that the future of the country lies in agriculture, hence through the Directorate General of Irrigation and other Departments it is doing its utmost to utilize the land and water in the best possible way. It is hoped that when all the projects are completed and the farmers are educated, prosperity will prevail over Iraq and the people will have a higher standard of living.

JORDAN

INTRODUCTION

Jordan has a population of 1,750,000 (approximately 70 per cent are farmers) with an area of 100,000 square kilometers. Roughly 1,000 square kilometers are under irrigation and 7,000 square kilometers are dry farmed. The remaining area is desert that receives less than 100 mm. of rainfall per year. Considerable progress has been made in the past few years in irrigation development. Several agencies, both governmental and private, have shared in this development. Adequate water for irrigation still remains a problem and development of both new and old sources has been carried on through the efforts of the East Ghor Canal Authority and the Central Water Authority. In cooperation with these agencies, the Agricultural Credit Corporation and the Cooperative Union make credit available to farmers for small irrigation projects. The Ministry of Agriculture through its Agricultural Extension Department and Research Department have made special efforts to assist farmers in becoming more efficient in their management of irrigation. This report therefore, deals with the progress of each department.

EAST GHOR CANAL AUTHORITY

Since the last Seminar the East Ghor Canal Authority has made the following progress :

A. The completion of the Main East Ghor Canal, a length of 47 kilometers. The completion of the distribution system of Section II of the project area serving 905 farm units of an average size of 30 dunums through 104 kilometers of laterals. The completion of the surface drains in Section II and Section III of the project area. Work is also underway in Section III to serve an additional 1,526 farm units through 171 kilometers of laterals of various sizes. Construction of works to serve an area of 100,000 dunums is expected to be completed by December 1964. When completely finished, the East Ghor Canal Project will serve an area of approximately 120,000 dunums of fertile land.

B. The Water Distribution and Maintenance Office was established in 1962, and is in charge of operations and maintenance work in the project area. This office is supplying water to all the farm units in Section I and II of the project area. Such farm units are receiving water according to the system described in our technical paper and are now entitled to water rights from the Yarmouk River, the source of water for the East Ghor Project.

C. The East Ghor Canal Authority now has trained and skilled personnel in all phases of the project *viz.* design, construction, administration, operations and maintenance such that it was possible to phase out consulting help from outside. At present all the staff of the East Ghor Project are Jordanian.

D. An important phase of the project is the land settlement programme. A total of approximately 70,000 dunums has been expropriated and redistribu-

ted amongst farmers according to the new ownership pattern set forth by the East Ghor Canal Law. At present the redistribution of the rest of the lands in the project area (50,000 dunums) is underway.

E. In December 1963 construction started on Wadi Ziglab dam. Wadi Ziglab is a side perennial stream flowing into the area. An (earth fill) dam on this wadi is to be built to store runoff water for use during critical periods of flow of the Yarmouk to supplement the supply for the East Ghor Project area. The capacity of reservoir will be 5,000,000 cubic meters.

In August, 1963, the East Ghor Canal Authority transferred the Farm Development Division to the Ministry of Agriculture and it has been continued through the Agricultural Extension Department. Progress shown in this report for the Farm Development in the East Ghor Canal Project is the result of efforts under the East Ghor Canal Authority prior to August 1963 and of the Agricultural Extension Department since that date.

MINISTRY OF AGRICULTURE — DEPARTMENT OF AGRICULTURAL EXTENSION AND RESEARCH

On completion of the irrigation distribution system in Section I in the East Ghor Canal Project, the Development Division in the East Ghor Canal Authority established a general programme for land development over this part of the Ghor area. Section I has a total area of 34,000 dunums which was divided to 956 farm units.

The Land Development Section in the field supplied the technical services, land development machinery and materials to the farmers to develop class 1, 2 and 3 land only. According to the preliminary surveys which were done over all the farm units of Section I, the following activities were accomplished to irrigate the farm units from the present distribution system :

A. **Heavy Leveling :**

1. Nonirrigable areas that needed less than 30 centimeters cut.
2. High irrigable land which could not be irrigated by the new system. Heavy leveling was completed in 145 farm units by using the development tractors and earth moving equipment. Other heavy leveling with more than 30 centimeters gut is still required in an area of 135 dunums scattered over 22 farm units. This will be the responsibility of the farmers and technicians offer the technical assistance only.

B. **Spot Leveling**

Spots which had an average of 15 centimeters cut or fill were levelled. All old ditches were filled. Eversman Land Levelers smooth most of irregularities in the farm units. Spot leveling was done in 380 farm units.

C. **Head Ditches and Structures**

1. Head ditches in 553 farm units were staked by the development technicians and opened by the tractors and the ditchers of the Development Division and the labourers which the farmer supplied.
2. To avoid erosion, 1,153 drop structures were installed along the steep slope parts of the head ditches in 231 farm units.

In July 1963, the Government modified the law of the Development Division in East Ghor Canal Authority. All the responsibilities of the Development Division were moved to the Ministry of Agriculture. According to this modification the Development Staff was transferred to the Agricultural Extension

Department to form the Agricultural Extension Office in the East Ghor District. East Ghor Canal Authority became responsible for leveling the nonirrigable spots and filling the old ditches in the farm units in Section II only. Agricultural Extension Office responsibility was limited to land development, soil and water conservation problems and extension services in Sections I, II and part of Section III.

To assist the farmers in land development and water conservation work in the East Ghor area an agreement between the Government of the United States of America and the Jordan Development Board was established for an Incentive Payment Programme. Approximately 750 farm units in Section I and II or approximately 22,500 dunums will benefit from this programme.

This programme is planned to carry out the following activities in the farm units :

1. Setting up irrigation methods for conservation of water.
2. Construction of farm ditches and water control structures.
3. Establishment of surface drainage systems and construction of control structures to protect farm units from erosion.
4. Planting berseem or alfalfa for the development of a livestock programme.

Farmers applying for the above activities can receive 50 per cent of the total cost estimates but not more than JD. 100.

The Cooperatives and the East Ghor Agricultural Extension Office coordinate with the farmer to do the work. The Cooperatives are financing this Incentive Payment Programme which is presented in another report for this Seminar.

CENTRAL WATER AUTHORITY

For increasing the water available to present irrigated lands and to make sure that what water there actually gets to the land, the Central Water Authority has completed eleven small irrigation projects, serving a total of 11,180 dunums of land and having a total effective water flow of 2,846 cubic meters per hour. The actual total cost expenses of these projects amounted to 97,790 Jordan Dinars.

Some of these projects have been in use since ancient times and have largely fallen into disrepair. After springs are cleaned out and the outlets lowered to make sure no back pressure is exerted on the spring source, the spring is covered in order to prevent contamination from flood flows, then the water is generally led through a covered canal or pipe to a location with enough head for a domestic fountain or faucets. After this, the water is led in an open channel to an animal trough and then to a night storage pool with sufficient head provided for efficient irrigation use. Small concrete-lined canals are used to assure that maximum water gets to the land.

Table I shows information about these small irrigation projects.

The actual costs include the spring developments, diversion head works, aqueducts, chutes, drops, etc., where and when necessary.

The Central Water Authority has completed a low, earth-fill dam at Qatraneh, located about 100 kilometers south of Amman, for the purpose of conservation and use of winter surface run-off in a desert wadi. The reservoir area has a capacity of 4,000,000 cubic meters. It was filled as a result of a storm almost immediately after it was finished. The dam has a maximum height of 12·5 meters and is 300 meters long. The total volume is 76,000 cubic meters and the total actual cost was 75,000 JD. including the expenses of 3,000 meters of irrigation earth ditch down stream for the use of 500 dunums of irrigable land. Although the main purpose of the dam was to provide water for irrigating the land below the dam, it was thought that the reservoir area of 2,500 dunums (1 dunum = 1000 m^2 = 1/4 acre) can be used for growing

grasses and other crops as the water recedes. The Agricultural Extension Department of the Ministry of Agriculture conducted trial plantings on 40 dunums to study the possibilities of cropping the land saturated with moisture in the reservoir area. The trials included field crops and vegetables. The results were very satisfactory especially local corn (maize), snake cucumbers, and water melons in spite of the fact that the date of start was at least one month later than the season.

The Central Water Authority has completed the construction of a small diversion earth fill dam with controlled outlets for the diversion of flood water flow. This was built on Wadi Abu Suwaneh and the project is called Qasr El Hallabat water spreading project and is located about 45 kilometers northeast of Amman in the desert area. The dam is 4 meters high and 250 meters long. The total earth moved is about 24,000 cubic meters and the total actual cost is about 6,200 JD. The project is serving 500 dunums for grazing purposes.

The Central Water Authority has made 26 reports for the Agricultural Credit Corporation for irrigation projects of surface, pumping, and drainage types in different parts of Jordan during the last two years. These projects were requested by the Agricultural Credit Corporation for loans purposes for individual and cooperative societies.

TABLE 1. SMALL IRRIGATION PROJECTS COMPLETED DURING 1962-63 BY CENTRAL WATER AUTHORITY

	Name of Project	Water flow in m^3 per hour	Area served in dunums	Earth canal lined with concrete in m.	Actual cost in JD.
1.	Ain Sidr	11·0	110	1000	4060
2.	Shammakh	3·0	50	750	4130
3.	Abu Makhtoub	6·4	100	700	3010
4.	El Lajjoun	40·0	440	350	1530
5.	Dhanah	19·6	500	40	3500
6.	Ainah	85·0	3000	3000	7050
7.	Dhour	2·6	200	+ 170 pipes 3000	7970
8.	Wadi Mousa	68·7	1560	11500	35120
9.	Hadeetheh	1530·0*	3000	+ 600pipes 4000	17660
10.	Wadi Fara'	180·0	1920	6000	11840
11.	Ruseifeh	900·0	300	100	1920
	Total	2846·3	11180	30440	97790

* Wadi flow — The others are springs.

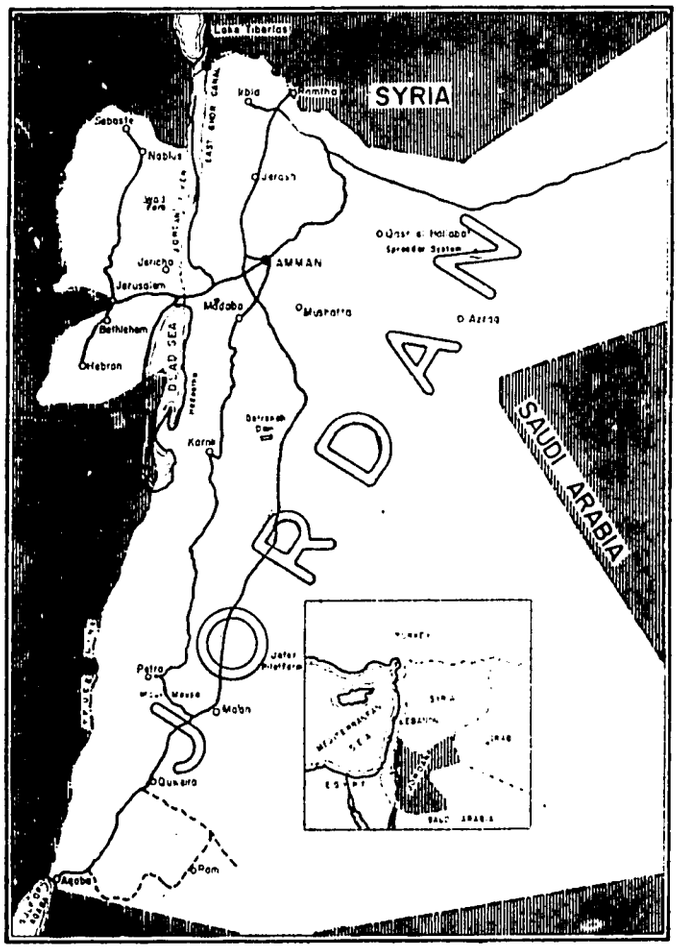
This Authority made the necessary field trips, surveys, plans and designs for each project and forwarded technical reports and recommendations for same. These projects are serving a total of 23,600 dunums of land with a total estimated cost of 134,000 JD.

The Ministry of Agriculture through the Research Department together with the Central Water Authority initiated an experimental farming project in the Jafer area. The project was called Jafer Pilot Farm and is located in the desert area, some 230 kilometers southeast of Amman. The plot is 45 dunums and will be irrigated by pump from one of the producing wells which were drilled by the Central Water Authority in that area. The total depth of the well is 51 meters and static water level is about 12 meters with a yield of about 150 cubic meters per hour while the draw-down is only around 1 meter. The T.D.S. was 563 ppm. and pH_8. as analysed during September 1961. The total actual cost of the well amounted to 893 JD.

The soil is high in salinity and possibilities of natural drainage are poor. If the experiments prove to be good and successful on this small project, there is a possibility at least of several thousands dunums being put under irrigation in that desert area.

AGRICULTURAL CREDIT CORPORATION

The agricultural Credit Corporation was established as a legal entity with an independent financial status. The main object of the Corporation is to provide supervised credit for farmers in Jordan. Approximately 131,500 JD. has been loaned directly to farmers for irrigation improvement. The Central Cooperative Union has received 11,840 JD. for the development of cooperative irrigation projects.



TURKEY

INTRODUCTION

This report follows the recommendations of the Fourth NESA Irrigation Practices Seminar, and includes progress in irrigation in Turkey since April 1962.

The first Five Year Development Plan, covering the period of 1963-1967, which emphasized the agricultural sector may be considered the most important single fact in the progress. A well balanced development plan is recognised as almost a magic device in exploiting natural resources of countries and there are good examples in Near East and South Asia.

The conception of development in a PLAN was accepted by many countries after Word War II. It became a main topic to be talked about, and between people. Today in Turkey, the Development Plan statement is trusted, respected common property.

The PLAN has the following characteristics :

a. It is an overall plan determining targets and amount of investment for each sector of economy.

b. The first plan is derived from a perspective plan for next fifteen years, as its part.

c. The plan is a law approved by the Parliament.

d. Annual plans may be revised and adjusted by the Government, provided the targets of the five years are not changed.

e. The plan gives the necessary measures to be taken and changes in procedures and in regulations.

DEVELOPMENT PLAN

The total investment over the five year period, 1963-1967, will be 59·6 billion T.L. which is composed 36·7 billion T.L. of Government and 23·9 billion T.L. of private investments. This amount accounts for 18·3 per cent of the national income which consists of 14·8 per cent national savings and 3·5 per cent foreign aid.

With 7 per cent annual increase, the national income of 52·7 billion T.L. in 1962 will go up to 145 billion T.L. at the end of fifteen years, an increase of 175 per cent.

Considering 3 per cent increase in population, the actual increase of per capita income will be 78 per cent.

Per capita income (Table 1), distribution of active population among sectors (Table 2), employment and unemployment levels (Table 3), and estimates of GNP and agricultural product (Table 4) are given in the following tables.

AGRICULTURAL SECTOR

Objectives of Agricultural Policy

The plan for agriculture gives due importance to the place occupied by this sector in the general economy. In conformity with the general objectives of the plan, the following

Note : This report was prepared by Salahattin Kilic, Chief of Investigation and Planning Division, General Directorate of State Hydraulic Works and Nurhan Gurel, Agricultural Engineer, Directorate of Soil Conservation and Farm Irrigation.

Table 1. Per Capita Income

Year	1962	1967	1977
Income T.L.	1790	2190	3200

Table 2. Distribution of active population among the sectors (per cent)

Sectors	1962	1967	1977
Agriculture	77·4	71·1	58·1
Industry	9·8	11·9	15·6
Services	12·8	17·0	26·3

Table 3. Employment and unemployment levels (million population)

	1962	1963	1964	1965	1966	1967	1972	1977
15-64 age group	15·7	16·1	16·5	16·9	17·5	18·0	20·9	24·2
Labour supply	14·2	14·4	14·7	15·0	15·3	15·7	17·6	19·9
Total volume of employment to be created	12·7	13·1	13·9	13·9	14·4	14·8	16·8	19·2
Unemployment	1·5	1·3	1·2	1·1	0·9	0·9	0·8	0·7

Table 4. Estimates of GNP and Agricultural Product

Years	GNP (Billion T.L.)	Agricultural product (Billion T.L.)	Agricultural product (as % of GNP)	Agricultural product per capita (T.L.)	Agricultural product per capita of rural population (T.L.)	Agricultural product per capita of active rural population (T.L.)
1962	52·7	23·1	23·8	785	1,000	2,400
1967	73·9	28·3	38·3	838	1,300	2,700
1977	145·3	42·7	39·4	941	1,900	3,800

objectives have been laid down for agriculture :

1. To maintain a 7 per cent rate of growth in gross national product without resorting to inflation ; at the same time, to raise agricultural production with a view to expanding exports and meeting the growing industrial needs for raw materials, thus fostering industrialization ;
2. To improve nutritional levels, by increasing the intake of protein and in particular of animal protein foods ;
3. To further the social aims of the plan by : promoting the increase of consumption with the object of reducing income disparties ; contributing to reduced unemployment ; hindering unplanned urbanization due to the excess flow of workers from villages to cities over and beyond the employment—creating capacity of non-agricultural sectors ; and, in general by encouraging agricultural and community development.
4. To achieve the long-term objectives of the plan by promoting the balanced utilization of land in the long-run, and in this way help to conserve resources as well as ensure their most efficient use.

Education and Training

The general policy of education and training as regards agriculture, consists of :

1. Preparing curricula related directly to specific problems in the agricultural sector.
2. Attaching importance to agricultural education and extension as well as to training in agricultural trades and handicrafts.
3. Organizing the training of skilled workers and of technical personnel at every level.
4. Providing courses on non-agricultural subjects for those who wish to leave agriculture.

Production Targets

Table 5 shows the change in the composition of agricultural production. The changes which have occurred in the relative importance of different products in total agricultural production are marginal. A radical change

Table 5. Composition of Agricultural Production (Percentage share in value of major groups of products within gross total production and production indices)

Groups of Products	1962	1967	Production Index (1962 = 100)
Cereals	23·1	21·3	115
Pulses	2·0	2·8	175
Animal feed	15·1	13·7	114
Fruit and vegetables	19·7	19·5	125
Industrial crops	10·6	11·6	132
Livestock products	26·5	27·7	131
Forestry products	2·4	2·6	138
Fishery products	0·6	1·3	280
Total	100·0	100·0	125·6

in the structure of agriculture, moreover, cannot be expected to take place within the fairly short period of five years. The factors slowing down such a conversion include old-established production and consumption patterns, the rapid growth of population and the resulting high demand for basic foodstuffs organization deficiencies and the short construction period for key investments. With the limited supply of arable lands now available, development in the coming years can be achieved only by the rational use of the limited investible resources and by higher productivity. Due to this, the rate of agricultural growth in the Five Year Plan period is estimated to be only somewhat higher than that in recent years. However, it should be remembered that this is a period of preparation in which the foundation will be laid for sustained development in the future.

As seen from Table 5 a more intensive farming system will be gradually introduced in the plan period as a consequence of better land utilization and a more balanced pattern of production.

Institutional Reforms

1. **Administrative Organization** : The statistics which serve as a basis for framing agricultural policy will be improved.

   In order to ensure that the information needed for planning is available, the collection and classification of agricultural statistics will be reorganized. In addition to the data furnished by agricultural censuses, information will be sought with regard to the following items : agricultural output, quantities marketed, stock estimates, prices received and prices paid by agricultural producers, farm incomes (including those of landlords sharecroppers, tenant farmers and livestock breeders), and outstanding debts of farmers. In obtaining this information, besides the usual statistical data, use will be made of questionnaires based on sample methods, cadastral surveys and studies of the budgets of farming families, and on agricultural credits. Considering that adjustments will have to be made in the plan, administrative measures will be taken to make it possible to obtain in a short time the statistical data required. Research on agricultural economics will be organized by the Ministry of Agriculture in liason with the Institute of Statistics.

2. **Administrative Reform** : After the services to be performed by the State in the Agricultural sector have been determined, the organization responsible for carrying out these services will be set up. This organization will be responsible for promoting the development of soil and water resources, of vegetable and animal production and for ensuring more efficient control of plant and animal diseases.

   Besides administrative reform, measures will be taken to ensure that the technical personnel is effectively engaged in productive work, and that advisory workers are not employed in administrative capacities.

   For the agricultural services performed by agencies which are not attached to the Ministry of Agriculture, care will be taken to ensure the conformity of these services with the objectives of agricultural policy.

Improvement of Agricultural Services

1. **Agricultural Extension** : In order to attain the agricultural objectives of the plan, extension services must be enlarged and made more efficient. In planning investments, provision has been made for meeting the estimated increase in vehicle requirements arising from the enlargement of services. It is estimated that extension

activities will require a staff of 7,700 trained workers (1) as against the existing number of about 4,400. (2) However, the effective number is in reality lower than 4,400 as these agents, particularly those who work in the field of crop production, are also engaged in activities outside extension. Extension services will contribute to a large extent to the attainment of the plan objectives and must therefore be intensified and improved.

2. **Agricultural Training** : Intensifying extension services and other agricultural services will not be possible merely by making better use of existing personnel. The training programme of the Ministry of Agriculture will have to be revised to include training courses for technical staff at high and medium levels. Provision has been made in the investment programme for the opening of new training schools.

3. **Agricultural Research** : Research will be carried out on the technical factors determining the relationship between inputs and yields, and practical conclusions will be drawn from these studies. The studies undertaken in order to determine the situation of land use in Turkey: namely the acreage of agricultural, pasture and forest land, will be accelerated and efforts will be made to ensure that land is used according to its classification.

Agricultural Credit

In order to attain the agricultural targets set in the plan, the activities of agricultural producers must be directed toward these targets. Agricultural credit will be an effective means of orienting agricultural activities and encouraging investments in structural and farm improvements. At the same time, agricultural credits will serve to encourage the wider use of inputs which help to raise productivity.

It is intended to start supervising credits to ensure that they are used for the purpose for which they were granted. Measures will be taken to ensure that fertilizers and quality seeds, in particular, are granted in kind.

A distinction will be made in practice between credits of an operational nature and those that are for investments. In conformity with the targets, medium-term credits for investment are to be raised ; in granting these credits, care will be taken to see that they are directed towards the fields of investment stressed in the plan. Operational credits will be given in the season in which they are required by procedures and repaid in the period of sale of the produce. The matter of security will be reviewed with a view to obtaining the best possible returns from credits.

The Agricultural Bank will determine, in cooperation with the Ministry of Agriculture, the fields in which credits will be assigned, the extent of credit requirements, the areas to which credits will be granted, and it will also supervise the use of these credits. The allocation, in conformity with the provisions of Law No. 2836 of 1 per cent of the budget to the Agricultural Bank for addition to its capital, will be continued in the plan period.

The Agricultural Credit Cooperative set up under Law No. 2836 to give credit to farmers will be authorized to accept deposits in order to channel agricultural savings to agricultural fields.

Marketing

1. The development of cooperatives, set up as joint marketing and credit organizations, will be encouraged.

2. Measures will be taken to encourage the private sector to set up marketing facilities in appropriate places chosen

with regard to their distance from production centres and markets. If need be, these facilities will be set up by the State.

3. Roads and transportation between centres of production and markets should be developed. To this end, account will be taken of the studies to be undertaken on the marketing situation of the different products in connection with the preparation of village and provincial road programmes.

4. Starting with export products, standards will be prepared by the Turkish Standards Institute. The Ministries of Commerce and Agriculture will inspect deliveries to see that they comply with the agreed standards. The cost of standardization, however, must not be such as to exceed the benefit which will accrue from its application.

Farmers' Organisation

Setting-up of cooperatives is recognized to be generally beneficial for agriculture. Studies will be made to determine whether there exist reasons which prevent farmers from setting-up cooperatives. Small and medium farmers, in particular, will be encouraged to form cooperatives so that they may benefit from the advantages enjoyed by large holdings with regard to production and marketing.

Agricultural producers will be encouraged to form associations. Chambers of agriculture will be set up, at first gradually and in certain districts, if it is not thought feasible to establish them in all parts of the country at once.

It is considered that organizing farmers within the framework of community development will also help to promote higher production. This subject is considered in more detail in the section on Community Development.

Measures to Stimulate Production

LAND REFORM

1. **Distribution of Ownership**

a. *Size of Holdings* : In determining the size of minimum holdings and ceilings for maximum holdings, the following consideration will be kept in mind : the reduction of excessive income disparties ; the minimum level of income necessary for the subsistence of a family ; the degree to which land consolidation can be carried out ; the possibilities for increasing the productivity of large and small holdings and the taxation of large incomes.

b. *Land Consolidation* : Though the fact that plots are scattered and fragmented helps to alleviate disguised unemployment, it is essential in principle that farming units should be contiguous to the extent permitted by physical conditions. Consolidation is one of the features of the agrarian reform to be carried out. In addition, importance is attached to the consolidation of holdings in areas where irrigation and soil improvement projects will be implemented and measures to this end will be taken.

c. *Rationalization of holdings* : Measures will be taken to ensure that both existing holdings and those created as a result of land redistribution will be managed on economic lines and in compliance with modern exploitation techniques. Measures complementary to land reform must therefore be taken in the sphere of training and extension to ensure the supply of means of production, to promote cooperative movements,

and in relation to taxation and public works programmes.

d. *Land for Redistribution* : Redistribution of land will concern, beside the lands owned or administered by the State, that part of private land which is in excess of the maximum limits to be set and which will be expropriated.

2. **Regulating Share-Cropping and Tenancy Conditions**

a. Share-cropping and tenancy rights will be based on precise contracts. Standard types of contracts will be prepared in which the rights of sharecroppers and tenants are protected.

b. The amount of the lease, the share of croppers and the conditions of payment will be determined with reference to specific conditions.

c. Production and investment outlays will be shared according to certain regulations.

PRICE POLICY

1. The price policy to be followed will aim at stimulating productivity in certain fields and will be used as a means of influencing the redistribution of income. The main principle will be to support input prices and to ensure that farmers pay low prices for feedstuffs, fertilizers and improved seeds.

2. In view of the inflationary effect of a general upward tendency in prices, it was considered essential that no price increases should be initiated in products whose prices are officially fixed.

In determining the prices of agricultural products, the relative prices of these products will also be carefully examined.

3. Price stability depends on credit and marketing facilities and on general conditions. The fact that agricultural producers contract debts with merchants or middlemen, or do not dispose of sufficient storage space, means that a large part of the crop will be sold at the time when it is most abundant, thereby creating marked price differences. The effect of credit and marketing facilities on prices is an added reason for improving these systems.

The stabilizing effect on prices of the existence of national foodstuff stocks has also been considered. The difficulty in this respect is to build up sufficient stocks in the initial period. The possibilities of making use in this connection with U.S. agricultural surplus goods will be fully explored.

As a means of preventing price fluctuations, consideration will also be given to setting up warehouses (from which purchases may be made) in small centres rather than large stores in the main consumption centres. This function can also be assigned to cooperatives. Encouragement will be given in particular to farmers' organizations in the field of such perishable products as fresh fruit and vegetables, and milk, with the object of stabilizing producer prices.

EXISTING IRRIGATION IN TURKEY

Turkey has been working on 47 large irrigation projects, since 1962, which are partly executed and presently supply irrigation water for 76,300 Ha. Upon completion these will ultimately cover 147,950 Ha. At the beginning of the 1964 irrigation season, 265,300 Ha. land was under irrigation in government built projects.

Crop distribution in the existing projects during 1963 was as follows :

49.5 %	industrial crops (cotton, sugar beets, tabacco, sun flower, anise, hemp etc.)
31.0 %	cereals (wheat, barley, oat, corn and millet)

9.0 % orchard and truck crops
2.8 % forage crops
7.7 % others

Irrigation Projects under Construction

According to the 1964 execution programme, the total number of irrigation projects underway, including recently started projects will amount to 58 projects which cover an area of 315,000 Ha. An area of 105,150 Ha. out of that 315,000 will be put under irrigation at the beginning of the 1965 irrigation season.

IRRIGATION ORGANIZATION

The functions and organizations of two main agencies, DSI and Topraksu; are given in the previous report.

The institutional development since last seminar is the subject matter of a separate paper, but may be summarized as some-improvement and establishment of supplemental units of DSI and Topraksu, as follows :

a. Nine "planning Field Offices" covering large river basins and important project areas were established by DSI. These units have similar responsibility to that of Central Investigation and Planning Division in preparing soil and water resources development plans. One of these offices in Diyarbakir, in south eastern Turkey to study Euphrates River Basin, is equipped with a soil and water laboratory.

b. Two regional offices, with some work units, three soil laboratories, two irrigation experiment stations, one soil conservation experiment station and four inventory groups were established and added to Topraksu.

c. The Agricultural Bank recently has established a central office and two regional districts to evaluate the economy and repayment of farm irrigation projects as a tool of controlled credit.

ACCOMPLISHMENT ON IRRIGATION

Education and Training

a. **Training of Professionals and Sub-professionals** : During 1962-63, 278 professionals (agricultural engineers) and 37 sub-professionals (topographers, operators and mechanics) were trained in Tarsus and Bornova Training Centres of Topraksu. The professionals were trained in engineering, soil surveying and farm planning for long term credit.

   Seminars were organized in order to train ditch riders by Eskisehir and Adana Regional Directorates of State Hydraulic Works co-ordinated with local organizations of Topraksu.

b. **Training of Farmers** : Topraksu Farmer Training Camps are organized to modernize the agricultural practices presently in application in order to increase agricultural production, to train farmers in the fields of irrigation drainage land and water conservation and to use man-power in agriculture effectively.

   During 1962-1963, 92 farmer work camps were operated and 10,900 farmers were trained.

Credits for Farm Irrigation

Topraksu credits, being parallel to the investments and extensively by the Government to develop the water resources, helped farmers in receiving the optimum benefit from the Government investments.

The controlled credit system on which the agricultural credit policy is based, has been established in agriculture through the application of Topraksu credit.

The total amount of credit extended was 7,775,000 Turkish Liras, which were loaned to 426 farmers to provide water for 6,556 hectares of land, in 1962-1963.

Drainage, Land Classification and Soil Survey for Irrigation Projects

During the period 1962-63 the following investigations were completed :

a. Land classification
   1. Semidetailed land classification on 1,330,800 hectares.
   2. Detailed land classification on 80,838 hectares.

b. Basic soil survey on 409,670 hectares.

c. Survey for soil conservation on 157,000 hectares.

d. Durng 1962-63, 922,000 hectares of land were covered by drainage investigations.

Inventories of Land and Water Resources of Turkey

The General Directorate of Soil Conservation and Farm Irrigation (Topraksu) is preparing inventories of land and water resources of Turkey. At the present, four inventory groups are working in Izmir, Mersin, Istanbul and Ankara Regional Directorates.

There are four professionals in each group, consisting of a chief engineer, a soil surveyor, a soil and water engineer, and an economist, assisted by eight sub-professionals. Each group has three vehicles. The group work under a programme covering primary and secondary watersheds in a region.

Inventory groups file data on the following aspects by filling out 42 different kinds of field record papers :

a. Natural factors
b. Land use capability classification
c. Geological feature
d. Present land use
e. Economic and social conditions
f. Engineering aspects
g. Industrial aspects

Inventories for 2,215,000 hectares of land have been made since 1962.

Small Water Development Projects

Since 1962, 472 small water development projects covering 56,260 hectares of land were constructed and improved. These were mainly built and operated by farmers. Government activities consist of technical help, financial assistance, and some construction works.

Farm Irrigation Systems

Since 1962, farm irrigation and drainage canals serving several units have been carried out on 16,330 hectares of land.

Drainage and Land Reclamation

Drainage and land reclamation measures have been taken on 18,580 hectares of land during the last two years.

PROGRESS MADE ON RECOMMENDATIONS OF THE PREVIOUS SEMINAR

The recommendations of the last seminar are being carried out to the fullest possible extent.

The progress made, is summarized as follows :

1. **Training**
   a. As mentioned above, farmer training programmes were extended during the last two years.
   b. Technical handbooks and other publications were published for the benefit of the technicians and farmers (a list is attached)
   c. A commission was established to prepare technical standards and specifications at the Topraksu Central Office

2. **Research and Experiment**
   a. Two new experiment stations have been established during the last two years

b. Other recommendations on research are taken into consideration for preparation of the research programmes.

3. Operations

On the various aspects of operation, maintenance and rehabilitation, activities are being carried out successfully.

Publications of General Directorate of State Hydraulic Works

1. Manual for Preconstruction Works on Small Irrigation Systems.
2. Operation Guide for Ditch Riders.
3. Determination of Water Losses from Canals.
4. Manual for Maintenance of DSI Irrigation Systems.
5. Fish Vocabulary for Inland Waters of Turkey.
6. Maintenance of Biological Resources of Natural and Artificial Lakes in Turkey.
7. Descriptions and Measurement Formulas for Irrigated Areas.
8. Field Demonstrations with Sprinkler Systems by Riza Tintas, Agricultural Engineer.
9. Proper and Perfect Irrigation by Sait Ozok, Ag. Engineer.
10. Instruction for Leveling and Field Irrigation Demonstrations in Irrigation Systems.
11. Burrowing Rodents and Their Control by Emin Hasipek, Agricultural Engineer.
12. Description and Structures of Agricultural Control Implements Used in Irrigation Practices by Yilmaz Taflioglu, Ag. Engineer.
13. Principles and Applications of Weed Control by Aromatic Solvent Naphta by Yilmaz Taflioglu, Ag. Engineer.
14. Vegetative Lining of Canals and Levees and Applications of Selective Herbicides.
15. Seed Growing Guide for Lining and Erosion Control by Riza Tintas, Agricultural Engineer.
16. Weed Control Guide for Laboratory Studies.
17. Physical and Chemical Analysis of Soils.
18. Statistical Methods on Hydrology.
19. Corrosive Effects of Water on Construction Materials.
20. General Principles on Watershed Improvement.
21. Slope Improvement in Watershed.
22. Hydraulics of Stream Gaging Stations.
23. Determination of the Quality of Irrigation Water.
24. Reclamation of Organic Soils.

UNITED ARAB REPUBLIC

Agriculture in U.A.R. engages about two thirds of the national capital invested in the various economic sectors and also about two thirds of the whole population. The gross area of the cultivated land is about 6 million feddan* representing 3 per cent of the total area of the country, but the increase in the cultivated area is far behind the rate of increase in the population which jumped from about 10 to 21 million during the first fifty years of this century.

The first concrete approach meeting this situation was taken by the Revolutionary Government in 1952 by formulating short and long term programmes for land reclamation, beside an integrated plan for improving the productivity of the cultivated area a considerable part of which was affected by salinity and alkalinity due to inadequacy of irrigation and drainage facilities.

The general agricultural development plan depends mainly on (I) Development of water resources, (II) better use of water resources, (III) drainage improvement, (IV) reclamation of new land, and (V) improvement of the cultivated area.

DEVELOPMENT OF WATER RESOURCES

As the country is practically rainless, agriculture depends on artificial irrigation with Nile water. Two irrigation systems are in use, perennial irrigation covering about 3·5 and 1·5 million feddans in Lower and Upper Egypt, respectively, and basin irrigation serving about 700,000 feddan in Upper Egypt.

To meet the requirements of agricultural expansion programmes, a series of projects were undertaken with the object of providing water supplies through better control of the Nile waters and utilization of drainage and underground water.

The High Dam

When completed, the High Dam will be a rockfill dam 111 metres high; with a total width of 1,000 metres and 32 metres at the base and at the road respectively, and a length of 3,500 metres. The dam is situated five miles upstream of the present Aswan Dam, and will create an artificial lake of 130 billion cubic metres capacity, the largest of its kind in the world, being 4,000 square kilometres in area.

On the east bank of the river, the flow of the Nile will be delivered by means of a diversion canal 1,200 metres long and 60 metres wide at bed level. It will be equipped with iron gates for the daily regulation of water discharge. On the west bank, an underground power plant will be constructed to generate an enormous amount of hydro-electric power, estimated at 10 billion kilowatt hours yearly. The dam itself will consist of three main structures, the upstream cofferdam, the downstream cofferdam and the main dam.

The question of silting was given due consideration. Out of the total storage

* A feddan = 4,200 square metres approximately.

Note: This report was prepared by Dr. A.I. El Shabassy, Head of Soil Research Department, Ministry of Agriculture; Dr. A.I. Mitkees, Director of Saline and Alkali Soil Research Section, Ministry of Agriculture, and Dr. A.I. Gohar, Director of Soil Chemistry and Physics Research Section, Ministry of Agriculture.

capacity, thirty billion cubic metres have been assigned for silt, and investigations carried out have revealed that it will take 500 years for silting this volume.

Besides insuring full and rapid utilization of the Nile water, protecting the country against the danger of high floods and the production of hydro-electric power, the High Dam will have the following agricultural advantages :

1. Beside guaranteeing the necessary water requirements of the present agricultural lands, the high dam will make available additional waters for the cultivation of 1·2 million feddan of new lands, the conversion of 700,000 feddan from basin to perennial irrigation, and the planting of 700,000 feddan of rice annually.
2. It will improve drainage conditions in the cultivated areas and will consequently increase their output.

Utilization of drainage water for irrigation purposes

The natural limitations on the available land and water resources in Egypt have made it imperative to rationalize their use with a view to increasing productivity to the highest degree possible. Given the limited supplies of water available, the need for more water for land reclamation and irrigation has become so pressing that the use of drainage water for these purposes has been explored and implemented.

The total drainage water supply exceeds at present 1·5 billion cubic metres annually. The suitability of waters from the main drains for irrigation purposes was studied. As a result of studies, waters of high, medium or low salinity are being utilized, saving equal amounts of fresh Nile water. Highly saline water is being recommended for leaching saline soils under reclamation while waters of medium or low salinity are used for irrigation purposes after taking into consideration certain precautions.

Conservation and Development of underground water Resources.

Special attention was directed towards the development of underground water resources especially in the following desert and semi-desert areas :

1. The Nile Delta fringe areas in the Western and Eastern Deserts.
2. The North western coastal zone.
3. The coastal areas from El-Arish to Rafah.
4. Selected oases in the Western Desert.

An oases survey was conducted and an attempt was made to provide the additional hydraulic and geological knowledge required to guide the maximum feasible development of new agricultural lands. A trial was also made to solve the casing corrosion problem in Dakhla and Kharga Oases. The survey conducted in some selected sections of the Western Desert coastal area aims at developing small-scale irrigation projects and public water supply facilities as the limited water tables of the Miocene limestone, the perched water supplies and other known or discoverable acquifers may permit.

In the year 1962-1963, about 140 wells were drilled in the Southern Sector of Tahrir Province, the New Valley and other localities. Also, 166 wells will be dug in the year 1963-64. Well discharges range between 4,000 and 8,000 cubic metres daily, an amount sufficient to irrigate an average of about 250 feddan.

Underground water studies in the Delta aim at investigating the underground water available for successful development and the utilization of well-water irrigation systems in areas not projected for irrigation, through using the water which will be available after the construction of the High Dam.

The programme set for investigating the ground water resources in the Delta aims at determining by geological survey the depths of the aquifer and the characteristics of the

water-bearing strata. It includes estimating the capacity and potentiality of the underground water reservoir through determining the separation zones between fresh and salty water, the quantities of fresh water which could be utilized within the safe limits of salt-water influx, the pumping periods and the proper location of the pumping plants.

About 160 observation wells covering the Nile Delta were drilled to depths ranging from 30 to 60 metres. Soil samples were taken and analyzed in order to determine the soil profile at the site of each well. Water samples taken every one metre depth was also analyzed before and after digging the wells. The effect of pumping on the soil salt behaviour was studied periodically.

Preliminary results of the investigation of the underground water resources in the Nile Delta can be summarized as follows :

1. The river Nile was proved to be the source which feeds the underground water reservoir in the Delta.
2. The underground water moves from south to north along the Delta all the year round.
3. The Damietta branch may be considered as the main source of the deep or confined ground water in the dry season.
4. The Ismailia Canal has a direct influence on the underground water movement.
5. The rate of depression in the ground water pressure is slower than the rate of fall of the water-levels in the river. The minimum pressures are ultimately reached in June and July.
6. The slope of the deep underground water varies from one place to another and from time to time, according to soil type, distance from the Nile and the water level in the river. The variation in the hydraulic gradient ranges from 5 to 40 cms./km.

BETTER USE OF WATER RESOURCES

Field crop water requirements were studied in Menufia Province which suffers from high water table. The study was confined to cotton and maize and covers the following two points :

1. The cyclic and seasonal gains and losses of soil moisture.
2. The effect of minimum, maximum and real amounts of irrigation water on crop yield.

The study of water table movement showed that the water table level in irrigated plots is not affected by irrigation in the adjacent areas and that it moves only within a very small range. It was shown also that the water table rises and falls in a rhythmic movement with every watering. The amplitudes of this movement differ owing to saturation rate and compactness of the subsoil. The average amplitudes of the cyclic waves of the water table are positively correlated with the total amounts of irrigation water regardless of the depth of the water table.

The study of crop yield showed that from different quantities of water applied at the normal irrigation rotation of 18 days, the maximum cotton yield is obtained by utilizing an amount of water less by 16 per cent than the conventional amount now in use. This means availability of additional water that will meet the shortages already experienced in bringing more lands under the plough.

A three-year study on water requirements was made on cotton, wheat, clover and maize in fine textured soils. It revealed that the root concentration of cotton, wheat and clover is mainly in the surface foot of soil. Temperature and daytime hours can be used as an index to irrigation needs because they were found to have the greatest effect on the consumptive use. In order to attain maximum yields, 0-10 per cent and 10-20 per cent of the soil field capacity in the root zone should be

added to each watering in Lower and Upper Egypt, respectively. The consumptive use coefficients when determined for cotton, wheat and clover were found to be 0·70, 0·44 and 0·64, respectively, while that of maize is still under investigation. Proper timing of irrigation was proved to be necessary for high yields. The amounts of water required to attain maximum yield (in cu. metres per feddan) which varied from one locality to another were 2,850-3,600 for cotton, 1,300-1,600 for wheat, 2,500-3,250 for clover and 2,150-2,900 for maize.

Studies made by the Ministry of Agriculture on the effect of high water table on cotton yield revealed that excessive use of water as well as seepage from canals saturate the soil and result in considerable loss in yield. Lining canals with concrete was recommended as a means of control. It was also suggested that lowering the water level in the canals and the adoption of lift irrigation will reduce seepage and overwatering.

Sprinkler irrigation was tested in sandy soils at Anshas Land Reform Farm and El-Tahrir Province in an area of 1,000 feddan in the first and 5,000 feddan in the second. These tests proved that this method saves in the amount of water needed for irrigation. In Tahrir Province only 6,000 cu. metres per feddan are needed annually under this system as against 20,000 cu. meters under surface irrigation. Sprinkler irrigation also reduces land leveling expenses and save manual labour in land reclamation work.

DRAINAGE IMPROVEMENT

An extensive network of principal and subsidiary drains was erected to prevent the deleterious effect of the rise in the underground water level. Many pumping stations were also constructed to lift water from drains in the Northern Delta which are deprived of free flow discharge throughout the year.

Many studies were carried out, at different localities, on open and tile drains. Trials were made on the effect of drain depth, spacing of drains, diameter of pipes in tile drainage and level of water in open drains as compared to the ground water level, on the efficiency of drainage. They also included comparison of open and tile drainage.

The study carried out in 1942 in Menufieh Province showed that the use of open drains would cause a loss of not less than 12 per cent of the cultivated land. Because of the general smallness of holdings, connection of open field drains with public drains presents special difficulties. Their clearance and maintenance needs continuous care. Tile drainage was therefore recommended, and it was further found that it would save about 0·25 million feddan of cultivable land.

The new policy of drainage which would cost L.E. 218 million pounds was based on the following :

1. The difference between the maximum water level in the public drain and the surface of the land to be drained will be 2·5 meters instead of the present 1·5 metres.
2. The length of public drains will not exceed 30 kms.
3. Providing the cultivated areas with efficient private and field drains, mostly tile drains.

RECLAMATION OF NEW LANDS

The short term programme which started in 1953, was based on the utilization of water that could be saved from the present water resources and the use of drainage and underground waters which prove to be chemically suitable for irrigation or leaching purposes. It aims at bringing under cultivation about 723,000 feddan, of which about 203,000 feddan were in desert lands during the years ending 1965.

The long term programme visualizes the reclamation of 1·2 million feddan depending on the waters that will be made available after the construction of the High Dam.

Reconnaissance soil surveys are undertaken in all new projects at the planning stage. Detailed periodical studies are made to follow up the progress of reclamation processes.

In planning, designing, and throughout the course of execution of new projects, complete cooperation among engineers, agricultural experts, soil scientists is ensured.

All research works needed for the investigation of reclamation and cultivation problems of the project areas are carried out.

The new reclaimed lands are distributed among small farmers, each of whom is entitled to have a small holding of not less than two feddan but not exceeding five feddan. Cooperatives are formed after the distribution of the land to help and provide farmers with production requisites.

IMPROVEMENT OF THE CULTIVATED AREA

A five year programme of agricultural development was planned in 1958. The over-all agricultural development programme of increasing productivity of present cultivated lands will cost about L.E. 55 million. The programme involves soil and crop improvement, crop diversification, crop protection, livestock production and protection, fisheries development, farm mechanization, food industries, agriculture extension, consolidation of agricultural holding and economic studies.

The implementation of this programme is expected to yield an increase of 22 per cent in agricultural production, 58 per pent in milk production, 26 per cent in meat production, and 33 per cent in fish production.

The value of agricultural production on account of this increase is expected to rise from L.E. 574 million to L.E. 730 million, whereas agricultural income will rise from L.E. 400 million to L.E. 562 million. This programme will also provide extra empolyment for about half a million agricultural labourers.

CHAPTER V

PROJECT PLANNING

GHAZVIN DEVELOPMENT PROJECT

by

Mohamad Ali Rejali*

SUMMARY

In September 1962 an earthquake destroyed or severely damaged about 50 per cent of the houses in 121 villages lying south of the town of Ghazvin about 120 kilometers west of Tehran. About 10,000 persons were killed along with large numbers of livestock. Because of the magnitude of the disaster and the urgent requirements for reconstructing the area and providing for the welfare of the destitute village people, emergency relief help was received from many Iranian and foreign agencies and the Iranian Government established the Ghazvin Development Authority to promote orderly modern redevelopment.

A team of foreign technicians was employed to assist in developing a modern integrated plan and programme for redeveloping this area. The objective is to integrate the physical and social development in such a way that the welfare of the village people can be improved in a manner that will set an example for development of other rural areas of Iran.

The water supply of the area has been very limited for the available of irrigable land. This supply is mostly from ghanats, many of which were damaged by the earthquake. Therefore, investigation of the groundwater resources of the area was given high priority during the reconnaissance planning studies. In these studies the need for improvement in agricultural practices was considered along with the potential for agriculture-based industry and the sociological problems of implementing modern improvements.

The reconnaissance studies indicate a capital investment need of 1600 dollars per family to increase the per capita annual gross income from 220 dollars to 62[illegible] dollars while at the same time providing ea[illegible] quake resistant modern housing.

GENERAL DESCRIPTION

The Ghazvin investigational area consists of a 378,000 hectare saucer shaped, flat plain at about elevation 1,200 meters bordered by mountains ranging up to 2,700 meters high.

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The streams are short and intermittent except for the Khar-Rud which generally flows from November to June. Drainage from the intermittent rivers and groundwater collects in a central swamp 300 square kilometers in size and any excess flows from the swamp by means of the Shur river which cuts through a ridge of hills and flows to the salt desert of central Iran.

The rainfall is only 200 to 250 millimeters annual average in the Plain. Therefore, the agricultural of the villages is dependent mostly upon irrigation which is dependent upon groundwater supplies for about 75 per cent of the supply.

About 250,000 people live on Ghazvin Plain of which about 93,000 live in the towns of Ghazvin and Takestan and the remaining 157,000 live in 300 villages having 25,000 farm families. About 10,000 village houses were destroyed by the earthquake of September 1962 which killed 10,000 and injured many more.

The area is about 120 kilometers west of Tehran and is served by national railroads and highways through the west and north portions of the plain. At the time of the earthquake the feeder roads to the villages were only meandering dirt roads.

The Ghazvin development area has been chosen as a pilot area for developing integrated rural development procedures and techniques, since :

(1) It was in great need of outside assistance at a time when the rapidly moving land reform programme of Iran was creating desires for modernizing.

(2) It was close enough to Tehran to serve as a good demonstration and training area for Tehran based government officials and technicians.

(3) Because of government efforts in aiding the villages they could be expected to be more cooperative than the average in trying new techniques.

PLANNING STUDIES

General. The plan for developing the Ghazvin Plain was divided into several different steps and sections. The first step was to provide emergency housing, food, and medical attention to maintain the earthquake stricken people. The second stage was to plan for reconstruction of the destroyed villages and to assist the villagers to obtain permanent type earthquake resistant housing and to repair the ghanats which provided the water supplies for village and irrigation use. Many different Iranian and foreign organizations participated in this housing reconstruction phase with the efforts being initially coordinated by the Iranian Red Cross organization. Later the Ghazvin Development Authority was established by decree of the Council of Ministers and a foreign team of technicians was employed to assist the Authority and the cooperating agencies such as the Irrigation Bongah in undertaking to develop the area in a well planned coordinated manner.

The third stage which occurred concurrently with the second stage was to make a general reconnaissance investigation and develop plans for the orderly comprehensive development of the Ghazvin Plain. This investigation was started in February 1963 and was completed in October 1963. The reconnaissance covered the subjects of geological survey, climatological data, soil survey, water resources survey, sociological survey, agricultural survey, industrial survey, and village planning and reconstruction survey. Simultaneously with the reconnaissance planning, village and housing plans were developed and reconstruction of permanent housing carried out in so far as financing permitted. Between October 1962 and October 1963 a total of 1964 houses were constructed about 200 kilometers of gravelled secondary roads were constructed, an agricultural experimental and demonstration farm was started, and 20 deep wells were drilled for village and irrigation supplies.

The fourth stage of development was started in January 1964. This phase includes.

(1) Carrying out of feasibility studies for estimating the ultimate development

of the water resources of the area and at the same time constructing about 370 deep wells considered to be safely within the framework of ultimate development potentials.

(2) Vigorously pushing the improvement of agricultural practices to more efficiently utilize the short existing water supply and to introduce the farmers to new crops and better agricultural practices.

(3) Constructing an additional sugar factory to provide a market for increased sugar beet production.

(4) Continuation of housing construction.

The final phases of the project are still not defined completely, but Iran is vigorously moving ahead to develop this pilot project in order to learn better methods of doing similar work in other areas and to train the Iranian technicians required.

Since this project is a rather unique example of trying to quickly integrate planning and construction under emergency conditions over a wide area it is providing Iran with some valuable lessons in how to coordinate long range plans with short range urgency over the total range of rural development requirements from geology to sociology. The following chapters of this paper provides a more complete summary of some of the interrelated problems and how they are being attacked.

WATER RESOURCE PLANNING STUDIES

Because of the urgency of the situation and the scarcity of easily developed dependable surface water resources, the water resource studies during the reconnaissance investigations were largely concentrated on making preliminary evaluation of the groundwater resource potential and delineation of the suitable lands on which to use it.

Geology. The geologic studies of the area covered the general geology, lithology, stratigraphy, and tectonics of the area. The plain of Ghazvin is an intermountain basin filled with young alluvial material composed of very permeable gravel strata interspersed with lenses and strata of less permeable materials and relatively impermeable clay strata, with the general permeability decreasing from the foothills toward the center of the plain. The surrounding mountains are mainly volcanic and sedimentary rocks, small portions of the foothills contain high amounts of salt. Two sets of fault lines were distinguished in the area, one running northeast and the other running northwest.

The general geologic structure of the plain was roughly outlined from about 30 existing semi-deep wells of from 110 to 150 meters in depth supplemented by some general geophysical work, observation of excavation from ghanats, and chemical analysis of water from ghanats and wells. From this information typical geologic cross-sections were constructed.

Soils. The soils of the plain were classified both according to their nature and their agricultural use. The principal characteristics of the soils analyzed were : colour, texture, structure, startification, organic material, gypsum, lime, salt, and other concretions in the profile. The following thirteen soil groups were identified : lithsols ; very shallow alluvial, colluvial soils ; medium textured gravelly alluvial, colluvial soils ; medium textured alluvial soils ; fine textured alluvial soils ; brown soils ; calcisols ; periodically flooded saline soils ; meadow saline soils (solonchak) ; alkali soils ; salt marsh soils ; eolian sand ; gypsiferous soils.

The 379,000 hectares of soils were divided into the five following groups according to their suitability for agriculture :

a. Soil suitable for irrigated agriculture without special limitations 231,000 hectares.

b. Soil suitable for irrigated agriculture subject to certain limitations 35,000 hectares.

c. Soils suitable for grazing and dry farming 67,000 hectares.

d. Saline and alkali soils suitable for grazing. 39,000 hectares.

e. Area suitable for sparse grazing only, 7,000 hectares.

Hydrology. By making field surveys of the present use of irrigation water and its source, the total use of water was determined to be 480 million cubic meters annually divided as to source as follows :

	million cubic meters
Ghanats	280
Wells	72
Intermittent Streams	48
Khar-Rud River	47
Abhar Rud River	33
Total	480

Of the total 37 million cubic meters was used in the towns of Ghazvin and Takestan and the rest was used in the villages for domestic and irrigation uses. The total seepage losses from ghanat discharges was estimated from field measurements to be 25 per cent. The annual rate of out flow from beneath the agricultural lands and into the central salt basin of the plain was estimated to be 90 million cubic meters per year. This was estimated from measurement of existing water uses, and from estimates of groundwater transmissibility obtained from pump tests and geologic studies along with determinations of the outflow gradients of the groundwater.

Water samples were collected from wells and ghanats and tested for chlorine content and other distinguishable chemical properties. The chlorine content in different locations was charted on the area map. The chlorine content increased rather uniformily from the hills to the central basin. In general the results of the tests indicated that in the periphery of the agricultural lands the chlorine content varies between 25 and 75 ppm. It rises to more than 1,000 ppm. near the central salt marsh and reaches 15,000 ppm. in the salt marsh.

Prior to 1963 no measurements had been made of river flows entering the plain and therefore, major consideration of the possibilities of storing or spreading the intermittent river flows was deferred for the feasibility studies which began in January 1964. However, the surface runoff wasting to the central swamp is estimated from local interviews to be 200 million cubic meters. Measures to conserve the wasted surface runoff will be considered in the feasibility studies. In 1963 four river gaging stations were established to developed the surface water hydrologic information needed for the best ultimate development of the area.

Irrigation development. The plan of development proposes to increase the irrigated area from the present area of 57,640 hectares to 77,000 hectares. This is to be done by intercepting about 80 million cubic meters additional groundwater now wasting to the central swamp and improving the efficiency of use of the present water supply. The additional 80 million cubic meters of groundwater is to be obtained by investing 474 million rials ($6,400,000) for development of 370 new wells. About 66 million rials ($ 880,000) is to be invested in improving small canals to reduce seepage losses and for miscellaneous water system improvements distributing the water from the new wells. The cost of developing the water supply from wells varies by zones from about 0·51 to 1·06 rials ($ 0·0067 to $ 0·014) per cubic meter. At present the cost of constructing and maintaining new ghanats varies from about 0·07 to 0·26 rials per cubic meter. However, most of the groundwater now going to waste can not be so easily captured from ghanats because of its depth and the flat ground slopes in the lower portions of the plain. Also the uncontrolled flow of ghanats has a large waste.

AGRICULTURAL PLAN

To plan the types of farms best suited to the conditions in the different investigational zones analysis was made of cost of production composition of the produce, marketing methods, and farmer's income. A detailed survey was made of agrotechnical and agricultural practices in 42 villages in the field by questionaries, in addition to questioning informed officials. The production and profit factors evaluated in these studies are summarized in the cost figures shown in the appendix.

The present farm income by types of crops is :

Field crops	435	million rials	16%
Industrial crops	291	,, ,,	11%
Vegetable	245	,, ,,	9%
Fruit	1,250	,, ,,	47%
Livestock	454	,, ,,	17%
Total	2,240		100%

The comparison of present and planned agriculture is indicated by the following statistics :

Indicator	Present	Planned
1. Area (in ha.)		
Area cultivated annually, ha.	92,060	81,520
Area irrigated annually, ha.	57,640	77,000
2. Water, cu. m./ha.		
Average quantity per irrigated, ha.	6,390	5,810
3. Production		
Average production, Rials per ha.	5,590	14,250
Crop production, Rials per irrigated ha.	7,110	15,020
Crop production, Rials per non-irrigated ha.	3,060	4,500
Fruit production, Rials per irrigated ha.	23,000	64,000
Production per 1,000 cm. of water for the whole cultivated area, Rials.	1,280	4,850
Average production per family, Rials	23,360	85,970

In addition to the investment required for water supply, an investment of 1,140 million rials ($ 15,200,000) plus working capital of 310 million rials ($ 4,130,000) was estimated to be required for agricultural development and production, exclusive of marketing. Loans to farmers for planting orchard would be repayable over 15 to 20 years ; loans for tractors repayable over 5 to 7 years ; and loans for working capital equal to 50% of total annual cash impute. The main changes proposed in the agriculture would be ; increasing value of production 300 per cent by broadening the variety of produce, expanding areas of sugar beets and fruit, extending the use of mechanical equipment, increasing the number of working days. Investments per farm unit would be :

Zone	Number of farming Families	Investment in 1,000 Rls.		Additional labour return in 1,000 rials	
		Per Farm Unit	Total for Zone	Per Farm Unit	Total for Zone
1	3,590	40·0	143,470	43·9	157,600
2	1,330	45·0	60,280	46·1	61,310
3	1,650	50·0	83,950	77·9	128,530
4	1,600	38·2	61,090	47·3	75,680
5	4,560	46·0	210,110	55·5	253,100
6	4,150	41·6	172,760	45·1	187,160
7	4,220	40·2	169,870	42·3	178,500
8	4,390	53·8	236,100	44·4	194,900
Total	25,490		1,137,630		1,236,780
Average per family		44·5		48·5	

INDUSTRIAL SURVEY

A survey was made to examine the extent and character of the industrial potential of the area in order to recommend what industrial plants would fit the agricultural production planned for the area. The survey indicates that the best agricultural industry which should be erected in the area is a sugar factory with a minimum annual intake of 100,000 tons. Also nut and fruit drying and packing plants for pistachio, almonds, raisins, and apples were considered to warrent special studies. Also the possibility of constructing an edible seed processing plant was studied in a preliminary way which indicated enough potential to warrent additional investigation.

SOCIOLOGICAL SURVEY

The sociological survey of the Ghazvin area was undertaken for the purpose of ascertaining the likely interplay between the existing demographic and social structure of the farming population and the proposed plans for economic and agricultural development of the area. To come to the right conclusions and introduce a workable plan for area development, a complete set of sociological data were collected which disclosed the following :

1. The families are limited in size. There is a high infant mortality rate. Woman marry young. There are great differences in age between spouses.
2. It can be assumed that the child mortality rate will decrease through improvement of sanitary conditions, health services, and family income.
3. Presently the villagers have divided themselves among working groups called Boneh. These Boneh have appeared largely for the better distribution of water which is rather scarce in parts of the areas. It is anticipated that the development programmes in the area could be accomplished effectively by working through these Bonehs.

VILLAGE PLANNING

For the villages destroyed by the earthquake, villages have been laid out and planned to provide for good layout of streets and community buildings and service facilities as well as provide designs for earthquake resistant housing with advances in design over those previously existing. Because of the great mixture of aid for housing reconstruction coming from numerous local and foreign sources, the cost of housing has not been included as project cost in the development programme, but the normal cost of housing has been around $ 1,300 per family for the 1964 earthquake resistant houses already constructed by outside agencies.

PROJECT DEVELOPMENT COST

The investments necessary for the realization of this project amounts to about 3 billion rials ($ 40,000,000) or about $ 1,570 per farming family, exclusive of housing. The breakdown of this by items is as follows :

	Million Rials	per cent of total
New source of water	540	18·0
Industrial processing	730	24·3
Agricultural and orchard expansion	890	29·7
Mechanical equipment and farm buildings	200	6·7
Livestock	60	2·0
Working capital	280	9·3
Unforeseen and contingencies	300	10·0
Total	3,000	100·0

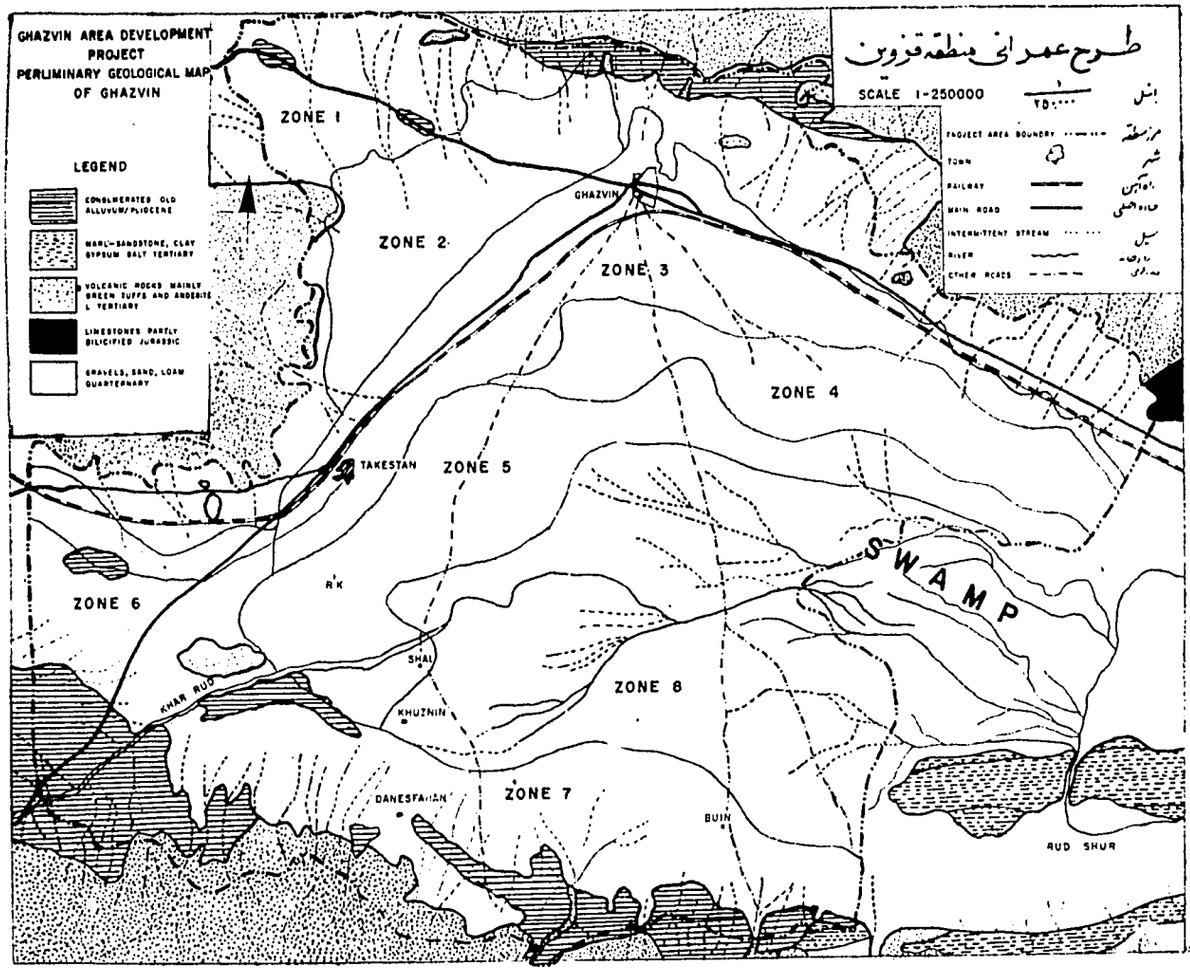

FIG. 1. Preliminary Geological Map of Ghazvin.

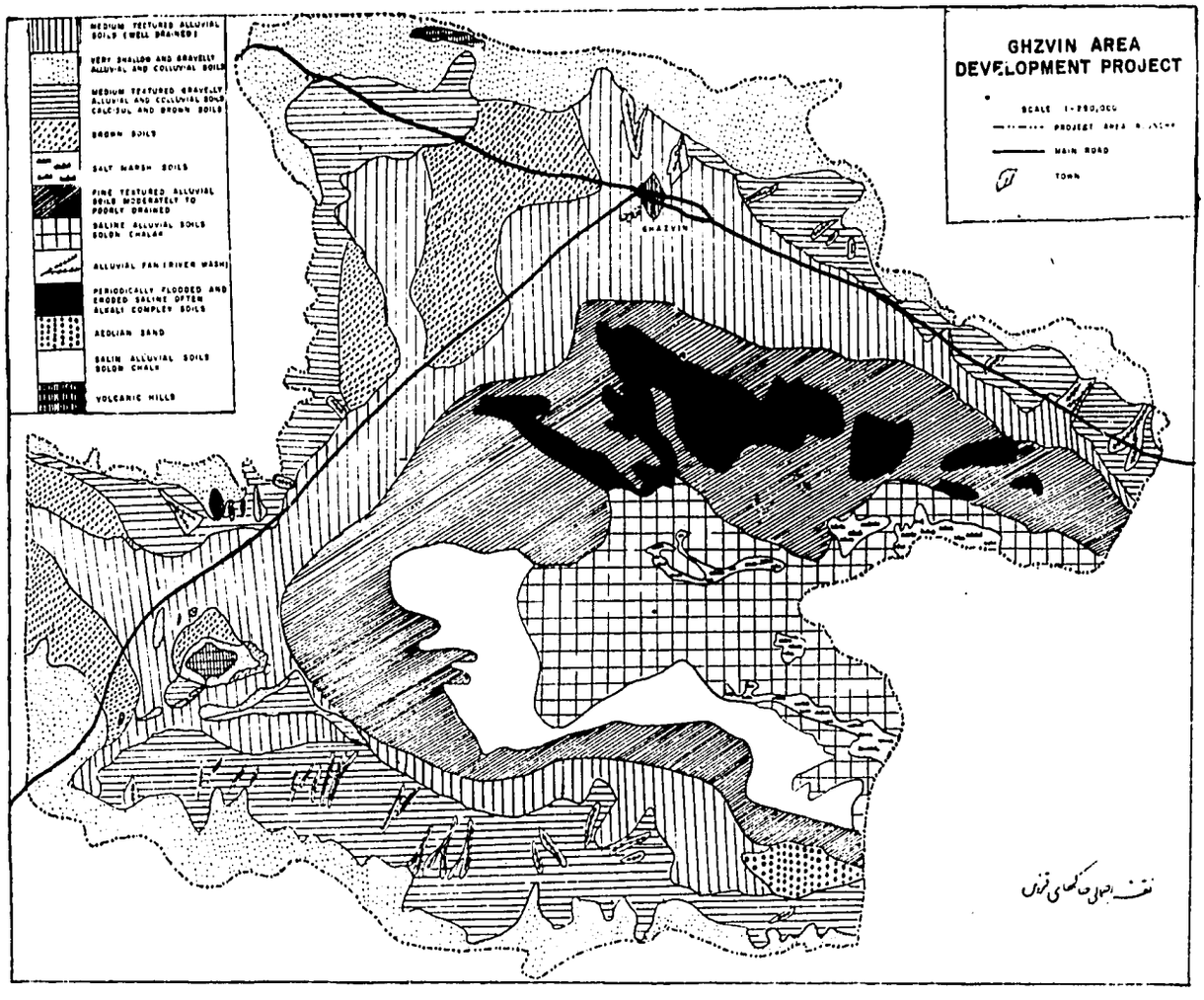

FIG. 2. Soil Map of Ghazvin Project.

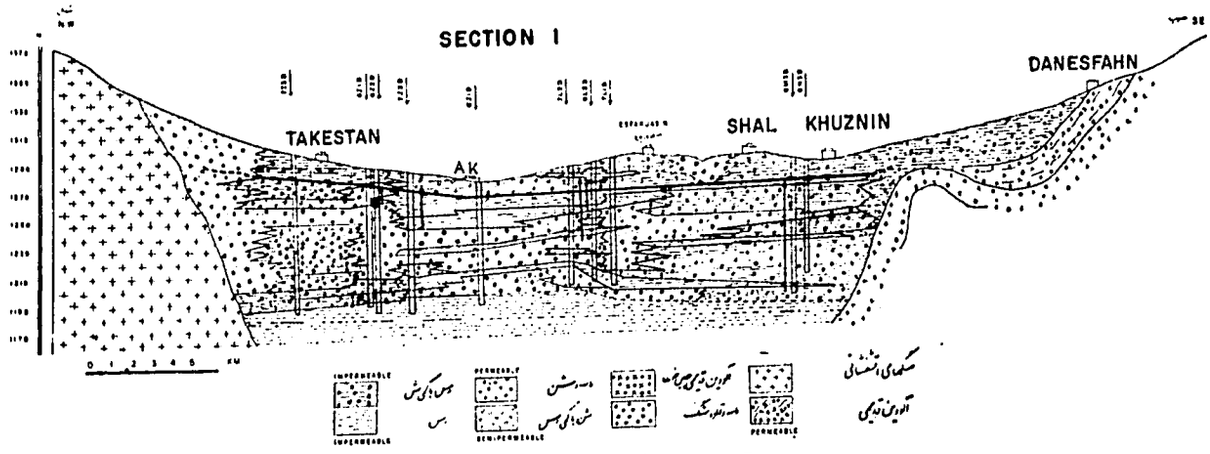

FIG. 3. Cross section of Ghazvin Plain.

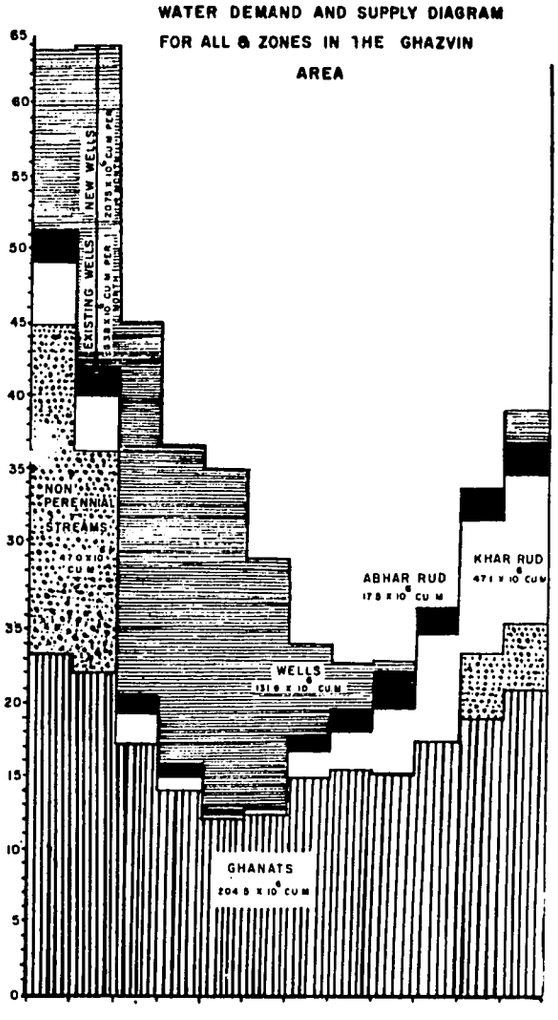

FIG. 4.

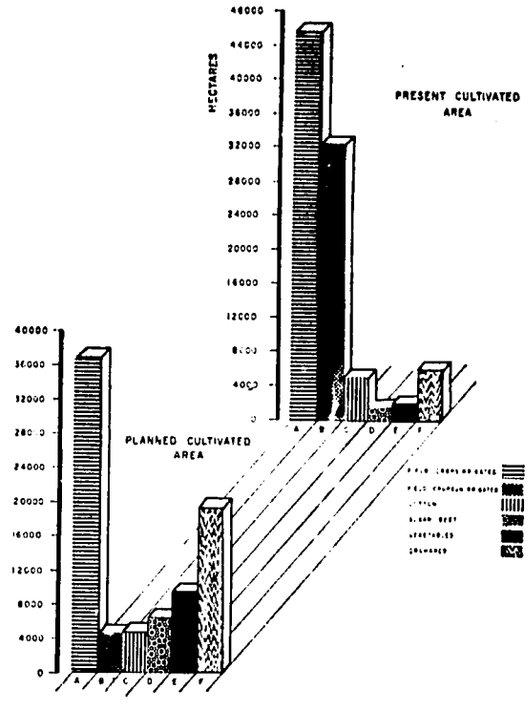

FIG. 5.

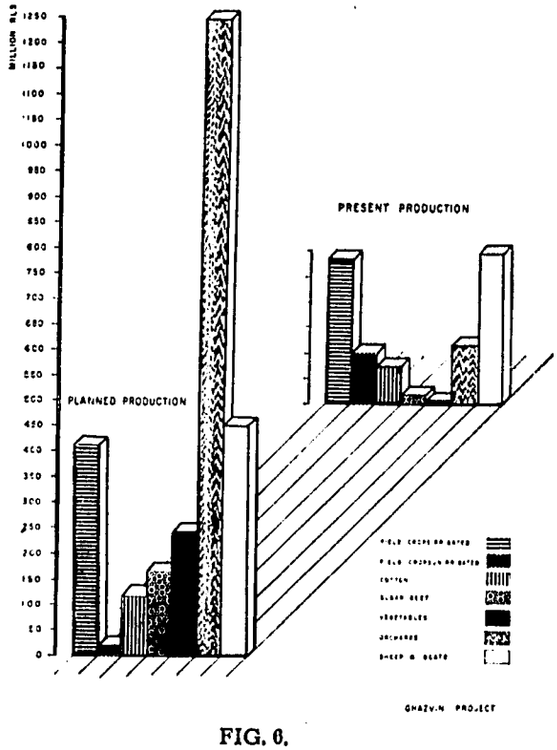

FIG. 6.

Appendix

ZONE 5

1. General data

a. Population :

Number of villages	45
Number of farms	6
	51
Total families	5030
Farming families	4560

b. Land :

Total area		35,100 ha.
Built-up area, ditches, roads, etc.	3000	
Land suitable for grazing only	7500	10,500 ha.
Suitable for cultivation		45,600 ha.

c. Types of soil :

About 80 per cent of the soil are medium to heavy alluvial soils, and the remainder are saline and alkaline soils suitable for natural grazing lands.

d. Water resources (annual amounts).

Available from ghanats	74·6 MCM
Available from floods	1·6 MCM
Available from streams	9·2 MCM
Available from existing wells	8·9 MCM
Planned yield of new wells	13·0 MCM
Total planned quantity	107·3 MCM

e. Water quality :

Conductivity 750-2250 micromhos. Crops irrigated with saline water with conductivity of 1250 micromhos and above should be alloted 10-15 per cent above the regular amounts of water.

f. Cost of water :

From ghanats	Rls. 0·07 per m^3
From wells	Rls. 0·53 per m^3
Average price for the zone	Rls. 0·16 per m^3

2. Planning data for a typical farm unit :

a. Land :

Annual cultivation	2·8 ha.
Fallow	4·2 ,,
Orchards	0·8 ,,
Natural pasture	1·7 ,,
Buildings and yards	0·5 ,,
Total	10·0 ha.

b. Quantity of water (annual amounts) :

Available from ghanats, floods, streams	18750 m^3
Required additional water from wells	4810 m^3
Total water per farm unit	23560 m^3

TABLE 3. ANNUAL PRODUCTION PLANNED FOR A FARM UNIT IN ZONE 5.

Crop or Branch	General Data								Expenses in Rls						Receipts in Rls.			
	Water Requirements			Labour			Yield per ha		Distribution of Expenses						Distribution of Receipts			
	Area (ha)	Per ha	Total	Man-power (days)	Animal (days)	Tractor (hours)	Main Crop (tons)	Straw and hay (tons)	Total	Tillage	Mate-rials	Water	Insecti-cides and misc.	Total	Cash	Home Con-sump-tion	Farm Use	Farm Earn-ing for Labour and Land
Wheat	1·5	4,500	6,750	51	..	15·0	2·0	3	4,460	1,290	1,880	1,080	210	17,250	9,950	6,000	1,300	12,790
Barley	0·2	3,600	720	7	..	2·0	2·0	2	520	310	80	110	20	1,600	..	..	1,600	1,080
Cotton	0·3	10,300	3,090	34	1·6	2·2	2·0	..	2,010	350	1,080	490	90	7,800	7,800	..	..	5,790
Sugar beet	0·7	10,000	7,000	59	7·0	5·2	25·0	..	4,310	1,060	1,930	1,120	200	18,200	17,500	..	700	13,890
Alfalfa	0·1	12,000	1,200	11	..	0·3	10·0	..	360	40	110	190	20	2,000	2,000	..	..	1,640
Total Field Crops	2·8	..	18,760	162	8·6	24·7	..	..	11,660	3,050	5,080	2,990	540	46,850	37,250	6,000	3,600	35,190
Pistachio	0·2	6,000	1,200	26	..	..	1·2	..	2,260	..	710	190	1,360*	14,400	14,400	..	..	12,140
Vineyard	0·6	6,000	3,600	78	..	..	24·0	..	5,520	..	2,430	580	2,510†	28,800‡	28,800	..	..	23,280
Total Plantation	0·8	..	4,800	104	..	..	..	..	7,780	..	3,140	770	3,870	43,200	43,200	..	..	35,420
Sheep and goats 10 head	..	..	..	20	..	..	..	..	8,600	..	8,600	..	..	18,600	16,600	2,000	..	10,000
Total per Farm Unit	3·6	..	23,560	286	8·6	24·7	..	..	28,040	3,050	16,820	3,760	4,410	1,08,650	97,050	8,000	3,600	80,610

‡ General Expenses and taxes 1,950
Annual payment for acquisition of land 5,630
Income for labour 73,030

Notes * Out of this 1,320 Rls. depreciation and interest
† Out of this 2,360 Rls. depreciation and interest
‡ 750 Rls. taxes to village authorities, 1,200 Rls. for maintenance of a donkey.

c. **Annual crop cultivation :**

Wheat	1·5 ha.
Barley	0·2 ,,
Sugar beet	0·7 ,,
Cotton	0·3 ,,
Alfalfa	0·1 ,,
Total	2·8 ha.

d. **Orchard composition :**

Pistachio	0·2 ha.
Vineyards	0·6 ,,
Total	0·8 ha

e. **Livestock and poultry :**

Sheep	10
Donkey	1
Laying hens	20

1. PLANNING DATA — PRODUCTION COSTS AND PRICES.

A. **Work requirements for plots smaller than 0·5 ha.**

(1) **Wheeled tractor : (working hours per ha.)**

Ploughing 20-25 cms.	5
Disking (2·4 m)	2
Cultivating	2·5
Cultivating between rows	1·5
Furrowing (60 cm. between furrows)	3

(2) **Animals — mules (working days per ha.)**

Ploughing between rows	2·5
Cultivating between rows	1
Harrowing	0·7
Levelling	0·8
Preparation for irrigation	1
Furrowing	2·5
Levelling the furrows	1

(3) **Manpower (working days per ha.)**

Seeding with hand tool	4
Seeding potatoes — after ploughing	16
Seeding by hand	0·8
Spreading fertilizers	0·4
Fertilizer top dressing	1
Thinning sugar beet or cotton	4
Thinning and weeding	6
Weeding and hoeing	6
Picking potatoes (2 tons per ha.)	30
Picking onions	24
Preparation of basins for irrigation	2
Furrow irrigation	1

B. **Production costs**

(1) **Tractor :**

Rls per working hour (including machine and operator)	103

(2) **Draught animal (mule) :**

Rls per working day	75

(3) **Fertilizers :**

46% Superphosphate per ton	Rls 9000
21% Ammonium sulphate per ton	Rls 6500
46% Urea per ton	Rls 12000
Organic fertilizer per ton	Rls 500

(4) **Seeds :**

Rls per kg. (Self supply)	
Wheat	5
Barley	3·5
Chick-peas (large)	10
Cotton	6
Potatoes	5
Onions — miscellaneous vegetables	400
Alfalfa	300
Watermelons	15
Sugarmelons	20

Remark : Working day = 10 working hours.

C. **Income from farm produce** (at farm)

(1) **Field crops :**

	Rls per ton
Wheat	5000
Barley	3500
Chick-peas	10000

(2) **Industrial crops :**

	Rls per ton
Raw cotton	13000
Sugar beets	1000

(3) **Vegetables :**

	Rls per ton
Potatoes	3000
Onions	2000
Watermelons	1500
Sugarmelons	2000
Miscellaneous vegetables	2500

(4) **Fruit :**

	Rls per ton
Apples and pears	8000
Almonds	20000
Pistachio nuts	60000
Fresh grapes	3000
Raisins	6000
Average for fresh grapes and raisins on the assumption that 30 per cent of the crop is sold fresh	2000

(5) **Herbage and straw :**

	Rls per ton
Cereal straw	500
Pulse straw	1000
Cereal hay	1500
Alfalfa hay	2000
Sugar-beet-top fodder	625

	Rls per kg.
(6) Milk	10
Meat	70
Wool (average)	70

2. WORKING HOUR COST FOR WHEELED TRACTOR — 60 HP

A. **Items calculated**

a. **Depreciation**

(1) Price of tractor 250,000 Rls
(2) No. of years 8 years
(3) Working hours per year 1250 hrs
(4) Salvage value 10%
(5) Insurance 0·3% per year

b. **Maintenance** (8 years)

(1) Two overhauls 24,000 Rls
(2) Six tyres 40,000 Rls
(3) Various repairs 30,000 Rls

c. **Operating expenses**

(1) Manpower 12 Rls per hr
(2) Fuel (Diesel oil) 6 litres per hr at 2·5 Rls per litre
(3) Lubricating oil 0·1 kg per hr at 30 Rls per kg

d. **Implements**

(1) Total cost of a set of implements 130,000 Rls
(2) No. of years 8 years
(3) Working hours per year 1250 hrs
(4) Repairs and maintenance through lifetime 130,000 Rls

B. **Working hour cost**

a. Depreciation	31 Rls
b. Maintenance	12 Rls
c. Operating expenses	30 Rls
d. Implements	30 Rls
Total	103 Rls

3. INPUT — OUT-PUT PER SHEEP OR GOAT

A. Items calculated

(1) **Total number of feed units***

For maintenance :
0·65 F.U. per day=230 F.U. p.a.
For gestation and milk : 80 litres of milk × 0·6 F.U. = 70 F.U. p.a.

Total	300 F.U. p.a.
By direct feeding	90 F.U. p.a.
By grazing	210 F.U. p.a.

(2) **Composition of the total F.U.**

a. **Direct feed in the winter months :**

30 Feed Units—	30 kg. barley	105 Rls
40 Feed Units—	200 kg. straw	100 Rls
20 Feed Units—	70 kg. hay	140 Rls
Total	90 Feed Units	345 Rls
Average price per Feed Unit		3·8 Rls

b. **Fattening ration during 80-90 days**

65 Feed Units—	65 kg. barley	230 Rls
20 Feed Units—	100 kg. straw	50 Rls
15 Feed Units—	50 kg. hay	100 Rls
Total	100 Feed Units	380 Rls
Average price per Feed Unit		3·8 Rls

(3) **Flock management :**

(1) Rams were not accounted for, assuming the price of meat would cover upkeep costs

(2) Upkeep expenses for a lamb till maturity :

120 F.U. at 3·8 Rls per Feed Unit	456 Rls
A year's grazing expenses	40 Rls
Total maintenance	496 Rls

Lambing percentage : 80 per cent of these 25 per cent (female lambs) replace the older ewes. The remaining 15 per cent of female lambs are sold as yearlings after a period of fattening.

(4) **The average weight** of a fattened lamb is 45 kg. liveweight or 22·5 kg. dressed meat.

(5) **The weight** of a 4-5 year old ewe, after a short fattening period, averages 50 kg. liveweight or 25 kg. dressed meat.

B. Production input and output per ewe or goat.

(1) **Input**

(1) Direct feed 90 feed days @ 3·8 Rls	342 Rls
(2) Grazing expenses	40 Rls
(3) Cost of replacement stock 496 Rls 4 years	124 Rls
(4) Risk and unforeseen expenses 10 per cent of total cost of maintenance	50 Rls
(5) Fattening expenses :	
a. Lambs (male and female) 0·55 marketable yearlings × 100 feed units × 3·8	209 Rls
b. Ewes 0·25 marketable sheep × 100 feed units × 3·8 Rls	95 Rls
	860 Rls

* Scandinavian Feed Units ; 1 kg. of barley = 1 Feed Unit or 1 F.U.

TABLE 4. DETAIL OF CASH EXPENSES PER HA OF DIFFERENT IRRIGATION FIELD CROPS

	Wheat		Barley		Chick-Peas		Sugar Beet		Cotton		Water Melons		Melons		Potatoes		Onion and misc.		Alfalfa		Pensilaria for Hay	
	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls	Quantity	Total Rls
Agr. implements (hours)																						
Ploughing	5	515	5	515	5	515	5	515	5	515	5	515	5	515	5	515	5	515	3	309	5	515
Disking	2	206	2	206	2	206	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	206
Cultivating and Levelling	3	309	3	309	3	309	2·5	257	2·5	257	2·5	257	2·5	257	2·5	257	2·5	257	..	..	3	309
Drought animals (days)																						
Harrowing	..	..	..	..	..	..	1·5	112	..	..	..	..	..	..	0·7	52	1·5	112	0·3	22	..	..
Sowing	..	..	..	..	..	..	8	..	..	..	..	..	..	..	4	300	..	..	..	..	..	..
Row crop cultivation	..	..	..	..	..	..	3	225	2	150	1	75	1	75	3	225	..	..	..	..	..	..
Furrowing	..	..	..	..	..	..	2·5	187	2·5	187	..		..	..	2·5	187	2·5	187	..	..	..	..
Levelling	..	..	..	..	..	..	1	75	1	75	..	..	..	..	..	..	1	75	..	..	..	..
Harvesting and Picking	..	..	..	..	..	..	2	150	..	..	..	..	..	..	4	300	..	..	..	..	..	..
Fert. & Seeds (kgs)																						
Phosphatic fert. (P_2O_5)	..	..	..	..	..	..	60	1,200	90	1,800	..	..	..	..	90	1,800	60	1,200	57	1,140	..	..
Nitrogenous fert. (N)	25	650	..	..	..	..	60	1,560	60	1,560	..	..	..	..	60	1,560	45	1,170	..	...	25	650
Seeds	120	600	120	420	50	500	20	..	50	250	35	52	25	50	2,500	1,250	8	3,200	10	10	30	300
Threshing (cost in Rls)	..	500	..	500	..	250	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Note :—1. 5% should be added to the expenses per ha for insecticides and miscellaneous
2. Input for water varies in the zones, depending on quantity and price
3. At this stage threshing machines are not suggested the price of threshing is calculated as 5% of the output
4. The calculation for alfalfa is based on the assumption that it will produce for 3 years only and the whole input is divided into 3 years

(2) **Output**

(1) 50 kg. milk for marketing or self-consumption @ 10 Rls per kg. 560 Rls

(2) 2·8 kg. wool @ 70 Rls per kg 56 Rls

(3) 0·55 lambs @ 22·5 kg. meat @ 70 Rls 866 Rls

(4) 0·25 ewes 25 kg. meat @ 70 Rls 438 Rls

1860 Rls

Gross profit per sheep— 1000 Rls

TABLE 5. DETAILS OF INVESTMENTS PER HECTARE OF ORCHARD

Details	Vineyard		Almonds		Apples and pears		Pistachio	
	Quant.	Total Rls	Quant.	Total Rls	Quant.	Total Rls	Quant.	Total Rls
(1) First year								
Ploughing with tractor (hrs.)	10	1030	10	1030	10	1030	10	1030
Cultivation (hrs.)	7·5	770	7·5	770	7·5	770	7·5	770
Organic fertilizer (tons)	10	5000	5	2500	5	2500	5	2500
Saplings (nos.)	1600	4800	400	8000	550	11000	200	6000
Insecticides	—	500	—	250	—	250	—	250
Labour (days)	80	6400	60	4800	60	4800	60	4800
Water (cu. m.)	3000	—	3000	—	4000	—	2000	—
Unforeseen, 10%								
(2) Maintenance up to first crop								
Cultivation	—	—	15	1540	—	—	30	3080
Organic fertilizer (tons)	5	2500	5	2500	5	2500	15	7500
Nitrogenous fertilizer (kgs. N)	40	5200	20	2600	40	5200	100	13000
Insecticides	—	2000	—	1000	—	1000	—	1500
Labour (days)	80	64000	60	4800	60	4800	180	14000
Water (cu.m.)	9000	—	13000	—	21000	—	20000	—
Unforeseen, 10%								

Note : In Table 6 "Summary of Investments" the input for water is calculated for each zone on the basis of the regional water prices.

TABLE 6. SUMMARY OF ANNUAL INVESTMENTS AND DEPRECIATION PER HECTARE OF ORCHARD INCLUDING INPUT FOR WATER BY ZONES (in Rls)

Zone	1		2		3		4	5		6		7		8
Fruit	Apples	Almonds	Almonds	Vineyard	Apples	Almonds	Pistachio	Pistachio	Vineyard	Vineyard	Apples	Apples	Almonds	Pistachio
First year investments	23,400	12,840	19,780	41,040	23,660	20,040	17,390	17,240	20.880	20,880	23,090	25,020	21,060	17,760
Additional investments to date of first crop	20,160	16,970	15,170	19,790	21,550	17,830	48,490	46,950	19,290	19,290	18,550	28,700	22,260	52,230
Total investments inclusive of interest during investment period	52,320	44,700	42,530	46,610	54,080	47,020	86,210	84,240	45,860	45,860	49,960	63,870	51,940	90,640
Total yearly depreciation	5,400	8,880	3,700	4,800	5,560	4,090	6,745	6,590	4,720	4,720	5,150	6,580	4,520	7,090

Note :

	Year of first crop	*Depreciation period* (years)
Apples	Fifth	15
Almonds	Fifth	20
Vineyard	Fourth	15
Pistachio	Eighth	25

7. DETAILS OF YEARLY EXPENDITURES PER HECTARE OF FRUIT-YIELDING ORCHARD

Item	Vineyard		Almonds		Apples or pears		Pistachio	
	Quant.	Total Rls	Quant.	Total Rls	Quant.	Total Rls	Quant.	Total Rls
Phosphatic fertilizer (kgs P_2O_5)	—	—	40	800	100	2000	—	—
Nitrogenous fertilizer (kgs.N.)	50	1300	40	1040	100	2600	50	1300
Organic fertilizer or compost (tons)	2·5	1250	2·5	1250	5	2500	2·5	1250
Insecticides	—	1500	—	1000	—	1000	—	1000
Water (m^3)	6000	—	5-6000	—	10000	—	6000	—

Notes :

1. The input for water is based on regional water prices.
2. During the first stage the cultivation of the newly planted orchards will be by hand because of locally accepted planting methods.
3. Due to organic fertilizer shortages it has been assumed that during the first stage there will be only limited use of organic fertilizer. Quantities of fertilizer will thus be smaller than the quantities considered optimal from the purely horticultural stand-point.

8. RECEIPTS AND EXPENDITURE PER LAYING HEN

(1) **Expenses for raising a crossbred young hen on the farm :**

Price of day-old chick	28 Rls
4·5 kg. feed mixture @ 10 Rls per kg.	45 Rls
Labour	12 Rls
Selection and mortality	10 Rls
Transportation	5 Rls
Total	100 Rls

(2) **Maintenance expenses of a hen during 18 months of egg-laying :**

Price of young chicken	100 Rls
15 kg. feed mixture until start of egg-laying period @ 10 Rls per kg.	150 Rls
60 kg. feed mixture during egg-laying period @ 8 Rls per kg.	480 Rls
10% mortality and miscellaneous expenses	70 Rls
Total	800 Rls

(3) **Production and income from a hen during 18 months of egg-laying :**

270 eggs @ 3 Rls per egg	810 Rls
2 kg. meat @ 60 Rls per kg.	120 Rls
Total production	930 Rls
Gross profit per hen	130 Rls

IRRIGATION CONDITIONS AND PROBLEMS IN IRAQ

by

Dr. Jamil Malaika*

ABSTRACT

In the land of the two rivers, where a highly developed system of irrigated agriculture flourished and declined in the ancient past, irrigation development of modern Iraq is relatively recent. Land and water resources are briefly reviewed, and the major water control schemes and irrigation works are outlined. Despite the immense potentialities in land and water, Iraq suffers heavily from shortage and inferiority of its farm produce. Problems that are associated with irrigation practice are denoted and discussed. It is concluded that the development of human resources is as basic to a successful irrigation system as land and water ; and that serious investigations into the possible methods for raising the living standards of the Iraqi cultivator are of the utmost urgency.

INTRODUCTION

Fertility of the Tigris-Euphrates valley made the first settlers of the country initiate one of the greatest civilizations of early history. Excellent water control and canalization schemes existed in old Babylonia ; the numerous antiquated towns and scattered traces of old channels, dikes and bridges stand witness to an intricate system of irrigated agriculture of those ancient times. Irrigation reached its climax during the Abbasside period when the valley was said to have accomodated a population four times that of the present. Subsequent weakening of the ruling dynasties and their neglect to maintain the irrigation works, together with the repeated floods and the destructive acts of the Mongol invaders of the thirteenth century completely demolished those excellent schemes.

Irrigation in modern Iraq is relatively new and about three fourths of its existing irrigation projects were constructed after the First World War.

The country is bestowed with great resources in land, water and minerals. The alluvial soils deposited by the two rivers and their tributaries in its delta land render it the most productive country in the Middle East. It also ranks among the most important oil-producing countries in the world. Despite quick progress and great prospects in the industrial sector however, Iraq remains principally an agricultural country. This is based on the realization of the fact that whereas the mineral reserves are exhaustible, the land and water, if properly utilized, are perpetual and self-preserving. Presently three fourths of the 6·9 millions population secure their income directly from agriculture, with about one fourth actually engaged on the farm.

In contrast with these riches, the standard of living for the majority of the people is overwhelmingly low. The average yearly agricultural per capita income is in the neighbourhood of 40 English pounds, barely enough for subsistence. Such adverse conditions merit full attention and investigation.

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THE LAND

Of Iraq's area of 453,000 square kilometers (175,000 square miles) nearly one half is desert land lying mainly in southwestern portion (*see* map). The arable lands presently used for cultivation comprise about one third of the remainder, or 7·5 millions hectares (18·5 millions acres). Although this area may be increased by two thirds if proper irrigation works and reclamation methods were available the area is only partially cultivated under the fallow system of irrigation.

Climatically the country may be divided into a rainfall zone and an irrigation zone. About one half of the cultivated area lies in the northeastern rainfed zone where the mean annual rainfall is about 400 millimeters (16 inches). The other half lies in the central and southern alluvial flat lands of the Tigris and Euphrates delta extending to the south of the line joining the towns of Beled on the Tigris and Hit on the Euphrates rivers. With a mean annual rainfall not exceeding 150 millimeters (6 inches) this area depends mainly on irrigation and is designated the irrigated zone. Within this area, pump irrigation is typical of the middle Tigris region where the lands are generally higher than the river water levels, while flow irrigation prevails in the lower Tigris and Euphrates regions where the topography and river water levels permit such practice.

THE RIVERS

Waters from the Tigris and Euphrates and their tributaries are more than ample for any ultimate agricultural development however ambitions. Records show that during a period of thirty years the Tigris brings a good annual mean flow of 42 billion cubic meters (34 millions acre-feet). The Euphrates gives a yearly average of 26 billions cubic meters (21 millions acre-feet). These figures may decrease to a minimum of two fifths or increase by a maximum of one half during an exceptionally dry or a very wet year respectively.

Major floods come on an average of once every two to three years. They carry with them an enormous load of silt which is estimated to be about five times that of the Nile. Normally there are two flood seasons, the first occurring due to major winter rainfall (December-March) and the second due to thawing of snow in the mountains late in spring (March-June). The latter is too early for the summer crop season.

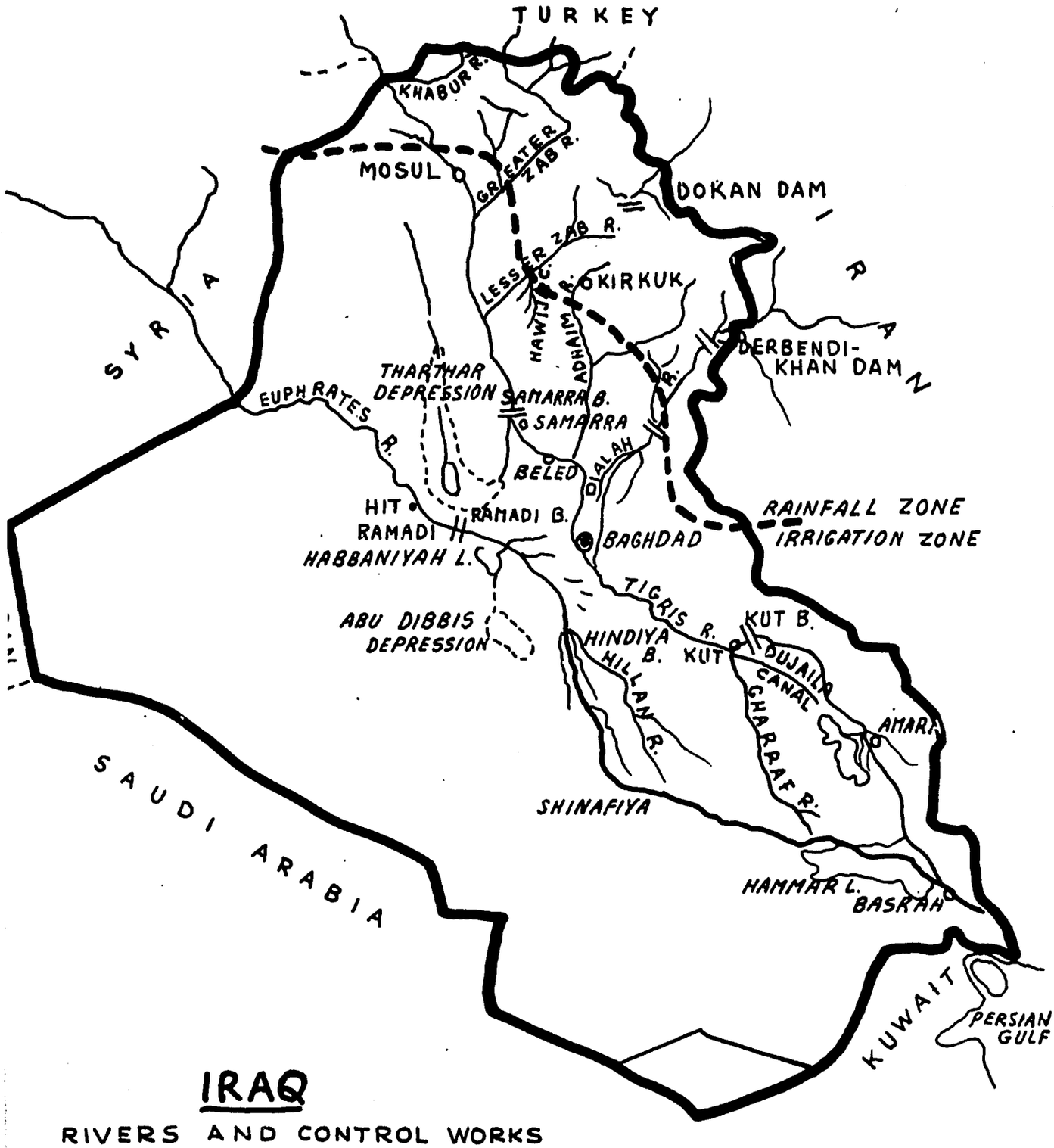
Both rivers have their upper reaches in Turkey. A good portion of the Euphrates extends through Syria before entering Iraq. Due to its steep slopes the Tigris brings destructive unpredictable flash floods. Five tributaries, all within Iraq (the Khabur, Greater Zab, Lesser Zab, Adhaim and Diala rivers), contribute about half of the Tigris flood waters. In contrast, the Euphrates with its longer stretch and flatter slopes has milder longer-lasting floods. The two rivers join together in the south to form Shatt-el-Arab river. Here, due to the tides from the Persian gulf, the water levels fluctuate daily up to a maximum of 1·70 meters (5·6 feet) in the summer.

PRINCIPAL CROPS

Barley and wheat are major winter crops (November-April), and are cultivated in all regions, Barley is predominant because it can thrive in severe weather conditions and saline soils and its produce per hectare is twice that of wheat which only prevails in the northern rainfall zone. Summer crops (April-October) come next in importance. They include rice and cotton which are mainly grown in the irrigated zone, with rice particularly prevailing in the marshlands of the lower Tigris-Euphrates valley.

Iraq is the most important producer of dates in the world. Nearly half of its thirty millions date trees grow in the Shatt-el-Arab region which is the most fertile spot for this produce.

Northern forests occupy less than 17000 square kilometers (6500 square miles) or about 4 per cent of the total area. They suffer from



IRAQ

RIVERS AND CONTROL WORKS

DAM OR BARRAGE

indiscriminate cutting for fuel, overgrazing and fires.

LIVESTOCK

Sheep and goats thrive despite poor pasture and are abundant in all regions. Cattle prevail in the northern regions where grass is left to grow for grazing, and in the central region. Water buffalo dominates the marshlands of the southern region.

IRRIGATION WORKS

The Euphrates. Major water diversion schemes include the Hindiyah barrage (1913) which diverts water from the Euphrates into its old course in the Hillah branch — which formerly irrigated Babylon — and into other smaller canals for reclaiming vast areas of fertile lands in the middle Euphrates valley.

The Habbaniyah flood control and irrigation scheme (1956) diverts Euphrates flood waters near the town of Ramadi into the Habbaniyah lake with a storage capacity of 2·8 billions cubic meters (2·3 millions acre-feet), and the Abu Dibbis depression. Stored water is later returned to the river through a lower channel for summer irrigation purposes. Six canals draw their waters directly from the river to irrigate, mainly by gravity, large areas to the west of the city of Baghdad.

Further downsteam from Hindiyah barrage the river diffuses to flood a large expense of marshlands used for rice cultivation. It emerges again to reform itself near the town of Shinafiyah.

The Tigris. The Kut Barrage (1939) near the town of Kut diverts water from the Tigris onto its old course in the Gharraf branch and the artificial Dujailah canal (1949), irrigating large areas by lift and by gravity.

The Diala weir (1928) raises the Diala river waters which are diverted through six canals onto the vast orchards of the Diala valley.

In the Tharthar flood protection scheme (1956) the Tigris flood waters are checked near the town of Samarrah and diverted through 65 kilometers (40 miles) into the Tharthar depression which has an enormous capacity of 70 billions cubic meters (57 millions acre-feet). Irrigation and power development will also be provided from this scheme.

Other flood protection structures include the Dokan dam (1959) on the Lesser Zab with a reservoir capacity of 6·8 billions cubic meters (5·5 millions acre-feet), and the Derbendi Khan dam (1962) on the Diala river with a capacity of storing 3·7 billions cubic meters 3 (millions acre-feet). These dams also have provision for future power development and will reclaim a great wealth of arable lands.

The Hawijah canal (1951) draws water from the Lesser Zab to irrigate a fertile expanse of land to the left of the river.

Six natural streams branching from the Tigris in the Amarah province irrigate by pumping and by gravity large areas where winter and summer cultivations are practiced.

PROBLEMS

Water Control-International Agreement. In addition to the water control schemes already mentioned, control works on the upper reaches of the Tigris and Euphrates rivers within Iraq will ultimately be required for complete flood control and irrigation expansion. The upper Tigris has power development possibilities in Turkish territory, and both Turkish and Syrian authorities contemplate irrigation and flood control developments on the upper Euphrates. Immediate international agreements will be absolutely necessary from the optimum operation of the existing and proposed multipurpose reservoirs.

Drainage and Salinity. A major problem of planning stems from the widespread neglect of drainage which nevertheless must go hand in hand with irrigation. During the First World War, when Iraq was an important supplier of food to the Allied Forces in the Middle East, several old irrigation schemes

were hastily reconstructed without having been furnished with adequate drainage. The practice continued for over a quarter of a century thereafter, resulting in the salinization and waterlogging of nearly two thirds of the flowirrigated lands. Almost one third of these areas were abandoned ; and the crop yield in some of the remaining areas was reduced by as much as a half. Since the delta land is of marine origin, there is a good deal of salts in its subsoil. As the ground-water table comes sufficiently close to the surface, salt is brought with it. As the water evaporates under the hot sun it leaves the harmful salt on the surface. Lavish use of irrigation water for washing the plant roots, as is commonly practiced, could eventually only raise the water table and hence increase the damage. Another disadvantage of the high water table is the prevention of growth of deep-rooted plants.

Expert studies indicated that drainage may rid the soil of the harmful salts (predominantly soluble chlorides) if it lowers the water table no less than 1·5 to 2·0 meters (say 5 to 6·5 feet) from the surface. Since drainage is a problem of immediate planning, and may be carried out much faster than the slow process of persuading the farmer to change his antiquated farming methods, it is considered the most urgent step for increasing and improving the farm produce. During the past fifteen years a number of drainage contracts have been awarded, and several completed, but a large part of the work is yet to come. Priority is given to the drainage of existing irrigation projects over the building of new ones. It is estimated that the cost of completely draining the flow-irrigated areas will pay for itself, through the great improvement of the agricultural productivity, within a few years, provided that the farmer builds his own farm drains.

Silt. Another problem encountered in project planning is the huge silt load brought by the rivers. The Iraqi rivers carry with their flood enormous amounts of sediment which greatly benefit the land but are very detrimental to reservoirs and irrigation canals. The Tigris flood, for example, carries with it a silt load which may reach 20,000 parts per million by weight, nearly five times that brought by the Nile flood. Annual silt clearance processes for most canals in the delta area cost enormous sums of money. A number of canals have already been abandoned because of silting. The two main irrigation systems of Hillah on the Euphrates and Gharraf on the Tigris are gravely affected by silt deposits. The proposed desilting works near the Hindiyah barrage for the former and the Kut barrage for the latter may eventually be found the only effective solution to this annoying problem.

Afforestation and Soil Conservation. Until recently the inextensive forest areas in the mountainous north suffered heavily from fires, clearance for cultivation and indiscriminate cutting for fuel and coal. All this leads to land erosion which eventually increases the stream sediments and threatens water control reservoirs with silting. Better attempts however have been made toward forest protection and afforestation since a general directorate of forestry was formed in 1952.

Farm Problems. In Iraq, the ultimate and most important step to be taken toward better irrigation development rests within the farmer himself. Unlike nearby countries, Iraq has enormous environmental potentialities per farm inhabitant. The problem is : How to help the farmer so that he makes the best use of these resources ?

a. Implements and Draft Animals : Farm implements are generally antiquated and the age-old stick plow is still in common use. Tilling methods barely scratch the surface and mostly fail to extract the weeds. A plow sole often forms under the shallow tilling depth. Furrows and borders are dug by a primitive hand-operated board hoe. Threshing is done by flaying and tramping of animals. Wheeled instruments are seldom seen on the farm

and almost everything is carried about the farm by man or animal. Cost of buying or renting a machine is very high as compared with the cheap cost of labour. Immediate steps toward improvement require the provision of simple farm tools and draft animals.

b. Soil Building Crops and Fertilizers : The Iraqi farmer is almost ignorant of the soil building crops and fertilizers. Many cultivators deplete the soil by failing to revive it with such crops and by allowing the growth of weeds for animal grazing. Rotation with deep-rooted forage crops is often prevented by a high water table resulting from excessive water use and poor drainage. Fertilizers are seldom applied to the land because the poor cultivator can not afford them. The common use of dung for fuel deprives the soil of its great fertilizing value.

c. Fallow Practice ; Extensive Cultivation : Fallow cultivation, where the winter crop lands are left idle in alternate years, has been practiced for thousands of years. Due to water shortage, and on the assumption that resting the land would revive its soil millions of hectares (normally up to one half of the total cultivable lands) are left untilled every year. The practice should not be devoid of its fertility retrieval benefits if it were to be properly applied. The crop yield nevertheless is greatly reduced and the weed growth, encouraged for animal grazing, makes for an inferior farm product. Furthermore, fallow practice makes it easy for the peasant cultivator to shift from one land to another, and hence leaves him with little incentive to retain one tract and improve it. Crop rotations are hardly observed and land use is very wasteful Double cropping is rare and the cultivator needs yet to learn about the advantages of intensive cultivation.

d. Water Use : Scientific irrigation procedures are not generally observed ; and with the primitive flooding methods used rather than borders, checks or furrows some crops get excessive amounts of water while others do not get it sufficiently. With the exception of date cultivation, the poor yield of barley, wheat, cotton and even rice-which suffers greatly from overflooding in the southern marshlands-indicate the need for improved methods of water management. Control of water for flow irrigation is not as it should be and, as earlier stated, there is tendency of the farmer to use water excessively for the purpose of washing the salt from land surface and plant roots. All this leads to a great wastage of irrigation water which, nevertheless, is very precious especially in summer.

Although pump lift does not exceed 2 to 3 meters (say 6·5 to 10 feet), pump irrigation is practiced on nearly half the irrigated area. Evidently the building of low diversion weirs for gravity irrigation at a much larger scale is far more economical than such unduly high investments by independent action of individual proprietors.

PROSPECTS

Iraq's agricultural need is not to increase its cultivated area but to improve cultivation on the land already in use. Helping the cultivator is among the most important factors in attaining this goal. In accordance with the present Five-Year Economic Plan, Iraq spends annually nearly 120 millions English pounds on development. A great portion of this money goes directly into the welfare of the individual. In the agricultural sector the plan includes strengthening of the irrigation departments for better performance of their duties in carrying out irrigation projects (with particular attention to drainage works) ; working towards mechanized agriculture through the formation of units and stations for rental of

tractors, combines and farm machinery to farmers and cooperatives with easy terms; training cooperative foremen, encouraging formation of cooperatives and assisting them in improving agricultural methods and marketing the farm products; developing rural life; expanding the agricultural bank financial abilities; encouraging scientific research; augmenting agricultural extension; distribution of seeds at reasonable costs to cultivators; extending help in pest control and, last but not least, the development of livestock breeding.

CONCLUSION

To the ordinary engineer's mind a wealth of resources in land and water is all that is needed for good and successful irrigation project. Iraq can never fall short of these means. For example, it has about 1·8 hectares (4·5 acres) of fertile and potentially irrigable land per inhabitant (nearly 15 times the value in Egypt). Nor has it lacked adequate technical advice. A number of excellent development studies have been made, formal reports submitted, and some captivating and excellent water control plans have already been completed. Nevertheless even the best engineering firms sometimes do not give proper heed to the great significance of considering the human resources. A thorough survey of human resources is of no lesser importance to sound irrigation planning than land and water. Unfortunately, until recently very little systematic investigation has been made into the possible methods of raising the standards of living of the Iraqi cultivator. The useful data about the society are negligible in comparison with those of the environment; and very little was spent in the past two decades on social welfare in comparison with expenditures on dams and reservoirs. As a result of this regrettable oversight, coupled with a number of short-comings in planning procedures, the far-extending fertile lands of the two rivers continue to suffer heavily from scantiness and inferiority of farm produce.

THE PROBLEM OF REPAYMENT

by

Mr. Korkut Ozal*

SUMMARY

Proper repayment policies are essential to the success of irrigation development. A well planned and executed repayment programme can contribute to the success of phases of the project such as the fair distribution of financial burdens, the best possible utilization of project water and the creation of an important source of capital.

The main problems encountered in the development of a repayment policy are : (1) Policy formulation ; (2) Cost determination ; (3) Assessment (4) Collection.

1. **Repayment Policy.** Since irrigation development may be launched for a number of different objectives, the formulation of policy varies from country to country. The following principles, however, need to be included in designing any repayment policy :

   a. The cost of development should be rapid by direct and indirect beneficiaries ;

   b. The repayment should be considered as one of the tools to be used in attaining the objectives of irrigation development ;

   c. The repayment obligation of any beneficiary should not, at any time, be greater than the benefits derived from the development ;

   d. The repayment procedure should be as simplified as possible.

2. **Cost Determination.** In the determination, distribution and assignment of capital, as well as operation and maintenance costs, a number of problems are associated. Those problems, which include such items as a long construction period, allocation principles, conjecture, differentiation among different services, and cost classification cannot, as it is observed in well-advanced countries in the field of irrigation ; be brought to accurate various solutions. So it may be advisable for emerging countries to adopt, at an early stage of their development, an approximate method to provide a fast, simple and reasonably accurate determination and assignment of the cost.

3. **Assessment.** It is observed that in the majority of existing irrigation works the total cost of development cannot be borne by direct beneficiaries, so indirect beneficiaries assume a part of the repayment by their direct or indirect contributions. The direct beneficiaries in this case are assessed in accordance with the value of service to them. The amount of water, the area to be irrigated, the property to benefit or mixture of these items have been used as the basis of

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assessment. Each of them have their advantages and disadvantages under special conditions. In selecting a proper basis factors such as fairness, past traditions, consistency and minimum possible overhead cost should be evaluated.

The rates may take various forms: Fixed, variable or flat. Proportional or two-part rates have been extensively used. An analysis shows that there are two distinct parts in the cost, (a) That component which has no apparent relation to the number (or area) of farms that demand water in a given year ; (b) That part which varies with the number of farms (or the area) which takes water in a given year. From this consideration (as well as from others) a two-part rate seems the best choice. In fixing the rates a number of factors again require consideration. Among these reasonableness, self-liquidation, fairness, and stimulation and redistribution of income are important. Marginal cost pricing is the best economic tool in meeting the objectives of development.

4. **Collection.** Collection of the assessments can be made in installments. Advance payments may be preferred in some cases. Delinquent payments may present a major problem. An effective treatment of this problem should include the refusal of any further water delivery. Heavy penalties for deferred payments are generally very effective.

CONCLUSION

Although they are rather elementary, the discussions presented in the paper may be helpful to those evolving a repayment system. It is the authors' opinion that the following principles can be applied to irrigation repayments in Turkey :

a. The cost of irrigation should be fully repaid by the direct and indirect beneficiaries ;
b. The repayment policy should be formulated in order to achieve the best attainment of the objectives of the irrigation development ;
c. The repayment procedure should be as simplified as possible in order to minimize the overhead cost and the confusion. Determination, classification, and allocation of capital and operation and maintenance costs should be made in such a way that a reasonably accurate and simultaneous repayment, starting from the earliest possible date, becomes possible ;
d. Irrigation assessments should be made as a two-part rate. The first as a constant amount per each water delivery and the second as a flat rate per the irrigated area of the land ;
e. Collection of the constant and variable charges should be made separately. The first one should be collected in advance. Delinquents should be refused water delivery until they pay the original assessment with extra expenses and penalties ;
f. In cases of partial or complete crop failure due to acts of God, collection of payment should be partly or fully postponed.

FOREWORD

Repayment policy is an important factor contributing to the success and continuation of the accelerated development of irrigation.

It is logical that the repayment of the cost of irrigation be borne by the beneficiaries of the development. Under such a concept a properly planned and executed repayment programme for irrigation work can attain one or more of the following objectives :

a. The fair distribution of financial burdens of the investment ;

b. The establishment of strong measures for the best possible utilization of project water ;

c. The creation of an important source of capital to perpetuate development.

Beside those objectives, the presence of repayment may to a certain extent increase competition with other types of development from public funds, and the provision of repayment may stimulate the loans for those projects.

From the standpoint of the main principles involved, it appears at first that the development of policies and procedure to recover cost connected with the establishment, operation and maintenance of irrigation projects is a relatively simple matter. However, the solutions to numerous and varied problems must be reached if the repayment process is to work properly and attain the desired objectives.

Some countries have already faced these problems and solved them. In some developing countries, however, the relatively small scale of the existing development partly curtails the manifestation of the importance of these problems. It is certain that repayment will be one of the important subjects to deal with when an accelerated irrigation development takes place in a rather short period.

A review of the repayment programmes instituted in the past by some of the countries more highly advanced in irrigation development reveals that insufficient consideration was given to the problems existing in :

a. Policy formulation ;

b. Cost determination ;

c. Procedure for assessment and collection of charges.

This paper is intended to cover those problems in general and then provide a more detailed discussion on the problems of repayment relating to recovering the cost share from direct beneficiaries—the farmers and landowners. It does not consider methods of repayment to recover cost from the sectors indirectly benefitted.

REPAYMENT POLICY

Generally speaking the formulation of repayment policy in a developing country is governed by the particular problems proposed to be solved through irrigation development. Depending upon the special conditions prevailing in one region of a country the development may aim to attain one or more of the following economic, social or political objectives :

a. Increase in stability and level of living of farmers ;

b. Increase of agricultural production to meet domestic food and fibre requirements ;

c. Increase in exportable agricultural production to maintain foreign exchange ;

d. Stabilization of certain industries (such as sugar, textiles, canning or livestock raising) ;

e. Satisfaction peasants' demand for land ;

f. Sedenterization of nomedic grazing population ;

g. The stabilization of population living along the national borders.

Those objectives which are fully economic in their character may permit a complete repayment by the direct beneficiaries. For other objectives having social or political implications the repayment cannot and should not normally be undertaken by the water users. In these cases indirect beneficiaries must cover a part of the repayment by direct and indirect contributions. Consequently, the repayment policy, which is built upon the main principles to be mentioned below, should be formulated in a manner which would provide the flexibility necessary to suit any type of development problem which may be encountered in any region of a country.

The main principles of a sound repayment policy should include the following :

a. The direct (water users) and/or indirect (regional or national) beneficiaries of irrigation development should repay the incurred cost of development proportionally with their respective benefits ;

b. The repayment should be designed so that the objectives of irrigation development can best be attained. These objectives can be expressed in terms of criteria such as the maximization of total product, maximization of net social returns, minimization of possible social cost in dry years, or maximization or minimization of the rate of social change ;

c. The repayment obligation of any beneficiary should not at any time be greater than the net benefits derived from the development.

d. The repayment procedure should be a simplified system which provides adherence to other principles of repayment and minimizes overhead cost.

REVIEW OF COST COMPONENTS

The costs which will be subjected to repayment includes capital and operating costs.

Capital cost. This includes those expenses which exist and remain constant whether or not an irrigation system is in operation. This cost generally includes such items as interest on borrowed money and bonds, depriciation expenses (in part), property taxes, rentals and insurance, etc.

Operating cost. This includes those expenses incurred to maintain and operate the system at the highest possible efficiency. It may be generally divided into two parts :

a. **Fixed operating cost** is that component of the operating expense which generally remains constant each year regardless of the area served with irrigation water, and in this respect resembles capital cost. It includes the cost of basic maintenance of the irrigation system, wages of administrative and supervisory personnel, general office expenses, etc. It differs from capital cost in that it can be eliminated in the event the irrigation system is discontinued for an indefinite period ;

b. **Variable operating** cost represents those costs which may be eliminated when the system is temporarily out of operation and which vary more or less directly with the size of the irrigated area. It may be worth mentioning that such a relation is only approximate. It is sufficiently close, however, to separate them from the previous two cost classes. Main components of the variable operating cost are wages of temporary personnel and miscellaneous costs incurred when the system is in operation (operating expenses of vehicles, billing and collecting expenses, etc.).

Demand cost. This represents the cost for which each potential water user is responsible regardless of whether he used water or not (capital and fixed operating and maintenance costs).

Service cost. This is the cost incurred when the water is delivered. It is proportional to the magnitude of water delivery (the amount of water or the size of the irrigated area).

Customer cost. This is constant per customer and varies with the number of them.

A review of the above cost classification reveals that regardless of how it is classified the cost includes two distinct parts :

a. The capital cost and fixed operation and maintenance costs which have no

apparent relation to the number (or area) of farms which demand water in any given year ;

b. The variable operating cost which is either proportional to the magnitude of delivery to each farm or is constant per irrigated farm and varies with their number.

DETERMINATION OF CAPITAL COST

The total capital cost of an irrigation system generally includes the following items:

Pre-construction cost. This includes those expenses which are incurred during the preliminary surveys, data collection, feasibility studies and other preparatory works for the contract bidding.

Construction cost. This includes those expenditures required for the realization of the engineering works (land and water rights, physical works, etc.).

Miscellaneous and supervisory cost during construction. During the construction of the systems certain expenditures are actually incurred. The usual items of expense of this period includes : organization expense, legal expense, engineering and supervision expense, interest during construction, operation and maintenance during construction and taxes and duties during the construction.

Of these three costs, the first is the most difficult to determine It often includes the cost of items which are generally performed on an overall programme basis by a single agency and consequently the separation and assignment of cost to individual projects becomes complicated. Furthermore, in many countries some of the development items in this category are performed as a public service and their cost is not considered for repayment.

It is less difficult to separate and assign costs for the second and third items in the capital cost. However, some of the following problems are encountered and must be considered in determining total cost.

Long construction period. The construction of an irrigation system, especially of large ones, may take many years. Therefore a part of the area may be put into operation while construction goes on in other areas. Consequently it becomes a difficult question to determine the annual capital cost of the area which is partially irrigated.

Distribution of common cost and overhead among a number of projects. In many cases in order to take advantage of minimizing the cost and overhead, a number of projects of the same (or different) character having common structures can be included in one contract and built as a single unit of work. In such a case the distribution of common cost and overhead expenses presents a rather complicated problem. All the solutions applied or proposed for application until the present depend upon some assumptions which are more or less arbitrary in their principles.

Changes in the purchasing power of money. In a developing country the purchasing power of money may rather quickly decline as a result of inflation in prices. Therefore the book value of a construction may appear too small in terms of the actual cost that would be incurred if a similar project were undertaken at the present time. Thus, a determination of the actual cost may be desirable. Such an attempt, on the other hand, will meet with the difficulty of determining the present cost of a hypothetical system built under the latest state of technology and will involve conjecture and dispute.

High cost due to inefficient management or too high design standards. Experience has shown that in some government projects the cost may be significantly greater than the cost which would occur if the work were carried on by the beneficiaries themselves. This may be because of either too high overhead costs or too high design standards. Although it may be difficult to prove

that the construction costs could have been less, there may be certain cases, however, in which this fact may be less, there may be certain cases, however, in which this fact may be quite obvious. Under such conditions certain provisions may be necessary.

An accurate determination capital cost is quite difficult, if not impossible. So the adoption of an approximate method is apparently inevitable. Various of this sort, each of which is favourable under the special conditions of a specific country, have been applied.

Countries which have not gone far in the repayment of a capital cost may, at early stages of their development, adopt a certain approximate method so as to provide a fast, simple and reasonably accurate determination. The legal basis for such methods can be provided through the amendments to existing codes or enactment of a new one.

Determination of Operation and maintenance cost.

Although similar problems are encountered determination of operation and maintenance cost is less complicated because there is usually a permanent organization to take care of this job and the duration of accounting is only one year. Particular problems are :

Distribution of common cost. In case several project of the same or differing character are operated by the same organization the distribution of common operation and maintenance cost may be important.

Differentiation among different services. In an irrigation project certain areas may receive water by gravity while some others may require pumping. Similarly, some areas may be very close to the diversion and their systems can be operated with relatively little expense, while some areas may be remote and need high operation and maintenance cost. If the repayment policy provides for differentiating among those situations, the cost accounting may be rather complicated.

Classification of cost. Expenses incurred during the operation and maintenance period may, in general, be classified under three groups :

a. **Operation and routine maintenance expenses.** These should be included among annual cost ;

b. **Replacements or major renewals.** Expenses of this category should be made from the depreciation funds since their purpose is to extend the service life of certain works ;

c. **Extensions or betterments.** These expenses should be added to the capital cost since they increase the assets of the system.

Carrying out an operation and maintenance cost accounting in an irrigation system is extremely difficult and may require an expert to differentiate among the various categories and their treatment.

As pointed out in the case of capital cost, it may be too costly to establish a very accurate system of cost determination and classification of the operation and maintenance cost. Consequently an approximate method to the one mentioned for capital cost may be desirable for operation and maintenance cost.

Principles of assessing the beneficiaries

The principles of assessment or pricing present different feature depending upon the type of enterprise which realizes the development. If the enterprise is a private one repayment has generally been made by the direct beneficiaries (water users) of the project. There is, however, a growing trend in many countries to subsidize private irrigation development through direct contribution or through indirect contributions such as exemptions and incentives.

Irrigation enterprise, in most cases, may be undertaken by one or more agencies of the government. In such cases distribution of the cost among beneficiaries can be more effectively controlled in order to suit the particular case.

Generally speaking the beneficiaries of an irrigation development are : (a) farmers, (b) the people or industries within the direct influence areas, such as a town in the irrigation area, or a factory which uses project products as raw material, (c) the nation through the achievement of national objectives.

The assessment to farmers is generally made in proportion to the cost, or value, of service provided to them. In the following paragraph a detailed discussion on this subject will be presented.

It is common practice not to directly assess the people living within the region. In some countries where the irrigation assessments are made by taxing the property within an area which is larger than the irrigation the contribution is made in the form of taxation since property which does not receive a direct benefit from irrigation is also taxed.

The contribution of the state to the development may be in various forms. Among these are : exemptions from interest or low interest rate ; deduction of that part of the cost which is deemed as serving the public interest, and longer development and repayment periods. In some multi-purpose projects the benefits of electric power may be used as to compensate for a part of irrigation expenses. Finally the allocation of cost may be used as a tool for providing a hidden subsidy to the irrigation project in general.

Basis of assessment

The basis of assessment (or the units for pricing) for irrigation repayment may be one of the following :

The area. The area which benefits from the irrigation may be taken as the basis. Certain rates may be applied in order to cover that part of the total cost to be repaid by farmers. Rates may either be determined at a flat rate per potentially irrigable hectare, or a flat rate per irrigated hectare, or at a diversified rate depending upon the type of crop and irrigated area.

Principal problems arising in using area as a basis are :

a. Determination of the potentially irrigable area boundaries may be extremely difficult and controversial (e.g. in case of inadequate water supply in comparison with the arable land), or lack of explicit criteria to determine the suitability of land for irrigation ;

b. In case of lack of cadastral maps the exact measurement of land tracts may consume too long a time and may be controversial ;

c. If the property is held by the deeds of deceased people and no transfer to the heirs has been made determining the individuals subject to the assessments may present a difficult problem.

The water. Repayment may be based upon the amount, or the maximum intensity, of water demand. Although this may appear more fair than the area basis, it also involves problems :

a. Installment of measuring devices even at moderate accuracy ranges may create a high extra cost, especially for small holdings ;

b. The measurement of water and the need to keep records thereof may be a major and costly item ;

c. In case of rotation type of water delivery because of lack of storage, water is generally delivered on prearranged schedules and any refusal of water may cause waste. Therefore measurement of water may not be of major importance.

The property. The value of the property within a certain area may be used as a basis for assessment. The problems in this case are in a way similar to that of the area basis.

Mixed systems. The above bases may be used in combinations. (For example water at lateral levels might be distributed and charged on a volume basis and sub-distribution to individual forms may be based upon the area and duration of water flow. Capital cost may be assessed as a property tax, while operation and maintenance cost may be covered by rates which are based upon water or area).

In selecting a proper basis for assessment the following points need to be evaluated :

a. The basis which have good correlation with cost, for example the capital cost has the closest relation to the potentially irrigable land while variable operating cost may best be based upon water ;

b. The past traditions and prevailing limitations of the country in relation to land tenure and irrigation practices ;

c. Maximum possible consistency in assessments and in rates ;

d. Minimum overhead cost for assessment and collection.

Rates

Determination of rates involved a number of factors. In order to establish a proper method of rate, (price), determination, various economic and social factors should be carefully considered. Among these the following are especially important :

a. Self liquidation

b. Reasonability

c. Fairness

d. Stimulation for productive investment

e. Redistribution of income

In the majority of cases irrigation enterprises cannot be self-liquidating and should not be considered so. There are number of reasons why self-liquidation of irrigation projects through their revenues is impossible or impractical. Among these are :

a. Although the benefits of an irrigation project exceed the cost, it is quite obvious that the revenues due the public, or indirect benefits, require a form of collection other than assessing farmers ;

b. Even the direct benefits to water users should not be considered a measure for revenue potential because : First, it is impossible to charge a price which will leave water users without any change in their income. Since the government of a developing country, like other countries, is also concerned with income distribution, rate structure may be effectively used to that end. Second, such a high charge may discourage farmers to make further productive investments.

A reasonable rate could be described as one that would put the irrigation service within the economic grasp of the mass of potential users. According to this definition, one can conclude that a reasonable rate should be limited by the value of service rather than the cost of service, so far as the value is less than the cost. A weakness of this approach is that the value of service may be different for various areas and crops within a single irrigation area.

Rates should be determined in such forms as to provide the best attainable fair distribution of financial burdens of the project. For example, the fixed operation and maintenance expenses aim to provide water service to all farms within the system. It will therefore, be fair to distribute that cost among all the farms regardless of whether they use water or not. Similarly, some part of the operation cost is constant for a farm regardless of its size. So a fair distribution of this cost may necessitate a constant charge for each farm.

One of the basic purposes of irrigation

development is to optimize the benefit from water, or to maximize the aggregate value in use which may be thought of as the sum of the successive marginal values in use. In order to attain that objective marginal cost pricing can be used as the best economic tool. In marginal pricing two cases may be encountered :

a. In projects of increasing cost, such as those irrigation projects which have already reached the capacity of their present supply and any further increase in supply necessitates the construction of costly storage or transmission works, the marginal cost price is greater than the average cost at the same point. Besides maximizing the aggregate value in use a net gain is also obtained ;

b. In projects of decreasing cost, such as those projects which have not reached the full capacity of their present supply, and marginal cost of supply is less than the average cost at the same point, consequently the use of marginal cost pricing results in net loss. Under such a condition the aggregate value of use may or may not exceed the aggregate cost. If it exceeds, such an excess becomes highest at the marginal cost solution. Therefore, such a solution might still be preferred, even though it may cost to make up the deficit. The deficit may be overcome by some form of subsidy.

Form of rates

Rates may be determined in different forms. There might be separate rates for capital and for operation and maintenance, or these may be combined in a single rate. In practice, however, separate rates have been favoured because of reasons previously mentioned.

Rates to cover the capital cost. Costs originating from the capital investment are generally distributed on a "potentially irrigable area" basis. In determining the total annual obligations of capital cost one must consider : (a) development period ; (b) repayment period ; (c) depreciation ; and (d) interest rate ;

a. **Development period.** Since the benefits of the project cannot be realized the early years of project operation, it is generally deemed reasonable to allow a certain development period (usually 5 to 10 years) between initiation of project operation and the beginning of repayment ;

b. **Repayment period.** The period during which the capital is to be repaid is governed by the economic features of the individual projects. Projects having a high rate of increase in farm revenues may have a shorter repayment period, while projects having a low return may use the maximum limit. Periods between 20 and 50 years even longer periods are usually employed ;

c. **Depreciation.** Depreciation has generally two purposes :

To provide for the recovery of capital over the life of the property,

ii. To enable a determination of the cost of depreciation over a unit of time or per unit of production of the project, so that it may be included as an expense of project production.

For the depreciation of capital cost two methods are widely used : (1) Straight line and (2) Sinking fund. Although they are equivalent from the economic stand point, straight line depreciation imposes heavier obligations at the earlier periods of project development and accumulates more funds during that period. Consequently, straight line may be favoured when project returns are high. Otherwise, and especially for capital

intensive projects, the sinking fund is the best choice :

d. **Interest.** Since irrigation works generally involve capital intensive projects, the effect of interest rate is strongly pronounced. Because of that reason interest rates can be and in fact have been effectively used as a subsidy measures. Some countries do not charge interest at all, and in others very low rates have been applied. Some opinions indicate that an interest rate at least measuring the risk should be employed.

The repayment of annual capital cost. The total annual obligation due to the capital cost is generally distributed on the basis of plain or weighted (which takes care of land classification) area of the potentially irrigable land. As an alternative method the repayment of capital cost can also be made through the taxation of the property within the area which will receive benefits from the development.

Rates to cover operation and maintenance. The cost due to operation and maintenance may be distributed in a number of ways each of which has its merits under certain conditions. In selecting a proper form for this expense the following aspects should be considered :

a. **Fixed vis variable rates.** Rates may be either fixed as a constant value for each farm or may be varied proportionately with the areas of utilization. The first form can be advantageously employed for "customers cost," while the second is suitable to cover the "service cost" ;

b. **Flat vis promotional (or discouraging) rates.** The variable rate may have either a flat value for each unit of basis or it may have a promotional (or discouraging) scale. While the first is advantageous from the simplicity standpoint, the second has the advantage of drawing a maximum amount from the "consumers' surplus" through the "utility discriminate" ;

c. **Diversification by crops.** Rates can be diversified for different crops to be grown. Such a basis has the potential of adjusting the prices in such a way as to encourage or discourage the planting of certain crops or to bring the repayment proportional with the direct irrigation benefits. From the economical standpoint, however, "the equimarginal value in use" is a sound principle to that end. The employment of such a principle in fixing the rate enables the allocation of water in such a way that all water users will derive equal "value in use" from the marginal unit of water consumed. Consequently the maximization of the aggregate value in use can be attained :

d. **Two-part rates.** Rates can be formulated in two parts.

   i. A lump sum amount for each farm regardless of whether it is irrigated or not. Such a rate may cover indirect operation and maintenancee expenses ;

   ii. A flat (or variable) rate per unit of benefits (water or area to be irrigated).

Besides being fair two-part rates have the advantage of being an effective tool to draw a maximum amount from the "consumers' surplus," which may be a remedy for the net loss that occurs in "decreasing cost projects".

Collection

Collection of capital and operation and maintenances charges can be made either separately or jointly. Each method may have certain advantage under special conditions. Collection can be made in one or two installments. Operation and maintenance expenses

(or a part of them) may be collected as advance payments. This method is advantageous if two-part rates are employed.

Formation of irrigation district organizations with statutory power of assessing lands to enforce collection dispenses with the necessity for individual collection. In this case that part of the capital cost allocated to be repaid by users is taken as a general repayment obligation of the organization.

Delinquent payments may present a major problem. In one of irrigation project in Turkey, only 81 per cent of the assessment could be collected after 3 years from the date of assessment. In the same project the collection of delinquent payments after the 5th year is generally found to be uneconomical. In another project the collection cost has reached one-fourth of the total assessment. A remedy can be refusal of water delivery until the dues, including additional collection expenses and penalties, are fully paid. Another method would be to impose heavy penalties and provide for collection following the provisions of the law for collection of taxes.

CONCLUSION

This paper has intended to present a general discussion on various problems in the field of repayment for irrigation development. Although it may seem rather elementary, perhaps it serves the purpose of reaching certain conclusions which may be helpful in designing a repayment system. It is the author's opinion that the following principles can be applied to irrigation repayments in Turkey :

a. The cost of irrigation development should be fully repaid by direct and indirect beneficiaries within their economic capability ;

b. The repayment policy should be designed so as to best attain the main objectives of irrigation development :

c. The repayment system should be as simple as possible. The determination, classification and allocation of capital and operation and maintenance costs should be designed in such a way that a reasonably accurate and simultaneous repayment, starting from the earliest possible date, becomes possible ;

d. Irrigation assessments should be made in two parts. The first as a fixed rate for each farm within the area and the second as a flat (or promotional) rate for the unit of the area to be irrigated.

The first item may, to a certain extent also stimulate the consolidation of extremely small holdings. If such a system is applied considerable changes in individual assessments may be expected. For example, in one of the projects in Turkey the constant rate per farm is found to be 15 T.L. for operation and maintenance only. If such a constant charge was applied the total assessment of a 20 hectares farm would be 682 T.L. instead of 1240 T.L. while the charge on 0·1 hectares farm would be 18·4 T.L. instead of 6·2 T.L.

The constant rate per farm can be assessed after a survey of potential water delivery demands without measuring the area of the land while the second item may be based upon a declaration of farmers which should be submitted to the organization in advance of water delivery. The provisions of heavy penalty in case of false statement may be an adequate measure for the successful application of such a method.

e. The fixed and variable charges should be collected separately. The collection of the constant rate from those who apply for water delivery can be made at the time of application as an advance payment, while the other may be collected after the harvest of the

crop. The collection of a constant charge from those who wont irrigate during the year may be subjected to the general principles mentioned above. Water delivery should be refused to delinquents ;

f. In case of partial or complete crop failures due to Acts of God, the collection of charges should be partly or fully postponed. In such cases, however, ample provisions of reserve operation and maintenance funds will be needed.

CHAPTER VI

EDUCATION AND TRAINING

TOPRAKSU FARMERS TRAINING CAMPS

by

Hulusi Ozguven*

SUMMARY

TOPRAKSU Farmer Training Camps (hereafter called TFTC) are organized to :

1. Modernize the agricultural practices presently in application.
2. Increase agricultural production.
3. Train farmers in the fields of irrigation drainage, land (soil) and water conservation.
4. Use man-power in agriculture effectively.

The first TFTC was opened in 1961 with the technical and financial assistance of AID. This camp was composed of four units. Each unit included 100 farm youth. Duration of camp was 6-10 months as determined by employment and climatic conditions of the area.

The expenditures of one unit, a 6-month duration camp, is TL. 300,000.

The TFTC organizations cooperating in selecting a camp project site are :

a. Technical Agriculture Directorates
b. Local Forestry Directorates
c. Local D.S.I. (State Hydraulic Works) Directorates.

In the selection of camp members, the village leader (Muhtar) and the teacher cooperate. The following qualifications are considered in selecting the camp members. The member should be :

a. A farmer
b. Twenty to thirty years of age
c. Literate
d. Have completed the military service
e. Be willing to participate
f. Be of good health.

Only 5 farm youths are accepted from the same village and in one camp unit there are farm youths from 15-20 villages.

At TFTC's "learn by doing" is essential. The camp members have to see, learn and participate in the various projects. Therefore, various work groups are given consideration when camp training programmes are designed. TFTC's are administered under directives of TOPRAKSU General Directorate. The TOPRAKSU organizations which operate the camps are :

a. Regional Directorates
b. TOPRAKSU Work Unit Chief Engineers
c. TOPRAKSU Research Station Directorates.

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For each camp ; one camp director, one assistant camp director and two instructors are assigned. The technicians of other organizations are also utilized as instructors in carrying out the training programmes.

The camp administrators and members live in tents, camp equipment must be cheap and portable.

Three meals are served daily. Cost does not exceed TL. 3·00 which is deducted from the wages of camp members.

The camp is provided with a medical doctor and a technician. The medical technician lives in the camp. The doctor visits the camp once or twice each week.

Members who graduate successfully are awarded a certificate. Technicians of TOPRAKSU and Technical Agriculture Organization "follow up" with successful graduates who are given technical assistance and credit projects are designed for them. Their applications for agricultural credits are given priority and opportunities are given them to apply what they have learned at camps in their particular fields.

TFTC activities for three years are as follows :

Camps of 126 units have been operated ;

A total of 12,553 farm youths have been trained ;

Soil and water conservation measures have been realized in an area of 282,423 decares ;

TL. 45,519,797 have been spent.

THE OBJECTIVES OF TFTC's

Development of Land and Water use in Turkey

Seventy-two per cent of Turkey's population works in the field of agriculture and makes a living from agricultural products. Forty-two per cent of the national income is obtained from the agriculture sector and is distributed to the farmers. This indicates that in Turkey the living standards of farmers are lower than for workers in other sectors.

The population is growing fast in Turkey and it is impossible to expand the agricultural land. Since the objective of TOPRAKSU is improvement of the living standards of farmers, two measures have to be taken. These are :

1. Reduce the number of farmers,
2. Facilitate the maximum use of farm land.

In the next 15 years a reduction of the farmer population to 58 per cent is a goal of the Five-Year Development Plan. For maximum use of per cent land, it is also planned that 17·7 present of total investments called for by the Five-Year Plan should go to agriculture. Turkey's present land use is as follows :

	Hectares	Percentage
Farm Land	24,972,000	32
Pasture Land	29,000,000	38
Forest	10,600,000	14
Other	12,428,000	16
Total	77,000,000	100

A total of 9,000,000 hectares of out of 29,000,000 hectares of pasture land is subject to a considerable amount of erosion, and requires extensive erosion control measures. The remaining 20 million hectares of pasture land badly needs development. Seventy per cent of forest lands also need some application of soil conservation measures to control soil erosion. The overall area of irrigable land, according to the general soil map, is five million hectares. Only one million hectares of this can be irrigated at the present time. The area of plain, with 0-3 per cent slope is 8,683,500 hectares ; 3,333,300 hectares of this area need drainage. Two million hectares of this same land is not in use because of salinity. There are 16·4 million hectares of normal agriculture land. This figure can be increased to 24·9 million hectares by opening new lands for agriculture totalling 8·5 million additional hectares.

TL. 24·8 million is needed for soil and water conservation measures in agricultural lands. This figure amounts to 23·7 million for pasture land. A total investment of TL. 48·5 billion is required for erosion control in Turkey. In the Five-Year Plan, a target investment of TL. 317,629,000 is allotted for erosion control.

The elements of success for erosion control practices are :

a. State capital investment ;
b. Establishment of land and water conservation districts ;
c. Long-term credits to farmers ;
d. State participation in private investments ;
e. Training of farmers.

TOPRAKSU Problems of Turkey and Training of Farmers as a Solution to these problems

TOPRAKSU (Soil and Water Conservation) problems should be understood by all of the farmers in Turkey. This is possible only by training them in these subjects. It is obvious that development efforts will be successful only when State and farmers cooperate. The number of villages in Turkey exceeds 44,000. A direct reach to all the villages separately, and individual training of villagers is very difficult. TOPRAKSU Training Camps provide training to the villagers of 15-20 villages at the same time.

One hundred farm youth, five each from 20 villages receive training in one camp. These are agricultural leaders of the future. They assist TOPRAKSU ; the organization for the conservation of soil, water and forest resources. The camp trainees and those who work with them can take leadership in the following subjects :

1. Adoption of agricultural concepts :
2. Development of land and water resources ;
3. Prevention of over-grazing of pasture land ;
4. Control of forest fires ;
5. Forest management.

The TFTC's are established on lands owned by the Government, or by a group of villagers. Primarily, those areas which need improvement are chosen. Camps help serve in :

1. Teaching the farmer methods of soil conservation, irrigation, and land improvement ;
2. Increasing agricultural production ;
3. Utilizing idle agricultural man-power ;
4. Helping overall development and training of people.

Service to Social Development and Training of People

The objectives of the camps are raising the living standards of farmers and social development along with providing training in agriculture. The camps achieve these objectives in the following ways :

a. 100 farm youth coming from 15-20 different villages live and work together ;
b. They acquire the habit of observing regular hours and programmes ;
c. They find opportunities of meeting and learning from local and foreign camp visitors ;
d. They acquire theoretical knowledge as well as new skills ;
e. The camp members and villagers in the vicinity improve their cultural and general knowledge through motion pictures shown at camps ;
f. Medical services are extended to the villages in the vicinity.

ESTABLISHMENT

Selection of TOPRAKSU Camp Sites

The camp sites are selected among the following project areas :

1. Watershed improvement (soil and water conservation flood control)

2. Irrigation development
3. Drainage and land improvement.

The project sites cover one or more villages, therefore cooperation between villages is required. Organizations cooperating in the selection of the camp sites are Technical Agriculture directorates, Local Forestry directorates, and Local Hydraulics Works directorates.

Information Concerning the Camp Members

The village leader (Muhtar) and the senior teacher select the camp members of their village together. The following points are taken into consideration in selecting the members :

1. Only 5 members are selected from one village
2. Members selected should be farmers and own land
3. Members should be willing to participate in camp programmes
4. Members should be between 20 and 30 years of age
5. Members should be graduated in primary school
6. Members should have completed their military service
7. Members should be strong enough for heavy work.

The members accepted for the camp should provide the following papers :

1. Birth Certificate
2. Reference letter from Mukhtar
3. Health certificate.

On the first day of the camp, each member is given boots and overalls. The cost does not exceed TL. 100·00. The members wear these outfits during the camp period.

Duration of the Camps

The camps are programmed for a period of 6-10 months according to the climatic and employment conditions.

ORGANIZATION OF CAMPS

The camps are administered by the local TOPRAKSU organizations under the directives of TOPRAKSU General Directorate. These TOPRAKSU organizations include Regional Directorates, TOPRAKSU Work Unit Chief Engineers, TOPRAKSU Research Station Directorates.

Administrators assigned to each camp include one camp director, one assistant camp director, two camp instructors, one supply agent and clerk, one purchasing agent.

Camp directors are agricultural engineers. If more than one camp is established in a vilayet (province), one camp director is assigned in both. Assistant camp directors are selected from assistant personnel of the organization. These administrators should have ability to meet the requirements of this position or should receive training prior to the assignment. Camp instructors are technicians of the organization. There are two guards, one for night and one for day-time, at the camps. Two janitors take care of daily work of the camps. Guards and janitors are selected from among camp members who take their turns for the job.

Housing

The following requirements are necessary in selecting the camp site :

1. It should be in a central position of project area ;
2. It should have water facilities ;
3. It should have road facilities ;
4. It should be suitable for demonstrations.

Camp administrators and members are housed in tents. Mattresses and blankets are provided. Offices and storage depots are all in tents. Kitchen, restrooms, baths and other facilities are all erected using materials available at the site, usually masonry. Thirty-three tents suffice for a one-unit camp. Power for lighting is obtained by a generator. In cases of emergencies, portable Kerosene type lamps are also available.

Food

The camp administration hires a cook for one camp. Camp members take turns as cook helpers. Meals are served at portable tables. These tables and chairs are used for several camp periods. The food administration is based on calory intake with respect to the physical work that the members do. A four men kitchen party takes care of all feeding and menu preparations. The daily cost of meals per person does not exceed TL. 3·00 and is deducted from the wages.

Wages

Wages are determined according to standards obtained from the local municipal government. They vary between TL. 10·00 to 15·00 per day. The wages of skilled members can be as high as TL. 25·00. Wages are paid at the end of each month.

Medical Services

A Medical doctor is assigned to each camp. He visits the camp once or twice a week. In emergencies he is called in. A medical aid is also hired for each camp. He lives in the camp. He carries out the medical services for the camp and keeps records. He is responsible for the cleanliness of the camp and is also a member of the kitchen party.

There is a medical tent in each camp. This tent is used as a field hospital. First aid kits and other medical supplies and equipment ordered by the doctor are kept in a cabinet in this tent. All members receive a medical check-up when the camp opens. Their health conditions are recorded. Those who are found unhealthy are refused. Health subjects of the camp training programme are taught by the doctor. The doctor also examines the villagers coming from nearby villages, and the camps also serve as medical centres for their areas.

TRAINING AT CAMPS

The main objective of the camps is agricultural training. A two-hour class-room training on four days a week is given to the members in groups of 25. Technicians from other organizations are also utilized as instructors. Such audio-visuals aids as teaching films, slides and photographs are used during class-room sessions. The publications of the Ministry of Agriculture and TOPRAKSU are given to members. These publications reach villages by way of the members. Many competitions, demonstrations, and diversions are organized. A six month class-room training programme generally contains the following subjects. These are simple but provide basic information at village level.

A. Information Concerning Government and Citizenship :

1. The mission and organization of the Ministry of Agriculture. The mission, organization and method of operations of TOPRAKSU.
   a. Investment policy
   b. Credit Policy
   c. Technical assistance policy
2. The scope, organization, and operation principles of TS camps and camp procedures relating to these subjects.
3. Citizenship
   a. General knowledge concerning elections and government formation and administration, tax collection and usage.
4. History (national days, etc.)
   a. Declaration of Republic
   b. Understanding of reforms
   c. Legends and heroes.

B. General Education

1. Geography
   a. Turkey's topography
   b. Turkey's population
   c. Turkey's neighbours
2. Commerce
   a. Export commodities of Turkey
   b. Turkey's main industries and factories

C. Information Relating to Village Life

1. Districts and Cooperatives
2. Laws protecting farmer's properties
3. How firewood and lumber needs of villages are met
4. Climate knowledge
5. Village handicrafts ; importance and development.

D. Health

1. Cleanliness and food for human health
   a. Diseases relayed through food and germs
2. First aid
   a. Poisoning
3. Stomach and intestinal diseases
4. Winter diseases.

E. Soil

1. Soil surveys
   a. Why they are done
   b. What is studied
   c. Land use capabilities
2. Erosion
   a. Types
   b. Causes
   c. Stages
   d. Control measures
3. Conservation measures
   a. Improvement of pastures for better usage
4. Soil-Water and vegetation relationship
   a. Factors affecting plant growth.

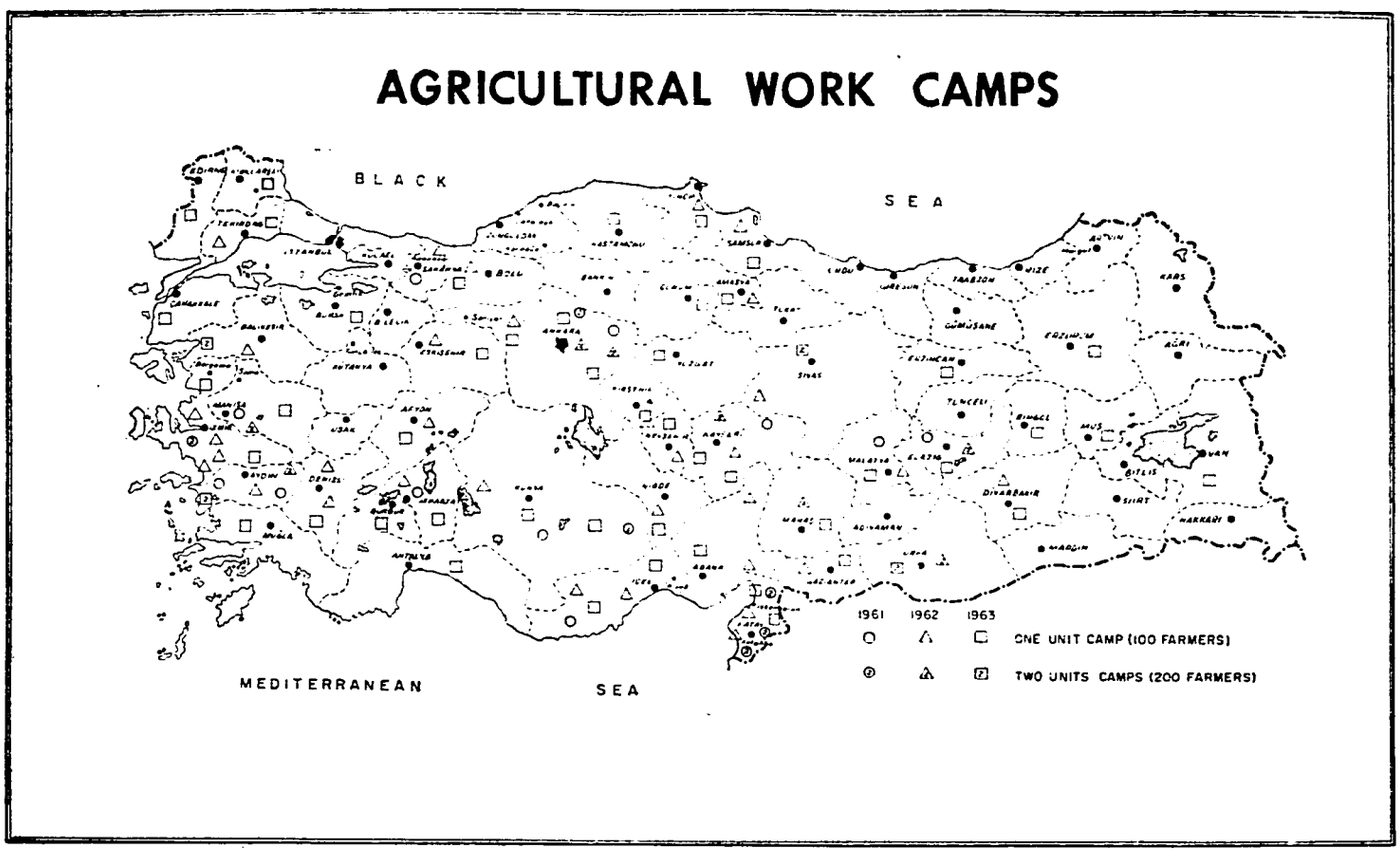
F. Water

1. Use of water in irrigation
   a. Providing irrigation water and resevoirs
2. Diversion channels, prevention and improvement of gullies
3. Drainage
   a. Types
   b. Advantages and maintenance of drainage systems.

G. General Farming Practices

1. Fertilizers
   a. Types and uses.
2. Seeds.
   a. Selection of good seeds
   b. Preparation of seeds beds
   c. Insecticiding of seeds
3. Orchard and vineyard growing on arid land
   a. Pruning and related practices for orchard growing
4. Poultry and how to start poultry farming
5. Fighting weeds ; Uses of discarded plants
   a. Plant insects ; how and why to fight them
6. Beekeeping
   a. Life system of bees
   b. How to start beekeeping
7. Construction of terraces and grass waterways
   a. Agricultural practices to be applied to terraced lands
8. Contour Farming
   a. Contour strip farming (cropping)
   b. Terraces and types
9. Animals
   a. Diseases
   b. Barn and pasture livestock raising
10. Pasture land
   a. Feed plants (Alfalfa, sanfoin, vetch and grass).

After all classes there is a summary of previous classes and a question and answer period. There are also discussions with members concerning the camps, and an analysis of the impression one camp period has made on members. There are various work groups in the application projects of TFTC. The camp members take their turns to work in these workgroups. Simple work-shops



LOCATION OF FARMERS WORK CAMP

such as blacksmith, carpentry, and general are also available for members to learn new skills on off-duty times.

ACTIVITY REPORT OF CAMPS

Camps are opened with a ceremony on scheduled days. Many farmers are invited for the occasion. Local government officials and camp administrators also attend the ceremonies. Speeches cover objectives of camps, Turkey's problems and their solutions, and farmers parts in these solutions.

Activities and the accomplishments of camps are reported monthly to the TOPRAKSU General Directorate. The following information is contained in these reports :

Activities of camp administrators
Activities of camp members
Practices
Training activities
Medical services
Relations with vicinity
Visitors
Monthly expenditures.

There is a ceremony at the end of each camp-period. Camp training certificates are awarded to graduates. At the end of each camp the camp director presents a report to TOPRAKSU General Directorate on camp activities. The contents of this report are :

Activities of camp for one period
Expenditures for one period
Influence of the camp on the members and nearby villages
Failures observed
Suggestions for future camps.

COOPERATION WITH GRADUATES

The farmers working in the camps return to their villages at the end of training. A follow-up programme is effected by technicians of TOPRAKSU and technical agriculture organizations. The outstanding trainees may be assigned as foremen in future camps. They become leaders in their village organizations. Demonstration projects are carried out on the land of these trainees, and priorities are given to them for their technical assistance and or

ROCK FACED TERRACING COMPLETED BY TOPRAKSU FARMERS TRAINING CAMPS

TABLE 1. ACTIVITY OF TOPRAKSU TRAINING CAMPS 1961-63

Nature of camps opened	1961				1962				1963			Total			
	Camp units	Number of members	Area covered, Decares	Investments, TL.	Camp units	Number of members	Area covered, Decares	Investments, TL.	Camp units	Area covered, Decares	Investments, TL.	Camp units	Number of members	Area covered, Decares	Investments, TL.
SOIL CONSERVATION															
Contour farming	22	2,153	31,221	7,183,293	44	4,400	83,175	14,086,321	50	136,975	20,425,652	116	11,553	251,371	41,695,266
Grass waterways															
Terracing															
Gully control															
Terraced orchard, vineyard															
Olive growing															
Rangeland improvement															
Reforestration															
FARM IRRIGATION															
Channel construction	1	100	1,300	175,000	...	...	...	...	4	17,900	1,650,348	5	500	19,200	1,825,384
Channel lining															
Land levelling															
Land consolidation															
DRAINAGE															
Surface drainage	...	...	...	...	4	400	9,852	1,566,582	1	2,000	432,565	5	500	11,582	199,147
Open drainage															
Underground drainage															
TOTAL	23	2,253	32,521	7,358,293	48	4,800	93,027	15,652,903	55	156,875	22,508,601	126	12,553	282,425	45,519,797

credit project applications. Opportunities are provided for them to apply their new knowledge on their lands.

ACTIVITIES OF TOPRAKSU CAMPS

Activities of 1961-1963

The first TSC with four units was opened in 1961 with technical and financial assistance of US AID in the same year, camps totalling 19 units were added by TOPRAKSU. During the three-year period 126 camp units were operated. Land and water conservation measures were taken in an area of 282,423 decares. The cost of the programmes was TL. 45,419,797.

Projected Activities 1964-1967

The programme for the next four years is as follows :

Years	Number of Camp Units	Number of Trainees
1964	45	4,500
1965	48	4,800
1966	50	5,000
1967	50	5,000
Total	193	19,300

Priority will be given to farm irrigation, drainage and land improvement project sites.

SURVEY AND EVALUATION OF TRAINING NEEDS AND METHODS

by

Shri Mohan*

SYNOPSIS

In the present fast-developing phase in India, when new irrigation facilities are being created on an unprecedented scale, and farming conditions are changing due to modified conditions of labour, water, population growth and modern technological development; need for training programmes in modern approaches to irrigated agriculture cannot be over-emphasized. A large number of training hands are necessary for assisting in implementation of the programmes on sound technical lines and also to guide the farmers in irrigation practices and applied phases of irrigation.

This paper presents an assessment of the training needs in India in the field of water use and irrigation and gives a detailed account of the different training programmes that are being organized in the country to fulfil these needs. In the various Departments/Agencies, that are concerned with irrigation development there are four categories of personnel: (a) The professionals (district level technicians), (b) The sub-professionals (sub-district level staff), (c) The Village Level Workers, and (d) The Farmers. Training needs have been indicated for each category of these personnel. In addition to the pre-service training that the professional and the sub-professional receive on the subject in their Degree and Diploma courses; specialized in-service training, on a regular basis, has also been organized for both these categories. Similarly, there are pre-service and in-service training courses for the Village Level Workers. These courses among other items cover the subject of Minor Irrigation and Water Use. During the in-service period, Village Level Workers are also imparted a specialised training on water use. There is also a programme of imparting practical training in water use to the progressive farmers in areas where irrigated farming is predominant. During these training sessions the farmers are instructed by lecture and demonstration, the remedies for their specific problems, the methods for controlled and efficient use of irrigation water and applied results of modern scientific investigations as suited to their areas for maximum production.

Efforts are made to make full use of the training imparted at various levels by an actual follow-up programme. Farmers improve their irrigation practices as a result of training obtained. The Village Level Workers help the farmers in surveys, levelling, farm layout and methods of water control. The sub-professionals and the professionals help the Village Level Workers in carrying out their duties efficiently at the field level.

INTRODUCTION

The importance of irrigation to the predominantly agricultural economy of the country needs no emphasis. The rainfall is capracious and erratic in agriculturally predominant areas of the country. For successful and reliable farming, irrigation is necessary in those parts of the country where rainfall is less than 30 inches. Supplemental irrigation is desirable in the 30" to 60" rainfall zone. With irrigation, land and labour can be put to profitable use, crop yields are enhanced and money return increased to bring about prosperity and self-sufficiency.

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Irrigated farming is not new to the Indian cultivator. Centuries old irrigation works are found in the country. Surface wells and ponds for impounding rain water were constructed in ancient times for irrigation purposes. Mughal rulers constructed a few canals as well. Since the middle of 19th century, irrigation development was started by the Britishers. Increasing number of multipurpose river valley projects have been planned and constructed, since 1951. Extensive areas have been brought under irrigation. To change from dry-farming to irrigated farming requries new cropping patterns, field preparaton and suitable implements, beside credit facilities to initiate the job. It is very difficult for the farmer to switch over to irrigated farming, unless he is guided with the proper know-how. Efficient utilization of water is necessary in projects nearing complete development.

Thus the dissemination of appropriate and up-to-date "know-how" is essential in all irrigated areas. Technical aspects deserve increasing attention to ensure proper utilization and maximum yields of the vast accelerating programme. There is urgent need for a large number of technical hands who may assist in implementing the programme on sound technical lines and also guide the farmer in construction, maintenance and operation of irrigation works. Major irrigation works in the country have been designed and constructed according to the latest and most appropriate technical "know-how". The utilization of irrigation water has not been satisfactory as the previous background of the entire community has not been adapted to efficient irrigation farming. Latest techniques in irrigation practices, developed through systematic and scientific research need to be brought to creative application at a rapid rate. Extension is always lagging scientific research ; however, the gap between the two has to be kept to a minimum.

Training is defined as the means to bring about continuous improvements in the quality of work performed by the staff and individuals. Training brings about an organised approach to achieve the objects of the scheme with uniform action and efficiency. It is very difficult to reduce training to an exact formula or sign, rather it must be made to fit the scheme, the organization and the individual. Without proper and correct training, many wrong habits, wrong techniques, and inefficient methods are liable to be intensified. The latest and the best methods should be made a part of the technicians operations. It has been found that good and effective training comes in active engagement rather than passive acceptance of what is heard or read. Practical training must, therefore, be given a very prominent place in a training course.

It is most desirable that the training is imparted at various stages. Personnel at different levels should be trained according to the needs and intellectual ability.

TRAINING NEEDS

Different government departments are concerned with various phases, i.e. conveyance, maintenances, regulation, realization of revenues, and utilization of irrigation water. Engineering aspects are the responsibility of the Irrigation Department ; agricultural aspects, that of the Agricultural Department. Extension and education is the concern of the Department of Community Development and Extension. All the three departments have their staff at three different levels i.e. district level, the sub-district level and the village level. The district level staff are designated as Engineers (Executive or Assistant), District Agricultural Officers, and Block Development Officers respectively. In the same order, the staff at sub-district level are Overseers, Agricultural Inspectors or Agricultural Demonstrators and Extension Officers. The field level staff are the revenue staff engaged in irrigation (Patrols and Amins), Assistant Agricultural Inspectors or Farm Mukaddams and Village Level Workers (V.L.Ws.). In addition to the three categories mentioned above, farmers and cultivators also need to be educated in various applied and practical

phases of Minor Irrigation and Water Use. The ultimate purpose of the irrigation programme would remain incomplete unless the farmers are enlightened.

Training to all these four levels is essential, besides follow-up and guidance to the farmer. The training for the four different categories has to be designed on the basis of need and intellectual capacity. The entire country has 320 districts and about 5,000 development blocks. Irrigation facilities are accessible to about 250 districts and 4,000 blocks. Accounting only for the irrigated districts and blocks, about 1,500 men are required to be trained at district level, 6,000 at sub-district level and 60,000 at village level. The success of the entire training programme lies in the expeditious implementation of the follow-up. The staff at the village level is required to make use of the information received during by dissemination at the field level. The field level worker is guided and helped by his superior officers.

It is also important to impart training to the farmers. In view of the large number, it may not be possible to extend the training to each and every farmer ; however, training should be given to a few selected progressive farmers in a community.

TRAINING PROGRAMME

As indicated, three levels of technical staff are engaged in the irrigation programme. They are required to execute, maintain and operate irrigation works. Assistance and advice to farmers in irrigation methods and practices is also provided by them. In general the technicians working at the district level hold degrees in Engineering or Agriculture. The staff of the sub-district level possess engineering diplomas or agricultural certificates. The village level workers do not possess any technical qualifications as they are educated upto high school stage. During the service period, these workers should undergo specialized training or refresher courses, from time to time.

The various in-service and pre-service training programmes on irrigation, in vogue, are described as under :

1. TRAINING OF DISTRICT LEVEL TECHNICIANS

In order that these technicians become thoroughly conversant with the applied phases of irrigation including engineering as well as agricultural aspects, it is necessary that they may undergo a brief orientation course on irrigation.

(a) **In-service Training**

(i) **Orientation Training in Minor Irrigation and Water Use**

The main objective of this course covers the applied and practical aspects of scientific and technical knowledge on irrigation works and water use. The two months' training includes theory classes as well as practical field work. Short field trips with descriptive handouts are also arranged. Specialists working on irrigation in various departments of State Governments, the Government of India, the Universities and Colleges, and foreign experts in the country, deliver lectures and arrange practical demonstrations.

The first session under this scheme was arranged during May 14—June 15, 1962 at Bellary (South India). Nineteen trainees participated from different States. During the two-month training period, 60 lectures of about 1½ hours each, where delivered and about 120 hours was spent in field practicals and demonstration. Twenty top ranking technicians from all over the country were invited to deliver lectures and arrange demonstration in their specific field of specialisation. Field trips were planned to major, Medium and minor irrigation projects. The trainees showed interest and enthusiasm in the training, which has proved to be of immense value.

About two of such Orientation training programmes are planned this year. During the previous session there was great difficulty

in getting the experts at the required time. A few more such courses will pave a way for setting up a central institution where technicians can be trained in larger numbers by various experts.

(ii) **Orientation Training of Block Development Officers**

The Block Development Officers (B.D.Os.) are trained to get an insight into the nature of difficulties they are likely to face and their possible solutions. The Government have established ten such centres in various parts of the country. The annual capacity of the centres is 1,800 and a total of 4,906 B.D.Os. have been trained so far. During the training period of 45 days, trainees are briefed in a number of subjects like land reforms, tenancy laws, agriculture, animal husbandry, co-operation, and village and small scale industries. Irrigation is one of the important items.

The syllabus followed for irrigation is as follows :

Theory

Minor Irrigation—different types of public participation in execution and maintenance

Financial assistance available to individuals and communities.

Under utilization—problems and solutions, village and field channels—their importance.

Different types of water lifts and their suitability.

Wise use of water.

Water logging.

Salinity and drainage.

Practicals

Observe and study economics of different methods and types of minor irrigation.

Study working of an irrigation co-operative society.

(iii) **Training in soil and water conservation.**

In 1955 Central Government established one training centre at Dehra Dun where Soil Conservation Officers, Revenue Officers, Forest Officers, District Agricultural Officers and Engineers receive theoretical and practical training. The training course is of six months duration. So far 260 technicians have received the training in 10 batches. Trainees learn surveying, levelling, design of cahnnels, irrigation systems and methods of crop rotations, manures and fertilisers and soil-plant-water relationships, etc. They are also taken round on an extensive field trip.

(b) **Pre-service training**

Technicians working at the district level hold degrees in their specific fields, i.e. engineering or agriculture. Degree courses in Civil Engineering, Agricultural Engineering and Agriculture are offered at a number of institutions in the country. The duration of the courses ranges from 3 to 5 years. The syallabus for civil engineering includes hydraulics, irrigation investigations, planning, design and construction. Lately water use has also been included. Agricultural Engineers learn more about irrigation practices and water use. They are taught surveying, levelling, hydraulics, irrigation systems and methods, their design and soil-water-plant relationships. Agriculture students cover soil-water-plant relationships, salinity and alkalinity, and agricultural phases of irrigation.

2. TRAINING OF SUB-DISTRICT LEVEL STAFF

Engineering Overseers, Agricultural Inspectors or Agricultural Demonstrators, Soil Conservation Assistants and Extension Officers are engaged in irrigation at the sub-district level.

(a) **In-service Training**

(i) **Training on Minor Irrigation and Water Use**

Under a scheme initiated by the Government of India practical training is provided

to Agricultural Inspectors, Engineering Overseers and other staff of equivalent status engaged in community development blocks and other departments connected with minor irrigation and agricultural developments. It is also proposed instructors for village level workers who train the V.L.Ws. in pre-service and in-service periods. This scheme has been organized on a regional basis, and in general, one training centre in each State has been planned. Training centres are located at existing Agriculture Colleges or Research Institutes considered most suitable by the concerned State.

Two specialists one in Engineering and one in Agronomy, and other affiliated staff is provided. The Engineer must have a good background of irrigation engineering related to minor irrigation works and water use. The Agronomist should be experienced in soils and irrigated land management practices. Specialists working in other departments of the States, the Government of India or other foreign experts deliver lectures on special topics.

Each individual course has a duration of three months. Three such courses per year are arranged at each training centre. Each course may have about 30 trainees thus each training should handle 270 trainees every year or 1,350 during five years of a Plan period.

The curriculum includes class-room lectures and field practicals with emphasis on practicals. A trainee is trained in such a way so that he is able to practically do the job himself and thus gains confidence and experience. The course includes about 150 hours of theoretical lectures and 210 hours on field practicals.

The syllabus broadly includes the following subjects :

1. Minor irrigation schemes ; scope, objective and salient technical features of different types.
2. Open wells ; design, construction, boring and deepening.
3. Water-lift appliances ; different types of man-powered, animal powered and mechanical powered appliances ; their design, construction, comparative performance and output ; further improvements.
4. Design criteria and standards for construction and restoration of tanks, storage works and diversions.
5. Surveys and investigations for minor irrigation works and preparation of fields.
6. Operation and maintenance of irrigation works ; regulation of supplies ; restoring channels ; concept of duty, depth, water allowance, outlet factor etc. ; crop planning for maximum production with available irrigation supplies.
7. Plant-soils-water relation ; physical and chemical properties of soils, suitability of soils for irrigated farming, need and advantages of scientific crop patterns ; suitable crop rotations ; water requirements of different crops under varying conditions of soils and climate ; crop evaluation in the field.
8. Irrigation methods and field preparation : selection of irrigation methods for cultivation of different crops under varying conditions of terrain and soils ; levelling and preparation of fields with improved implements and in a scientific manner ; fixation of field size and slope according to in-take rate and discharge of the water course.
9. Irrigation farm structures, water distribution, regulation and measurement ; alignment, construction and lining of field channels ; cheap designs for and construction of field channels, crossings, falls, use of parshal flumes, wooden regulating boxes, canvas dams

and syphon tubes, gated pipes and other devices for measuring water-supply to fields.

10. Soil and water conservation practices ; contour bunding, terracing, gully plugging etc.

11. Drainage-water-logging ; quality of water, salinity, alkalinity and their cure. Taking soil samples for salinity and alkalinity examinations. Taking water samples, taking leaf samples recognition in field of saline soil, alkaline soil and deficiency symptoms to accompany leaf samples.

During the field practicals, trainees are required to survey the areas, prepare maps and plans and execute them in the field using improved and appropriate implements, the land is prepared for irrigation by the most suitable method. Various implements are used for proper seed-bed preparation for irrigated crops of the area. Trainees also learn construction of water channels and installation of necessary water control devices. Finally the trainees learn by observing and irrigating the plots themselves. Thus the course meets all of the recommendations, for education and on-the-job training of the Fourth Irrigation Practices Seminar.

Training has been initiated so far in 13 different States. At 5 centres the scheme has made good head-way and about 100 technicians have been trained. At other centres the preliminaries are over and training courses are expected to be in full swing this year.

(ii) Training of instructors to village level workers

The instructors responsible for training of village level workers at the Extension Training Centres are trained by the experts at the Extension Education Institutes. The first extension education institution was established at Nilokheri in Punjab during 1959. Two additional institutes have since been established at Hyderabad (Andhra Pradesh), Anand (Gujarat). These institutions are located at agricultural colleges. Training is of six weeks duration. So far 368 principals and instructors have received training. The subject-matter under irrigation includes :

Wise use of water for irrigation-need for proper manuring and good cultivation. Cropping schemes to utilize the irrigation water fully, distribution and rotation of water, sowing in compact blocks for better water utilization, methods of irrigation, size of beds and frequency of irrigation. Role of community in maintaining irrigation works and water distribution channels, minor irrigation works, wells, tanks, bunds and tubewells. Capacities of different water lifts.

Special training in irrigation and water use : Special water-use workshops have been arranged at two Extension Education Institutes. These sessions of two weeks duration were mostly practical work and demonstration with theory on agronomy, soils and engineering, relevant to irrigation. They were held at Nilokheri in north India and in central India, at Hyderabad, and trained 87 personnel. Two more in-service training programmes, one in western, and one in eastern India, are planned for the near future.

(iii) Training in soil and water conservation

The Government has a programme of in-service training for affiliate field staff of the soil conservation works. Soil conservation assistants, forest range officers and agricultural demonstrators are deputed for this training, which is of six months' duration and includes theoretical and practical work. Trainees are also given an extensive field tour. Subjects relating to irrigation are taught under engineering, soils, and agronomy. The engineering syllabus includes surveying and levelling, methods of irrigation, irrigation implements, and soil-water relationships. Under Agronomy is included water requirements of crops and irrigated agriculture. Salinity, alkalinity, remedial measures and reclamation, water holding capacities of soils, quality of irrigation water are also included.

Four centres trained 1,404 technicians during 18 batches, since 1954.

(b) **Pre-service training**

Sub-district level technicians are either engineering overseers or agricultural men, with different designations.

Overseers have successfully completed course work for the Civil Engineering Diploma. There is a net-work of institutions offering this course. These courses last from 2 to 3 years and instruction includes surveying and levelling, engineering drawing, building and structural design and irrigation, etc. Under irrigation is included execution and maintenance of irrigation works and regulation and distribution of available supplies. Agricultural and water use aspects of irrigation are included as background.

Agricultural technicians hold degrees in agriculture. Their pre-service training is the same as for district level technicians. The sub-district staff are promoted to district staff after adequate experience.

Sub-district level staff are given refresher training in irrigation from time to time during their service period.

3. TRAINING OF VILLAGE LEVEL WORKERS

Community Development staff members at field level are designated Village Level Workers. About 10 V.L.Ws. are posted in one Extension Block. The staff members of the agricultural department at this level are assistants to Agriculture Demonstrators.

(a) **In-service training of V.L.Ws.**

The V.L.Ws. cannot efficiently discharge their responsibilities unless they are up-to-date in their knowledge of technical developments. Thus arrangements have been made for in-service training at 24 special training institutions. The duration is of two months. V.L.Ws. are expected to undergo this training after 4 to 5 years field experience. To date 6,300 V.L.Ws. have received training and by 1965-66 (end of Third Plan), it is expected that 30,000 will have been served.

Irrigation as well as other subjects like economics, social science, land development, plant protection, animal husbandry, soil conservation, etc. is covered.

The talks on irrigation include :

Wise use of water for irrigation, need for proper manuring and good—cultivation. Cropping schemes to utilize the irrigation water fully, distribution and rotation of water, sowing in compact blocks for better water utilization. Methods of irrigation, size of beds and frequency of irrigation. Role of community in maintaining irrigation works and water distribution channels, minor irrigation works, wells, tanks, bunds and tubewells. Capacities of different water lifts, drainage, reclamation of waste, alkaline and acid lands. Role of irrigation and better fertility in reducing the fluctuations in yield of crops. Irrigation planning for full utilization, wastage, seepage and leakage. Water rates, maintenance of minor irrigation works.

(b) **Pre-service training of V.L.Ws.**

Newly employed V.L.Ws. are high school graduates. Additional professional training is provided before assignment to the field in order to obtain the desired results of the agricultural phase of the community development programme. The training is designed to make the V.L.Ws. competent to communicate the results of research to cultivators and thereby induce them to adopt improved practices for higher production of crops.

This training programme was initiated in 1952 when five training centres were established. By the end of the First Five Year Plan i.e. 1955-56, 1,200 V.L.Ws. had been trained at these Basic Agricultural Schools. There are now 100 Baisc Agricultural Schools where training of two years is provided prior to assignment to field operation.

So far 53,969 V.L.Ws. have completed this training and 9,155 are enrolled. By the end of the Third Five Year Plan i.e. 1965-66, 75,000 V.L.Ws. will have received training. The syllabus includes training in soils, tillage and tillage implements, manures and manuring crops, husbandry, and agricultural engineering, etc. The following syllabus in irrigation is followed :

Methods and practices for conservation of soil moisture.

Water lifts and pumps, cost, output and source of availability, comparative cost of irrigation.

Water charges of Government canals and tube-wells.

Rational use of water and avoidance of water losses, adverse effect of improper irrigation.

Drainage and its importance. General idea regarding major, medium and minor irrigation works.

(c) Specialized training in irrigation of V.L.Ws.

It is felt that in certain areas the V.L.W. needs specialized training in one field. General refresher training, though useful, is not a complete answer to many problems faced in the field. A new training programme during the Fourth Plan will, therefore, be started for experienced and selected V.L.Ws. This will cover water use and soil conservation. Five centres will be started at Government Farms and other Agricultural Institutes. Twenty-five such centres are planned. At each 20 to 25 V.L.Ws. will be trained for a period of six weeks. It is planned that 750 such courses will train 15,000 V.L.Ws. during the Fourth Five Year Plan.

4. TRAINING OF PROGRESSIVE FARMERS

Progressive farmers need to be trained by effective demonstration and simple explanation of practical and applied irrigated farming in specific areas. In old projects, irrigation methods have developed as a result of experience. Farming conditions are changing due to modified conditions of labour, water, population growth, and modern technological developments. Some areas face severe problems of salinity and alkalinity after years of irrigation.

Within the last few years a beginning has been made. Practical water-use workshops of 10-day duration have been arranged. During 19 such workshops, 400 farmers were exposed to the training. The daily programme included about one-hour talks on applied phases of irrigation engineering, agronomy and soils. The rest of the time was devoted to field practicals and demonstrations. Short educational tours were also arranged. Improved bullock drawn implements, methods of irrigation, water controlling devices and suitable cultural practices were demonstrated. Many farmers were able to adopt new irrigation practices as a result of this training.

A programme for the exchange of farmers with those of the U.S.A. has already been taken up on a restricted scale.

(d) Follow-up programme

The previous discussion gives a detailed account of all the training programmes at different levels ; i.e. the district level, the sub-district level, the village level and the farmers level. The final objective of the entire training programme is to educate technicians and farmers in order to keep them uptodate technical know-how according to their requirements and intellectual capacity. Training of the technicians would enhance the implementation and efficiency of irrigation schemes. Efficiency in the use of irrigation water would be increased as a result of proper training to the farmers ; and guidance and technical advice from the technicians. The final objective will be achieved only when a higher production is obtained. In order to achieve the objective it is most essential that technical men trained in the field of irrigation and water use guide farmers to enable them to achieve greater returns. The progressive

farmers trained in irrigated farming would themselves adopt improved irrigation practices suited to their conditions and circumstances. The village level workers would help these farmers in survey, lay-out, and improved irrigation practices. The technicians working at sub-district and district level would assist in solving the difficulties of the village level workers. The Training at different levels would be utilized in field application of the knowledge.

Starting in 1962 such an intensive follow-up programme has been arranged in South India. Twenty-four trained hands were deputed for a period of two months during which each person was required to survey, lay-out, level, crop and irrigate one farm of about 10 acres area. Demonstration and technical guidance led to preparation of 88 farms instead of 50 as targetted. At present about 1,500 farms are in the process of lay-out and preparation. Response from farmers has been immense and a great number of them have come forward to obtain the necessary technical assistance.

DEVELOPMENT OF AGRICULTURAL SCHOOLS IN IRAN

by

Eng. Abdollah Jenab*

INTRODUCTION

Eighty per cent of Iran's 23 million people are directly dependent on agriculture. Iran's economy is heavily based on its agricultural production. Dried fruits, pistachio, sheep skins, and carpets form the main agricultural exports of the Country.

This being true, much emphasis should be given to educating the farmers who are producing these products. They should be taught how to irrigate the lands, how to control pests, and how to solve numerous other problems. For a number of years, the Government of Iran has made some attempts to educate the farmers in improved methods of agriculture.

In this paper a brief history of the agricultural schools and their programme will be presented, but the main purpose will be to discuss the Karaj Agricultural College. The curriculum and the programme of some other colleges are based on the curriculum at Karaj College.

AGRICULTURAL SCHOOLS BELOW COLLEGE LEVEL

Brief History

In 1901, one Agricultural School was established in Tehran. This school was named Kazaffari School, after Mazaffaredin-Shah. The head of this school was a Mr. Disher from Belgium. A village named Beheshty was engaged for the practical training of students.

The purpose of this school was to train young farmers in the best methods of irrigation and cultivation. After finishing school these young fellows went to their villages and showed the other what they had learned about agriculture.

The school had a three-year curriculum. In addition to agricultural courses, other courses such as Persian, French, Arabic, Geography, and Arithmetic were taken. In the summer, the students went to the farm and participated in field work. This practical training was a required part of the total course. In 1907 this school was closed down.

In 1918 the Government of Iran decided to set up an Agricultural High School at Karaj. This school was headed by a Mr. Mans Schriker. Courses in Botany, Agronomy, Fruit Trees, Animal Husbandry, Land Reclamation, Agricultural Machinery and Dairy Production were offered. The students were trained mainly to manage a good agricultural unit and to work in the Ministry of Agriculture.

In 1942, this high school was closed down. Up to 1951, several other agricultural schools were set up and had begun to function.

In 1951, the compulsory agricultural training law was passed by the Congress. This law specified that one agricultural training centre should be established under which different levels of agricultural education could be given. In 1958 schools under this centre

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numbered 284 and a total of 8,544 students had been graduated.

Agricultural Training Centre

The graduates of the above mentioned schools did not satisfy all of the needs of Iran. More specialized students with different levels of education were needed for various sections of the Ministry of Agriculture. So the Ministry of Education decided to set up a different system of agricultural schools with various levels of education. These schools were organized and functioned under a common constitution which was regulated by the Agricultural Training Centre.

The schools and their purposes are as follows :

1. **Teacher Training Centre.** The purpose of this organization is to train teachers for the agricultural schools which are located in the villages. Up to 1962, 3,941 students have been graduated from this type of school. Most of them are now teaching, but a few of them are working in different branches of the government such as in the Extension Service, Community Development, Banks, and the Ministry of Agriculture. There are now 14 schools of this kind scattered over Iran, with 1,448 students enrolled.

2. **Secondary Cycle Agricultural High School.** The purpose of this kind of high school is to teach some agricultural courses to young people who wish to work in agricultural organizations or in private companies. Due to lack of the budget, the Ministry of Education decided to locate these schools in the same places with teacher training centres. These are three-year schools. In the first two years, the students take some general agricultural courses. In the third year they take specialized courses in either Horticulture, Agricultural Machinery, Rural Industry or Extension. Thirteen such schools have been established and have graduated 117 up to 1961. Total enrollment in 1962 was 773.

3. **Extension Agent Training Centre.** To educate farmers in new agricultural methods, the Ministry of Education decided to establish an Extension Agent Training Centre. To date 1,300 students have graduated from this kind of school. Most of these graduates are now working in the extension service or in the land reform organization.

4. **Practical Agriculture High School.** In 1959, a practical agricultural high school was established at Shahryar. The main purpose of this school was to train agricultural technicians. A similar school has recently been established in Ali Abad (Fars).

5. **Girls Teacher Training School.** This school was established in 1955 near Ghaleh (Varamin) to provide Home Economics Training. Graduates from this kind of school go to the villages, live there, and provide rural training and handicrafts. They also teach in night schools for women.

Karaj Vocational Agricultural Centre

This centre was established in 1962 at a location 12 kms. south west of Karaj and occupies 40 hectors of land donated by the Bureau of Agricultural Engineering.

The budget of this organization is provided by the Ministry of Education and the U.S. Agency for International Development. This centre is the best equipped agricultural high school in the country.

The students should be from secondary towns or villages with a background of three years of high school. The main purpose is to train those who have some agricultural background and who will subsequently work in agriculture. They must be between 16 and 25 years of age. Students eat in a restaurant which is based on the cooperative system and operated by the students themselves. Each student pays 1,000 Rials as the membership fee and 1,500 Rials each month for board.

Freshmen are given one month of practical training on the farm. This training is very hard and is mainly to determine if the students can stand it or not. During this period, those who cannot do such hard work quit the school. After approximately one

month, classes start and the curriculum includes both theory and practical work. In the mornings students have theory, and in the afternoon they do practical work in different laboratories and in the field. This is a three-year school. The first two years are general course, and the third year provides specialization in one of the branches of agriculture.

During the year, the students have a one and a half months vacation period. This vacation is staggered so that the school is never closed as the students go on vacation one group at the time.

KARAJ AGRICULTURAL COLLEGE

History

In 1927 a three-year agricultural college was established by the Ministry of Agriculture in Karaj. Students attending this school received free tuition, board and room and were trained for Government positions especially for the Ministry of Agriculture. When they completed the theoretical and practical programme they were given a diploma considered equivalent to B.S. degree.

In 1945, the college was transferred from the Ministry of Agriculture to the University of Tehran. The curriculum was revised and the college came under the constitution of the University. Members of the Tehran University professional academic staff must pass a special examination before they are employed. The students also take entrance examinations and are admitted if their grades are satisfactory. The present entrance examination system is under study and will be modified.

Scholarships and Fellowships

In 1927, when the college was started, only a few students enrolled. To encourage students, the college made some scholarships available. Students were provided free board and room and there was no tuition.

In 1953, the college reduced the free board system to provide scholarships and free board to 35 students who had the best averages. No tuition was charged.

In 1962, the scholarships were reduced and only the room with no charge was provided. According to the new regulation, each student pays a tuition equal to 10,500 Rials ($ 136) per year. Students of poor financial status who have a good average may use loans provided by the university to be repaid after graduation. Students can work 2 or 3 hours a day in the college for money. Each year, the government of Iran makes some scholarships available for a few foreign students.

Curriculum

From 1927 to 1945, emphasis was given to the practical subjects rather than the theory. The curriculum included 2,442 hours of course work and 1,033 hours laboratory work for 27 months plus they had 9 months of practical work on the farm. The programme was weak in mathematics and engineering. In 1945, when the college was transferred to the University of Tehran its curriculum was revised.

This programme did not satisfy the needs of the country, however, since more specialized graduates were needed, in 1955, the three-year programme was changed to a four-year one principally to add more mathematics and engineering. According to this curriculum, Freshmen and sophomors take common basic courses and Juniors and Seniors, specialized courses along with a few general courses. In 1955 majors were offered in Irrigation and Reclamation, Pest Control, Forestry, Agronomy, General Agriculture, Horticulture, and Mechanics.

In 1962, the regulations of Tehran University were changed and the "Full Time" law passed by the Congress. In the new constitution the following regulations were set up : (1) All the professors, associate professors and assistant professors should work full time in the university, none can have job outside the university. (2) Each subject should be taught in its own department. Formerly each college taught basic subjects, *i.e* , Engineering taught its own physics course.

Along with this educational revolution, the Agricultural College changed its curriculum.

The Freshmen will choose their majors and continue the schedule in the particular department. There are 10 departments as follows :

1. Department of Irrigation Engineering and Land Development
2. Department of Forestry
3. Department of Agricultural Industry
4. Department of Agronomy
5. Department of Soil Chemistry
6. Department of Mechanics and Machinery
7. Department of Horticulture
8. Department of Animal Husbandry
9. Department of the Basic Science
10. Department of Biology

Research and Investigations

Increased attention is being given to research in different branches of agriculture. According to the full-time law each person must allocate part of his time to research and each school reports the results of his studies to a committee set up especially for this purpose. Each department is entitled to write some detailed research projects with required budget and send it to the Plan Organization. The Plan Organization studies the proposal and if, it is approved by the research committee, provides the funds. The head of the department which has proposed the project is responsible to carry on the research and report the result to the Plan Organization.

At present the Irrigation Department is studying the following subjects :

1. Determination of the consumptive use of different crops in Karaj area.
2. Lining canals with different materials and studying its cost and durability with Iran's condition.
3. Soil moisture determination with neutron meter.
4. Comparing the efficiencies of sprinkler irrigation and furrow irrigation and studying the crop production under the two methods.
5. Raising tea trees with sprinkler irrigation in hilly areas of north Iran where the precipitation is not adequate.
6. When and how to irrigate orchards.

Also, research programmes are carried on by the other departments of the college.

Students are involved in carrying out the research.

OTHER AGRICULTURAL COLLEGES

In 1955, the Ministry of Education established other agricultural colleges in Shiraz, Ahwaz and Tabriz. The main purpose was :

1. To increase the number of the college level graduates, and
2. to take account of variations in regional agriculture due to geographical and climatic differences.

These were originally three-year colleges. However, in 1960, they were changed to four years, and have accepted the curriculum of Karaj College.

CHAPTER VII

INSTITUTIONAL DEVELOPMENT

DEVELOPMENT OF INSTITUTIONS FOR IRRIGATION IN JORDAN

SUMMARY

Irrigation in Jordan is an important factor in the development of the country. Since 1959 several agencies have been established, and others reorganized, in which part or all of their efforts have been devoted to the improvement of irrigation.

The East Ghor Canal Authority was organized under Law No. 51 in 1959 and construction of the project began soon after. The Authority instigated a reform programme for land ownership and water rights making it possible to establish new farm boundaries in a distribution system where water from the Yarmouk River was diverted to lands lying East of the Jordan River.

The Central Water Authority became operative in 1960. The Authority was established as "The Law for the Organization of Water Affairs". With the exception of the area under the East Ghor Canal Project, which was established for the development of one irrigation scheme, the Central Water Authority has jurisdiction over all of Jordan in the development of water resources for Domestic, Municipal, Industrial and Agricultural purposes.

The Agricultural Extension Department under the Ministry of Agriculture has been successfully operating in Jordan for more than 10 years. During 1963 a new division was established known as the Land Development and Water Conservation Division. The division was organized for the purpose of covering the needs of farmers in the development of irrigated land. This division has made available to farmers ; Farm planners, Irrigation engineers, Agronomists and others who will work with them in the development of irrigated farms.

The Research Department under the Ministry of Agriculture has carried on irrigation research on their experiment station and in cooperation with East Ghor Canal Authority, Central Water Authority and Agricultural Extension.

The Agricultural Credit Corporation was established as a legal entity with eleven districts in order that it might better serve the credit needs for farmers. The Agricultural Credit Corporation lends money to farmers for irrigation development and employs an engineer to assist farmers in the construction of irrigation projects.

The Ministry of Social Affairs has an active department of Cooperatives and has encouraged and assisted in the organization of more than 275 Agricultural Cooperatives in Jordan. Cooperatives have been established as irrigation districts or associations. The Jordan Central Cooperative Union, which is not a government agency, borrows money from the Agricultural Credit Corporation and reloans it to farmer cooperatives for irrigation development.

The combined efforts of the agencies named above to improve irrigation in Jordan have been an important factor in the achievement of food production goals.

Note : This paper was prepared jointly by representatives of the institutions in Jordan concerned with irrigation development. It was presented by Usama Yacub Kakish, East Ghor Canal Authority.

The Central Water Authority upon request will furnish engineering services to the Agricultural Extension Department, the Research Department, the Cooperatives and the Agricultural Credit Corporation. The East Ghor Canal irrigation project has received assistance from the Ministry of Agriculture in farm development. There has been mutual benefit derived from the joint efforts of the Cooperatives, Ministry of Agriculture and the Agricultural Credit Corporation in the improvement of projects developed by the Central Water Authority.

The coordinated services in engineering, agriculture and credit have made available to farmers, the specialized skills of personnel in those agencies concerned with the development of irrigated agriculture in Jordan.

INTRODUCTION

Jordan is one of the Arab agricultural countries, traversed by small rivers and streams, whose waters are the life-blood of the people. The development of these waters for irrigation offers one of the best opportunities for Jordan to feed its own people as well as provide much needed exports to neighbouring countries.

The successful achievement of these goals requires development of all available water sources, conservation of water and soil, improvement in irrigation methods and farming practices and the education of the people in the proper use of land and water. The Government of Jordan has established agencies staffed with specialists in the field of Agriculture, engineering and agricultural credit who are working with cooperatives and other private enterprise to achieve these goals.

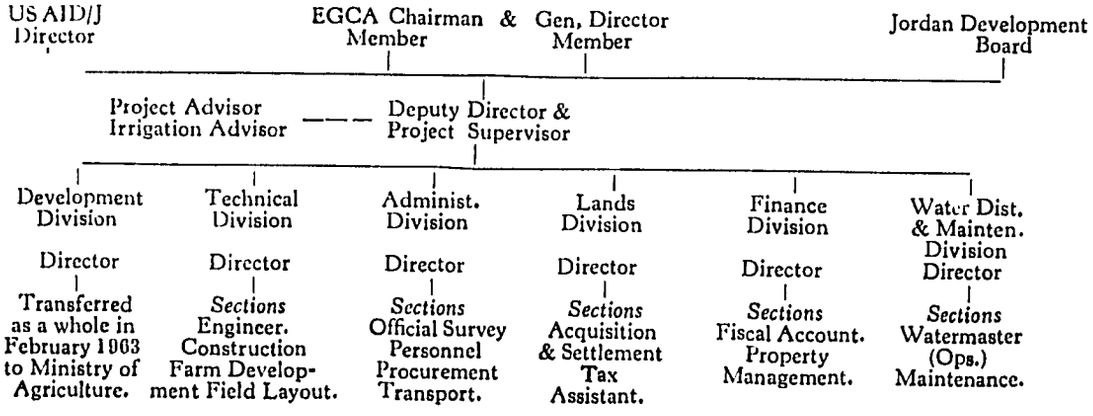
The Chief Government Agencies interested in some phase of irrigation are : The East Ghor Canal Authority, The Central Water Authority, The Ministry of Agriculture through The Agricultural Extension Service and The Research Department, The Agricultural Credit Corporation and the Ministry of Social Affairs through the Cooperatives.

This paper will show the organization of these agencies, their function and their cooperative efforts in supplying farmers and groups of farmers with the services that are needed to insure successful irrigation farming. This cooperation between agencies has meant conservation of personnel resources and has made talent available for all phases of irrigation development.

In order to see clearly the manner in which these agencies are cooperating, it is first necessary to present the internal organization of each agency and then describe the procedures established in their cooperative efforts.

EAST GHOR CANAL AUTHORITY

The law that created the East Ghor Canal Authority was passed in 1959 and construction of the project began soon after. The law was very broad in scope allowing for design and construction of the main canal and distribution system, as well as a land reform programme which made it possible to design and construct a system without regard to old land ownership patterns. The organization of the Authority is as follows.



The East Ghor Canal Authority was established solely for the development of one irrigation project. A summary of duties and method of operation will be described as follows :

Design and Construction

A detailed description of the project design has been presented in former seminars, and this will not be discussed in this paper. At this time this distribution system has been completed in the first two sections and it is anticipated that by the end of 1964 the first three sections will be completed with a distribution system to approximately 100,000 dunums.

Land Reform

Land reform with East Ghor Canal Authority has meant the expropriation of land and water rights, the reparcellation of land, and redistribution with a new pattern of ownership.

Evaluation and Expropriation of Land and Water Rights. Special committees have been established by law in which the farmers of the area are represented. They evaluate all lands within the project area with all permanent crops, structures and water rights. Prices of water will be discussed later in more detail. Evaluations are announced and land owners have the right to appeal if they are dissatisfied with prices. An Appeals' Committee in which the farmers of the area are also represented considers the appeals and may raise or lower the prices or refuse the appeal.

Reparcellation and Pricing of Land. The old parcellation of lands was abandoned and a parcellation adopted that will fit the new distribution system. The average farm unit is 30 dunums of class 1 or 2 land, or 50 dunums of class 3 land. Deviations from this are permissible for technical reasons. After the new parcellation is final and the distribution system is actually constructed the new farm unit boundaries are located in the field and mapped by the Lands and Survey Department ; the official government agency responsible for mapping all lands in the country. The new cadastral maps of units or parcels are superimposed on the old cadastrals of the abandoned parcellation and each new farm unit or parcel is planimetered for area in terms of the old parcellation i,e. each portion of an old parcel entering the new unit is measured for area. By referring to the evaluation sheets the price of the new unit or parcel is obtained by adding up the values of all the pieces of old parcels forming it. An additional amount of JD. 20 per dunum is added for water rights, regardless of the value of the water rights that belonged to the old parcels. Areas and prices of new parcels or units are calculated and the redistribution of land is the next step.

Distribution of Land. Special committees, called farmers' selection committees, distribute the new farm units to farmers according to the East Ghor Canal Law.

A maximum of 200 dunums is allowed for a land owner and a minimum of 30, thus large ownerships are broken ; and small land owners, whose ownership in many cases did not exceed a few dunums will get a minimum of 30 dunums. A balance is made between the capital worth of each farmer as obtained from evaluation sheets and the price of the new parcel or parcels he is to receive. The difference, debit or credit, is paid in annual installments. Thus the East Ghor Canal Authority is, theoretically, not taking any loss or making gains in prices of land. The Authority will pay for all rights of way for the distribution and drainage systems and roads, that are now government property.

Water Management

Operations and Maintenance Office. This office is the agency responsible for operating the project after construction is completed and farm units are handed over according to the new settlement plan. Hence the major responsibilities of this office are :

1. Operation, i.e. water distribution.
2. Maintenance of distribution system.

After a farmer receives a title for the new land he signs an agreement with the Water Office which agrees to furnish water for irrigation and in which the farmer agrees to abide by the general regulations of the office concerning measurement of water, erosion control, efficient use of water and maintenance precautions.

Organization. The Operations and Maintenance Office is headed by an Irrigation Specialist (M.Sc. in Irrigation). He has an aid a civil engineer for maintenance work and a general assistant and a water distribution master for each section of the project area, usually a B.Sc. in agriculture. The Water Distribution Master is helped by water masters who supervise and inspect the work of the ditch riders. Ditch riders control the water at the deliveries of the farm units. The water distribution master plans the water distribution in the lateral depending on the applications for water.

Method of Water Distribution. A combined rotational demand system is followed in water delivery. A farmer is allowed to receive water once a week for a 6-hour period, a 12-hour period, and 18 or 24-hour period depending on his requirements. He is free to skip his turn for any period of time. The farmer applies, through the ditch rider, for the amount of water he requires twenty-four hours before it is delivered to him, and states the length of time he needs it, i.e. 6, 12, 18 or 24 hours. The water distribution master calculates the gate gauge opening needed to supply the farmer with the amount of water required during the time interval stated in the application.

The ditch rider is instructed accordingly and water is delivered at the time requested. A farmer who is putting in new seedlings or is in need of water for newly seeded areas has the right to get water out of his weekly turn. This pattern differs from a strict rotation in the fact that the amount of water is at the request of the farmer and he can change his turn according to his demands.

Prices for Water. A basic charge of JD. 20 per dunum of irrigable land (classes 1, 2 and 3) was added to the price of each unit as a water right charge. Previously water right charges varied due to the fact that irrigated lands received water as water shares on a strict rotation system from perennial streams that varied in discharge among them and from year to year. Water shares, when priced by the evaluation committees, varied from JD. 7 to JD. 34 per share.

All lands are entitled to full intensive irrigation, the price is equalized throughout the project.

An operation and maintenance charge of 1 fils per cubic meter (1,000 fils = 1 JD. = 1 Sterling pound) is paid for the water used by farmers at the end of each month. The charge is raised to 2 fils per cubic meter when the water used by each dunum exceeds 1,500 cubic meters per year. This is done to encourage farmers to use water efficiently and reduce losses to a minimum. Most crops do not use more than 1,500 cubic meters per dunum per year except high water use crops such as bananas.

Problems

Two major problems face the Operations and Maintenance Office at present :

1. The difficulty of having the farmers accept the new semi-demand system. These farmers were accustomed to the rotation system where they never worried about time, quantities, payments, or anything of the sort. They did not have to apply for water 24 hours beforehand or pay a bill at the end of the month. With time they are learning and accepting the new system. They did not have any idea about quantities of water consumed ; all they knew was that their turn had come and when it was over, they never worried about how much water they received, whether it was adequate or not. Now they are learning and

can predict with a certain degree of accuracy how much water is needed per dunum for different crops.

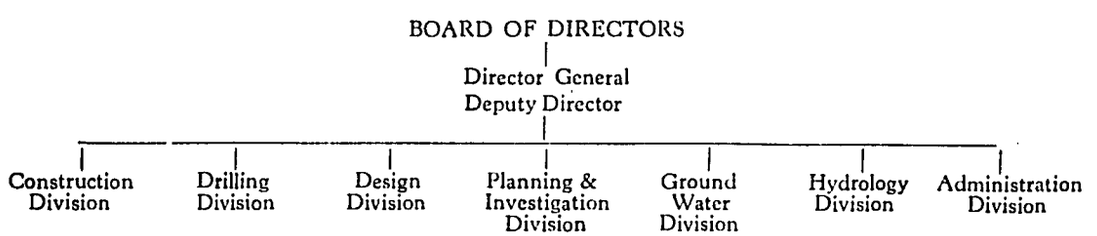
2. The rotation once-a-week rotation is not the most ideal for farmers. It would be much more ideal if a farmer could get water any time he needs it. But on the other hand it would be too costly and very difficult to have a strict demand system, because it involves more ditch riders jumping from one place to the other. In addition it will be very difficult for the water distribution master to determine each day how much water to divert from the main canal into each lateral, consequently it would be very difficult to control the level of water in the main canal along a 70 kms. stretch with a number of check structures and gates and spillways.

CENTRAL WATER AUTHORITY

The Central Water Authority was established in 1960, as "The Law for the Organization of Water Affairs". The Authority was established for the purpose of investigating, planning, promoting, implementing, constructing ; and to the extent necessary, managing and operating a comprehnsive programme for development and control of the water resources of the Kingdom of Jordan ; to determine maximum feasibility for domestic, municipal, livestock, industrial, irrigation, hydro-electric power and other beneficial purposes. The area of the East Ghor Canal Authority is excluded.

The Central Water Authority is an autonomous Authority headed by a Director General responsible to a Board of Directors. The Board of Directors is composed of the Prime Minister, who is the President of the Board, the Minister of Health, the Minister of Agriculture, the Minister of Interior, the Vice-President of the development Board and the Director General. As an autonomous Authority it has its own basic procurement, contracting, financial and personnel regulations patterned after the usual government regulations, although somewhat streamlined for efficient application. Its basic financing comes from the Government budget and works within the requirements of government budget procedure.

ORGANIZATION OF CENTRAL WATER AUTHORITY



The scope of work for each division is covered by an organization within the division. The summary of the duties relative to irrigation development are as follows :

Planning and Investigation

To make preliminary investigations and prepare plans and submit preliminary reports with estimates on projects submitted by agencies such as Ministries, Agricultural Loan Agency, Agricultural Extension Service, Cooperative Societies, Desert Command as well as CWA work.

Design Division

To produce designs, drawings and specifications for the various water resource engineering works. These works vary in size and kinds and are constructed by the different agencies. Designs are carried out for irrigation schemes, spring development, storage projects, small domestic schemes and desert

projects to be accomplished by the Authority itself.

Construction Division

The division is responsible for all the construction activities that are carried out by the Authority. This division has also constructed irrigation projects for the Cooperative Union and pilot projects in cooperation with the Ministry of Agriculture.

Drilling Division

The division drills wells, and installs pumps that are the responsibility of CWA. It also operates a service rig that services wells and pumps for other government agencies and quasi-government agencies.

Ground Water Division

The purpose of the Ground Water Division is to conduct geological studies, mapping and investigations to the end that the maximum ground water of the Kingdom will become available for use.

Hydrology Division

Knowledge of surface water, its intensity, and frequency of flow, its availability and quantity is necessary in order to fully develop irrigation in Jordan. This division gathers hydrological information and by proper analysis can closely estimate river, stream, dry wadi and spring flow for the purpose of planning and designing irrigation systems.

Services of the Central Water Authority

The Central Water Authority renders a variety of engineering services in the development of water for agricultural, domestic, industrial and municipal purposes. The development of water for agricultural purposes is of major importance, and, for the purposes of this paper, only those services rendered in the development of irrigation will be discussed.

A large number of small irrigation projects have been developed in which the Authority did all planning, investigation, design and construction of the water distribution system. Those projects completed within the past two years have been listed in the country report.

One of the chief functions of the authority has been to cooperate with other agencies in the development of irrigation. The Ministry of Agriculture, the Cooperative Union and the Agricultural Credit Corporation have had interests in the development of irrigated agriculture, but have not had the technical staff available for the engineering services necessary in proper development of irrigation. Agreements have been entered into between these agencies and Central Water Authority in which Central Water Authority agrees to make preliminary investigations, provide cost estimates, furnish preliminary design of the system and in some cases construct the distribution system.

The Cooperative Union provides money for organized cooperatives and the Agricultural Credit Corporation for individual farmers.

Application for irrigation loans are received by the lending organization and referred to the Central Water Authority planning division. The planning division then sends an Irrigation Engineer to the proposed project who makes the necessary surveys to determine feasibility (engineering) and prepared a cost estimate for the project. The plans and estimates are then returned to the lending agency. The lending agency makes determinations as to the economic feasibility of the project. If the loan is made, the Central Water Authority may again be called into the picture to assist in the preparation of plans, or in some cases they may be called upon to completely construct the irrigation system.

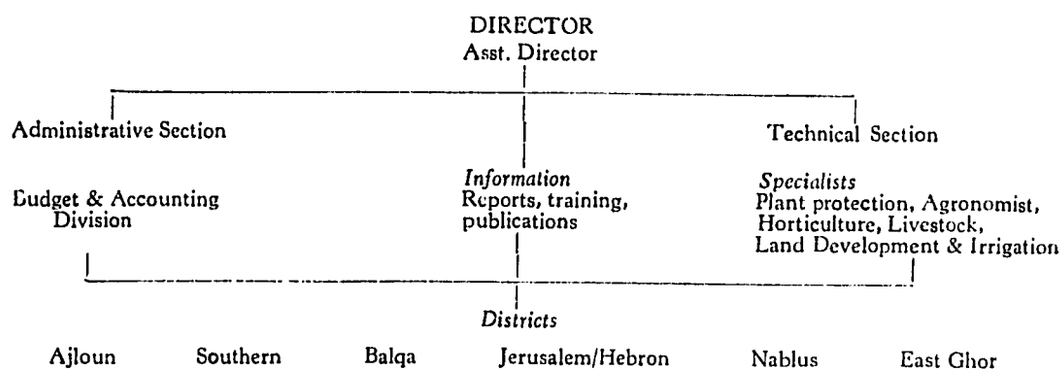
Cooperation with the Ministry of Agriculture through the Extension Department and the Research Department is of another type. In this case Central Water Authority asks for the cooperation of the Ministry in the development of the agricultural aspects of a project. The construction of flood control systems in the Desert has been carried on for

several years. Several dams and water spreading systems have been constructed in the desert; Qatrana and Sultana Dams, the Halibat spreader system in which the Agricultural Extension Service has established trial plots for utilization of the flood water for irrigation. The Research Department under the Ministry of Agriculture is conducting research projects in the desert and utilizing water from wells that have been drilled by Central Water Authority. The complicated problems of saline soils and drainage are receiving attention in a cooperative effort between the Central Water Authority and Department of Research at Jafer on a 45 dunum experimental plot where water is furnished from a well drilled by Central Water Authority.

MINISTRY OF AGRICULTURE THROUGH AGRICULTURAL EXTENSION DEPARTMENT AND DEPARTMENT OF RESEARCH

The Agricultural Extension Department has been organized in Jordan for more than 10 years. The entire country of Jordan is organized under the Extension Department by districts and supplies many services to farmers. Within the past year a special division has been established within the Department known as "Land Development and Irrigation". This division functions in all of Jordan and some of its activities have been described in its cooperation with Central Water Authority. The major activity of the division has been in the East Ghor District where the East Ghor Canal Authority has turned the land development responsibility to the Extension Department.

AGRICULTURAL EXTENSION DEPARTMENT



Most districts have, in addition to Extension Agents, specialists in Plant Protection, Agronomy, Horticulture, Livestock, (Land Development and Irrigation in East Ghor).

Agricultural Extension in the East Ghor Irrigation Project

The East Ghor Irrigation Project has been established as an Agricultural Extension District in order to facilities extension work in an area of similar agricultural problems. The services to farmers in the irrigated area cover those required in any irrigated farming area. In addition to the regular services, special emphasis has been placed on Land Development and improvement of irrigation methods and practices. Any farmer may make application to the Extension Department for the services of Technicians who will help him plan and construct an irrigation system on his farm. This service agricultural specialists, engineers, surveyors and farm planners who will go to the farm with the farmer and make topography maps, land use maps and design an irrigation system that is best suited to his needs.

The farmer must pay his own costs in the

construction of a system but the services of the extension technicians are furnished by the Government with no charges to the farmer.

An important factor in the operation of the Land Development and Irrigation Division has been its cooperation with other agencies interested in irrigation development. Farm credit is essential to farmers who are developing new farm units. Credit may be obtained from the Agricultural Credit Corporation or through the Cooperatives. In order to assist and encourage the farmers in the development of their new farms, an Incentive Payment Plan was established where by a farmer can receive from the Cooperative Union 50 per cent, but not more than JD. 100 ($280) for the following operations in the development of his farm.

1. Land levelling and construction of an irrigation system.
2. Farm ditch construction.
3. Drainage ditches and structures,
4. Forage crop seedlings.

Money for this Incentive Payment Plan has been provided jointly through U.S.A.I.D. and the Jordanian Government and is administered by the Cooperative Union. Approximately 750 farm units (22,500 dunums) will benefit from this plan.

The following description of the Incentive Payment Plan will provide information on the Cooperative efforts of the agencies interested in improved irrigation practices.

The Incentive Payment Plan

To receive the incentive payment, a farmer must be a member of a cooperative. The farmer makes application through his cooperative. The cooperative certifies to the eligibility of the applicant and forwards the application to the Agricultural Extension Department. The extension staff then visit the farm with the farmer and develop plans for the farm unit, and submit to the cooperatives an estimated cost of the development. The farmer then deposits with the cooperatives one half the estimated costs of development (up to JD. 100) which is matched with an equal fund from the Incentive Payment Plan (up to JD. 100).

The Agricultural Extension Staff in the Incentive Payment Plan consists of the following technicians :

1. The Agricultural Extension Supervisor : Head of the office and works as a Land Development Specialist ;
2. The Surveyors : There are three crews of surveyors. They prepare the preliminary survey, stake the land for levelling, head ditches, irrigation and drainage structures. They check also the completed work and train the extension agents to handle simple survey instruments and read maps ;
3. The Draftsman : Prepares all the needed plans ;
4. Land Levelling Supervisors : Supervise the earth moving equipment and labourers. They submit reports to the Agricultural Extension Supervisor on hours worked by equipment and labourers and the quantity of materials used in the work.

The Extension Department has some equipment for land development which will be rented to the farmers for a nominal fee. This equipment is not adequate to meet the demand. Some farmers will employ contractors to do the work. The cooperatives expect to rent some equipment to the farmers and to take care of it in their workshop in Wadi Yabes. The Agricultural Extension Department supplies the technical supervision for operating this equipment :

Incentive Payment Administration

1. **Responsibilities of the Cooperatives.**
   a. Inform the farmers of procedures to be followed and the benefits to be obtained from this plan.
   b. Accept applications from the farmers.

c. Forward the applications to the Agricultural Extension Office.

d. Accept the final records from the Agricultural Extension Supervisor. These records show the total cost of the work completed, and the cooperatives make payment to the farmers.

2. **Responsibilities of the Agricultural Extension Office.**

a. Receive the applications from the cooperatives.

b. Plan and estimate the cost of all the development and water conservation work.

c. Meet with the farmer and the U.S.A.I.D. technician in the farm unit to discuss all the work.

d. Inspect, supervise and approve of all work.

e. Prepare the final records for the work completed, and forward them to the cooperatives.

3. **Responsibilities of the U.S.A I.D./J. Technician.**

a. Review plans, specifications, and cost estimates with the Agricultural Extension Supervisor.

b. Meet with the Agricultural Extension Supervisor and the farmer in the farm unit to discuss all the work.

c. Supervise and approve the completed work.

4. **Responsibilities of the farmer.**

a. The farmer must be a member of the cooperatives.

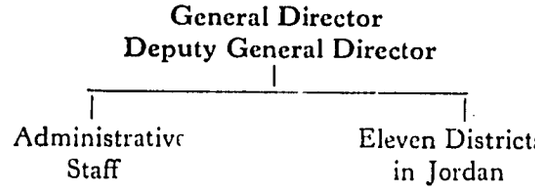
b. He must agree upon all the work which will be done in his farm.

c. He must pay his share from the cost estimates to the cooperatives before the work starts.

AGRICULTURAL CREDIT CORPORATION

The Agricultural Credit Corporation was established as a legal entity with an independent financial status in 1959. It is headed by a General Director responsible to a board of directors consisting of representatives of Ministries of Agriculture and Finance, the Jordan Development Board and five non-government members appointed on a rotating basis.

ORGANIZATION OF AGRICULTURAL CREDIT CORPORATION



The main objective of the Corporation is to provide credit to farmers. The farmers are given advice and personal service by members of the technical staff. Loans issued by the ACC are strictly supervised to insure most efficient use of loan funds. Medium and Long Term Loans are made available to farmers for land reclamation, planting trees, livestock, machinery, farm buildings and irrigation. Loans for irrigated farming operations include pumps, motors, pipes, canal lining and land development.

AN ANALYSIS OF FUNCTIONAL SERVICES IN WATER RESOURCE DEVELOPMENT FOR IRRIGATION

by

A. W. Plummer*

SUMMARY

Water and soil development programmes are constantly changing both as to magnitude and character. Each nation is faced with the problems of maintaining or acquiring the technical services required to implement its development programmes to good technical and economic standards on schedule.

This paper outlines the types of specialized functions required for soil and water resource development along with others required for total rural development. It points out that technicians must be specialized in order to keep up with the fast rate of technical discovery, but the degree to which an organization can afford to specialize depends upon the size and kind of work load it has.

The writer concludes that for a country to develop its own technical capabilities rapidly, it must have specialized technicians, but when doing so it must also develop the organizational structures and managerial abilities to keep the work flowing smoothly between the various specialists involved. Without developing good managers, administration, and organization, the degree of specialization will have to be limited and more required specialists will have to be imported from foreign countries. Since each developing country is interested in developing better jobs and living conditions for its people, it is time for each country to develop its technical managerial ability to more fully utilize the latent potential of its own people in developing their own country. The engineers of each country must rise to the challenge of providing modernized technical management or bow to the orders of non-technical managers or foreign technical managers.

INTRODUCTION

One of the major problems of developing countries today is how to best make the transition from the individualized **one-at-a-time** handicraft approach, to the more efficient energized mass production approach necessary to meet the expanding needs and aspirations of the common people. Most of us have no problem visualizing these two different approaches as they apply to making wagons one at a time in a rural town or making 1000 automobiles per day in a modern factory. However, we have very much difficulty in visualizing the way in which to mass produce the technical services and the scientific control required to move water resource development at the speed needed to meet the expanding aspirations of a nation.

The production control engineer at the Chevrolet car assembly plant states that the quality of the cars coming off the assembly line is higher when producing 60 cars per hour than when producing fewer. This is because each man is required to do fewer different jobs when the assembly line is running at full capacity. Also each man can be more quickly trained to do his job. By organizing the car assembly line into many simple jobs, inexperienced workers with proper apptitudes can be trained to do these simple jobs in only a few days right on the job under experienced supervision. Converting to

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assembly line, mass production methods reduces the range of skills required by the common factory worker, but increases the need for rigid timely discipline of the worker so that he performs his simple task dependably and repetitiously on time all day long to the prescribed standard. Creating the required conscientious personal discipline is likely to be more difficult than mastering the job techniques. It requires clear definition of job requirements and rigid supervision with authority and power to enforce proper work performance. Whereas the mass.production system reduces the range of skills required of the common worker, it greatly increases and complicates the job of organizing, coordinating managing and trouble shooting to keep the jobs moving ahead efficiently.

In this paper the author outlines ideas of the processes by which countries might evolve from the inefficient **one-at-a-time, do-it-all yourself** approach into the organized mass production approach for efficient water resource development with special reference to irrigation development. Each country is in a different stage of development and has different requirements as to the type and quantity of water resource development it can finance or implement. We can best deal with the problem by first briefly identifying and grouping the most prominent functions involved in rural development and then more specifically consider the functions involved in water resource and irrigation development.

RURAL FUNCTIONS

The development of a rural area involves many functions which are all interrelated to some extent. The extent to which the multitude to functions can be grouped together in order to decentralize the administration is dependent on the types of professional personnel involved, the magnitude of the activities, the degree to which one group may be given a job to perform with the minimum need to receive service from another group, and the geographical distribution of the work. Considering these factors the principal groups of functions shown in Table No. 1 in more detail are :

1. Rural public works
2. Agricultural Production
3. Forestry
4. Commercial activities
5. Financial activities
6. Community activities
7. Civil administration
8. Courts and justice
9. Cross-functional planning
10. Special organizations

The job of water resource development is primarily within the function of rural public works, but is closely related to the other rural functions especially agriculture.

SOIL AND WATER DEVELOPMENT ORGANIZATIONS

Need for specialization. The development of the soil and water resources of a country is the primary concern of this seminar. Today the concepts of comprehensive planning for the most economical development and coordination of integrated development are generally accepted, whereas 10 to 20 years ago the single purpose project was receiving most of the attention. In recent years engineers are turning away from building only conventional type irrigation systems depending entirely on natural river flow, masonry structures, and ancient farm irrigation methods without adequate drainage systems or attention to adequate transportation and marketing facilities. Today engineers are involved in multipurpose storage projects, economically sized and staged irrigation projects with adequate drainage. They are looking forward to properly integrating modern farm irrigation system into comprehensive regional development projects aimed at raising the living standards of people rather than just growing crops.

The change is like going from the wagon to the automobile. It is occurring in the countries in this part of the world at a time when they are trying to catch up in 10 years

TABLE 1. PARTIAL GROUPIN

	RURAL PUBLIC WORKS	AGRICULTURAL PRODUCTION	FORESTRY	COMMERCIAL ACTIVITIES	FINANCIAL ACTIVITIES
NATIONAL LEVEL *****	PLANNING Hydrology Economics Soils Power Geology Topography Drafting Planning DESIGN Dams Irrigation system Mechanical, Electric General civil CONSTRUCTION Contract Adm. Specifications Costs estimates Inspection ENGINEERING LABS. Concrete Soil mechanics Materials Hydraulic MACHINERY Well drilling Portable Repair shops OPERATIONS & MAINT. Operations Maintenance Proj. Evaluation Water user lieson WATER RIGHTS Investigation New rights Water masters SOIL & WATER USE Farm development Irrigation pract. Conservation ADMINISTRATION Personnel Records & Comm. Training Travel O & Methods FINANCE Statistics Accounting Budget PROGRAM	FIELD CROPS Wheat & barley Sugar beets Cotton Melons Vegetables Oil crops FORAGE CROPS Alfalfa Clover Grasses ORCHARD & VINES Citrus Dates Olives (Apples & pears, Pommegrenade) Stone fruit Grapes LIVESTOCK Veterinary Sheep & goats Beef cattle Dairy cattle (Horse, donkeys, camels) FARM MACHINERY Evaluation Operation Repair PEST CONTROL Virus Insects Migratory insects PLANNING Statistics Economics Reports RESEARCH & TRAINING Soil fertility Agronomy Livestock Horticulture Machinery Pest control Training Farm operation FINANCE ADMINISTRATION PROGRAM	MANAGEMENT Surveys Plans ENGINEERING Roads Logging REFORESTATION RANGE MANAGEMENT EXPLOITATION & USE Lumber Plywood Pulpwood Fiber board Containers PROTECTION Fire Insects Diseases RESEARCH FINANCE ADMINISTRATION PROGRAM	PRODUCTION COMMODITIES Tools Machinery Fertilizer Seed Insecticides Packing materials Misc. COTTAGE INDUSTRIES TRANSPORTATION MARKETING PROCESSING Cotton Sugar Rice Wheat Dates Canneries Dried fruits	FARMER CREDIT LAND REFORM COMMERCIAL LOANS Commodity productio Marketing Processing Cottage Industry
OSTAN LEVEL *****	REGIONAL DIRECTORS PLANNING DESIGN & CONSTR. Design Construction Labs. Machinery WATER USE O & Maintenance Soil & water use Water rights ADMINISTRATION Personnel Records Finance	PROVINCIAL DIRECTORS FIELD & FORAGE CROPS ORCHARD & VINES LIVESTOCK FARM MACHINERY PEST CONTROL PLANNING RESEARCH & TRAINING ADMINISTRATION	REGIONAL DIRECTORS FOREST MANAGEMENT COMMERCIAL OPERATIONS PROTECTION Law enforcement Fire Disease & pests REFORESTATION RANGE MANAGEMENT ADMINISTRATION	PROVINCIAL DIRECTORS PRODUCTION COMMODITIES MARKETING PROCESSING	
DISTRICT LEVEL *****	DISTRICT ENGINEERS OFFICE ENGINEERING FIELD ENGINEERING MECHANICAL ADMINISTRATIVE	DISTRICT DIRECTORS CROPS LIVESTOCK AGR. ENGINEERING	DISTRICT FORESTER MANAGEMENT PROTECTION REFORESTATION ADMINISTRATION		
GOVERNMENT					
LOCAL PEOPLE District Local Technician (Technical) (Supervision)	DISTRICTS TECHNICIANS LEVEL & DIST. TECH. CONCRETE & MASONARY CARPENTER EARTHWORK WATER USE	DISTRICT TECHNICIANS ANIMALS FIELD CORPS ORCHARDS MECHANIC FERTILIZER PEST CONTROL		DISTRICT TECHNICIANS PRODUCTION COMMODITIES MARKETING PROCESSING	
Area Local Technician (Consolidation) (of Problems) (& Programing)	AREA LOCAL TECHNICIANS	AREA LOCAL TECHNICIANS		AREA LOCAL TECHNICIANS	
Volunteer Village Assistants (PROBLEMS)	VILLAGE ASSISTANTS	VILLAGE ASSISTANTS		VILLAGE ASSISTANTS	

)F RURAL FUNCTIONS

COMMUNITY ACTIVITIES	CIVIL ADMINISTRATION	JUSTICE	PROGRAM PLANNING	SPECIAL ORGANIZATIONS
EDUCATION	ELECTIONS		CROSS FUNCTIONAL PLANNING	COOPERATIVES
PUBLIC HEALTH	LAWS & REGULATIONS		PROGRAM FORMULATION	BUSINESS SOCIETIES
HOME ECONOMY			PROGRAM PROGRESS	LABOR UNIONS
YOUTH ACTIVITIES	LEGAL RECORDS		GOVERNMENT FINANCE	PROFESSIONAL SOCIETIES
SOCIAL AFFAIRS	Of people			USER ASSOCIATIONS
	Contracts			RELIEF ORGANIZATIONS
	Landownership			
	TAX COLLECTION			
	LAW ENFORCEMENT			
	EMPLOYMENT SERVICE			

PROVINCIAL DIRECTORS	PROVINCIAL GOVERNORS
EDUCATION	RURAL AFFAIRS
HEALTH	(URBAN AFFAIRS)
SOCIAL AFFAIRS	LAWS & REGULATIONS
	LEGAL RECORDS
	TAX COLLECTION
	LAW ENFORCEMENT
	EMPLOYMENT

DISTRICT DIRECTS	DISTRICT CHIEF
EDUCATION	
HEALTH	
SOCIAL AFFAIRS	

DISTRICT TECH.	DISTRICT
SANITARIANS	
MEDICAL TECH.	
SOCIAL WORKERS	
HOME ECO. TECH.	

(DAYARS)	AREA COUNCIL
(School Teachers)	VILLAGE COUCIL

with what the western countries learned in 50 years and at a time when the world is doubling its scientific knowledge every 15 years. The pace of discovery of new knowledge and techniques is exploding into the computer age. Each country is in a dynamic race with the rising level of expectation of its people and their rapidly expanding wants. Whether we like it or not we are being forced to handle more complicated problems at the same time as we are being forced to turn out more and better quality of soil and water development work. As the wagon gave way to the automobile, the generalist one-at-a-time craftsman is giving way to the specialist. The only way the countries in this part of the world can hope to catch up quickly with the technical competence of the more developed countries is to develope specialized engineers and coordinate their knowledge and efforts with good management and administration.

Degree of specialization. Just as the degree of specialization in the automobile factory depends on the rate of production, so does the degree of specialization in the technical offices working on water resource development. Therefore, each organization and each office in that organization must be designed for the job to be done in much the same way that each factory must be designed for its peculiar set of conditions and requirements. There is no simple formula for this. It is a job for managerial judgement guided by certain scientific management principles.

As a help in thinking of the degree of specialization and types of offices best suited to carrying out development work, Table No. 2 has been constructed to illustrate a likely growth in work load, staff and types of offices from the single job situation to the large complicated highly specialized national organization. Although this chart, naturally, does not fit any country exactly, I invite you to see how closely your own country situation compares with some column of it. The per cent cost of engineering and administration is shown as rising from 10 per cent to 25 per cent instead of going down with increasing work load. However, this in actual practice will be compensated for by better quality of planning, design, construction, and operation. Generally a greater degree of public service and understanding will be rendered and as the national development expends the development projects will likely require more study and be more complicated. Another major reason for increasing the per cent for engineering is that for a single job the planning and construction do not occur at the same time whereas in a large organization the planning, design, construction, and operation and maintenance of different projects in different stages of development occur simultaneously.

The main purpose of Table 2 is to illustrate the problem of balancing the staff with the number and kinds of jobs and the high volume of work required to support the formation of strong regional and district offices in addition to a specialized central headquarters staff. Roughly speaking the annual development budget needs to be around 10 million dollars per year to support a highly specialized staff and still be able to staff the field offices as required for data collection and construction. In order to justify regionalization, the development budget would likely have to be around 20 million dollars per year, and to support weak district offices between the regional and job offices, the development budget would likely have to be over 40 million dollars per year spread over many small widely scattered projects having poor transport and message communications availability. Technical literature is very devoid of the kind of figures presented in Table 2 and the figures will vary greatly according to each country's situation. However, there is a need for greater exchange of information between countries concerning the management and administrative problems inherent in managing a large water resource development programme. For this reason the writer believes that it would be helpful if each country represented here could prepare and present to the secretariat of this seminar an organization chart of the organization in their country

TABLE 2. APPROXIMATE STAFF AND TYPE OF OFFICES FOR DIFFERENT MAGNITUDE OF NATIONAL WATER RESOURCE DEVELOPMENT PROGRAMMES

Type of Office		Situation Number								
		1	2	3	4	5	6	7	8	9
	Number of jobs, large	1	—	—	1	2	4	8	16	24
	Number of jobs, medium	—	—	3	5	10	20	40	80	120
	Number of jobs, small	—	10	20	30	60	120	240	480	720
	Number of dollars in million/year	3	2	5	11	22	44	88	200	300
National Headquarters	Number of technicians, local	5	20	90	210	600	800	1000	1500	1800
	Number of technicians, foreign		3	6	10	12	15	15	5	5
Regional	Number of technicians, local					200	400	1200	3000	4000
	(Number of offices)					(4)	(6)	(6)	(8)	(8)
District	Number of technicians, local						500	1300	2500	3500
	(Number of offices)						(25)	(40)	(50)	(50)
Job	Number of technicians, local	25	30	70	150	500	1050	3500	6000	7000
	Number of technicians, foreign	10	0		8	12	18	25	40	15
Total	Number of technicians, local	30	50	160	360	1300	2750	7000	13000	16300
	Number of technicians, foreign	10	3	6	18	24	33	40	45	20
Per cent engineering and administration		10	15	15	15	20	20	25	25	25

along with the numbers of foreign technicians, and the number of national professional, technical aids, and others ; along with a summary of each country's budget and programme and the portions developed and supervised by local or foreign consulting firms.

Evolution of organization

The theme of this paper is analysis of the functional services required in water resource development. Enumeration of the functions is a matter of degree. One could say to you as an individual that your job was to "develop the water resources" and tell you to get busy all by yourself. In the beginning of water development this was the case and the farmer within his own resources and concepts had the job to do. The other extreme is to specialize somewhat more than our largest United States organizations have. To go from the simplest of organizations to the highly specialized is a problem of national evolution and concepts obtained in jumps rather than in a perfectly smooth rising line. The problem is one of how much to subdivide the functions according to the size of programme, capabilities of personal, and location of the work. To help visualize this evolution, Table No. 3 has

TABLE 3. ORGANIZATION OPERATION

LOCAL SELF SUFFICIENCY

1. FARMER
   USING
   RAINFALL

2. FARMER
   USING
   IRRIGATION

3. FARMER
   LOCAL TECHNICIAN

ENGINEERING TEAM OPERATION

4. FARMERS
   LOCAL TECHNICIAN
   AGRICULTURAL ENGINEER

5. FARMERS
   TECHNICIAN
   CIVIL ENGINEER
   AGRICULTURAL ENGINEER

6. TEAM CHIEF
   - TOPOGRAPHER
   - SOIL SPECIALIST
   - CIVIL ENGINEER
   - CONSTRUCTION ENGINEER
   - CONSTRUCTION FOREMAN
   - MECHANIC

7. TEAM CHIEF
   - TOPOGRAPHER
   - DRAFTSMAN
   - SOIL SPECIALIST
   - AGRICULTURAL ECONOMIST
   - ENGINEERING GEOLOGIST
   - HYDROGEOLOGIST
   - HYDROLOGIST
   - DESIGN ENGINEER
   - CONSTRUCTION ENGINEER
   - CONSTRUCTION INSPECTOR
   - MECHANIC
   - IRRIGATION SPECIALIST
   - TECHNICIANS
   - ELECTRICAL ENGINEER
   - WELL DRILLER
   - CLERK
   - SECRETARY

FUNCTIONAL OPERATION

8. MANAGER
   PLANNING

9. MANAGEMENT
   - PLANNING
     - TOPOGRAPHY
     - HYDROLOGY
     - SOILS
     - AGRICULTURE & ECONOMICS
     - GEOLOGY
     - PLANNING AND PRELIM. DESIGN

DESIGN & CONSTRUCTION

DESIGN
- DAMS
- IRRIGATION SYSTEMS
- MECHANICAL & ELECTRIC
- GENERAL CIVIL

CONSTRUCTION
- CONTRACT SUPERVISION
- SPECIFICATIONS
- COST ESTIMATES
- INSPECTION

HEADQUARTERS STAFF

10. TOP MANAGEMENT
    - PLANNING
      - TOPOGRAPHY
        - Aireal mapping
        - Precise surveying
        - Toporaphy
        - Office computation and records
      - HYDROLOGY
        - Hydrography
        - Groundwater data
        - Analysis
          - Flood studies
          - Water supply
      - SOILS
        - Soil surveys & classification
        - Drainage investigations
        - Salinity & special studies
        - Laboratory
          - Soil tests
          - Water quality
      - AGRICULTURE & ECONOMICS
        - Agriculture economics
        - Project economics
      - ENGINEERING GEOLOGY
        - General geology and minerals
        - Detail mapping
        - Planning
          - Preliminary design
          - Report writting
          - Report publication
      - POWER STUDIES
      - SMALL PROJECTS
    - DESIGN
      - STORAGE DAMS
        - Earth & rock
        - Concrete
        - Spillways & outlet works
      - DIVERSION DAMS
      - CANAL & DRAINAGE SYSTEMS
        - Layout and functional design
        - Canal structures
      - STRUCTURES
        - Tunnels & conduits
        - Buildings & powerhouse
        - Architectural
        - Bridges
      - MECHANICAL
        - Gates and valves
        - Piping systems
        - Hydraulic machinery
        - Stationary equipment
      - ELECTRICAL
        - Generators and motors
        - Instruments and equipment
        - High voltage transmission
        - Low voltage systems
      - GENERAL CIVIL
        - Roads and camps
        - Water & sewage systems
      - RIGHT OF WAY
    - CONSTRUCTION
      - CONTRACT SUPERVISION
      - SPECIFICATIONS
      - COST ESTIMATES
      - INSPECTION
      - SAFETY

10. SPECIAL OFFICE
    - PLANNING
    - DESIGN & CONSTRUCTION
    - OPERATION & MAINTENANCE
    - ADMINISTRATION
    - FINANCE

FIELD OFFICE
- FIELD ENGINEERING
- OFFICE ENGINEERING
- ADMINISTRATION

	MACHINERY OPERATIONS REPAIRS	MACHINERY SUPPLY & SPARE PARTS MOTOR POOL CONSTRUCTION EQUIPMENT OPERATIONS WELL DRILLING OPERATIONS SHOPS & REPAIRS
	ENGINEERING LABS	ENGINEERING LABS SOIL MECHANICS CONCRETE MATERIALS HYDRAULIC
OPERATION & MAINTENANCE	OPERATION & MAINTENANCE OPERATIONS MAINTENANCE PROJECT EVALUATION & STATISTICS	OPERATION & MAINTENANCE OPERATIONS River control River diversions Power operations Flood control Irrigation system operation Recreation, tours & guards MAINTENANCE Dams & major structures Canals & drains Stationary equipment Weed control PROJECT EVALUATION & STATISTICS Inspections & evaluations Water rates and contracts Statistics & publications
	SOIL AND WATER USE LAND USE PLANNING AND DEVELOPMENT IRRIGATION PRACTICES SOIL AND MOISTURE CONSERVATION	SOIL & WATER USE LAND USE PLANNING & DEVELOPMENT Plan & design Construction IRRIGATION PRACTICES SOIL CONSERVATION Crop adaptability Plan & design Construction TOPOGRAPHY TRAINING
	WATER RIGHTS INVESTIGATIONS RECORDS & PERMITS WATER MASTER SERVICE	
ADMINISTRATION	ADMINISTRATION COMMUNICATIONS & RECORDS PERSONNEL & TRAINING TRANSPORTATION SUPPLY LEGAL DRAFTING & MAP FILES	ADMINISTRATION COMMUNICATIONS & RECORDS PERSONNEL Recruitment Position classification Salary & allowances TRAINING Technical library Translators In service training Foreign training TRANSPORTATION Travel orders Rates & schedules SUPPLY Expendable office supplies Office equipment PROPERTY STORES AND CONTROL LEGAL CENTRAL DRAFTING & MAP FILES
	FINANCE ACCOUNTING BUDGET CONTROL	FINANCE ACCOUNTING AUDITING BUDGET CONTROL
	PROGRAM	PROGRAM
	JOB OFFICES FIELD ENGINEERING OFFICE ENGINEERING ADMINISTRATION	

been prepared to illustrate the possible stages. In the first stage there is only the all purpose farmer relying only on himself for his subsistence. At the other extreme is the highly specialized large organization with its central staff of top specialists and its line of regional, district, and job offices with generally less specialization, but each designed to meet the special development conditions which are constantly changing. The rate of change in required offices and staffing changes so rapidly that good management of a large engineering and development organization is one of the most difficult jobs in the world and really a job for the expert manager well versed in this special kind of work.

The stages of the organizational evolution could be considered as follows : Stages I thru 3-Local self sufficiency ; Stages 4 thru 7-Technical team operation ; Stages 8 and 9-Functional operation ; and Stage 10-Organizational operation. The need to move from one to the other is primarily dictated by the management requirements of limiting the span of direct control of directors and supervisors to between 6 and 15 employees and to divide the work in such a way that responsibility for a specific major finished product can be definitely placed on one man. With this in mind along with the fact that one man is only able to keep up with modern practices in a limited specialty, the water resource functions are listed on Table No. 3 by function and specialties. The size and type of development programme and the competence of the staff will dictate which column of the chart is most adaptable to the needs of each country. There is no simple formula for the design of an engineering organization any more than there is for the design of a water project. Each organization must meet the special conditions encountered, but the listing of possible functional units of an organization may prove helpful. The problems of water resource management are just as real and important as the technical formulas.

Staff flexibility.—

As the work loads shift the manager should attempt to maintain the functional stability of his top specialists in each subject while permitting mobility and flexibility in shifting the less specialized personnel from unit to unit as required to keep the production of the organization moving briskly in accordance with programmed priorities and deadlines. Therefore, no attempt has been made herein to state the number of staff required for each organizational unit. A director should recognize that he can never have a top rate specialist in any one specialty if he keeps moving him out of that specialty for prolonged periods of time or permits the top specialist to lose out salary wise to the administrative generalist, or doesn't require the specialist to keep up with the fast evolving foreign and local literature within his field of specialty.

Within the terminology of the functions listed there is room for much difference of interpretation of organizational responsibility and the director and his assistants must conceive clearly the lines of division of responsibilities and authority and enforce them. There will be special cases primarily caused by logistical problems which will call for special short term doubling up of responsibilities, but all concerned should recognize these as exceptions and they should be held to an absolute minimum or the lines of responsibility will become so mixed that the responsible employees will lose interest in exerting their initiative to properly handle their stated responsibilities.

The writer wishes to make it clear that the job of the government agencies is to provide service to the producing farmers and other people. All the organization we have been discussing is useless if it does not add to the productive capacity of the nation.

In following the evolution of a water resource organization we started with the self sufficient farmer, and then followed with teams of technical generalists. We should understand that as the technical organizations develop, they are added on to the existing base of society and constitute an added overhead

that must be sustained by increased production. The millions of individual farmers still remain the real basic producers and the general technicians still have large roles to play in the scheme of society. Since the farmer is the real producer of basic commodities, let us now go back and see what his functions are in modern irrigated agriculture and how the government technical organizations can assist him sufficiently to justify the existence of government organizations.

THE FARMER—THE WORKING PRODUCTION MANAGER

In considering the structure of a nation as related to irrigated farming, we have considered the need for a few specialists in each subject to develop or bring to the nation specialized modern knowledge. We have recognized the need for many more generalists as we difuse organizationally toward serving the farmer. Now let us look at the farmer and his problems and needs. The farmer has to integrate and apply the available knowledge and abilities as best he can toward raising his productivity. If the farmer does not apply modern agricultural knowledge, it brings no useful result.

The following tabulation lists the different operations or functions that a farmer is confronted with and which outside segments of society are likely to be concerned with assisting the farmer. It should be noted that many of the farmers needs can be met by private contractors and commercial companies. The growth of such private enterprises should be fostered by the government just as much as governmental technical organizations.

FARMER OPERATIONS	OUTSIDE ASSISTANCE FROM
Development operations	
Acquiring land	Bank, private realestate agent or layer ; land reform office
Protecting landownership	Title insurance Co., Abstract office, gov't Legal records, Law enforcement.
Acquiring capital	Banks and other credit sources
Acquiring labour	Employment office
Acquiring construction materials	Private commercial dealers, cooperatives
Acquiring water supply	Public works agency
Clearing land	Private contractors
Designing farm irrigation system	Agricultural engineers
Topography	—do—
Soils data	Soil science
Cropping plan	Agricultural engineers and extension services
Water requirements	—do—
Field ditch layout	—do—
Hydraulic elevations	—do—
Drainage requirements	—do—

Constructing irrigation system	Agricultural engineers for demonstration and government projects ; private contractors for individuals farms.
Clearing	—do—
Land shaping	—do—
Ditching for field canals drains	—do—
Water control structures	—do—
Constructing house and barn	—do—
Obtaining drinking water supply	Public works agency, private contractors and Public Health Department.
Agricultural Production Operations	
Power for working soil	Private dealers and contractors
Implements for working soil	Private dealers ; coops
Seed and seeders	—do—
Fertilizer and applicators	—do—
Insecticide and applicators	—do—
Harvesting containers	—do—
Knowledge of correct practices	Extension service, Commercial Co.
Plowing and preparing land	Private contractors
Planting	—do—
Fertilizing	—do—
Watering	—do—
Cultivating	—do—
Spraying	Private contractors, and government
Thinning	—do—
Harvesting	Private contractors
Transporting from field to packing plant	Private contractors, coops
Marketing Operations	
Selling to jobber	
Grading and packaging	Private Co., coops
Storing	—do—
Transporting to market	—do—
Selling to wholesaler	—do—
Selling to retailer	—do—
Selling to consumer	—do—
Human Welfare Operation	
Family health	Private doctors, public health dept. home economy agents
Child education	Education dept., extension service
Family consumption	Private merchants
Social activities	Local government and societies

Regional Services

Road system	Public works agency, local government
Irrigation water supply	—do—
Electricity	—do—
Truck transportation	Private truck companies, coops
Bus transportation	Private bus companies
Mechanical equipment repair	Private repair shops and equipment dealers
Fuel supplies	Oil companies and private dealers

After looking over the long list of different operations that the farmer is confronted with, one can easily see that the successful farmer that uses the best of modern practices must become a good working manager in order to properly obtain and utilize all the resources available to him. In the past the farmers, because of their ignorance of modern agricultural methods, have restricted their production to a very few basic crops for which they had learned the traditional methods of agricultural operations. They have kept their operations simple and within their ability to perform even though the operations were not necessarily the best. Most farmers can not read or write and believe only part of what they hear and understand even less. There are millions of farmers that must be taught modern farming practices in order to have a substantial effect on the national income. To adopt some of the modern methods of agriculture requires money for operations and development. Obviously the government can not immediately provide all the added capital investment needed. Also it is obvious that the farmers cannot immediately learn all of the best practices, nor can the government acquire or afford sufficient technical service to meet the needs of each individual farmer. Obviously there are going to be large gaps in organization, capability, and facilitating services to the farmer for many years to come. Therefore, each country and each farmer must develop its own strategy of operation including selecting the best priority of development.

There are numerous strategies employing different schemes of priorities. For example, one group may believe that the first priority is to educate all rural children. The second group may believe that the first priority is to teach the existing farmer better production methods, then he can afford to pay for educating his children. A third group may believe that first priority should go to making a healthy farmer so that he will have the vigour necessary to learn and produce. Some groups believe that more of the outside assistance to the farmer should come from governmental services. Others believe that private contractors and companies with a personal profit motive can best provide the service. Some think priority of development should be given to certain geographic regions. Some think it should be given to certain crops or practices.

The point I am making is that because there are many different ways of improving irrigated agriculture, there is a great need for improved management both on the individual farm and within the government service and private companies. Since there are millions of farmers in many of your countries, there is a need for mass producing the introduction of modern methods to your farmers. You as leaders within your respective countries have the responsibility to work out practical ways of mass producing the modern techniques and practices for the uneducated farmer in order to increase rapidly the national income and raise the standard of living of the farmers that constitute the majority of your fellow countrymen. To do this you must not be just good technicians, you must be good planners and managers with an intimate knowledge of the factors of irrigated farm production and how they are related to the

farmer, the government, and the private sectors of your national economies.

In closing the writer would like to emphasize that management is the art of getting the job done through people, including yourself. Supervisory personnel should identify the problems and functions involved. They should plan for the solution and clearly define each person's responsibility for carrying out well defined jobs in accordance with a timetable that will keep the total job moving at the programmed rate to produce a quality product at a low price through organized, well managed mass production. The incomplete listing of factors presented in this paper may assist in developing more understanding of the problems which you and your nations farmers must manage.

AN ANALYSIS OF INSTITUTIONAL DEVELOPMENT RELATED TO IRRIGATED AGRICULTURE IN TURKEY

by

M. Dursun Kesimoglu*

INTRODUCTION

It has now become apparent that the subject of water and irrigation has not been given the required amount of emphasis in agriculture. Most underdeveloped areas of the world are presently either engaged in speeding-up their irrigation operations or in establishing the needed facilities.

To our opinion, all of the countries represented at this Seminar, i.e. Near East and South Asian countries, as well as Turkey are presently at this stage of development. This is the reason for these seminars which are being held every 2 years.

During these seminars it is possible to exchange ideas on prevailing irrigation techniques and management problems, and to have an idea regarding other countries' efforts in this field. I shall therefore try here to present a picture of Turkey's existing institutions in the field of irrigation development and provide information on needed new organizations.

ORGANIZATIONS DEALING WITH IRRIGATION IN TURKEY

Since we have mentioned Turkey's existing organizations during an earlier seminar, we shall only mention the organizations interested in irrigation practices :

A. DSI, (Directorate of State Hydraulics Works)

B. TOPRAKSU (Directorate of Soil Conservation and Farm Irrigation)

C. Agricultural Bank of Turkey

D. Universities

Since ample mention of the first two has been made in previous papers, I shall briefly mention the other two organizations :

Agricultural Bank

The sources for the credit operations of the bank are :

1. **The Bank's own resources.**

2. **Credits under A.I.D. assistance.** Information in this will be given later in this paper.

3. **I.D.A. World Bank Credits.** Under an agreement reached with the World Bank in 1963, Development of the Seyhan/Cukurova River Basin has been programmed. With the $ 20,000,000 received under the Development Loan Fund, irrigation of a total of 170,000 hectares shall be assured as follows :

53,000 hectares during 1st phase of development

34,000 hectares during 2nd phase of development

83,000 hectares during 3rd phase of development

Bank provides two types of credits

a. Agricultural credits

b. TOPRAKSU credits

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TOPRAKSU credits are those credits directly related to irrigation development. Present distribution of TOPRAKSU credits is carried according to the following procedure.

1. The order of priority for TOPRAKSU credits is (1) Irrigation, (2) land reclamation, (3) soil conservation and the order of priority for utilizing this credit is as follows :
   1. Irrigation districts and local irrigation organizations
   2. Farmer's cooperatives
   3. Groups of farmers
   4. Individual farmers
2. Branch offices of the Agricultural Bank are henceforth authorised to extend loans directly for projects costing up to 50,000 TL. and agencies for projects up to 25,000 TL.
3. Loans exceeding 200,000 TL. shall not be made to any individual. Maximum credits extendable to Districts Cooperatives for irrigation, conservation, or reclamation projects shall be in the amount of the project survey costs, and the securities shown.
4. Interest at the rate of 5 per cent shall be charged on TOPRAKSU credits. This rate shall be increased to 7 per cent delinquent payments in excess of 3 months. After 3 months, the rate of interest shall be 10 per cent.

Ten per cent interest shall also be charged to those who use the extended credit for purposes other than the indicated one, such interest will be charged starting from the date of the loan.

The Interest of Universities

The Technical University of Istanbul is greatly interested in irrigation development, and is training irrigation engineers with a view to fill the gap in water-soil-plant relations.

Graduates of the Agricultural College are not deemed adequately trained in engineering operations. Accordingly, under an agreement between the Faculty of Agriculture of Ataturk University and TOPRAKSU, future agricultural engineering curriculae shall be reinforced as follows :

Subjects to be Taught

1. Higher mathematics
2. Surveying
3. Technical draftsmanship
4. Statics mechanics
5. Timber and reinforced concrete construction
6. Soil mechanics
7. Hydraulics
8. Hydrology
9. Materials and construction techniques
10. Irrigation practices
11. Irrigation facilities
12. Drainage facilities ; land reclamation
13. Soil conservation and river basin developments.

New Irrigation Units Needed and Creation of Local Sense of Responsibility

During the previous seminar, we reviewed operations related to supply of water for irrigation purposes. It has been noted that the individual farmer who will benefit from irrigation facilities is not fully assuming his part of the responsibility, but is expecting the government to assume the whole responsibility. Efforts should be made to ensure the farmers' participation in maintenance, group observation and repair of the facilities to be provided. With this end in view, incorporation of the following type of organizations is now sponsored and encouraged by the Government of Turkey.

Districts for Development of Agricultural Resources

It has been observed that American irrigation, drainage and soil conservation districts have played an effective role in the development of U.S.A.'s natural resources. In Turkey, income per capita in the agricultural

sector is only one-third of the revenue realized in other sectors. This means that optimum output is not being obtained from the available farming units and existing man-power. To remedy this situation a **Draft Bill** on the establishment of "Districts for Development of Agricultural Resources" has been prepared. Local Districts as sponsored under this law, shall try to jointly solve all existing problems handicapping the desired stepped-up development in Turkey's agricultural programme.

Advantages expected from establishment of Districts

a. Eliminating waste of available man-power by putting it to use in the development of existing resources.
b. Making it possible for the smaller-sized farming units to benefit from the services and facilities to be set-up.
c. Ensuring the government's leadership in stepping-up local and individual productivity.
d. Assuring cheaper services and more rational use of facilities.
e. Together with the needed investments, providing the needed assistance, advice, and recommendations to farmers.
f. Adapting the services and installation to be provided to the actual needs and local requirements.
g. Reducing costs through establishment of cooperation between small farming units and stepping-up their productivity.
h. Increasing savings of individual farmers and helping them in better investments.
i. Preventing disputes among farmers, and eliminating causes of low productivity.
j. Integrating public utilities services under specific projects.
k. Ensuring proper maintenance of Government owned installations.
l. Invigorating the sense of self-help on the part of farmers by training.
m. Creating side-lines for needy farmers to enable them to make surplus money in fields of activity other than farming.

The recent Draft Bill is especially designed to provide assistance to farmers associations and districts in connection with Government aid in the form of loans, equipment, machinery and technical personnel. It is expected that application of this law will help to create the desired basis of cooperation between farmers and the Government.

Soil Conservation, Irrigation and Land Reclamation Cooperatives

I. **Objectives**

1. The Cooperatives shall review farmers' requests and evaluate them according to a standard procedure.
2. Since lack of title deeds is handicapping small farmers in receiving TOPRAKSU credits, the Cooperatives will provide guaranties for individual farmers.
3. The Cooperatives shall extend technical assistance to farmers in the construction and maintenance of TOPRAKSU —sponsored installations and projects.
4. Cooperatives shall ensure participation, within their capacities, of individual farmers in Community Development projects sponsored and supported by TOPRAKSU consequently :
   a. Public investments shall be encouraged and increased.
   b. Idle man-power shall be put to good use.
   c. Farmers shall have a hand in the building of the necessary constructions.
5. Cooperatives will provide at least partial assistance until the "Agricultural Resources Development Associations Law" is passed.

6. Cooperatives shall prepare the necessary groundwork and atmosphere by motivating farmers to form "Agricultural Resources Development Associations".

Characteristics of Statutes on Cooperatives

1. **Legal Basis.** The proposed Cooperatives shall be established under general provisions of law 6762 on Cooperative Associations. A basic statute drawn-up for this purpose will serve as a guide-line to farmers who wish to establish Cooperatives. Although Cooperatives designed to undertake TOPRAKSU services may be incorporated outside of the provisions of this statute, loans and other assistance shall be extended on priority basis to Cooperatives established in compliance with the Statute.

2. **Right of Control.** Although administrative and financial control over the proposed Cooperatives has been authorized to the Agricultural BANK, the same right shall be exercised by TOPRAKSU which will serve as a bridge between the Bank and the farmers, and also provide technical assistance to the Cooperatives.

3. **Technical Fundamentals Underlying the Basic Statute.** The above mentioned statute was prepared after a detailed study of farmers' associations in the U.S.A. in France and the Cooperatives previously established in Turkey.

SUPERVISED CREDITS

Background information on Supervised Credits

Initial studies were started in the year 1960 by the Agricultural BANK to adapt the credit extension policies to present-day requirements. Under A.I.D.'s help, Mr. Ralph Battles came from the United States to prepare a report on the workings of this system. Mr. Darrel A. Dunn has also assisted with the new credit project. Time was devoted from 1961 to the middle of 1963 to complete necessary preparations for implementation of the supervised credit system.

Objectives

Normal and long-term credit extension is within the scope of the supervised credits system, with the following objectives :

1. A reasonably satisfactory standard of living for the Turkish farmer.
2. The farmer shall be enabled to repay the extended credits.
3. The farmers shall also be able to meet current expenses, and save something for the future.

Implementation

1. **Funding.** In addition to the Agricultural BANK's own resources, A.I.D. shall also provide financial assistance in the implementation of the Supervised Credits Plan. The amount allocated for the first year is 25 million TL each, to be increased to 100 million TL during subsequent years. The agreement reached with A.I.D. in this connection shall expire in 1968 after which it is expected that the Agricultural BANK shall finance the supervised credits plan with its own resources.

2. **Procedure.** Denizli and Erzincan provinces have been selected as pilot areas for implementation of this project, since funds as well as trained personnel are too limited for its application all over Turkey. Denizli operations will start soon. In Erzincan province operations are scheduled to begin during the second half of 1964.

3. **Administrations involved :**

   (a) **At the Centre.** The "Pilot Region Supervised Credits Service" attached to the Agricultural

Credits Directorate of the Agricultural BANK in Ankara.

(b) **At the Provinces.** Agricultural BANK Branch Directorates and Agencies, organized with special staff and technical personnel.

4. **Mode of Application for Credits.** Applications' requests shall first be studied by the Bank's technician. The latter shall forward requests that he deems eligible to a selection committee, comprising the local Agricultural BANK director ; the Cooperative Director ; the senior local teacher, the country agent and the Muhtar.

If the request is approved by the Selection Committee, a Credit Project is drawn-up. Applicants may file an appeal against the decision of the Bank's technician to the Selection Committee. Credit projects shall be drawn-up by the technical staff of the BANK with the technical assistance of the Ministry of Agriculture. Projects for which the estimated costs amount to 50,000 TL or more shall be approved by Agricultural BANK branch-offices ; projects exceeding this sum shall be approved by the TOPRAKSU.

Government Subsidy on Farmers' Investments

Designed to create local responsibility, the plan to subsidize farmers' investments, although showing some progress, has not been completed as yet. However, the following provisions have already been decided on :

1. Government participation in the cost of land to be purchased from private individuals for land and water development projects shall be ensured under the terms of the 5-year Plan.
2. The Turkish Government shall subsidize construction of irrigation systems over and above the investment capacity of farmers.
3. Subsidies shall be approved for operations of a permanent character rather than temporary or mobile installations.
4. The Agricultural BANK shall establish a special Fund to be owned by the Ministry of Agriculture for the implementation of the above-mentioned operations.

The "Land and Water Development Assistance Law" shall be forwarded to Parliament when preliminary studies are completed.

Institutional Operations

The 5-year Plan. The Country Report includes appropriate information.

Land Reform. The draft of Land Reform Act being prepared by the Ministry of Agriculture provides for the following :

1. Rational management measures shall be introduced into farming units the sizes of which are presently under study considering regional climatic and soil conditions.
2. Large enterprises shall be converted into more productive economical units.
3. Applications of the Land Reform Act shall be given preference in irrigated farming areas.
4. Land consolidation measures shall be introduced.
5. Fragmentation of lands through sales and inheritance shall not be allowed.

Tax Reform. Henceforth taxes shall be collected from well-to-do farmers who practice large-scale farming. A draft Bill drawn up in this connection has been delivered to the parliament.

Water Rights

A Draft Bill on water rights is being drawn-up and will provide for the following :

1. Rational methods of benefiting from available sources of water shall be introduced.
2. The Draft Bill comprises proper utilization measures for both surface and

ground waters. Drainage and water-conduit systems, shall fall within the scope of the provisions of this projected Bill.

3. The Bill places all water resources under government control.

4. Acquired rights and expropriation principles for waters under private ownership ; government assistance rates ; penal clauses, technical assistance to be provided, etc., are considered under this law under priority order.

Extension Services

Although extension services are being rendered independently by each organization dealing with irrigation, these services are becoming more efficient through a close cooperation between the General Directorates of the State Hydraulic Works (D.S.I.), the Soil Conservation and Farm Irrigation (TOPRAKSU) and the Extension Service.

The role of the Extension Service is of great importance due to the fact that the Service has countrywide access to all villages. Thus, the establishment of both farmers cooperatives and irrigation districts will be encouraged through necessary contacts with farmers and audio-visual aids.

Farmers are encouraged to organise by establishing cooperatives and irrigation districts and they are informed about the important role of proper irrigation in getting increased yields. These organizations are designed to attain the following aims :

a. Prevent waste of labour and money by individual farmers ;

b. Assure maintenance of structures through a common sense of responsibility aroused among farmers ;

c. Increase agricultural development through credit extensions secured under joint liability ;

d. Increase the repayment capacity of the farmers who are acquiring the "spirit of close cooperation and team work" leading to increased productivity.

INSTITUTIONAL BASE OF IRRIGATED AGRICULTURE IN THE UNITED STATES

by

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INTRODUCTION

During 1961 an official from another country visited a rather new irrigation project in Western United States. Over and over he exclaimed, "I have never before seen such prosperous neat looking farms". He noted the clean orderly tree-caressed farm buildings, the weed free fields, the quality of farm equipment and the busy confident farm people. His question were, "how did it happen? Where is the touchstone that created this man-made garden in an otherwise bleak expanse of arid county?" The answer is that many fortunate circumstances combined to make this possible. The availability of good irrigable lands, a large water supply, credit to finance machinery, livestock and buildings were all favourable elements to success. Also involved was the culmination of years of trial and error, of some success and some failures. Certainly, the results represent accumulated knowledge in the agricultural and engineering sciences. They represent sound economic understanding of the factors implicit in an irrigated agriculture and they encompass the application of sound organizational knowhow. While conditions may differ in different countries, perhaps something can be learned from the experience in the United States.

The purpose of this paper is to highlight the institutional and organizational factors that have played a primary roll in the growth of irrigation agriculture in the United States —laws, customs, practices and systems which through usage, trial, and error have proven their worth. Without this base a large part of 30 million acres under irrigation in Western United States would not have been developed. Engineering design, hydrology, soil science and economic theory, fundamental though they be, must include this mortar of institutional laws, usages, rules and procedures to create a successful irrigation enterprise.

In summary, the basic institutions to a successful irrigation agriculture have been:

1. Settlement of the Western United States under the provisions of the Federal Homestead Laws. A vast country rich in agricultural resources lay empty and unused. This farsighted programme initiated in the 1860's resulted in the establishment of hundreds of thousands of family size farm units in the hands of owner operators. The Homestead Laws provided that any adult citizen could file on 160 acres of public land and by living on the land and placing it under cultivation could become the owner of a farm. The Homestead Laws acted as the pattern for size of farm units permitted under the Reclamation Laws. Further the Homestead Laws and the Reclamation Law made firm the policy that projects financed by the people of the United States should not be used for speculation or for the massing of personal wealth by a few people.

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2. The assurance to irrigators of a firm water supply resulting from state codes and laws that established and defined the rights to water use. The first citizen who could put the water to productive use received the first right. The innovation of these laws was the basic provision for appropriation of water supplies in accordance with need and priority of use. This became a fundamental principle of all state water right laws. It assumed an effective and prompt administration of these laws. It paved the way for efficient use of natural stream flow because it recognized beneficial use as the basis, the measure and the limit of a water right.

3. The creation of irrigation or reclamation districts under a body of state laws that provided for their organization and administration. The districts made the local people responsible for successful operation and maintenance of the projects and for their financial security. They gave initiative and control to the water users themselves.

4. A great institution for irrigation development was creation of the Land-Grant Colleges and universities by Congressional Act in 1862 (a measure supported by President Abraham Lincoln). Resulting education and research in the sciences of engineering hydrology and agriculture nurtured water development in the western states. These colleges produced large numbers of well trained and highly disciplined graduates who assumed responsibility for planning, construction and operation of projects and for vastly improved agricultural production on the farms. Much of the credit for increase in farm production is due to the creation of an Agricultural Extension Service under an Act known as the Smith-Lever Act. This Law brought agricultural education to every farm and demonstrated to the farmers the scientific knowledge gained by research by the Experiment Stations of the Land-Grant Colleges.

5. Financial assistance for irrigation development through taxation of the people of the United States. This programme, commencing in 1902 with passage of the First Reclamation Act has grown steadily until it now provides over $ 300,000,000 annually for planning, construction and operation of multi-purpose irrigation, hydropower, and flood control projects.

6. Compacts between the states for regulating the flow and use of interstate rivers and streams. Such compact agreements are now in effect on the Colorado, Columbia, Rio Grande, and Arkansas Rivers and many lesser streams. These compacts provide for irrigation, navigation, and pollution control. They permit efficient utilization of the water without destroying the multiple values of the river. They recognize the rights of the individual to use the water in promotion of the public welfare.

7. Then in the 1930's occurred a great awakening in America. The missionary voice of Dr. H.H. Bennett reverberated throughout the nation warning the people that misuse of the soil had taken a terrible toll in loss of fertile land and that action must be taken at once to conserve soil and moisture. The Congress did act fast. Soil Conservation laws were enacted and each state enacted enabling legislation permitting the formation of soil conservation districts. Perhaps no agricultural programme in the history of the United States had a more dynamic effect on the nation's farms—both irrigated and non-irrigated. Almost the entire agricultural area of the nation

is now covered by Soil Conservation Districts and hundreds of thousands of farms are operating under cooperative agreements for soil conservation. This programme has permitted the United States to prevent many of the problems of soil destruction troubling some other countries.

8. Above all, the basic philosophies and laws of the United States ; a Country that emphasizes the rights and opportunities of the individual ; a Country that thus creates a great medium for personal initiative ; a Country that offered settlement opportunity for masses of land hungry people from Europe and from Asia and from throughout the nation.

Not all of these basic institutions can be afforded detailed discussion in a paper designed for presentation in forty minutes. These closely allied to the immediate problems of irrigation development will be expanded.

Institutional Phases in Planning an Irrigation Project

How does a new irrigation project start ? The answer is that the local community must want a project and organize themselves to take the steps leading to project realization. Experience dictates that a period of 25 years may elapse between the time a large project is conceived and the first lands are irrigated. The easy projects have been constructed. Most present day irrigation enterprise involves a heavy outlay of funds for storage and distribution systems. They are usually beyond the financial ability of the local community.

The landowners are a party to the project from the very beginning. Those desiring the new irrigation project form an association which acts as a sponsoring body. This organization contacts a state or federal agency and requests that the project be investigated. That agency is usually the Bureau of Reclamation of the United States Department of the Interior, though it may be the Soil Conservation Service of the Department of Agriculture. Also, some states provide funds and organizations for planning irrigation projects.

The Bureau of Reclamation makes a reconnaissance examination of the proposed project to determine if the land is irrigable ; if the water supply is adeqate in quantity; and quality ; and the feasibility of storage and distribution systems. If the reconnaissance survey is favourable, the sponsoring groups' next step will be the circulation of petitions among all prospective water users asking them to indicate their willingness to approve the formation of a legally constituted irrigation district. While this step is in progress the planning agency, federal or state, will commence the preparation of a definite plan.

The statutes governing formation of irrigation districts are state laws. They vary somewhat in detail but are very similar in basic context. They require that a majority of the land owners and usually more than 50 per cent of the irrigable lands must vote in favor of the proposed district. These laws also specify the nature of the district organization. They place responsibility for management and for success of the project on the people benefiting by the project not as individuals separately responsible to the government but as a group with the welfare of all a primary consideration. The districts are empowered to levy taxes and toll charges against the land and the land owners for the purpose of meeting the annual cost of operation and maintenance and annual repayment of construction costs. They place responsibility for financing, operation and maintenance of the project in the hands of a district board of directors. This elected board varies from 3 to 7 or more directors though the laws of the states differ considerably in the composition of the district organization.

If the irrigation project is constructed with public funds the board's first duty will be to negotiate a contract with the United States or other loan agency for repayment of construction costs. These contracts have become

voluminous documents because they not only bind the district to repay the costs of the projects but they make provisions covering operation and maintenance of the irrigation system, land reclassification, proper accounting, protection of project lands against improper use of water and the making of rules and regulations acceptable to the loaning agency.

Two classes of irrigation districts are common in the western United States. Class one, the traditional irrigation district as set forth in the statutes of each of the 17 western states, includes within its boundaries lands which will receive an irrigation water supply from specifically identified storage and distribution works. Only the farms on lands to receive water from the project are obligated to pay water costs and these farms and farmers must be responsible through the district for payment of all such costs.

Obviously an irrigation project produces benefits, both direct monetary returns and indirect benefits, to many people other than the irrigation farmers. For this reason some of the states in the west have enacted laws permitting the formation of districts which encompass within their boundaries the cities, towns and industries expected to benefit directly from the irrigation project. These districts are usually known as water conservancy or reclamation districts. In such districts all property is assessed to help pay the cost of the irrigation project. Notable examples of this class of irrigation district are found in Colorado, Wyoming, Nebraska and North Dakota. The states which have enacted conservancy district laws have in every case placed a ceiling on the amount of the tax assessment which can be levied against all property. This ceiling usually does not exceed two-tenths per cent of the property assessed valuation. (Twenty cents on each $100 of assessed valuation).

It is interesting to note that both kinds of irrigation districts ; the traditional district, and the conservancy district, may be formed to administer a single irrigation project. In these instances the traditional district usually assumes responsibility for meeting the operation and construction costs of a defined distribution system and the conservancy district meets the costs of operation and maintenance and the allocated construction costs of the storage system or what is defined as the water supply system.

Irrigation district organizations throughout western United States abide by the highest standards of democratic belief. They are governed by laws which emphasize equitable treatment to every farmer or land owner in the district. The landowner irrigators elect the governing board and can remove the entire board or individual members. The board functions under closely defined authority. For example, the board is limited in its authority to create indebtedness against the water users. Any indebtedness must have approval by general election. Lands cannot be added to the district without approval of the majority of the electors. It is noted, however, that irrigable lands can be, in some instances, deleted from the district by the board. This act usually requires the approval of a court of competent jurisdiction.

Planning an Irrigation Project—The Old and the New

The planning of a modern irrigation project in the United States is becoming in itself an institution. Gone from the American scene is the western irrigation project of sixty or seventy years ago. Then, all too often four or five farmers working with a man, they called a "surveyor" staked out a stream diversion and distribution system called the ditch. They dug the ditch using teams of horses and scrapers. When the job was completed each farmer built his own farm turnout and there were no water measuring devices worthy of that name. Almost immediately after water was turned into the ditch, quarrels started over the distribution of the water. Sometimes these were violent fights involving shovels and guns because no one was really

certain of the share of water to which each so called mutual ditch company owner was entitled. The value of each irrigated farm was determined by its proximity to the head of the ditch. A farm on the tail-end of the ditch sometimes could not be sold at any price. Crop production was simply too uncertain. It must not be assumed, however, that all early projects were as haphazard as this. Many projects were well planned and well constructed. True, they were simple stream diversion type but they have operated for 100 years and the crop production on some of them is higher now than when they were first conceived.

The process, the objective, and the results, have changed. Multiple use of the water resource is a primary consideration. Hydro-power, flood control, soil conservation, fish and wildlife are all made a part of the plan in addition to irrigation.

Today, planning an irrigation project is a well organized and scientific process. It involves the best in the disciplines of engineering ; civil, mechanical and electrical. It utilizes the most modern developments in hydrology. Planning a project includes the sciences of soils, agronomy, horticulture and livestock management. The planning process utilizes modern economic principles involving allocation, benefit, and costs analysis, water user repayment ability all derived from accurate estimates of crop yields and market outlook.

Planning technicians are selected with outstanding education and experience in the field of irrigation and multi-purpose water development.

Few single purpose irrigation projects are under investigation in the United States. Practically all projects of material scope (excluding some pump irrigation projects) require large storage facilities to capture "surplus and off season" stream flows. In recent years many of the plans have included watershed management and improvements and soil erosion control both on the upstream water producing area and on the downstream irrigated lands. A notable Federally financed project employing all of these elements is the 52,000 acre Farwell Project in Nebraska. The plans authorization, and the appropriations for this project are a package deal including the irrigation of project lands and the protection of related watersheds. Agricultural aspects of an irrigation plan are given full consideration. Water requirements for crop production, rate of water application for maximum yields, crop adaptation, crop rotation, are all considered and made part of the plan. The plan fixes the time when project repayment will commence and suggests a development period during which no repayment is required. The amount of repayment is also set forth based on the ability to pay such costs.

A typical project planning organization as used by the United States Bureau of Reclamation and the United States Soil Conservation Service on a medium size multiple-purpose water development project might be as follows : Bureau of Reclamation : One planning engineer in charge ; one office engineer : one field engineer ; two engineers ; three draftsmen ; four engineer aides ; one Chief of Surveys ; two survey crews of four men each ; three hydrologists ; one agriculturist ; two soil scientists ; two labourers ; one economist ; one report writer ; one drill crew of four men ; and necessary stenographic and clerical help. Laboratory testing of drill cores and soil samples will be conducted in a central laboratory. Geologic assistance will be provided as needed. Preliminary designs and cost estimates of major structures will be made by the Chief Engineer's organization in his centrol office.

Soil Conservation Service : One conservationist in charge ; two irrigation engineers ; four farm engineer layout specialists ; one hydrologist ; one sedimentationist ; one agriculturist ; one soil scientist ; necessary clerical help ; and laboratory facilities for soil testing and testing of construction materials as needed.

Most of the western United States has now been organized into soil conservation or watershed management districts. Therefore, those districts and the Soil Conservation Service have available technical personnel qualified to assist the Bureau of Reclamation and the irrigation districts in providing erosion control and watershed management data to the irrigators at the time the water development plan for the irrigation project is initiated.

The first step in investigation of an irrigation and water development project is determination of quantity and quality of available water supplies. This is an extremely important beginning of the project because not only must hydrology of the surface and ground water be determined but the legal matters involving water rights must also be cleared. Simultaneous with the water supply studies is the mapping of arable lands into two or three classes. This is followed later by the selection of irrigable lands from the arable land area. That determination is, of course, based on location of project distribution system and farm ditch layout.

While these activities are in progress, engineers are selecting storage sites and locations for canals and laterals. Anticipated cost of construction, operation and maintenance, timing of water deliveries, seepage losses are all factors in selecting the route of a distribution system.

Cropping plans including crop distribution and water requirements for each crop are determined. Economists will make studies of benefits and costs, the amount that the irrigators can afford to pay for water and allocations of costs to each of the projects multi-purposes ; such as, irrigation, power, flood control, wild life recreation, pollution and sediment control.

The procedure outlined may seem complicated but when properly organized and executed, the resulting project can be depended upon to produce calculated benefits at calculated costs. The costs of the investigation itself will range from four to ten per cent of total project costs depending on the size and scope of the undertaking. On most multi-purpose projects, investigation costs will not exceed five per cent of total costs. This figure does not include construction designs or inspections which are deemed a part of construction costs.

When the plan is completed, it is published in volumes identified by subject matter ; such as, hydrology and water supply, engineering design, land classification, economics and agriculture. The plan is used for many purposes :

1. It is the standard for project construction and operation and maintenance.
2. It is the criteria for formation of the irrigation districts.
3. It is the basis for financing the project and for repayment contracts.
4. It is used in securing congressional authorizations.
5. It is a guide for farmers in developing cropping plans.

These are a few of its uses.

The basic criteria for an acceptable irrigation project under regulations of the United States Bureau of Reclamation are as follows :

1. The land to be irrigated must be determined irrigable by a land classification survey.
2. The water supply must be adequate within the range of tolerable shortages based upon years of historic drought. (Usually 75 per cent or more of an optimum water supply).
3. The benefits of the project must exceed the cost.
4. Annual water charges must be within the calculated ability of the water user to pay such charges.
5. No project will be constructed if the water users, as a minimum, can not meet the annual cost of operation, maintenance, and replacement of facilities allocated to irrigation use.

The problem of knowing when to call a plan complete has never been solved satisfactorily. It continues to be the source for high level conferences. It is for this reason that a planning engineer must be the most experienced, the most artful and the most able of decisive judgment of anyone in the business of developing irrigation projects, and he must not be timid in the exercise of that judgement.

Institutional Developments in Relation to Operation and Maintenance of Irrigation Projects

Years of experience in operating irrigation projects have proven conclusively that regardless of who may construct the project the sooner it is turned over to the farmers through their district for operation and maintenance, the better for all concerned. The agency financing or constructing the project is usually the Federal Government, the State, or a private entrepreneur. Regardless, such entity should stay on the job only long enough to ensure the complete operability of the irrigation system. The irrigation district board will usually try to defer acceptance of responsibility for operation and maintenance on grounds that some element of the construction may prove faulty. The United States Bureau of Reclamation had a long and trying experience in this regard until it became convinced that successful maintenance means maintenance by the water users. Frequently, the irrigation works—notably minor facilities like laterals and diversions—deteriorated rapidly because the water users were opposed to paying the full cost of the maintenance programme. When a canal broke or a syphon leaked, the water users instead of making repairs, would call the government office; saying, "come and fix your ditch". However, once the human tendency to delay the takeover is overcome, the water users—through their hired organizations—usually do a good job and they seldom express any desire to return operation and maintenance responsibility to a government agency.

The board of directors of an irrigation or reclamation project is authorized by law to employ a staff needed to operate and maintain the system from its headworks to the farm turnouts. A typical operation and maintenance organization for a 50,000 acre project in Colorado, Wyoming and Nebraska is as follows:

Number Required	Position
1	Manager
2	Watermasters
1	Clerk (Water records and cost accounting)
1	Clerk-Stenographer
12	Ditchriders through irrigation season
1	Maintenance Foreman
12	Maintenance Crew (truck-drivers, concrete, etc.)
3	Equipment Operators (dragline, tractors, road patrol, etc.)

One watermaster district usually consists of 25,000 to 30,000 acres

One ditchrider can serve an average of 4,000 acres

can deliver 40 to 50 heads of water
and drive 50 to 60 miles per day.

In figuring personnel requirements on a project, generally one man year is required for each 1,500 acres.

Ditchriders are employed on maintenance work during winter months.

The district board of directors must act as a group never as an individual member of the board. The board must agree on the policies for operation and maintenance, must then turn them over to the manager, and must see that he puts them into practice. The surest way to destroy the effectiveness of an operating organization, and this has happened many times, is for one board member to give orders to the manager. It is, of course, even worse when a board member gives instructions to men in the field working under the manager. It has taken years of dismal failure to fix once and for all this simple basic truth.

Thus the irrigators in the United States finally learned how to organize irrigation enterprises and they learned how to carry on the relationships between the policy-making group (the board of directors) and the management of the project. The next big problem, and one that has taken years to resolve, is how to make certain that the job of maintenance is actually performed. Deferral of necessary maintenance has caused endless trouble on irrigation projects throughout the world. Operation of the project cannot get far in arrear because the irrigators will object strenuously when their crops dry up. Maintenance, on the other hand, can be an insidious perplexing proposition. Inadequately maintained irrigation projects can bring about economic disaster. One poorly maintained project in southwest United States finally, and after many years, paid all of its construction obligation ; however, the cost of deferred maintenance was so great that the water users had to bond themselves in an amount greater than the original indebtedness in order to make the system operable.

In recent years, the problem has been resolved by the establishment of written standards of maintenance enforced by the annual inspection of all irrigation facilities. The inspectors are competent irrigation engineers. When they look at a lateral, a canal, a diversion or a dam, they do so with the skill acquired by training and experience.

A good example of maintenance standards for an irrigation project were adopted in 1962 by the Frenchmen Valley and H. & R.W. irrigation districts in Nebraska. These are new reclamation projects recently completed by the United States Bureau of Reclamation. The introductory statement in the document setting forth the standards of maintenance reads like this: "Keeping maintenance work current on all irrigation facilities is the keystone to a sucessful enterprise. No poorer form of economy exists than slighting annual maintenance needs. The history of irrigation is replete with examples of failures caused by inadequate maintenance. Improper repairs and neglected maintenance costs far more than keeping the system in top operating efficiency at all times".

The first requirement in a set of standards provides for an annual inspection, a detail report of that inspection, and the recommendations for maintenance work that must be performed within one year and before the next inspection.

The document describes operation of the system including water supply, water measurements and records. It indicates order for reservoir releases and the procedure that must be followed by each water user in requesting an irrigation supply. Incidentally, most districts require the users to order water by mail or telephone at least 48 hours ahead of delivery.

The standards include the design criteria for each canal, lateral, diversion and storage facility. Each measuring device is identified by size and flow regulation. Waste-ways are described as are all drainage inlets. Tolerance for sediment accumulation in the canals and laterals is given and cross-sections for measurement of sediment accumulation are located.

On all projects constructed by the Bureau of Reclamation, an inspection of minor structures and facilities is made once each year, usually as soon as possible after the end of the irrigation season. By minor structures is meant the distribution system including diversions, canals, laterals, turnouts, waste-ways—in fact, all small structures down to the farmer's headgate. The inspection team includes at least two top flight engineers acquainted with project facilities. One or more members of the irrigation district board are always asked to accompany the inspectors. The district manager or superintendent is also included with the group. They spend sufficient time to thoroughly examine the condition of each facility, to make notes of their observations and sometimes to photograph conditions that require maintenance work.

Inspection of major facilities such as dams, spillways, power plants, turnout valves and similar facilities is made once every two or three years, in accordance with a pre-determined schedule. On all reclamation projects the provisions for inspection as well as the requirements for maintenance are set forth in the repayment contract between the United States and the irrigation district. Since this matter of maintenance is so important to the success of every irrigation project, the governing board of every irrigation enterprise is urged to secure a copy of a set of documents reporting the results of inspections for maintenance. These are usually available in the regional offices of the United States Bureau of Reclamation or in the office of the Bureau's Chief Engineer in Denver, Colorado.

Another matter of prime concern to an irrigation district is the kind and amount of equipment needed to maintain the project works. There follows a list of the equipment required for a 50,000 acre project in Wyoming. Again the United States Bureau of Reclamation publishes excellent documents describing equipment, its capacities and proper uses. These are usually obtainable.

Item	No.	Type or Size
Dragline	1	¾ cu. yd.—caterpillar type
Trailer	1	Lowboy—sufficient to carry dragline
Dragline	1*	⅜—½ cu. yd.—similar to Quickway
Tractor	1	D6 or equivalent with dozer
Carry-all Scraper	1	To accommodate D6 tractor
Tractor	1	D4 or equivalent with dozer and loader
Carry-all Scraper	1	To accommodate D4 tractor
Tractor	1	Rubber-tired for mower, etc.
Mower	1	To accommodate rubber-tired tractor
Weed Burner & Spray	1	Combination for rubber-tired tractor
Motor Patrol	1	10′—12′ blade—hydraulic control—50 H.P.
Trucks	1	2 ton flat-bed or stake body
Trucks	3	1½ ton, flat-bed, side dump
Trucks	3	1½ ton, dump body
Trucks	3	½ — ¾ ton, pickup body
Automobiles	3†	1 Sedan and 2 coupes
V-ditcher	2	1 large and 1 medium, hydraulic controls
Concrete Mixer	2	1 sack on rubber tires
Compressor	1	125—185 cu. ft. portable with hammer & drills
Pump	1	4″ discharge, portable motor driven
Light Plant	1	1000—1500 watt, probable

* A D6 tractor with dozer, Hystaway dragline attachment, carry-all scraper and V-ditcher can be substituted for the Quickway or similar dragline.

† Does not include ditchriders' cars.

Equipment requirement depends on the location, the length of the irrigation season, the system of operations and many other factors such as climate, watershed cover and weed problems. Every project manager can gain by studying material made available through the Chief Engineer of the Bureau of Reclamation. These documents are well illustrated by design sketches and photographs.

The method of making water charges is another important phase in the operation of an irrigation project. Long experience dictates that the best way to charge for water is by measurable quantities ; in other words, by a rate per acre foot, or 1,000 gallons, or cubic meter (though the latter measurement is seldom used in the United States).

There is a very definite two-fold psychological reason for preferring a rate charge to a flat charge per acre. The rate charge tends to prevent overuse of water with resultant loss of fertility, alkali problems, and seepage. Secondly, it husbands the available water supply, thus assuring more water for project use during periods of protracted draught. Many of the irrigation districts in western United States, resort to a combination of water charges. They use both the tax assessment and rate per acre foot toll charge. They divide the annual budget into fixed obligations (established by legal statutes) and obligations which may vary from year to year. This arrangement permits flexibility, both as to time and amount of collection and is usually more acceptable to the water users.

Drainage of farm lands in irrigation districts has been and always will be a problem of continuing importance. Loss of crop production by seepage burdens the financial structure of the entire irrigation district because if the seeped land cannot be replaced with productive land, the remaining productive lands must meet the annual water charges. In districts where irrigation is a seasonal and not a year-round programme, the irrigation superintendent employs part of his labour force to construct drainage work on irrigated farms. For example, some irrigation districts in Kansas, Colorado, Nebraska and Montana, encourage land owners to make application for needed drainage when they observe that water tables are rising. The district then uses its off-season workers to accomplish the needed drainage on a "first come first serve basis". Rights-of-way for drainage are essential on all irrigation projects. Insofar as possible, they are acquired at the time the rights of way for canals and laterals are purchased. If additional rights of way are needed, they are purchased by the district.

Like drainage work, land reclassification to weed out unproductive land is more or less a continuing programme. Seepage and erosion are culprits tending to change the productive value of irrigable lands. Also effecting the irrigable area in a district are new roads, expansion of city boundaries and new industrial plants. It is a common practice for the districts to reclassify the irrigable lands within their boundaries at fairly regular intervals (five to ten years). The Federal Reclamation Laws recognize this fact and provide the legal machinery for reclassification of lands on all projects constructed by the United States. The government makes available the necessary soil scientists and the cost of the work is rapid by the water users.

The Federal Reclamation Laws as a Basic Institution in Irrigation Development

The United States of America is a nation governed by laws, not by men. The law in a democracy, like an organism, grows as it is nurtured. Nurtured in this case by the wants and needs of its human society.

A man dressed in overalls and rubber boots carrying an irrigation shovel ; a long train loaded with fruits and vegetables, cattle and hogs, cotton and wool, grinding its way along a steel track ; the deafening roar of sugar mills and cotton gins ; a young man and a young woman standing at the church altar taking marriage vows ; a youngster in a boat on a lake fishing ; can all of these sights and sounds be related to anything as deadly monotonous as a set of green books called the Federal Reclamation Laws ? Yet, so they are.

The Reclamation Laws record the evolution of thought in the field of irrigation and water resources development. They are a chronological record of institutional progress.

At the beginning of the 20th Century, the growth of irrigation in western United States

had reached a stalemate. Those with money to loan were little interested in financing irrigation projects. The water of most streams was over appropriated and numerous speculative projects had failed to assure a late season water supply because of inadequate stream flow. Further development for irrigation meant storage reservoirs and this, in turn, meant greatly increased project costs. A new concept was necessary or a vast segment of the United States—the arid west—must cease to grow. Thus, the first Federal Reclamation Project Act of 1902 sparked new life into the western states. Here is what it did :

1. The Act created a reclamation fund derived from public land revenues, (oil royalties, sale of public lands, land rental fees), all to be used in financing irrigation projects.
2. It permitted the withdrawal of public lands for irrigation purposes.
3. It set a limit on the size of an irrigated farm-not less than forty acres of irrigated land in one ownership nor more than 160 acres.
4. It gave the government the right of eminent domain to enter private property (after payment of just compensation) for the purpose of constructing reservoirs, canals, laterals and appurtenant irrigation works.
5. It recognized the rights of the states to control, appropriate, use, or distribute its waters.
6. It required the water users to repay to the reclamation fund their proportionate share of project costs in ten annual instalments. This requirement is basic to all Reclamation Law and has had the very beneficial effect of assuring great integrity in the realistic appraisal of land, water supply capabilities, land settlement policies, as well as engineering and financial considerations.

During the subsequent 61 years the Reclamation Law has been changed to further encourage irrigation and related water development projects. The most basic of these changes and additions are listed :

1. The repayment period has been extended to forty years instead of ten.
2. A farm development period is recognized permitting the water user up to ten years before he must start repayment of construction costs a period when his farm costs will be high and he can least afford the burden of paying for the project.
3. It recognizes that a project may have water surplus to its needs and permits the sale of such water as a means of repaying part of the construction costs.
4. It brought about hydro-power development at reservoir sites as another means of permitting more rapid repayment of irrigation construction costs.
5. It recognizes the principle that the water users shall not be asked to pay water charges in excess of ability to pay.
6. It recognizes that wastage of soil and moisture resources on farms and watersheds is a menace to the national welfare and provides permanently for the control and prevention of soil erosion.
7. It provides for reclassification of irrigable lands at five-year intervals.
8. It provides assistance to the various states in bringing about river basin compacts for inter-state streams.
9. It provided for financing of "small projects" as well as "large projects".

The Reclamation Laws have kept pace with the needs of a dynamic society. They are a basic institution to the development of irrigated agriculture in the United States.

Irrigated Farms and Farmers

The number of irrigated farms is small in proportion to the total number of all farms in the United States. Never-the-less, their influence on the national economy is great. Many of the Nation's food crops are grown almost exclusively under irrigation. Among these are fruits, nuts and vegetables. Practically the entire acreage of sugar beets is grown on irrigated farms as is the acreage of rice. Because of high yields an increasing percentage of the cotton crop is grown on irrigated land. Alfalfa, corn, potatoes, and beans are important irrigated crops.

Livestock production, especially feed lot cattle and sheep and dairy cattle, is an important enterprise under irrigation. In fact, the high yields from irrigated land is contingent on fertile soils made so by heavy applications of livestock manures. The range of crop yields on class one and two irrigated land give some idea of the relative importance of these lands as compared to non-irrigated lands. Alfalfa yields from three to seven tons per acre, depending on length of growing season. Sugar beets yield from 16 to 26 tons ; potatoes from 400 to 600 bushels per acre ; and cotton runs from two to two and one-half bales per acre.

Irrigated farms, like all farms in the United States, are tending to become larger. Farm management studies reveal that larger farms-those in the range from 300 to 500 acres or larger— are more profitable than smaller farm units. Undoubtedly, this trend is influenced by modern farming methods which call for large investment in power machinery and an efficient farm organization in a highly competitive agriculture ; an agriculture frequently finding itself confronted with surpluses of crops in excess of market demands.

The irrigation farmer relies heavily on credit to finance his operation. He tends to use short-term credit to secure funds for planting and harvesting. He usually borrows money to stock his feedlots or dairy barns, liquidating the loan at the time his livestock is sold or his dairy is able to produce optimum yields of milk and butterfat. The local banker handles most of this normally. Their interest rates are stable and not exhorbitant.

Indeed, irrigation farming in this day requires a heavy capital outlay. For example, a good one-hundred acre irrigated farm in the Central West will cost $ 40,000 to $ 60,000 for land and improvements. The cost to adequately equip such farm with modern machinery ranges from $ 20,000 to $ 25,000, depending on the kind of crops to be grown. Livestock may cost another $ 10,000 or more. Capital value of the farm will range from $ 75,000 to $100,000. Few young farmers have this kind of money. To get started the young farmer must rely on both long-term credit and short-term credit. This is one of irrigation agriculture's vital problems.

The Farm Credit Administration was created by the Farm Credit Act of 1933. Subsequently, this credit institution was improved and made more flexible to meet the challenging needs of all agricultural credit. The Federal Land Bank was created as part of the Farm Credit Administration's programme. This Agency makes long-term farm loans (33 years) at low interest rates. More recently, there was established the Farm Home Administration which permits financing of farmers where the credit risk is greater. It is in this Institutiont hat young farmers on newly irrigated lands may reach for help. Never-the-less, the credit structure is still a problem on irrigated farms ; no form of credit yet available is fully tuned to the particular needs of new irrigated projects.

A successful owner-operator on an irrigated farm is much more than a "rube" or "peasant" farmer. He is, in fact, a trained business man qualified to hold position in one of the Nation's most competitive businesses agriculture. He is frequently a college graduate ; he has knowledge of how and when to plant and harvest ; of how and when to fertilizer and control pests ; and of how and when to apply water. In brief ; he is an

agriculturist but he is more than that he is a financier, an efficiency expert, a personnel officer, a marketing specialist, a mechanic, and a trouble shooter.

A successful irrigation farmer is competent, he has initiative, he loves his work, he has the respect of his community and he intends to stay there. Indeed, he is a basic institution of irrigated agriculture in the United States.

Perhaps it is well to summarize some of the things that the institutional structure has done for the irrigation farmer :

1. The farmer is a participant in the plans for the project. He has the right and responsibility to help make decisions pertaining to District formation, levy of taxes and toll charges to pay irrigation costs, and organization for operation and maintenance.

2. The farmer is assured of a firm right to his water supply that cannot be taken away. In time of water shortage he will receive his proportionate share of the available supply.

3. He knows that the project will be administered under laws which recognize his property rights.

4. He knows that qualified technicians will construct the project and that it will operate efficiently.

5. The farmer can secure credit for his farms operations realizing that the bank or loan company is government supervised to assure fair and proper interest rates.

6. The land owner whose lands are acquired for project purposes knows that he will be paid the full value for his land as established by competent appraisal.

These are some of the institutional benefits to the farmer and land owner.

CHAPTER VIII

OPERATION AND MANAGEMENT

OPERATION AND MAINTENANCE OF IRRIGATION PROJECTS IN TURKEY

by

Kemal Ertunc*

INTRODUCTION

The Development of Operation and Maintenance in Irrigation Projects

Modern and effective irrigation can be realized with the completion of two distant steps. The first step is to supply irrigation water to the farmer's turnout and the second is to assure that this water be utilized efficiently on the farm.

Supplying irrigation water to the farmer's turnout is possible only if there is an adequate supply of water and properly designed and constructed irrigation system. Maximum utilization is possible when the lands are prepared for uniform distribution of irrigation water and protected from flood water and high water table by adequate drainage systems. Successful operation of an irrigation system requires regular maintenance of the system and close cooperation with the farmers to prevent wasteful operations and maintenance practices.

Operation and Maintenance

The irrigation installations constructed by D.S.I. (State Hydraulic Works) are operated by Operation and Maintenance Engineers. The operating organization includes irrigation, maintenance, power and dam operation services. This staff can undertake the operation and maintenance of a system containing up to 10,000 Ha. Projects smaller than 10,000 Ha. are operated by irrigation personnel working in field offices and attached to the Operation and Maintenance Engineers. For projects larger than 25,000 Ha. more extensive organisations should be established.

The Development of Irrigation Projects in Turkey

Approximately 25 per cent of Turkey's water resources have been partly developed. The remaining water resources should be developed as soon as possible for suitable crop-lands are limited and the population density is increasing at an accelerated rate.

During the period 1943 to 1963 gross area of projects carried out by the Government increased from 54,000 Ha. to 251,127 Ha. In addition to this development and in accordance with the Five-Year Plan, the total area of "big" projects will be 625,000 Ha. and addition of 415,000 Ha. to the 210,000 Ha. already developed. In addition to this 625,000 Ha. area, 100,000 Ha. of land will be developed under the programme of small irrigation projects during the five-year period.

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Brief descriptions of the big projects operated and maintained by the State Hydraulic Works Department (D.S.I.) follow :

1. **The Lower Seyhan Project.** The total area of the project is 186,000 Ha. Distribution system has been completed for 20,000 Ha. The water source for the Seyhan Project is the Seyhan River. Necessary irrigation water for the entire Adana plain is stored in the Seyhan Reservoir which has a capacity of $1500 \times 10^6 m^3$. This project will be completed during 1969.

2. **The Berdan Project.** The water source is the Berdan River. The project's gross area is about 60,000 Ha. however only 7,000 Ha. can be irrigated at the present time. The Mersin orchards irrigation project is a unit of the Berdan Project. Water supply for this 3,000 Ha. area will be pumped from the Berdan right main canal. The water distribution system for this particular project will be underground concrete pipelines.

3. **Lower Goksu Project.** The Silifke plain has 5,200 Ha. of irrigable land. Water is taken by a diversion dam on the Goksu River.

4. **The Anamur Project.** 3,000 Ha. of land are available for irrigation in the plain. At the present time the project is not in operation as construction of the irrigation system will not be completed until 1965.

5. **Alanya—Dim Project.** The project, with 1,050 Ha. area, is already fully developed. The distribution network uses both gravity and pumping systems.

6. **Manavgat Project.** There are 1,500 Ha. irrigable land in the project. Construction work has been completed and the project is in operation.

7. **Lower Aksu Project.** The project area of 19,000 Ha. is located on the right and left banks of the Aksu River. Construction of the right bank distribution system for 3,600 Ha. has been completed. The other units are under construction and will be completed during 1966.

8. **Kirkgozler Duden Project.** The project contains 6,500 Ha. and construction will be completed in 1965 ; 2,900 Ha. of land are under irrigation at the present time.

9. **Fethiye—Esencay Project.** The project contains 2,900 Ha. and has been in operation approximately fifteen years.

10. **Upper Menderes Project.** The Isikli and Irgilli projects are two separate projects with a total of 8,400 Ha. Both projects are now under construction. Construction work will be completed in 1964.

11. **Middle Menderes Project.** This project has three units : Denizli—Saraykoy (7,000 Ha.), the Yenice—Saraykoy (5,600 Ha.), and the Nazilli unit (14,000 Ha.). Total project area is 26,000 Ha. and the water source is the Great Menderes River. Each project has a separate irrigation organization.

12. **Akcay Project.** This project area with 3,000 Ha. is down-stream of Kemer Dam. The distribution system is under construction and should be finished in 1965.

13. **Gediz Project.** The water source for this valley is the Marmara Reservoir with a capacity of $350 \times 10^6 m^3$ and the Demirkopru Reservoir which stores $1,300 \times 10^6 m^3$ of irrigation water. The units of the projects are : the right and left banks of Ahmetli containing 27,000 Ha., the right and left banks

of the Adala contains 15,200 Ha. and the Menemen project with 15,000 Ha. This project, totalling 57,200 Ha. will be completed in 1966.

14. **Bursa and Iznik Project.** This project contains two small irrigation projects. One is the Iznik with 1,200 Ha. capacity, and the other is the Bursa plain irrigation district containing 1,750 Ha.

15. **Porsuk River Project.** The Porsuk Dam with capacity of 160×10^6 m^3 is the water supply source for the Eskisehir irrigation project. The project contains 22,000 Ha. The Kutahya project is located upstream of the Porsuk Dam and has 2,400 Ha. Both projects are fully developed.

16. **Uluirmak Project.** Mamasin Dam, which can store 98×10^6 m^3 of water, is the source of water for this project. The distribution system for the irrigation project is under construction and 5,000 Ha. will go in to service in 1964. The remaining 11,500 Ha. area will be irrigated during 1966.

17. **Cumra Project.** This project, being fifty years old, is the oldest irrigation system in Turkey. Rehabilitation work is being undertaken to provide more adequate distribution and drainage systems.

    The water source is Beysehir lake. Apa Dam was constructed down stream of Beysehir lake; and supplies additional irrigation water to the Cumra project. The project area contains about 45,000 Ha. The Konya plain irrigation project which includes Cumra, May, Sille and Konya projects and contains 80,000 Ha. of land will be completed during 1970.

18. **Ayranci Project.** The construction of Ayranci Dam with a storage capacity of 30×10^6 m^3 has been completed. Although there are 30,000 Ha. of irrigable land in the plain only 5,000 Ha. of land can be irrigated because of insufficient water supplies.

19. **Upper Yesilirmak Project.** The project units are the Erbaa irrigation district, 3,000 Ha.; Right bank Kazova district, 8,100 Ha. ; and Amasya with 2,200 Ha. These projects have been fully developed. Almus Dam, located on the Yesilirmak River can store 950×10^6 m^3 of water. This is the source of water for the 18,200 Ha. of irrigable land in the basin. Omala, Turhal and Kazova left bank irrigation units are under construction and will be completed in 1966.

20. **Malatya and Dogansehir Project.** The Malatya plain contains 9,000 Ha. The Dogansehir project is fully developed and providing irrigation water to 1,500 Ha. After completion of the Surgu, Sahnahan and Medik Dams, which are in the upper Euphrates basin development, irrigation water will be available for 48,000 Ha. of land. In addition to surface water, under ground water is available for irrigation purposes. Four-hundred Ha. of land can be irrigated by artesian flow or pumped wells.

21. **Erzincan Project.** The irrigation network of right bank has been completed and 3,000 Ha. are being irrigated. The distribution system for the irrigable 26,000 Ha. of land on the left bank is under construction. With the completion of Tercan Dam, 30,500 Ha. of land will be irrigated in the plain. The project is scheduled to be completed in 1970.

22. **Igdir Project.** This irrigation project, with 35,000 Ha. gross area, is under construction. The water source is the Aras river. Minimum flow of the Aras river is not sufficient to irrigate the entire area. Investigations are now underway to determine the

feasibility of construction of the Ahuryan storage dam which would increase the size of the project area.

23. **Nusaybin Project.** The Cag-Cag stream with a minimum flow of 8 m^3 per second is the water source for the 7,000 Ha. project which is fully developed.

24. **Van Project.** The project area contains 7,000 Ha. and has several water in sources; the Samran canal, five storage dams and historical under ground galleries. Gross and net irrigated area and irrigation percentages are shown in Table 1.

TABLE 1. GROSS AND NET IRRIGATION AREAS

Name of Project	Gross project area (Ha.)	Net irrigated area in 1962 (Ha.)	Irrigation Percentage
Menemen Ovasi	15,000	8,147	54
Salihli Ovasi	1,250	3,923	100
Nazilli Ovasi	14,000	10,886	78
Denizli-Saraykoy	7,000	4,985	71
Malatya-Ovasi Su.	6,000	3,852	64
Adana Seyhan Su.	20,000	16,882	85
Tarsus-Berdan Su.	7,000	2,989	43
Tokat-Kazova Su.	8,100	3,873	48
Amasya Bahceleri	2,200	1,502	70
Alanya-Dim Su.	1,050	832	80
Konya Ovasi Sul.	45,000	26,601	59
Van Bolgesi Su.	7,000	4,075	58
Ankara-Cubuk Su.	300	75	25
Dogansehir-Surgu Su.	1,500	1,197	80
Manisa-Mutevelli Su.	3,400	1,513	45
Manavgat-Ulualan	1,500	1,041	70
Eskisehir-Alpu Su.	22,000	2,995	14
Nusaybin Su.	7,000	4,342	62
Silifke Ovasi	4,000	2,703	68
Erzincan Ovasi	4,800	1,290	27
Fethiye-Esencay	2,900	426	15
Tunceli-Peri	500	92	19
Elazig-Uluova	1,500	530	36
Erbaa Ovasi	1,000	937	94
Sahnahan Ovasi	8,600	1,790	21
Yenice-Saraykoy	5,000	3,943	79
Kutahya Ovasi Su.	1,650	202	12
Aksu Sag Sahil Su.	1,600	1,737	100
Bursa Ovasi Su.	750	739	98
Sille Baraji Sul.	350	87	25
Ayranci Baraji Sul.	4,100	5,635	100
Urgup-Damsa Su.	500	444	89
Kirkgozler-Varsak	485	485	100

The Operation and Maintenance of Irrigation Projects

The factors which affect coordination of operation and maintenance of projects are the size of the project areas and the number of operation and maintenance activities which the projects contain.

There are two types of operation and maintenance organizations.

a. Those in which operation and maintenance is carried out by an Area Operation and Maintenance Engineer who is directly responsible to his Regional Director. Thirty-one of the existing 34 projects are in this group. These projects do not have limited budgets as costs of Operation and Maintenance activities are included in the general budget of D.S.I.

b. The remaining three are limited budget type irrigation projects. Their operation and maintenance budgets are limited to the income received from the water users and the Regional Directors are responsible for administration and technical supervision only. The projects containing from 5,000 to 20,000 Ha. are operated and maintained by the Regional Operation and Maintenance Engineer.

Projects smaller than 5,000 Ha. are usually operated and maintained by area irrigation offices which are responsible to a Regional Operation and Maintenance Engineer. For example, the operation of the Kutahya irrigation project which contains 2,400 Ha. is under the responsibility of the Eskisehir Region Operation and Maintenance Engineer.

Operation and Maintenance Organizations.

There are two different types of organization charts. One type includes only maintenance and operation services for the projects which contain a diversion dam and distribution system. The second type includes dam, hydroelectric power plant, and distribution system operation and maintenance.

Income from the Irrigation Projects.

The D.S.I. Organizational Law states that the land owners must repay the original construction as well as operation and maintenance costs. At the present time all of the projects are either under construction or have been recently completed ; therefore, are still in the allowable grace period when only operation and maintenance fees are collected.

As the projects are not in full operations the fees do not meet the expenses of operation and maintenance. (*See* Table 2).

The Operation and Maintenance Fee List is prepared by the Ministries of Agriculture, Public Works, and Finance each year before the irrigation season considering the operation and maintenance expenses of the previous year. Fees are computed for each project and taken into account the kind, value and water needs for the different crops.

Kazova Right Bank Irrigation Project.

To further explain the problems of determining operation and maintenance procedures, water rate charges, and related subjects the following study is made of the Kazova Right Bank Irrigation Project located in the Upper Yesilirmak Basin.

(a) Location of the Basin. Project area has been located to the north-east of Anotoly, bounded on the east by Coruh and, on the south by the Kizilirmak and Euphrates basins. The area covers 36,114 km^2. There are 3,400,000 decares of land in the basin. Land classifications indicate that of the total commanded area of 2,910,000 decares, only 1,623,000 decares are suitable for irrigation ; 50,000 decares are marshy land and 80,000 decares need drainage facilities.

The Kazova Right Bank Irrigation Project is one of the units of the upper Yesilirmak basin with an area of 81,000 decares.

(b) Climate. The climate of the basin varies between the rainy climate of the Black Sea and the central Anatolian dry climate. Therefore, it is hot during the summer and

mild in winter. Ample precipitation, averaging 440 mm., is available only for winter crops. To increase production, summer irrigation is required. The growing season begins on November 15, an average of 215 days per year. Evaporation in the area is fairly important especially in summer when it increases the water needs of the crops.

(c) **Topography and Soils.** Elevation of the plan is 600-660m. The land is flat along the river as it has been built up by the sedimentation materials carried by the Yesilirmak River. On the hill side alluvial lands came into being as a result of the floods from the northern mountains. The general land slope from east to west and north to south to the Yesilirmak River, which provides a good drainage outlet.

The soils of the basin are of varying combination of clay sand and silt. Fifty per cent of the soils have heavy and medium characteristics. Results of land classification are tabulated below :

I class	15.50%	2,172 Ha.
II ,,	23·43%	1,867 Ha.
III ,,	43·47%	3,464 Ha.
IV ,,	5·02%	400 Ha.
VI ,,	12·12%	966 Ha.

Class V land, which represents 19·99 per cent of the area, could be developed with the installation of sufficient drainage systems.

TABLE 2. INCOME FROM IRRIGATION PROJECTS

Years	Number of Irrigation Projects	Actual irrigated area decares	Irrigation income minus O and M cost
1943	2	171,984·508	— 75,156·61
1944	6	18,1551·760	— 51,030·79
1945	7	209,608·497	— 83,123·73
1946	9	213,929·170	— 228,906·31
1947	9	385,352·049	— 287,701·01
1948	10	300,744·327	— 190,805·68
1949	11	402,708·671	— 597,457·69
1950	12	419,392·766	— 337,432·18
1951	13	551,312·299	— 220,423·04
1952	15	591,792·218	— 398,325·31
1953	15	580,044·910	— 321,041·27
1954	15	543,480·668	— 739,574·81
1955	15	726,711·639	— 733,725·41
1956	17	709,976·485	— 342,102·53
1957	18	777,516·769	— 392,532·23
1958	23	826,173·522	— 1,330,349·38
1959	23	876,335·515	— 1,421,524·04
1960	25	892,032·000	— 1,614,679·06
1961	26	1,041,101·259	— 3,346,364·80
1962	34	1,232,930·045	+ 84,770·95

Minus Sign (—) indicates cost in excess of income.

(d) **Plant Adaptation.** The hill side area which begins just below the main canal is favourable for orchards. The flat area which goes along the river is available to grow wheat, sugar beets and pasture grasses. Before the irrigation project was constructed, wheat was the major crop of the area. Cropping of sugar beets, fruit trees, vegetables, clover, grapes and melons began with the application of irrigation water.

(e) **Irrigation Water.** Water for the project is supplied from the Yesilirmak River. The irrigation water does not contain harmful quantities of salts, therefore, it can be used without danger of crop damage.

(f) **Basic Units of Upper Yesilirmak Project.** This project is a multipurpose project providing irrigation, flood protection and production of electric power and includes the Almus Dam, Gomelek Diversion Dam right and left banks distribution system, pumping station for irrigating high land, and the Omala, Turhal and Amasya irrigation. The entire project is scheduled to be in operation during 1970.

(g) **The Existing Installations.** 1. Gomelek diversion dam : Water is distributed to the right and left main canals by this regulation structure.

2. The right bank main canal : having a length of 43,850 Km. conveys irrigation water to 81,000 decares in the project area. The canal has 6 m^3/sec. capacity at the diversion dam. Concrete lining is provided for 4,375 meters and the remaining part is earth. There are 9 secondary canals with a total length of 73,620 Kms. and 11,000 Kms. of these are concrete lined. The average capacity of the secondary canals is 0·4 m^3/sec. The total length of tertiary canals is 195,750 Kms. and all are unlined and have an average capacity of 0·05 m^3/sec. There are 22,600 Kms. of main and 62,420 Kms. of lateral drainage canals in the project.

Water losses are important on the main conveyance canal and the distribution system. Approximately 30 per cent of the diverted water is lost by seepage and evaporation from the main canal. To reduce these losses and prevent rise of the under ground water table, the main canal should be lined Water losses are also considerable from the secondary canals.

Lining of the main and secondary canals is included in the rehabilitation programme which is lining a segment of the system each year.

Communications are accomplished with a telephone system. Sixty kilometers of telephone line connects the ditch riders with houses and the office. There are seven ditch rider houses on the project area, one operation building, garage, repair, shop and five employees houses.

(h) **Operation and maintenance organization.** The existing organization chart for the Kazova Right Bank Project follows. The operating organization includes the irrigation and maintenance sections :

EXISTING OPERATION AND MAINTENANCE ORGANIZATION

Maintenance Service	*Operation Service*
1. Construction Workman	1. Operation Technician
2. Joiner	2. Ditchrider (9)
3. Telephone Line Operator	3. Workman (3)
4. Designer	4. Driver
5. Watchman	
6. Collector of Taxes	

(i) **Machinery and equipment needs of the Project.** At the present time the Kazova Irrigation Project does not have its own operation and maintenance equipment. When available the Regional Office will furnish construction equipment for operation and maintenance purposes, however, these cannot be efficiently used because of their excessive capacities. To provide regular

maintenance activities, the following equipment is required :

One	50 Hp.	Grader
One		Gradell
One	3/4 cy.	Excavator
One	D-6	Dozer
Two	2-3 cy.	Flat bed truck

(j) **Agricultural Development of the Project.** Land distribution by size of unit is shown in Table 3. Table 4 shows development of irrigated area since 1964. Table 5 shows irrigated area and revenue for the same period. The year 1960, when 28,504·6 decares were irrigated may be used for an economic comparison, as follows :

	Total	Per Decare
Value of crops before construction	4,040,500 TL.	141·75 TL.
Value of crops after construction	13,659,678 TL.	479·20 TL.
Gross income increment	9,619,178 TL.	337·46 TL.
Net income increment	4,983,113 TL.	174·81 TL.

TABLE 3. DISTRIBUTION OF FARM UNIT SIZES

Unit Size Decares	Number of Units
1- 10	2,006
11- 20	535
21- 30	165
31- 40	80
41- 50	42
51- 60	17
61- 70	11
71- 80	7
81- 90	6
101-160	3
161-450	8
451-870	7

TABLE 4. CROPPING PATTERN KAZOVA RIGHT BANK

Crops	1945	1946	1947	1948	1949	1950	1951	1952
Wheat	7,000	10,204	10,642	4,015	8,271	9,256	11,984	6,290
Barley	2,164	2,327	3,782	1,814	2,488	3,403	4,347	1,697
Corn	776	1,808	1,954	1,753	3,628	2,717	1,502	1,671
Oats	—	6	—	—	—	—	—	—
Beans	—	28	122	146	332	278	427	329
Peas	76	211	299	92	220	322	—	245
Soy beans	86	137	64	—	—	—	—	—
Tobacco	352	1,120	591	409	364	522	425	397
Sugar beets	3,600	4,234	4,399	4,577	4,942	4,700	7,727	5,963
Nursery Garden	30	34	128	341	385	550	643	605
Vineyard	184	236	275	237	265	318	521	498
Vegetable	782	1,050	665	1,070	1,430	1,283	1,674	1,994
Melons	714	1,316	1,225	1,636	1,151	741	428	796
Alfalfa	43	117	130	134	153	365	899	364
Fruits	51	79	131	120	119	101	150	180
Poppy	—	—	14	—	—	—	—	—
Sun flower	—	—	—	—	—	—	—	33
Hemp	—	—	—	—	—	—	—	2
Winter irrigation	—	—	—	—	—	—	—	—
TOTAL	1,5863	22,911	24,427	16,348	23,753	24,560	30,729	21,071

IRRIGATION PROJECT AREA IN DECARES.

1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
7,961	10,583	13,536	12,142	12,430	7,219	4,732	2,958	10,678	10,267	4,893
892	1,196	1,459	1,622	1,798	1,268	1,005	720	1,840	1,530	494
902	1,554	765	1,209	867	340	354	485	963	1,025	700
25	17	33	17	15	12	2	—	168	13	—
340	788	425	254	225	197	426	457	382	348	447
140	373	325	404	364	265	115	355	396	410	34
—	50	—	3	—	4	—	4	—	—	—
223	296	378	533	326	304	279	335	213	218	230
6,626	13,640	10,216	9,350	9,742	9,508	11,987	12,279	11,283	10,977	10,909
865	1,726	2,134	1,216	1,730	1,472	933	1,154	1,846	1,698	2,007
695	1,194	1,890	1,477	1,680	1,915	2,182	1,751	1,709	2,274	2,009
2,172	4,168	6,729	3,640	3,449	5,386	3,368	3,356	4,125	4,382	4,043
982	1,935	2,286	1,523	2,872	910	1,153	980	1,298	1,231	983
476	308	699	2,082	607	1,451	1,613	1,512	2,018	1,723	793
250	999	1,056	607	720	970	2,069	1,875	2,055	2,522	3,290
—	—	—	14	9	2	—	—	—	—	—
61	—	114	—	—	—	—	—	4	—	—
48	336	82	145	268	544	351	229	66	101	128
—	—	—	—	5,383	2,081	—	1,037	32	6	—
22,666	39,169	42,134	3,6244	42,493	33,853	30,576	29,494	39,081	38,729	30,967

TABLE 5. AREA IRRIGATED AND INCOME KAZOVA RIGHT BANK PROJECT

Year	Irrigated area Decares	Annual cost TL	Annual income TL
1945	1,585	21,845	14,199
1946	22,742	65,096	20,411
1947	24,426	52,954	21,271
1948	16,349	48,448	15,620
1949	23,753	75,087	21,350
1950	2,456	49,988	34,142
1951	30,790	44,198	42,481
1952	21,072	48,905	31,931
1953	22,660	47,366	34,905
1954	27,214	85,833	39,559
1955	35,450	1,12,520	52,822
1956	36,244	1,26,115	79,113
1957	36,333	3,12,800	77,873
1958	31,232	3,90,521	75,794
1959	32,429	2,11,009	1,24,291
1960	29,790	1,95,000	1,26,822
1961	39,085	12,21,309	1,71,415
1962	38,729	11,83,151	3,09,803
1963	30,897	5,26,000	2,81,369

Note : Project area is 81,000 decares. Construction cost to date is 6,273,000 TL.

REHABILITATION OF SHABANKAREH PROJECT

by

Engineer Asghar Azarnia*

SUMMARY

An irrigation project to irrigate 12,000 hectares of land along the Persian Gulf was commenced in 1941 and after various delays was irrigating about 4,000 hectares of land including 400,000 date trees in 1957. Provision for drainage was not included in the original project and by 1957 the water-table was so high and the salt accumulations so bad that most of the date trees stopped growing appreciably. Agricultural returns were low and many people believed the project should receive no more government support as it was in a dying condition.

A rehabilitation programme was initiated in 1957 to revive the project. The first emphasis was placed on drainage of the high groundwater. Later the canals were improved and some were lined. Access roads were constructed and a 17 Kilometer feeder road was constructed from the project to the national highway. The project farmers were employed during the off-season to do most of this work at prevailing local wages or with part of the wage in wheat.

By 1959 the project income began rising. The total family income of the average farmer rose from about $113 per year to $286 per year from 1957 to 1963 due primarily to the increased agricultural production and supplemental wages from working on rehabilitation of the project.

During the drought of recent years the farmers of this project were very well off compared to those in the neighbouring villages and the farmers are now planting additional date and lime trees and investing in improving their farms. The project is now considered a success although much improvement in agricultural yields is still necessary.

HISTORY

The project is located on the vast Shabankareh costal plain some 60 Kilometers north of Bushehr. The plain slopes gently from the foothills of the Sefid Kuh 50 Kilometers towards the coast. The Shabankareh Irrigation Project has an average elevation of approximately 70 meters. Maximum temperatures during the summer months may reach 52° Centigrade (126° Fahrenheit) while a minimum winter temperature of—4° Centigrade (25° Fahrenheit) has been recorded.

Rainfall ranges from 85 to 370 millimeters. The project itself has a potential area of perhaps 12,000 hectares of which some 5,000 hectares are currently under cultivation. A population of approximately 6,500 persons including 1,000 private landowning farmers, occupying 16 villages benefit directly from the project. The normal size of a farm is 5 to 10 hectares. Some eight hundred farms produce dates from 450,000 trees which are regarded as the principal crop. In addition citrus, small grain, (wheat and barley), mellons, onions, and garden crops are produced. Cotton is also grown in a very limited quantity. During the past two years some sorghums, alfalfa and sugar beets have also been produced. A small but reported successful planting of potatoes was conducted

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on a trial basis by the Fertilizer Division last year.

Irrigation water is diverted directly from the Shahpour River by means of a concrete diversion dam completed in 1941. Following completion of the dam further development of the project was delayed due to many adversities suffered within the area. During the period 1948-1951 further irrigation development of the project was undertaken. The area selected had for generations been used both for dry farming and various systems of rather primitive irrigation.

Due to a rapidly rising water table, a saline soil and a somewhat salty water supply plus the lack of proper irrigation farming principles, vast areas of the project became waterlogged, crusted with salt accumulations and swampy.

REHABILITATION PROGRAMME

The objectives of rehabilitation of the irrigation project were :

1. To take better advantage of the availble irrigation water resources.
2. To increase agricultural production and thus increase the individual income and raise the standard of living of the farmers.
3. To make it possible for the farmers to do more work and thus reduce idleness and provide social stability in the rural areas.
4. To encourage the farmers to help themselves by investing more of their private capital in order to obtain the above mentioned objectives.

The Engineers of the Irrigation Corporation, with the guidance and assistance of Point Four (US AID) and F.A.O. Technicians, performed soil and drainage studies. Commencing in 1957 the Irrigation Corporation undertook to rehabilitate the Shabankareh area.

Today, after six years I can proudly say that in spite of financial problems, as a result of devoted efforts of a group of experienced and skilled engineers towards the reclamation of Shabankareh lands, we have gained a great and outstanding reward.

There are no more traces of swamp or water logged lands. The date trees which were threatened by the rising water table are growing again and the young citrus trees, which have been established since 1957, have this year produced around 75 tons of crop.

Since 1957 some 90 Kilometers of main canals and laterals have been rehabilitated and/or reconstructed. Twenty five Kilometers of new canal servicing 1,500 hectares have been completed.

Concrete lining has been installed in some 3 Kilometers of main lateral.

Drainage canals and ditches amounting to 30 Kilometers in length have been excavated. Various water control structures including sluiceways, siphon, turnouts, etc., have been constructed in the main canal and laterals.

Present and future programmes at Shabankareh have been designed to extend both the irrigation and drainage system, to improve operation and maintenance including water application and water mastering services, and to improve cultural practices and crop adaptions. These programmes also envision the eventual formation of a local water users association, an accelerated training programme for project technicians and assistants on-project training for project assistants and local farmers in the proper management and use of water, and improved cultural and related practices. A project has been started to encourage the processing and packaging of locally grown dates. Construction was started on this facility.

PROJECT ECONOMICS

Figures 1 and 2 reflect production and income from the various crops produced on the project as well as total income for the period 1956 to 1963.

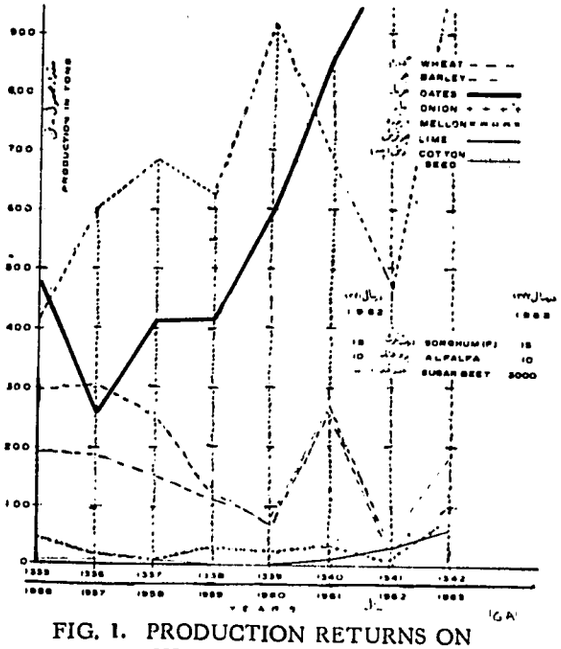


FIG. 1. PRODUCTION RETURNS ON SHABANKAREH PROJECT

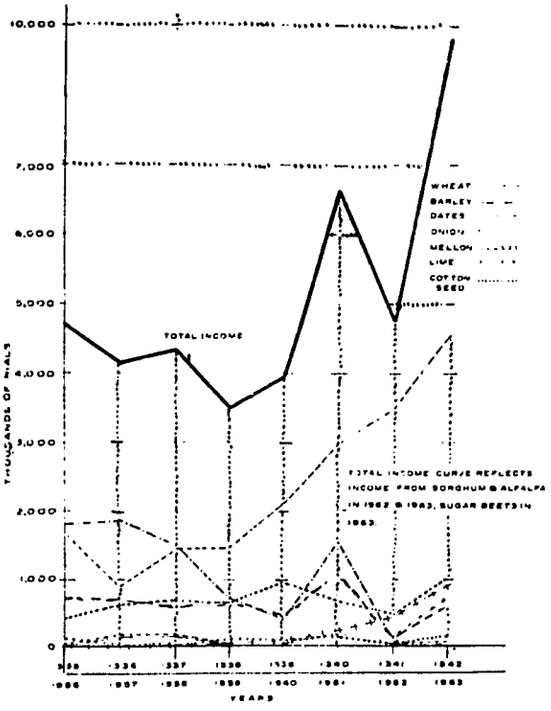


FIG. 2. INCOME ON SHABANKAREH PROJECT

The Shabankareh project clearly demonstrates the importance of developing and fully utilizing existing or potential small irrigation projects so prevalent in Iran. A summary furnished by the Operation and Maintenance Division of the Irrigation Corporation, values the dates and citrus groves on the project at 520,000,000 rials ($ 4,000,000). Direct expenditure for construction of the diversion, distribution system, drainage, etc. are shown to be some 70,000,000 rials and the present value of the system to be 50,000,000 rials. Thus the indicated value of the improvements on the project as it stands today omitting any reference to land values, appears to be in the neighbourhood of 500,000,000 rials or 100,000 rials ($ 1,300) per hectare.

It is hoped that project operations rehabilitation and/or expansion will continue at a rapid rate to the extent that water and land are available.

In the current year, Plan Organization has allocated 10,000,000 rials for the completion of the existing irrigation and drainage system US AID has provided 1,000 tons of "Food for Work" wheat.

During the past four years the farmers of Iran along the Persian Gulf have faced famine conditions due to locust invasions and lack of normal rainfall which practically eliminated any production from dry land wheat farming. Extensive food relief programmes were necessary to relieve the hunger. From 1957 to 1963 the total income of the Shabankareh farmers increased from about 8,500 rials to 22,000 rials per year or about 160 per cent due primarily to the rehabilitation work conducted on the project. The value of agricultural production increased 140 per cent in addition 300 to 500 of the farmers were given off-season employment during about 3 months in the winter in repairing and improving the irrigation and drainage systems of the project. This off season work permitted the farmers to live at home and work on putting the project into shape to better serve themselves. The average worker earned about 7,000

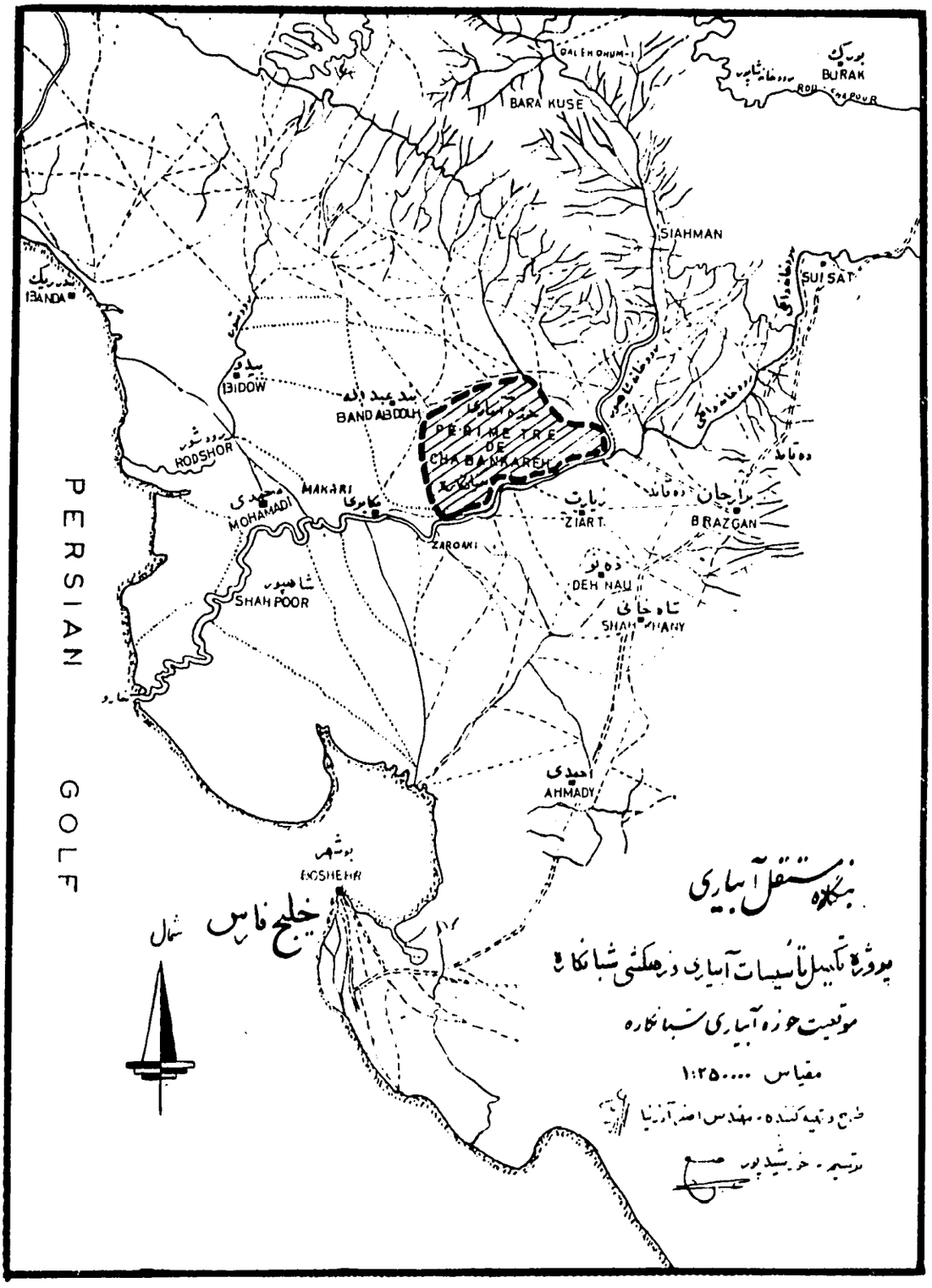
rials per season working on the project, increasing from about 4,700 rials in 1957 to 10,000 rials in 1963. This provided him with a substantial increase in income. With the improvement in the project agricultural yields and the increased interest of the Irrigation Corporation in improving the project, the farmers gained confidence in the ultimate success of the project and began investing their increased income in planting new date and lime trees and taking an interest in supporting the local primary school. They also are showing increased interest in obtaining the date packing plant. With the construction of a gravel surfaced feeder road from the project to the local commercial centre on the national highway, the farmers are becoming interested in growing more winter and spring vegetables and diversified cash crops, many of which bring premium prices when exported across the Persian Gulf to the arid Sheikhdams that are rich in oil money. Local buses and trucks are beginning to provide nearly daily transport service from the project villages to the local commercial centre and some of the farmers have this year bought pickup trucks of their own. Whereas six years ago the project was an isolated declining area, today it is one of the most prosperous farming areas along the Persian Gulf and is setting an example of the potentialities of other such areas.

The most important economical difficulty, which I imagine is not exclusive to Shabankareh alone, but is widely found in most near East countries, is the common poverty existing among the natives of the areas to b irrigated. If the government would make the commitment for the whole expenditure of irrigation development including the roads, schools, agricultural and housing investments, it would amount to about $1,250 per hectare. Therefore, the complete development of 10,000 hectares would cost a large amount of money for a relatively small area which most governments would find difficult to supply in so concentrated amounts. To find a suitable solution for this problem was the outstanding objective of the Shabankareh development programme. Through encouraging and stimulating the self-help sense of the farmers a satisfactory result has been obtained. As the completion of the irrigation net work approached, the farmers were encouraged to invest in the development of farms. In order to assist them to invest, they were assigned to work for the irrigation project in the season when the agricultural work was relatively little. The result was excellent. Not only the need of borrowing from the bank and other credit sources has been largely eliminated, but they also raised their yearly agricultural income by about 140 per cent over the six-year period. There is still much room for increasing the farm income through pest control in the dates, better salinity control and cultural practices for field crops, and a better understanding of the economics and cultural practices for winter vegetables and forages for which there is an abundant winter water supply as contrasted to a very restricted summer water supply. Efforts are now being made to introduce new crops to the area and to train the farmers in modern agricultural methods which would increase their net income.

This project demonstrates the benefits to a local area that can come through introducing the proper technical leadership and utilizing the off-season time of the farmers to improve their own project. About 35 per cent of the farmers time is available for non-agricultural work. If this time is not utilized for constructive work, it is wasted to the nation, the farmer's income is more restricted and he is unable to invest rapidly in development of his necessary farm improvements. If countries can find means of utilizing this off-season farm labour within walking distance of the farmer's home it will greatly promote the welfare of the farmer and the nation and lead to greater social stability and national productiveness.

SPECIAL PROBLEMS

The problems which have been faced during the operation, maintenance and improvement of the Shabankareh project which


BURAK
BARA KUSE
SIAHMAN
SUISAT
BANDA
BIDOW
BANDABDOLH
PERIMETRE DE CHABAHAREH
RODSHOR
MOHAMADI
MAKARI
ZIART
BRAZGAN
ZAROAKI
DEH NAU
SHAHPOOR
SHAHMIANY
AHMADY
BUSHEHR
PERSIAN GOLF
خلیج فارس
شمال
بنگاه مستقل آبیاری
پروژه تکمیل تأسیسات آبیاری و زهکشی شبانکاره
موقعیت حوزه آبیاری شبانکاره
مقیاس ۱:۲۵۰۰۰۰

should be considered in dealing with similar irrigation projects in other areas are outlined below :

1. The land must be properly shaped and prepared for efficient irrigation.
2. The farmer must obtain and properly plant good seed.
3. The farmer must be taught proper irrigation and agricultural practices.
4. The soil fertility must be built up with proper crop rotations and fertilizer.
5. The insect must be controlled.
6. More money must be invested for land development, fertilizer, seed, insect control and education of the farmers in agricultural and irrigation practices. This requires more trained instructors and farmer short courses and demonstrations as well as larger amounts of credit to the farmers, but the returns in agricultural production will return the added investment in one or two crop seasons.

Activities like shaping and preparing land for planting, providing good seed, training the farmers for proper irrigation and agricultural practices, building the soil fertility, insect control and capital investment are separate factors which are ordinarily not performed by one governmental or private organization. Coordinating the activities of different organizations might appear easy, but actually is usually difficult. Another problem is the farmers illiteracy and their ignorance of proper irrigation practice. By spending a large amount of money it is possible to build a dam in a very short period or build a net work of canals using the latest methods. But to teach a group of ignorant farmers how to read and write is a different matter. Other problems which could be removed by investing in rehabilitation of the Shabankareh project, are the following :

a. Irrigation and land levelling. The importance of land preparation cannot be over emphasised.
b. Some main irrigation canals pass through sandy soils and sandy loams, causing waterlogging. These should be lined.

Apparently most crops climatically adapted can be grown in the Shabankareh project. The saline condition of the soil and relatively high water table, two conditions which are improving and the water supply may limit the selection somewhat. Summer water supplies are limited, although are generally adequate for the present cropping pattern. Considerable expansion of crops may be expected when storage regulation of available water supplies is attained since the winter flows are relatively large and comparatively free of salt.

REHABILITATION OF OLD IRRIGATION SYSTEMS BAGRAMIE PROJECT—AFGHANISTAN

by

Abdul Mahbuub*

A programme of development of new land and water resources, rehabilitation and improvement of old irrigation systems, and effective use of these resources has been launched by the Government of Afghanistan.

As a result of this emphasis on irrigation, newly irrigated areas have been developed and new water conveyance and distribution systems have been constructed. However, large areas are yet to be developed during the next few years.

The programme of rehabilitation and improvement of old irrigation systems has resulted, very recently, in the reclamation of certain irrigation schemes in the country. In addition, certain canal systems are presently under construction while preliminary plans and surveys have been made for others.

The rehabilitation of the Bagramie Valley system was selected as a pilot project under the Self-help Irrigation Programme where the farmers contribute all of the labour, share in the construction costs, and provide the maintenance after completion. The selection of this area was made upon agreement between the farmers, Ministry of Agriculture, and the local government.

The Bagramie Valley is located approximately 15 kilometers southeast of Kabul city. From the standpoint of agriculture, this valley is one of the most productive of Kabul Province. Its location near the city of Kabul provides excellent possibilities for improvement of agriculture and other general development.

Since it is located near a high population centre a relatively high proportion of agriculture income is derived from vegetables and fruit.

The soils of the valley are deep alluvial, highly productive, and suitable for the production of vegatables, fruits, and small grains. When an adequate supply of water is available, two crops per year are easily produced in the valley.

Almost all of the agriculture in the valley is dependent upon irrigation as in practically all of Afghanistan. Dryland farming is almost non-existent due to low annual rainfall. Although some dryland wheat is raised in the South and Eastern foothills of the valley, the yields are very poor.

The entire valley is served by three main canals from the Logar River. These canals include the Kamari, Shewaki, and the Shina. A small portion of the valley is irrigated from the Ghazi Reservoir which is located in the southeastern part of the valley. This reservoir, however, only collects flood water during the spring for use later on during the irrigation season.

The major problems of the area represent typical problems existing in almost all of Afghanistan. One of the most serious is the shortage of water in the lower sections of the canal. Such shortage of water is caused mainly by an improper water distribution system. As a result, the farmers upstream use more water than they actually need while those downstream receive less than the required needs

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of the area. Upstream on the canals one sees orchards, vegetables and other high income crops, while it is hard to find, in the downstream areas of any of these canals, crops being grown which require large quantities of water. In fact, a large area is left fallow each year due to shortages of water while observations have shown that the soil in these downstream areas has the potential of being as highly productive, or even more so, than the soils of the upstream areas. As a result, the income from almost one-half of the area is far smaller than could be realized if a proper irrigation conveyance and distribution system were in operation.

As a programme of rehabilitation of the old irrigation systems, the government is interested in the improvement and possible relocation of the Bagramie Valley irrigation and distribution system. This is to be used as a demonstration and training project. The experience and training obtained from the project will be used in other parts of the country where similar problems exist.

KAMARI CANAL

The total length of the canal is 23 kilometers with turnouts approximately 50 to 60 meters apart. Occasionally they are much closer and it is estimated that there are a total of 1,500 turnouts throughout the length of the canal. The total area irrigated by the canal is estimated to be 1,600 hectares. The flow in the canal, as measured, is 3·5 to 4·0 cubic meters per second. A flour mill is located 200 meters from the intake which uses ·5 to ·7 cubic meters per second. This water, of course, returns to the river leaving 3·0 to 3·3 cubic meters per second of water for irrigation. Even though this flow is more than adequate for area served by the canal, there is a shortage of water downstream.

The temporary diversion and intake, which diverts the entire Logar River into the canal during the irrigation season, is made of stone, brush and sod. (Figure 1). It is similar to most of the temporary diversion intakes in the country and is always subject to being washed out by floods several times a year.

SHEWAKI CANAL

The intake of this canal is approximately 1·5 kilometers downstream from the Kamari Canal intake. The total length of the canal is approximately 19 kilometers and it serves 1,100 outlets to laterals and small farm ditches. The area irrigated by this canal is estimated to be 1,000 hectare.

This intake is also a full river-width diversion and is similar to that of the Kamari Canal diversion and intake. The flow in this canal is from seepage to the river and from the flour mill below the Kamari intake. The flow is approximately 1 cubic meter per second.

SHENA CANAL

This canal is relatively much smaller and serves but a small area compared to the Kamari and the Shewaki canals. It has, however, the same problems.

The general problems of the area have been pointed out and it is easy to understand that the distribution of water between numerous turnouts (many of which serve small fields) is a tremendous job and results in a great loss of water.

Many of these turnouts are made of brush, mud and stone (Figure 2) and when washed out are difficult to reconstruct. A few of these turnouts consist of a large stone in which a hole has been hewn (Figure 3). Such holes are for the purpose of permitting a certain amount of water through in proportion to the land they serve but they are by no means exact methods of measuring or regulating the irrigation water.

It is evident that control and proper distribution of irrigation water from these turnouts is impossible. As a rasult, it was decided to develop a new plan of water distribution and improvement of the entire canal system. Construction work is expected to start in the spring of 1964.

Result of a preliminary survey revealed that only 22 turnouts (instead of 1,500) from

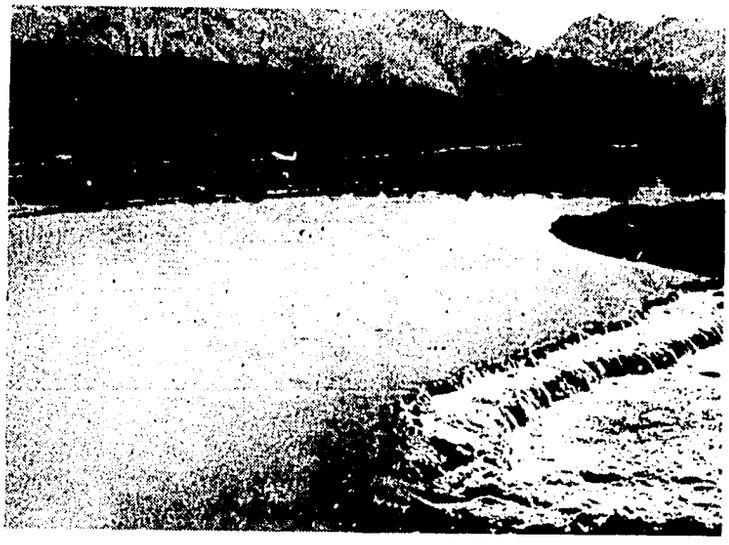

FIG. 1

ROCK AND BRUSH DIVERSION AND INTAKE

FIG. 2

ROCK, BRUSH AND MUD OUTLET

FIG. 3

STONE OUTLET WITH HEWN HOLE FOR WATER DISTRIBUTION

the Kamari Canal could serve the entire area and thus eliminate the primitive turnouts, prevent waste of water, and definitely ease maintenance work on the canal.

For the Shewaki Canal it was found that only 18 turnouts (instead of 1,100) would be sufficient to provide water to the area being served by the canal. In each case the number and approximate location of the turnouts were determined from an aerial photo map of a scale 1/25,000 then checked in the field.

It is estimated that each of these newly selected turnouts will serve an area of 50 to 100 hectares.

In addition to constructing the new turnouts, it is planned that a new intake diversion structure will be built combining both the Kamari and Shewaki Canals. Approximately 3 kilometers downstream a bifurication structure and branch canal will be constructed to divert water into the present Shewaki Canal. This will eliminate one diversion from the Logar River, one flour mill, and 2 kilometers of main canal which presently parallel each other.

At present, the survey and maps of the L-section as well as a C-section at 200 meters intervals for both canals have been completed. Also, the topographic map of the area which will be used to determine water distribution and area to be served by each turnout, and relocation of present canals will be completed in the near future. The topographic survey of the areas where major structures will be constructed has been completed and the design of some of the structures will be started very soon.

In addition, the required number of gates and an equal number of Parshall flumes have been ordered from Jangalak factory. The maximum capacity of each gate and Parshall flume is 80 liters per second.

The preliminary costs of the project are estimated to be 10 million Afghanis. Labour for excavation and general work is to be supplied by the farmers under a self-help Programme.

It is estimated that the improvements to the irrigation system and redistribution of the water will increase the total production by 50 per cent. The benefit-cost ratio for the project will be 1·75.

CHAPTER IX

DRAINAGE AND SALINITY

IRRIGATION AND DRAINAGE PRACTICES IN RELATION TO SALINITY CONTROL IN SOILS OF EDKO DISTRICT U.A.R.

by

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INTRODUCTION

Edko district is that area of dried land located at the Northern end of Edko Lake and on the route from Alexandria to Rashid.

The reclamation of this area was first decided upon in 1955, with the purpose of distribution of the land among the farmers of Edko. Soil survey, drainage, irrigation and economic studies were made. The permanent Organization of Land Reclamation began reclamation processes in 1956.

The gross area of the project is about 2,700 feddan* surrounded by a ridge and is divided into Eastern Edko, (1460 feddan) and Western Edko (1,240 feddan).

Edko drainage separates the two plantations and removes the drainage water by pumping to the Mediterranean Sea.

GENERAL CONDITIONS

Climate. The daily maximum temperature ranges from 18·8°C in January to 31·8°C in August, and the daily minimum, from 6·7°C in January to 20·1°C in July. The mean relative humidity is 68 per cent in May and 79 per cent in January and December. The rainfall is about 41 mm. in December, 36 to 37 mm. in January and February and the rainless season extends from June to September.

Topography and Relief. The lands are flat ranging from 0·3 to 0·8 meters below the sea level.

Irrigation. The lands are irrigated by Edko Canal. The saline drainage waters of Bosseli Main Drain were used in leaching saline soils under reclamation.

Drainage. Using information on soils, under-ground water, crop patterns and climatic conditions, the drainage system was planned by civil engineers. The field drains were 90 to 100 cm. in depth, 60 to 70 m. in length and 25 to 30 m. apart ; the secondary drains were 110 to 120 cm., 250 to 350 m. and 140 m. ; and the main drains were 130 to 140 cm., 600 to 700 m. and 300 to 350 m.

* Feddan=4,200 m²

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Soil Characteristics. The soils of Edko area are generally lucastrine saline soils. Soil texture varies from sandy to clay loam in the surface layers while the subsoil layers are heavy clay. The structure of the light surface layers is friable and granular while that of the subsoil layers is highly compacted. The infiltration rates of the surface layers were adequate for good reclamation and irrigation practices, but those of the subsoil layers were very low. The total soluble salt content of surface layers was very high reaching about 10 per cent, but the subsoil layers were less saline. Sodium chloride was the dominant salt while magnesium chloride, magnesium sulphate and calcium sulphate occurred in less but appreciable proportions. The soluble calcium percentages tended to be low. The cation exchange capacities of surface layers ranged between 7 and 15 M.E. per 100 gms. of soil, and reached 47 M.E. per cent in subsoil layers. The exchangeable sodium percentages varied between 6 and 22 in the surface layers while they reached 38 in subsoil layers. Considering high salinity, the pH values appeared to be somewhat low, ranging between 8·0 and 8·4. The total carbonates were very high, reaching about 17 per cent due to the presence of shells and calcium deposits in soil profile.

The Scheme of Soil Reclamation and Improvement

After the construction of the artificial works, installation of irrigation and drainage systems and levelling partitions; detailed investigations dealing with the different conditions prevailing were conducted. The features of soil improductivity, the degree of salinity and alkalinity, the depth and salinity of groundwater, etc., were fully described and soil and water samples were taken and analysed. A systematic scheme for the reclamation and improvement of this area was planned considering to the following unfavourable natural conditions.

1. Very high soil salinity (more than 9 per cent)
2. Extremely great salinity of high underground water reaching 90,000 p.p.m.
3. Very low degree of infiltration of the highly compacted subsoil layers.
4. The different conditions contributing to rainsing the underground water-table, such as direct and indirect influence of tides, the hydrostatic pressures from the sea and the Rosetta Nile branch, and the extremely flat relief.

Control of salinity and improvement of the soil were attained through two successive stages.

A. The leaching and reclamation stage which included :

1. Heavy leaching which was done by repeated floodings at rates amounting to 600 cu. m./feddan accompanied by efficient drainage. These aimed at reducing the salts to 0·2 per cent, reducing the salinity of the groundwater to less than 2,000 p.p.m., and lowering the water-table. Due to the local soil conditions, it was found necessary to carry out deep ploughing and subsoiling before leaching.
2. Applying artificial gypsum during late course of leaching in order to prevent alkalinization. The drainage water of Bosselli drain was successfully used for leaching.

B. The cultivation and improvement stage which included :

1. Maintenance of the reclaimed soil and prevention of resalinization and alkalinization by providing efficient drainage, especially by intensive pumping of drainage water from transporting collectors; by continuing periodical and seasonal heavy leachings, for several years; and by cultivation of salt tolerant crops, practicing suitable rotation and adopting agricultural techniques suitable for saline soils.
2. Improvement of soil physical, chemical and biological properties by periodical

subsoiling or changing secondary drain locations to overcome the unfavourable conditions caused by the highly compacted subsoil layer ; and by enrichment of soil with organic matter and adequate fertilizers in order to improve its structure and compensate for plant nutrients leached out. During this stage, a permanent source of suitable irrigation water was used.

It was of great importance to follow the progress of soil desalinization through periodic soil and water analyses in order to fix the end of heavy leaching and beginning of cultivation for different partitions.

Edko District (1959)

Soils samples from different partitions representing different degrees of productivity, as well as samples of drainage and underground water, were taken for analysis. The degree of soil productivity and its agreement with salinity and alkalinity are clearly shown in Table 1.

TABLE 1

Degree of soil productivity	Area	Cultivated crops	Salinity	Alkalinity
Good	26%	Good cotton. rice and maize	Low	Almost free from alkalinity but poor in soluble calcium contents
Fair	30%	Fair rice, maize and tomato	Medium	Free from alkalinity but almost poor in soluble calcium content
Poor	27%	Very poor crops and heavy grasses	High	Free from alkalinity
Barren	17%	Almost barren	Very high	Free from alkalinity

Water Studies

Drainage water used for irrigation. Table 2 shows the analysis of different drainage waters which were partially used for irrigation during the cultivation and improvement stage.

Although six water samples are of low suitability for irrigation purposes they can be used successfully in leaching the highly saline soils, or for a limited number of irrigations, either alone or after mixing with appropriate amounts of suitable water.

Collector Drain water. Table 3 shows that the drainage water of the eastern plantation was much less saline than that of the western. The leaching processes were faster in the eastern than in the western plantation, which was shown to be in need of further salt removal. These results generally correlate with productivity (Table 1).

There was remarkable removal of harmful sodium and magnesium salts as well as appreciable loss of soluble calcium.

Ground Water. Table 4 shows the chemical analysis of ground water samples. The under-ground waters of both plantations were still very highly saline, but less concentrated for the easter plantation, confirming the fact that the leaching processes proceeded faster in the eastern plantation

TABLE 2. IRRIGATION WATER ANALYSIS.

Sample No.	Location	T.S.S. P.P.M.	Anions Meq/100				Cations Meq/100			S.A.R.	pH.
			CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na		
1.	Irrigation of West Plantation	2934	—	5·0	34·20	3·98	5·43	10·53	27·22	9·72	8·7
2.	Bousali drain (West. plant.)	1947	—	4·71	22·94	2·77	5·42	5·21	20·78	9·02	8·60
3.	Bousali drain in connection to Edko Canal	1770	—	4·71	20·52	2·98	6·52	4·12	17·57	7·0	8·75
4.	Bousali drain under Mayah bridge	1643	—	4·79	20·52	3·16	6·52	4·12	17·83	7·75	8·6
5.	Edko drain in front of part 3 Halk El Gamal	2149	—	4·87	27·26	5·31	6·52	8·37	22·65	8·39	8·75
6.	Edko drain in front of the new drainage station	2123	—	4·79	23·94	5·09	4·35	7·35	22·12	9·22	8·6

TABLE 3. COLLECTOR DRAIN WATER ANALYSIS

Sample No.	Situation	T.S.S. P.P.M.	Anions Meq/L				Cation Meq/L			S.A.R.	pH.
			CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na		
7.	Eastern Edko collecting drain of Howashes 3,4, 7, 8, 12 and 13	3868	—	6·0	46·17	5·94	8·69	8·33	41·09	14·1	8·6
8.	For Howashes 17, 2,20,21,24 and 25	4019	—	5·23	47·88	9·66	15·22	3·93	43·58	14·1	8·7
9.	For Howashes 1, 2, 9, and 10	3843	—	5·5	47·88	6·17	8·69	8·33	42·53	14·61	8·7
10.	For Howashes 15, 22 and 23	4854	—	5·67	61·56	9·03	8·69	12·59	54·98	16·86	8·65
11.	Western Edko general drain at old drainage station	12·640	—	7·17	188·100	16·82	5·22	39·03	157·84	30·35	8·55
12.	Housha 2	24977	—	11·33	376·20	30·46	5·22	80·52	322·25	46·7	8·60
13.	Housha 9	5056	—	6·50	64·98	10·35	8·69	13·65	59·49	18·03	8·75

TABLE 4. ANALYSIS OF UNDER GROUND WATER SAMPLES

Sample No.	Situation	T.S.S. P.P.M.	Anions Meq/L				Cations Meq/L			S.A.R.	pH.
			CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na		
14.	Eastern Edko Housha 17 prof. 4 depth 80 cm.	57460	—	10·08	930·57	30·36	61·95	217·83	691·23	58·48	8·05
15.	Housha 6 prof. 1	43448	—	14·17	689·37	30·37	36·95	105·28	546·68	56·63	8·30
16.	Western Edko Housha 3 prof. 1 depth 50 cm.	91035	—	10·00	1542·1	30·06	36·95	270·49	1236·82	70·55	8·40
18.	Halk El Gamal Housha 6 prof. 3 depth 50 cm.	72582	—	2·54	1179·42	30·55	42·39	239·52	848·60	79·91	8·00

TABLE 5. EASTERN PLANTATION SOIL SALINITY SAMPLES

Housha No.	Profile No.	Depth cms.	Total soluble salts % of air dried soil	Anions Meq %				Cations Meq %			Productivity
				CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	
1	8	0-25	0·51	0·37	1·68	4·67	2·07	1·35	0·52	6·92	Good
		25-50	0·52	0·47	1·68	5·10	1·35	1·17	0·19	7·24	
		50-100	0·93	0·37	2·43	11·90	1·06	0·43	0·70	14·48	
2	6	0-25	1·01	0.28	1·82	11·90	2·55	0·78	1·09	14·68	Fair
		25-50	1·47	0.28	2·01	19·38	4·34	0·65	1·26	24·10	
3	3	50-100	2·78	0·19	1·73	39·78	4.87	1·41	3·06	41·60	
		0-25	0·49	0·19	2·53	4.08	1·23	0·78	0·54	6·71	
3	3	25-50	0·70	0·37	2·34	6·46	2·47	1·32	0·67	9·75	
		50-100	1·40	0·66	2·25	15·30	4·64	0·52	1·23	21·10	
1	1	0-30	4·16	0.00	1·31	51·34	18·68	17·39	17·29	36·65	Barren
8	3	0-30	0·77	0·12	1·59	10·88	0·87	1·48	1·87	10.18	Fair
14	3	0-30	2·90	0·19	1·31	33·32	12·23	5·65	6·37	36·03	Barren
17	3	0-30	0·81	0·28	1·45	6·46	4·85	3·65	2·73	6·66	Fair

The high salt concentrations in the underground waters show that the reclamation had not come to completion, since they appreciably exceed the critical limit (2000 p.p.m.). Therefore, seasonal and periodical leachings, must be continued for several years.

Laboratory Soil Investigations

The analytical data shown in Tables 5 and 6 are examples of soil salinity and generally agree with the corresponding productivity. Sodium chloride and sulphate remain the dominant salts, while calcium sulphate represents a lesser proportion. The presence of carbonate ions in the 1 : 20 soil-water ratio indicates the beginning of soil alkalinization which is confirmed by a criterion based on the ratio of soluble sodium to calcium plus magnesium ions adopted by the author to differentiate between different degrees of soil salinity and alkalinity. The exchangeable sodium figures were used to calculate gypsum requirements for leaching soils of low salinity.

The highly compacted subsoil layers at about 50 cm. depth are alkali due to the high underground water having extraordinarily high salt concentrations and very high S.A.R. values. Deep ploughing, subsoiling, artificial application of gypsum, and organic manuring are of great importance in reclaiming this subsoil layer.

In 1961, the reclamation of Edko area was completed and the soil productivity was considered to be fairly good. The new reclaimed lands were distributed among the Edko farmers and cooperatives were established to provide farmers with production requisites.

TABLE 6. WESTERN PLANTATION SOIL SALINITY SAMPLES

Housha No.	Profile No.	Depth cms.	Total soluble salts % of air dried soil	Anions Meq.%			Cations Meq. %				Productivity
				CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	
3	1	0-25	3·34	0·19	0·47	42·84	7·30	5·23	6·09	39·48	Barren
		25-40	1·11	0·19	0·65	15·30	1·51	1·61	1·23	14·81	
		40-70	1·11	0·28	0·70	14·96	1·37	2·21	1·30	13·80	
5	1	0-25	1·05	0·28	1·87	9·17	4·16	0·76	0·65	14·7	Poor
		25-60	1·20	0·37	1·68	12·58	4·56	0·56	0·77	17·86	
6	1	0-25	1·31	0·28	1·03	13·60	5·86	1·45	1·75	17·57	Poor
8	1	0-30	1·70	0·19	0·94	17·00	8·18	3·01	0·31	22·99	Poor
11	1	0-30	1·01	0·28	0·94	12·92	1·05	0·88	1·07	13·24	Fair
13	1	0-30	0·76	0·19	0·94	7·14	2·21	0·96	0·95	8·57	Fair
16	1	0-25	0·73	0·56	1·78	7·41	1·15	0·52	0·49	9·96	Fair
19	3	0-30	0·61	0·19	1·03	6·46	1·18	0·68	0·60	7·58	Good
20	1	0-25	3·54	0·00	0·47	33·32	20·28	8·64	7·76	37·67	Barren
22	1	0-25	3·49	0·00	0·65	29·58	23·19	9·65	7·33	36·44	Barren
25	1	0-30	2·73	0·19	0·73	28·56	11·16	3·01	3·04	34·59	Poor

Soil water ratio 1/20

DRAINAGE DEVELOPMENT AND PROBLEMS IN IRAQ

by

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SUMMARY

Drainage problems and the implementation of necessary drainage projects have been the acute concern of the responsible authorities in Iraq in recent years. The need for drainage has been realized in the past few decades, but its implementation has not been quite accomplished. Even at present, among the very few executed projects, there is no one single drainage project which is functioning completely.

The need for drainage has been realized only as an outcome of the deterioration and the dangerously decreasing fertility and productivity of agricultural lands due to their salinization, solonization and solidization. Drainage now is the main hope for restoring these lands to their once fertile and productive state, improving their produce, increasing their yields and ultimately furthering the economic development of the country.

Historical and some archeological investigations and studies made have shown no indication of artificial drainage having been practised in Iraq during the past 6,000 years of irrigation agriculture and land development. But the hazard of salt accumulation in the soil was realized long ago and efforts were made to combat it. The flat sedimentary alluvial plane of central and southern Iraq however, could not and cannot but require artificial drainage as an effective step for removing excess irrigation water and controlling the water table at a desirable level. Modern irrigation projects which were started around the period of the First World War and until the last decade were constructed without drainage schemes.

Drainage investigations are now being carried out gradually in an effort to provide in the future, an area of about 18,000,000 misharas (equivalent to 11,100,000 acres) of land, under-drainage a collosal task which will require about 500,000,000 Iraqi Dinars (equivalent to 500 million Pounds Sterling) for its completion. Drainage projects already executed constitute only a small percentage of what is required in area or expenditure. Even in this small portion of executed drainage projects, only the outlet pumping stations and few main and lateral collector drains have been completed. The problem of constructing the farm drains, the search for a more favourable and less hazardous drainage outlet, aside from the Tigris and Euphrates rivers, and education of the farmers for better understanding of more efficient irrigation water use are among the main drainage problems being studied.

INTRODUCTION

Drainage in Iraq, as well as in any other country, is an important and integral part of agricultural land and water use. It is therefore a complementary element to irrigation, soil and agricultural studies and implementations in any agricultural land development. Any negligence or mishandling of any of these elements will affect the other and ultimately affect the whole development. On the other hand such elements, whether directly or indirectly, are affected by the social, political and economical standards of

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the country. Any progress or decline of standards will undoubtedly affect these elements. Prosperity of certain eras in agricultural development has been observed to have been associated with high social and economic standards and powerful government policies. On the other hand civilizations were wrecked, cities were ruined and lands were abandoned in the past not mainly because of political wars and invasions but due to negligence or ignorance in any one feature of agricultural land and water use. The lack of adequate drainage, whether due to ignorance or negligence, and which lead to soil salinization and alkalization and hence to nonproductive state of land is a vivid example both in ancient and modern history.

Iraqi soil is no longer the fertile productive soil it was in the past. It is estimated that nearly two-thirds of the agricultural land in Iraq is either saline or alkaline to some degree. This has been mainly due to lack of drainage. Drainage therefore is the only hope for restoring productivity to these lands.

The topography of Iraq is such that only in the northern part are slopes adequate for natural drainage. The central and southern flat alluvial plains with there generally fine-textured soil require artificial drainage. Fortunately appreciable quantities of gypsum, lime, calcium and magnesium cations are found in the soil and irrigation water. With better irrigation methods, with more efficient use of water and with adequate artificial drainage poorly productive and non-productive soils can be made productive.

Although the need for drainage has been only recently realized, great efforts are now being exerted in the necessary planning so that in the near future new, as well as present, irrigation projects will be provided with adequate drainage. The problems of drainage are numerous and difficult, and require immense financing, time, and wise and efficient planning and management.

HISTORICAL DEVELOPMENT

Agricultural land and water use in Iraq is not a new trade. Old canal banks, ruins of old cities and archeological discoveries all show that for 6,000 years, irrigation agriculture has been well-known practice. Many ancient systems of water networks have been effectively used as the basis for new modern systems. Historical studies indicate that water-use for agriculture was simple in the old days. Pre-historic and early historic settlers started using water from naturally regimed water courses. Artificial water courses were not used. Uncontrolled flooding through breaches made in the banks was probably the main, if not the only method, for water application. Agricultural settlers were therefore confined to narrow, isolated strips of land along the banks of short water courses. They sought level lowlands that could be easily flooded. Short water courses simplified their problem of clearing the silt which later ruined canals and caused their abandonment.

Cycles of land abandonment, traced historical studies, show a composite of natural, social and political reasons. Immediately before the Christian era and shortly after, a revival of land development was marked both by an increasing density of population and of water course networks. During the early statemanship of the Abbasides this reached its peak. Water was drawn inland long distances from the main source through an expensive artificial network of water courses. Means for controlling use of water was highly developed. This expansion, however, required a high degree of maintenance which was later neglected. This was followed by a sharp decline in land development which reached a low stagnant period continuing until the early part of the present century.

There are no indications that artificial drainage occurred during all this time. This shortcoming coupled with the flat slope of the alluvial plain and with the accumulation of salts brought gradually to the lands by irrigation water, has caused the soil to salinize. Salinization, therefore, has accompanied the history of land and water use. The danger of salinity has always been realized.

As lands became less productive and more salt tolerant crops were used. Methods of combatting salt accumulation apparently were inadequate. Water-tables, which today would be controlled by artificial drainage, were then lowered by indirect means such as avoiding over-irrigation, practice of weed-fallow in alternate years and, if necessary, abandoning the land for some long period. Historical findings have shown that the problem of salinity started about 2000 to 3000 B.C. in the southern part of the country and continued to menace other parts at different times. The last decline due to the salt problem, was some few hundred years ago. Historians state that the break-up of the ancient Sumerian civilization and even the disastrous decline in land productivity during the latter period of the Abbasides was mainly due to salinity.

This brief historical review notes that artificial drainage as it is now practised did not exist in the past. The old methods practised did not prove to be adequate. The change in the soil to a finer texture due to silt deposits ; the flat slope of the plain which prevents natural drainage ; the intensified use of land for agriculture ; the over irrigation to wash down the salts, (only to cause a rise in the water table) all must be treated through artificial drainage. While in Iraq, the need for drainage was realized a few decades ago, full investigation and execution of drainage projects, did not start until the last decade. Drainage now constitutes the top concern of the responsible authorities of the country.

HYDROLOGICAL AND TOPOGRAPHICAL REVIEW

Climate in Iraq is a composite of continental and mediteranean basin types, with local differences. The presence of mountains in the north, the alluvial plain in the central and southern parts and the desert section in the western and south western areas are the reasons for the complex nature of the climate.

Rainfall in Iraq is seasonal. It varies from a maximum in the north of 400 mm. and higher annually 100 to 150 mm. in the central and southern part of the country. Rainfall occurs mainly during November through April, with 50 per cent or more occurring between January and March.

The temperature change between winter and summer is great, as it is between day and night. July and August are the hottest months of the year, when the temperature in shade may get as high as 120°F. or more, with a low humidity averaging 15 per cent. In winter the temperature may fall below freezing (to 20°F.) with an average humidity of 50 per cent. Diurnal variation range from 85°F. to 19°F. during winter and from 120°F. to 65°F. during summer.

Tigris and Euphrates rivers are the life blood of Iraq. They have their head waters in Turkey. The Euphrates passes through Syria before entering Iraq. They join to form Shutt Al-Arab about 130 kilometers north of the Arab Gulf. Tigris has five tributaries in Iraq, whereas Euphrates has none. Together they provide about 75 milliards of cubic meters per year, 44 milliards from Tigris. The drainage area of the two rivers in side Iraq is about 359,300 square kilometers of which 221,000 is in the Euphrates basin. The flow in both rivers varies immensely during the year. Tigris has recorded an average minimum of 170 cumecs around September and about 4,000 cumecs, in April in Baghdad ; with a registered maximum of 8,100 cumecs in 1946. Euphrates has an average of 210 cumecs around September and an average maximum of 3,800 around April, with a registered maximum of 5,300 cumecs in 1929. Unlike the Nile river in Eygpt, the Tigris and Euphrates flood late in the spring ; to late for the winter crops and to early for the summer crops. Several reservoirs have been built and others are planned for storing excess flood waters to be diverted back into the rivers during deficient period of flow. Water of the two rivers is classified as Class I for irrigation. It contains between 200 to 400 parts per million dissolved salts, with the

amount increasing towards the southern part of the country.

Groundwater in the alluvial plains is salty and unsuitable for irrigation. Due to lack of drainage and the flat slope groundwater rises close to the surface in most parts of the alluvial plain, causing water logging in some parts.

The topography of Iraq is a composite of rugged mountain terrain reaching 4,000 meters elevation, and foot-hills in the north and plateaus, flat alluvial plains and desert areas in the central and southern parts and reaching to see level elevation at the Gulf. The western and south-western desert areas are barren or with desert grasses, camel weeds, and herbaceous plants as common vegetation. In the southern and southeastern areas several marshes still exist. These contain dense vegetation of reeds, sedges, water lilies, Bermuda grass and other types of grass.

Of the 452,500 sq. kilometers of land in Iraq, 190,000 sq. kilometers is desert where irrigation is not possible. Thirty-six thousand sq. kilometers is mountainous area where water and rainfall are sufficient for the vegetation that can grow there. The remainder is a sedimentary alluvial plain which forms the most important part for agricultural development.

The slope of the alluvial plain is nearly flat, only about six centimeters per kilometer between Baghdad and the Gulf a fact which clearly dictates the necessity for artificial drainage in this area. The rapidly increasing slope to the north of Baghdad presents possibilities for natural drainage.

The soils of Iraq have developed under the influence of sub-tropical, continental and arid climates from such parent materials as limestone, sandstone, conglomerate, basalt and andesite. The prevailing taxture of the soils is silty clay loam or silty clay, and they are in general calcareous. Many of the soils have become saline or alkaline due to lack of drainage and continuous accumulation of salt from the irrigation water. Presence of gypsum, calcium and magnesium cations, however, will facilitate the problem of reclamation. In the southern part of the country especially, where boron is found in the soils of some lands, reclamation may not be feasible economically.

From this review of the hydrological and topographical aspects of Iraq it is clear that the semi-arid climatical condition resulting in scarcity of rainfall ; generally warm weather, together with the high water table ; the flat slope and the fine textured soil condition necessitate artificial drainage in the alluvial plains for any new irrigation project as well as for existing ones ; the latter being for the purpose of reclamation and maintaining them in a cultivable state.

PRESENT AGRICULTURAL LAND AND WATER USE

There is about 48 million misharas of land in Iraq which is suitable for agriculture. This constitutes about 25 per cent of the total land area. Slightly less than 50 per cent of this suitable area is now under agriculture. This may be divided into three categories : (a) The dry farming area, which is about 50 per cent of the area and is in the northern part of the country where rainfull is adequate, (b) the pumping irrigation area which constitutes about 25 per cent of the area and is along the banks of the two rivers in the central and southern parts and (c) the gravity irrigation area, which is also about 25 per cent of the area.

The method of farming practiced in Iraq presently is the fallow system. where only 50 per cent of the land is cultivated, and the rest is left fallow, with an annual rotation in cultivation between the two halves of the area. During summer only a small portion of the allowable cultivated part is actually put under cultivation for summer crops. This is due to the deficiency of water supply and the increasing demands for water for summer cropping. The fallow system has been practiced for several reasons, among which the inadequacy of water supply, allowing the soil to

become nutritious (since fertilization is not adequately practiced), and finally to permit the water to recede in level in the uncultivated section. Intensive agriculture to replace the fallow system is being studied for future application using water from reservoirs during summer to supplement the river water together with necessary drainage system.

Irrigation projects in the modern history of Iraq were started during the second decade of this century, following report submitted to the government by Sir William Willcocks in 1911. In 1914 the first Hindiyah Barrage was built on the Euphrates River. Later, other irrigation projects were begun. However, they were not based upon a comprehensive plan for the whole country. Politics and the influence of the feudal system affected the choice and execution of the projects. Drainage did not accompany irrigation project development, an omission, regardless of the reasons, which has greatly aggrevated the problem of soil salinity and alkalinity. The reduction of the productivity in some areas was so great that lands were deserted and farmers were moved into cities, especially Baghdad.

Many of the agricultural lands in Iraq were under the feudal system until establishment of the Agrarian Reform Law after the Revolution of 1958. Under the feudal system, where in some cases immensely large areas were owned by individuals, the irrigation systems were built to suit such large areas. A great many of these areas were too large to be properly cared for and were left undeveloped. This, coupled with unwise of use water, poor management of the soil and lack of drainage lead to lower land values. Agricultural yields at present have been valued at about three to five Iraqi Dinars per mishara annually. With proper practice of irrigation, drainage, and soil management this value could be raised five times or more.

Agricultural land values in Iraq are very low compared to other similar areas. Statistical studies have shown for example, that the ratio between the production of some crops in Iraq, Egypt, The United States and The United Kingdom is as 1 to 4, 2·5 and 5·5 respectively.

The Agrarian Reform Law has not yet completed land division and distribution. In general it provides for allocating 1,000 misharas of irrigated land and 2,000 misharas dry farm land to old land owners formerly possessing larger areas. The remaining areas are to be divided among farmers into areas of 40 to 60 misharas depending on the productivity of the land, its closeness to main roads and other social aspects being taken into consideration. With Agrarian Reform, irrigation and drainage systems built for the already cultivated areas will have to be revised and remodelled to suit the smaller land divisions. Higher investment per unit area will now be required. The problem is still under study to find the best solution.

Farmers in Iraq are uneducated, especially with regard to efficient use of irrigation water. Irrigation efficiency is low. Farmers tend to over-irrigate. In some cases purposely to wash down excess salts, but with the lack of drainage systems this aggrevated salinity conditions. Although advisory centers for farmers have been formed, the number is quite low and such centers have to be increased and their programme of work revised and expanded for more effective results.

One of the serious social problems which has arisen and still causes serious concern is the migration of farmers from the country to the cities, especially to Baghbad. This condition still prevails at a time when the rural areas need more attention and development. This an unbalanced state will continue until means for raising the productivity of the lands are placed in operation and the Agrarian Reform Law is fully applied.

REALIZATION OF THE NEED FOR DRAINAGE

Early efforts to lower water table by weed fallow system or by restricted water use had limited application, since with growing land

development and more intensified agriculture, they did not prove adequate or lasting. With the down-fall of the Abbasides and the continuous negligence in agricultural land and water use lands continued to deteriorate and the salt problem to become more acute.

The need for drainage was finally realized after the first quarter of this century, and the first drainage and salinity investigation was carried out around 1927. However, irrigation projects which were constructed after that date were still without drainage schemes. Abu Ghuraib, Saqlawiya and Yousifiya irrigation projects, the earliest of the modern irrigation projects constructed about a quarter of a century ago, had no drainage systems*.

More drainage investigations conducted on experimental plots or carried out on a large scale for large project areas were continued and intensified in different parts of the country. Drainage projects were then studied and planned according to information obtained from the investigations, and execution of some parts was started. However, this included only excavation of the main and some lateral collector drains, with pumping stations to pump the drainage water into the rivers. Pumping in all completed projects and in most, if not in all, future projects seems to be inevitable because of the flat nature of the land.

Executed drainage projects to date do not include farm drains, thus no drainage project is yet functioning completely. The main reason for not constructing the farm drains is financial. The question as to whether expenses of construction of such drains should be borne by the government or by the land owners, especially when the small land owners financially unable to pay for them still needs a satisfactory answer. This is one of the main drainage problems confronting the country at present.

DRAINAGE PLANNING AND SCHEMES

For a proper drainage system a well-balanced drainage investigation must be carried out, which will allow a reasonably accurate, feasible and economical design. In 1927 the first investigation was begun on a small experimental plot near Aqar Quf. Less than twenty years later a more comprehensive investigation was carried out near the same site. Other similar experimental plots, such as that in Dujaila (near Kut city) and at Twaireej (near Hilla city) and others, were also established. In addition, consulting firms working in Iraq were entrusted with wide scale drainage investigations covering large project areas. The experimental plots varied in size and shape, ranging from small circular trial plots surrounded by one drain and less than half a mishara in area to a rectangular plot of several misharas with a grid of covered or open drains of various depths and spacing. The experimental plots aimed at collecting and analysis of all basic data necessary for salt removal, drainage design and successful cultivation ; namely leaching requirement, soil permeability (hydraulic conductivity), drain spacing, drain depth and drainage coefficient.

The large scale drainge investigations armed at collecting information of the soil profile characteristics, both physical and chemical, and ground water conditions. Investigation for the top five meters of the soil profile was intensive. One point for each 400 misharas of land was used. For deeper soil profile investigation this density was reduced to one tenth or less.

Drainage investigations need to be accelerated diversified information has so far been obtained. For example, values for drainage coefficient ranged from one cumec per 50,000 mesharas to one cumec per 20,000 misharas. Drain spacing differ according to soil permeability and depth of drains. Variations in

* It is of interest to note that the main canals of these three projects were constructed practically on or near the same locations of three older canals dating back to 1,300 years ago, then named Issa, Sarsar and Melcha.

spacing of drains from 50 meters to 1,000 meters have been reported. Soil permeability varies greatly ; however, presence of gypsum, roots and natural holes have caused an increase in the effective permeabilities of heavy soils.

The field drains, being the working part of a drainage system, should be designed before constructing any part of any drainage project, since all other elements of the drainage system depend on them. Construction of main and lateral collector drains, without investigations and design of field drains may lead to future complications and improper functioning.

Although covered drains have been used on the experimental plots the trend in Iraq is to use open drains. This is because of the low cost of construction and the very low value of land. The salty condition of the soil has shown that even in many heavy soils open drains should have a side slope of one and a half to one or flatter to avoid collapse of soil from the sides.

The choice of the right depth and spacing of the farm drains, after having fixed the desirable depth to the water-table (which ranges from one to one and a half meters) is a matter of economy. It is a fallacy to state that with deeper drains and hence wider spacing, the cost will always be less. Fig. 1

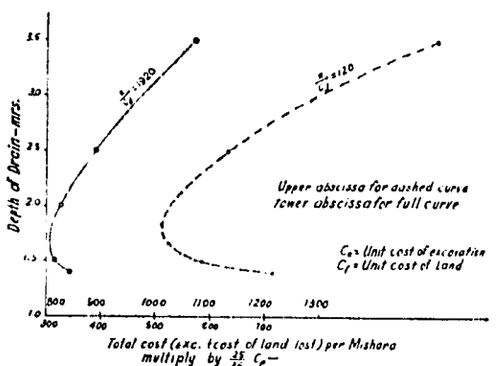

FIG. 1

shows that there is a minimum cost for one depth of drain*.

The outlet for all existing drainage systems is either Tigris or Euphrates. The danger of salty ground water pumped into the two rivers has been considered, but as yet the effect has been found to be negligible due to the small amounts of drainage water compared to the large flows of the rivers. When all drainage project schemes are properly and completely functioning, the effect of increasing the salinity of water in the two rivers will be appreciable, especially during summer when the flow in the rivers is low. A serious study of this problem is being made. A main central outfall to collect drainage waters and discharge it into low marshes of the south has been considered, but is still under study. Adequate drainage systems for existing and for future irrigation areas are being provided for, with priority given to the existing developed areas. Such provisions for most of the projects however is still in the investigation and design stage. The task is an immense one, requiring huge financial potentialities and long periods of time for execution. It has been reported that 17,400,560 misharas of land is being considered for drainage. An estimated cost of I.D. 586,920,000 for complete execution will be required. Of this sum it is estimated that I.D. 295,000,000 will be required for the field (farm) drains and small collector drains, excluding cost of land reclamation (leaching and nutritioning of the soil). Thus the cost will be about 32 I.D. per mishara for complete work, of which I.D. 17 is for the field and small collector drains. In some southern parts a value of 50 I.D. per mishara has been reported necessary for complete drainage and reclamation. Considering the very low yields of the developed lands (3 to 5 I.D. per mishara annually) full reclamation of certain areas may prove to be economically unfeasible. However it is hoped

* This graph was established by the author using a formula developed to find the most economical depth for field drains, in a paper yet unpublished) entitled "Economical Depth of Drains".

that in the long run and through desalinization and improvement of land, the productivity will be increased to justify such development operations. The following figures show the areas of land in misharas and the stage of drainage work.

Under investigation and design	Partly executed	Mostly completed	Total area
11,199,910	5,649,650	551,000	17,400,560

Existing Drainage Problems

The foregoing presentation of the drainage conditions in Iraq brings to light certain problems that will need careful study and practical solution. These problems occur in three categories :

(a) technical (b) financial and (c) social.

Technical Problems

1. Drainage systems, economically, should be provided for already developed areas before attempting to develop new ones. This means that drainage schemes have to be laid out to fit as nearly as possible the present lay-out of irrigation systems. This may not always be possible and remodelling of the present irrigation systems may be necessary in some areas.

   Application of the newly-created Agrarian Reform Law, although necessary, creates a further burden of work, since the lands will be divided into small areas. This will require a wise solution to problems of water distribution, rights of way and operation and maintenance.

   Available data already collected, is insufficient for starting proper complete designs. Adequate data are not available on drainage coefficient, soil permeability, and leaching requirement as related to both irrigation requirement and drainage coefficient. More drainge experimental plots should be established at selected typical areas and full drainage and reclamation studies should be conducted for at least two agricultural seasons.

3. The effect of salts in drainage water on the salinity of Tigris and Euphrates, although not appreciable so far, has to be carefully studied since it may easily be highly important in the future. The proposed central main collector drain as an outlet for the drainage waters so far presents an apparently satisfactory solution, but further and deeper studies of its feasibility from technical and economical points of view are needed.

4. Maintenance of drainage systems, especially when open drains are used, must be a continuous operation for the life of the drainge system. Many parts of completed drains have been partly buried due to (a) collapse of soil material from the side and (b) sand deposited by windstorms. A side slope of one and a half to one or flatter is more adequate than one to one. The problem of sand storms will have to be solved through forestation. Maintenance of the drains will be continuously required in order to have them free from deposits that may interfere with the flow.

Financial Problems

1. Due to the high cost and immense total investment required drainage projects will have to be executed gradually according to their importance and the productively of the land. However complete execution, including field drains is necessary, otherwise none will function properly.

2. The cost of the farm drains is nearly half of the total cost. Small land

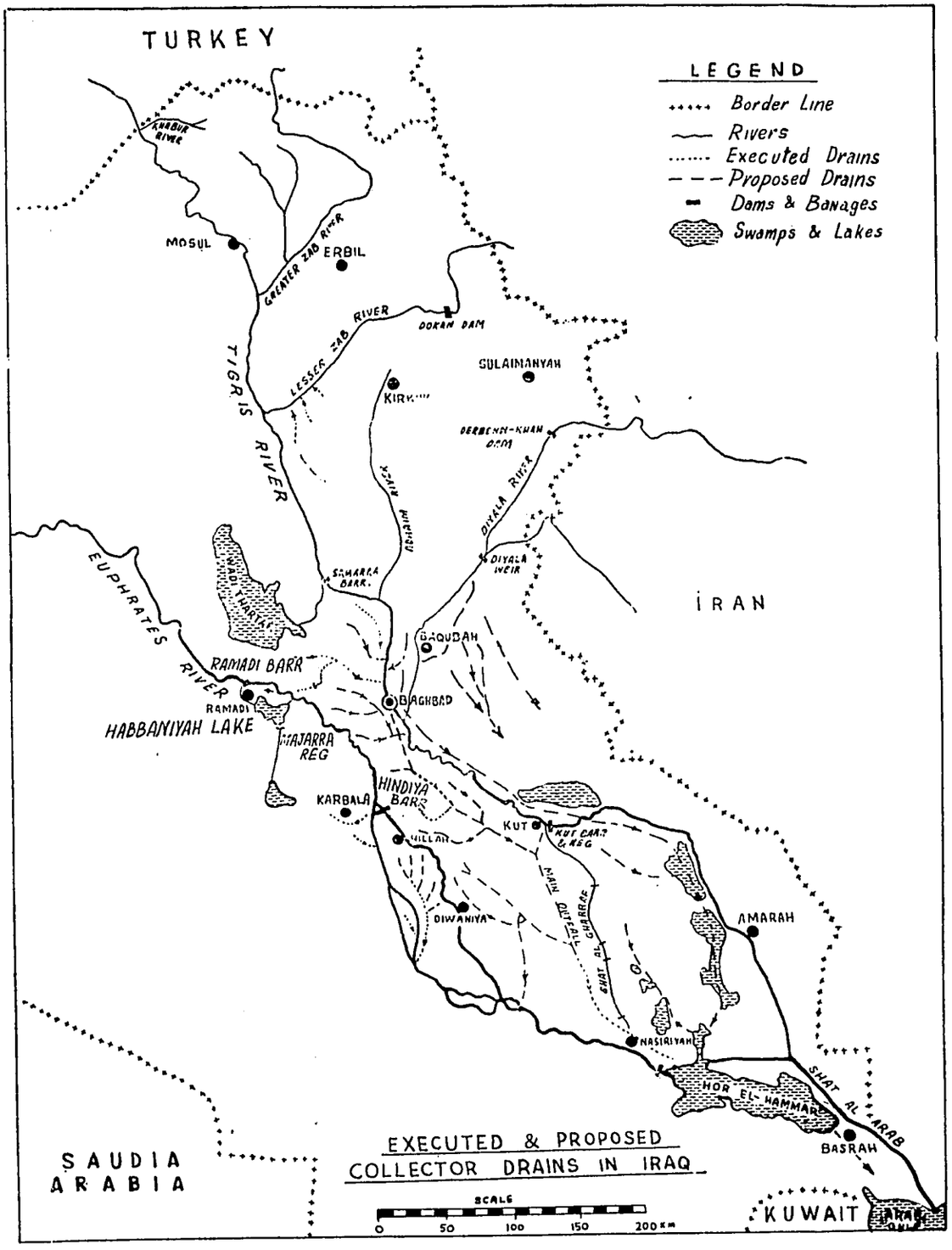
TURKEY
LEGEND
Border Line
Rivers
Executed Drains
Proposed Drains
Dams & Banages
Swamps & Lakes
MOSUL
ERBIL
GREATER ZAB RIVER
LESSER ZAB RIVER
DOKAN DAM
SULAIMANYAH
TIGRIS RIVER
DIYALA RIVER
DIYALA WEIR
SAMARRA BARR.
EUPHRATES RIVER
RAMADI BARR
RAMADI
HABBANIYAH LAKE
BAGHDAD
HINDIYA BARR
KARBALA
KUT
DIWANIYA
AMARAH
NASIRIYAH
HOR EL-HAMMAR
SHAT AL ARAB
BASRAH
IRAN
SAUDIA ARABIA
KUWAIT
EXECUTED & PROPOSED
COLLECTOR DRAINS IN IRAQ
SCALE
0 50 100 150 200 KM

FIG. 2.

owners and farmers cannot bear this huge expense. The farm drains on the other hand must be executed immediately. Long term loans offered to farmers, whether by agricultural cooperative societies or by the Government may offer a solution. The problem has to be studied economically in order to find a satisfactory answer to this urgent problem.

Social Problems

1. Farmers in Iraq have learned from their ancestors and therefore old methods of farming and water use are dominated by old inherited traditions. Irrigation efficiencies are very low and soil management very poor. Farmers therefore must be educated to use modern methods of agriculture and more efficient methods of irrigation and soil management, in order to increase land productivity.

   The problem is aggravated by the poor financial condition of the farmers who cannot afford expenses of modern agriculture. Through agricultural cooperative societies, and through advisory centers established at various and numerous areas in Iraq farmers may be assisted financially and helped, advised and educated on modern and efficient land and water use.

2. The problem of migration of farmers from the country into big cities will have to be solved. Improvement of country social conditions, providing the farmers with means for land development, providing necessary irrigation and drainage and encouraging them through their respective advisory centers, are all means that may check such migration.

3. Once the hazard of salt is minimized, adequate irrigation and drainage systems provided and productivity of land increased, economic and social changes are to be expected and adequate housing, schooling. roads, medication and other similar amenities will have to be provided. Then farming areas prosper and their people will be freed from the grip of poverty and ignorance, all will aid in setting the national economy firmly on an upward path of self-sustaining growth.

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DRAINAGE AND SALINITY IN IRAQ WITH SPECIAL REFERENCE TO DUJAILAH EXPERIMENTAL STUDY

by

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SUMMARY

This paper describes the general phenomena of drainage and salinity of irrigated lands in Iraq. It also deals with the results of those parts of the Dujailah drainage and land reclamation experiments pertinent to the subject.

The drainage and salinity problem is significant, owing to the highly depressed crop yields and intensive salt accumulation on or near the soil surface. The source of salinity is the salt content of the alluvial plain and that of the surface applied water from the two main rivers, together with the absence of natural or artificial drainage.

The predominant salt in the Iraqi soil is sodium chloride which amounts to about 70 per cent of the total. Lime varies between 20 per cent and 30 per cent, while gypsum varies between 0·20 per cent and 2·5 per cent. The calcium supplied by the gypsum to replace sodium ions are only of significance at the beginning of the leaching and reclamation, as the gypsum is washed downwards quickly. The exchangeable sodium percentage (E S P) was reduced from about 34 per cent in the Dujailah experimental plot to a minimum value of 4·0 per cent.

The process of desalinization after the leaching of 1 to 2 meters of the soil was found to proceed slowly to the deeper layers in compliance with the flow line patterns of the ground water flow towards the drains.

The Dujailah soil profile consisted of silty clay loam which at 60 cm. depth changes into silty loam. However, sometimes stratified layers of sand or clay were found. The average moisture content of the saturation paste was about 52 per cent. In a specific plot of the soil profile was found to consist of 4·5 m. stratified silt-loam, clay-loam and light clay underlain by heavy dry, dense and impermeable clay to a depth of more than 7·0 meters.

The average field-measured hydraulic conductivity by the Augerhole method according to Hooghoudt and Ernest for the soil below the water table between 0·60 and 4·5 m. depth was about 0·77 m./24 hours. The theoretical computations based on this value for the relation between the hydraulic head and the drain discharge showed close agreement with field data.

The Dujailah experiment revealed that better drainage can be obtained from narrow spaced drain pipes than from deep and wide spaced open ditches. The amount of drainage water in winter was 3 to 4 times that in summer.

The investigations and experimental studies showed the feasibility of drainage and land reclamation with little or no difficulty.

INTRODUCTION

Iraq is an old famous agricultural country. Its two well-known great rivers are the main source of irrigation supplies. They run along its entire length. The economy essentially depends upon its fertile land together with the water supply of those rivers and the year-round sunny climate.

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The climatological and topographical conditions prevailing in Iraq divide it into three principal irrigation Zones viz ; the rainfall zone in the north, the pumping zone which includes the high lands adjacent to the banks of rivers and canals, and the flow irrigation zone which constitute, the low lands and amounts to approximately 32,000,000 mesharas (8,000,000 hectares).

The application of water to the land with drainage deficiency natural or artifical causes the water-table to raise especially in the low lying delta of Iraq where the high ground water-table is rapidly set up by seepage from high-level canals and rivers.

The investigations carried out in the last decade on vast areas indicate that the drainage defficiency and soil salinity is a serious problem which calls for a special attention.

Generally speaking the lower part of the Mesopotamian plain in addition to the high ground water table marshy lands also containing salts. The accumulation of salts in the soils south of Baghdad is a main cause for the low crop yield, and for putting out of production large areas. Since the process of salinization is continued as long as there is no salt balance, it is expected that more areas will eventually be abandoned.

Steps for reclamation for such soils were recently initiated. For proper design, thorough investigations and experimental studies are required. For this purpose an experimental area in Dujailah Project was selected.

SOURCE OF SALINITY

The salinization process in the lower Mesopotamian plain is a natural phenomena as a result of the climatological and hydrological conditions. It, is, therefore expected that saline soils will occur all over the plain. The actual salt content and salinization type varies considerably over a short distance as these depend on local conditions, e.g. soil type and conditions, depth of water-table, irrigation practices, etc. Moreover, the salt content of the surface soil varies with the season of the year and the vegetation and soil treatment in use. In Table 1 some soil salinity data are given which show the variation of salinity in various projects.

The above data concerns the surface soil in which the root zone is developed. It is clear that the salinity decrease rapidly with increase of rainfall. This is obvious on the Eski Kelek project which is under rainfall cultivation.

Table 2 shows the salinity distribution in the soil profile in one specific area up to 20 meter depth.

At a depth of 20 meters, all soils tend to become salty. The total amount in the upper 5 meters of the soil of the project areas in south and central Iraq is roughly estimated at 1 milliard (10^9) ton. The estimate was based on an average salt content of 1 per cent over 6 million mesharas. Following the leaching of the top 1 to 2 meters desalinization will proceed slowly to the deeper layers according to the flow line patterns of the ground water towards the drains.

During irrigation, in which part of the land is irrigated and part is left fallow, more salt is brought in. The salt already accumulated is pushed down from the irrigated plots and up in the fallow plots. Salts can only be removed from the top soil and out of the area if drainage facilities exist.

Ground water depth varies from 3 to 5 meters, however, the response of the water-table to irrigation is very fast. The presence of salt in the subsoil may be partly attributed, highly saline water percolating through the soil. The salinity of ground water in many places was found to be 5 per cent or more, less in some other places. Variation of the subsoil-water salinity is due to variation in natural drainage pattern and the occurrence of sweet water at the surface (seepage and rainfall).

TABLE 1. SALINE SOILS AS PERCENTAGE OF PROJECT AREA

Project	Area 1,000 mesh.	Per cent of Project area		Av. Yearly rain fall mm.	Av. Yearly Temp. °C.	Station of observation
		EC>8	EC>16			
Eski Kelek	53	0·4	0·2	382	19·4	Mosul
Makhmour North	1,000	1	0	380	22	Kirkuk
Makhmour South		7	1			
Lower Diyalah	1,714	37	17			
Adhaim Left Bank	541	54	19			
Adhaim Right Bank	242	64	25			
Ishaqi	390	49	23	140	22·6	Baghdad
Nahrawan	152	81	62			
Dujailah	400	86	—	139	24·1	Hai
Gharraf Extension	664	85	61	120	23·8	Nasiriyah

TABLE 2. SALINITY DISTRIBUTION IN THE SOIL PROFILE OF HUSSAINIYAH AREA.

Bore Hole No.	No. of Samples	EC in mmhos/c.m. at a depth of				
		2 m.	5 m.	10 m.	20 m.	30 m.
1	3	—	3	3	4	13
1	2	—	1	1	20	30
1	2	2	1	1	24	7
1	1	9	13	13	10	8

The total salts in surface waters in parts per million are given in Table 3.

Although the salt content of the surface waters is low, the amount of salt which could be brought by winter irrigation period is about 1·5 ton per hectare and about 4 tons by summer irrigation period. Therefore, if no leaching occurs in one year irrigation, the salt imported on the land will be sufficient to make a ¼ hectare saline out of every one hectare non-saline soil.

SALINITY CLASSIFICATION

Salinity values are classified according to the scale given in Table 4.

TABLE 3. TOTAL SALTS IN SURFACE WATERS

River and Location	Year of Record	Total salts in surface waters in parts per million											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Tigris, Baghdad	1924-52	260	260	220	190	190	190	230	280	300	320	330	370
2. Euphrates Fallujah	1950	255	328	388	484	470	422	420	410	270	394	404	296
3. Tigris, Amarah	1957	—	442	440			250	208					
Quarnah	1957	565	700	515									
4. Dujailah Canal Km. 29	1958				220	310	290	380	535	440			

TABLE 4. SALINITY CLASSIFICATION

EC Class	Ec Value	Salinity
1	<2	Non—Saline
2	2—4	Non—Saline
3	5—8	Slightly Saline
4	9—16	Moderately Saline
5	17—32	Strongly Saline
6	33—64	Very Strongly Saline
7	65—128	Very Strongly Saline
8	129—256	Extremely Saline
9	257—512	Extremely Saline
10	>512	Extremely Saline

SALINITY OF DEEPER SUB-SOIL

Soil samples at intervals of 1 meter were taken and tested for salinity for the deep borings. The salinity class distribution of the 78 regularly distribued deep borings are given in Table 5. This subsoil is strongly saline, mainly Class 6.

LOCATION OF THE EXPERIMENTAL SCHEME

The experimental area of 900 mesharas (225 hectares) is situated near kut in Canal Division 8 between the northern branch of Canal 8 and a main drain the site had been abandoned because of salt.

TABLE 5. SALINITY OF DEEPER SUBSOIL

Mean Subsoil Salinity 5—10 m. Below the Surface

Salinity Class	EC × 10^3	Percentage
1—4	0—16	14
5	17—32	27
6	33—64	46
7	65—128	13
8—10	>128	0

(Ref. Hillah-Diwaniyah Drainage Study, Final Report 1959).

TABLE 6. TYPES OF DRAINAGE SYSTEMS IN DUJAILAH (8) AREA

Division No.	Drain type	Drain Depth below G.L. in m.	Drain spacing in m.	Area in meshara	Tile diam in c.m.	Tile length in m.
I	Tiles	1·20	25	6	5	750
II	Tiles	1·50	25	6	10	600
III	Tiles	1·50	50	9	8	450
IV	Tiles	1·80	50	12	15	600
V	Ditches	1·80	50	15		
VI	Tiles	1·80	100	48	10,15	1,200
VII	Ditches	2·10	100	48		
VIII	Ditches	2·25	150	50		
IX	Ditches	2·10	300	100		
X	Ditches	2·10	300	100		
XI	Leaching on main drain			63		
XII	Reserved for additional experiments			400		
XIII	and for untreated compansion plots					

Investigations made by Mr. Turcan in 1952 revealed that for depths up to 2·0 meters total soluble salts ranged between 0·10 per cent and 5·0 per cent with an average of 1·8 per cent.

LAYOUT OF THE EXPERIMENTAL SCHEME

The general layout of the experimental scheme is shown in Figure 1. The area, comprising nine farm plots, was divided into thirteen divisions. The type of drainage provided for each division is shown in Table 6. Tiles and open drains with different depth and spacing were used.

OBJECT OF THE FIELD RESEARCH

The purpose of the field work may be summarised as :

(1) To show the farmers that it is possible and economically justified to reclaim salty, unproductive soils, although it may be difficult sometimes. Also to demonstrate, the method of construction of field drains, of washing the salts out of the soil.

(2) To gather data for assessing the intensity of field drainage systems, the kind and construction of field drains, and the method for leaching salt out of soil in relation to soil properites, local conditions and economy. For instance studies were made of :

a. The required depth and spacing of field drains in relation to the hydraulic conductivity of the soil.

b. The quantities of water and the time required for leaching salty land, both with respect to the intensity of drainage system, the salt content of the soil and other soil conditions.

c. The possibility of tile-drainage especially if closed drains are used.

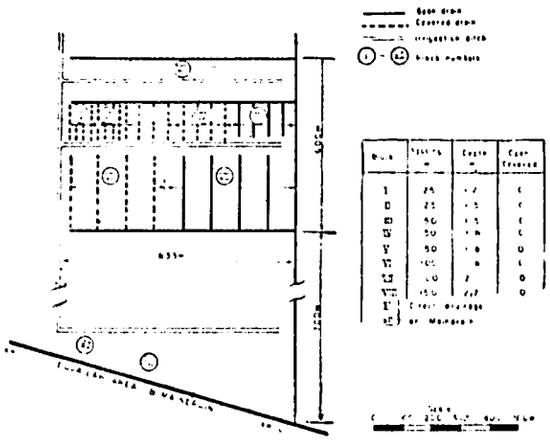

FIG. 1

PROGRAMME AND PROCEDURES OF RESEARCH

The experimental work started in 1955, where leaching of some land close to the existing main drain was began during May, June and July 1955. The primary object of this experiment was to give an insight on the suitability of the proposed technique and equipment and to provide general information on the drainability and suitability of some very salty soils in the Dujailah area.

The following observations were made during the leaching experiments :

(1) Applied quantities of water.

(2) Discharge of the drains.

(3) Evaporation.

(4) Changes in the moisture content of the soil.

(5) Changes in salt content of the soil and soil water during leaching and after leaching.

(6) Salt content of drain water.

(7) Subsoil water levels.

LIME AND GYPSUM CONTENTS

Iraqi soils are characterised by the high lime content which ranges between 20 per cent and 30 per cent (Table 7).

The gypsum content of Dujailah soils varies from 0·2 to 2·5 per cent. Since the gypsum is readily soluble, it can be seen from Table 8 that the gypsum content of the soil profile of plot I dropped considerably after leaching with a depth of 1·40 m. of water and was reduced to nil in the top 60 cm.

This indicates that during reclamation, the the Calcium ions supplied by gypsum to replace sodium ions at the adsorption complex is only of significance at the beginning of leaching as the gypsum quickly is washed downwards. Accordingly, the gypsum content in the rootzone of saline soils may be completely lost by leaching. The origin of the lime is probably the river water as it was found proportionally divided over the sand, silt and clay fractions. Most of the gypsum is formed by precipitation through evaporation of the subsoil water.

MECHANICAL COMPOSITION OF DUJAILAH SOILS

The soil profile of the experimental area consists of silty clay loam which changes into silty loam of about 60 cm. depth. Stratified layers of more sand and clay are sometimes found in the profile. In Table 9 the mean of 10 mechanical analysis the moisture content of the saturated paste and the exchange capacity of the adsorption complex are given.

The mechanical composition of the 100-150 cm. layer contrasts with the other layers. The moisture content and exchange capacity indicate that the clay percentage should be higher than that obtained from the single analysis, therefore it was assumed as 20 per cent, since the accuracy of the moisture content determination is rather high, being based on the mean of 50—100 determinations for each layer.

DISTRIBUTION OF SOLUBLE SALTS

Accumulation of ions is influenced by several factors, such as dryness of climate, natural leaching conditions, composition of irrigation and subsoil water, etc. The Na cation under cultivation conditions was found to constitute about 70 per cent of all cations, similarly for the Cl anion. The remaining cations were about equally divided between Ca and Mg, with the rest of the anions almost completely SO_4. This distribution is found to be uniform except for an increased amount of SO_4 at the expense of Cl from the surface to 60 cm. depth. The ratio of Cl to SO_4 decreased from about 6 in the top 30 cm. to about 2 at 60 cm. depth, and it is fairly constant below this depth.

During leaching, the ratio of Cl to SO_4 in the top 30 cm. changed to 1, and at a greater depth it was reduced to 0·60 and after one year of cultivation it was still below 1.

The relation between Cl content and salinity of great number of water samples and soil extract is shown in Figures 2 and 3. Since in both figures a good relation exists, the salinity may be expressed in terms of the EC based on the Cl concentration, particularly in the case of water samples of high salt contents.

Figure 4 shows the relation between the Na in m.e./100 g. and the sum of the cations (Na+Ca+Mg) in m.e./100 g. while figure 8 gives the relation between the EC and the total soluble salts.

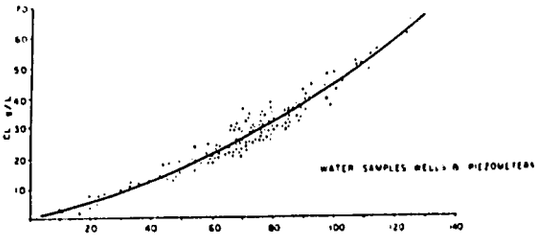

FIG. 2

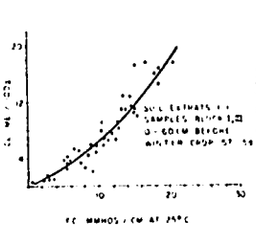

FIG. 3

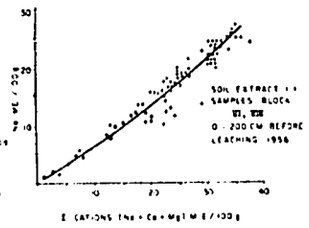

FIG. 4

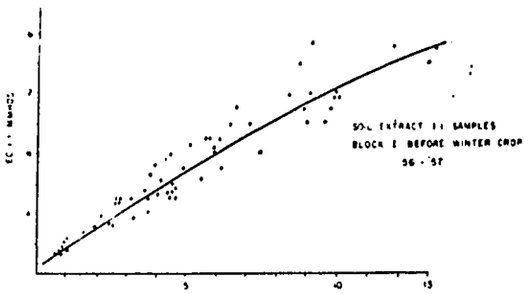

FIG. 5

A relationship between the salinity of saturation extracts and 1 : 1 extracts for Dujailah soils was established. The relation between EC and Cl content in 1 : 1 extracts and saturation extracts respectively is given in Figures 6 and 7. The agreement between the slopes of the two lines indicates the

possible conversion of the salinity data of the 1 : 1 extract to the saturated paste on the principles of the moisture content of the soil paste. In Table 10 the measured mean moisture percentages and the calculated conversion factor are given.

SALTS AND WATER MOVEMENT DURING LEACHING OF SALINE SOILS

Salt movement is naturally a function of water percolation through the soil. The leaching curve shown in Figure 8 was obtained from field experimental data and shows the relation between the fraction of the initial salt left in the soil and the depth of leaching water percolated through the soil. The abscisa gives the total measured discharge of the pipe drains and the direct discharge to the deeper collector drain as calculated from the water levels. Therefore these totals represent the actual amounts of drainage water percolated through the profile and need not be corrected for evaporation losses or water used to saturate the soil.

Figure 9 shows the same data of Figure 8 represented in such a way that the fraction of the initial salt remaining in the soil is given as a function of the depth of leaching water per unit depth. A correction was made by subtracting from both, the salinity before leaching and that after leaching a constant value of ECe representing the minimum salinity which can be finally achieved under normal irrigation practices. This constant depends on the quality of the irrigation water and the ratio drainage/irrigation. The average value of the salinity of the Dujailah irrigation water was considered as EC = 0·6 mmho. Taking the average value of drainage/irrigation of about 20 per cent, the EC of the drain water in the salt balance case was estimated at 3·5 mmhos. which agrees with an EC of saturation extract of the soil of 2 to 2·5 mmhos. The ECe of 2·5 mmhos. was considered as minimum average salinity for Dujailah area.

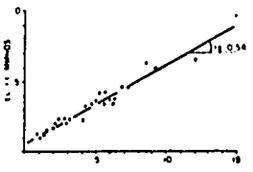

FIG. 6

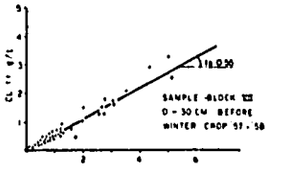

FIG. 7

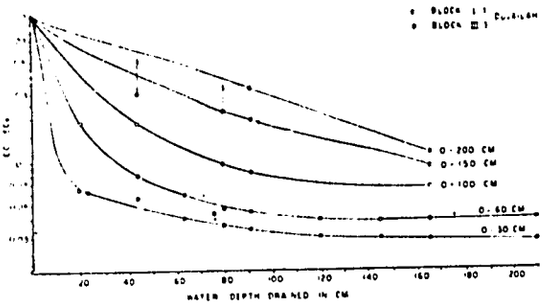

FIG. 8

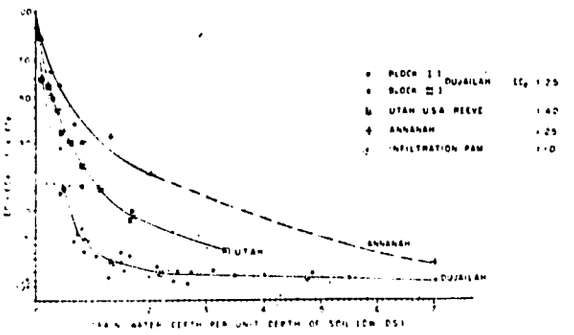

FIG. 9

Comparison of the three curves in Figure 9 reveals that leaching of the Dujailah soils is more efficient than the other two reported. The technical informations required for designing leaching reclamation may be summarised as :—

1. The quantity of water required to reduce the salinity of the soil to a specified level.
2. The salinity level to which the soil should be leached prior to cropping.

TABLE 7. LIME AND GYPSUM CONTENT OF SOME IRAQI SOILS

Dujailah			Anannah			Hillah			Gharraf East	
Depth cm.	Lime %	No. of Samples	Depth cm.	Lime %	No. of Samples	Depth cm.	Lime %	No. of Samples	Depth cm.	Lime %
0—30	26	39	0—20	23	20	0—30	22	45	0—10	24
30—60	27	45	20—60	23					20—30	14
60—100	27	45	60—100	23					50—60	26
100—150	26	44							120—130	
150—200	27	30								

TABLE 8. GYPSUM CONTENT OF DUJAILAH SOILS

Depth in cm.	Plot XI and XII			Plot I (before leaching)			Plot I after leaching		
	m.e./ 100 g.	Gypsum %	No. of Samples	m.e./ 100 g.	Gypsum %	No. of Samples	m.e./ 100 g.	Gypsum %	No. of Samples
0—30	7	0·60	22	11	0·95	9	0	0	9
30— 60	5	0·43	22	3	0·26	15	0	0	9
60—100	6	0·52	22	19	1·64	15	12	1·03	7
100—150	19	1·64	22	29	2·50	15	19	1·64	7
150—200	19	1.64	22	12	1·03	15	8	0·69	7

TABLE 9. MECHANICAL COMPOSITION, MOISTURE PERCENTAGE OF SATURATED PASTE, AND EXCHANGE CAPACITY OF DUJAILAH SOILS

Depth cm.	Sand %	Silt %	Clay %	Moisture % of sat. Paste	Exchange Cap. m.e./100 gm.
0— 30	21	58	20	53	18
30— 60	13	65	22	55·5	17
60—100	12	68	20	51.5	18
100—150	40	52	10	50	18
150—200	28	61	11	45·5	14

3. The drainage water required under cropping conditions. The leaching requirements can be found from the leaching curve if the soil salinity and the maximum desired salt content are given. Table 11 shows the effect of leaching on the removal of salt per unit area.

LEACHING AND THE EXCHANGEABLE SODIUM

According to USDA Handbook No. 60, alkali soil is defined as having E.S.P. greater than 15 ; the pH value of the saturated soil is greater than 8·5 and the ECe is less than 4 mmhos/cm. at 25°C. A saline-alkali soil has an E.S.P. of more than 15, the pH is less than 8·5 and the ECe is more than 4 mmhos/cm. A saline soil has the E.S.P. less than 15 and the ECe is more than 4 mmhos/cm.

Table 12 shows the effect of leaching on the exchangeable sodium in Dujailah soil.

Table 12 also shows a considerable drop in the E.S.P. and even at a depth of 2 m. the E.S.P. dropped from 42 per cent before leaching to 31 per cent after leaching and 3 cropping seasons. Moreover, the lower value was about 4.

Figure 10 shows the correlation between the E.S.P. and the salinity at constant pH., which indicates that the E.S.P. increases with salinity increase.

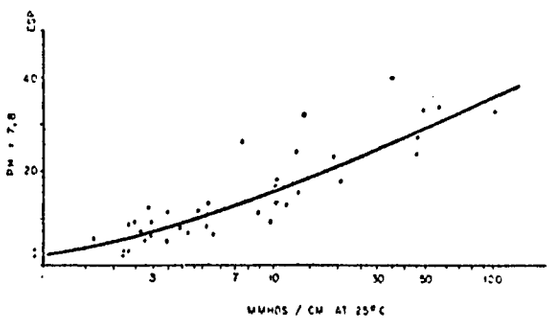

FIG. 10

SALT BALANCE AND RESALINIZATION

The result of extensive analysis in three plots in Dujailah experimental area was summarized as follows :

1. An equilibrium salt content of ECe = 2 mmhos/cm. may be considered as the average minimum value during the winter cropping period for intensively drained soil.
2. The salinity of the soil increases to an average ECe value of 3 mmhos/cm. during summer cropping under the same conditions.
3. The upward movement of salt which occurs during summer fallow depends upon the drain depth and spacing.

Upward movement was found to be negligible for intensively drained soils while it was considerable for the well-leached but less-intensively drained basin.

The leaching requirement can be expressed as a percentage of the irrigation water which should be drained. The salt brought in by the irrigation water should be nearly totally removed by deep percolation or drainage since the salts taken up by the field crops is insignificant

The leaching ratio in a steady case is given by

$$LR = Ddw/Diw = ECiw/ECdw$$

where, Ddw and Diw are the depths of drainage and irrigation waters respectively and ECiw and ECdw are the electrical conductivities of irrigation and drain water respectively. Since for Dujailah the irrigation water had average EC = 0·6 the leaching percentage is

$$LR = 0{\cdot}6/EC\ dw \qquad \ldots \quad (1)$$

The EC of the drain water and the EC of the saturation extract of the soil are comparable but not identical. The moisture content of saturated soil *in situ* is about 30 per cent, and that for saturated soil paste is

TABLE 10. CONVERSION FACTOR f = ECe/EC 1 : 1

Depth cm.	Slope of Cl line	Av. % water Sat. paste	No. of Samples	Conversion factor
0— 30	0·53	53·0	275	1·9
30— 60	0·55	55·5	140	1·8
60—100	0·52	51·5	100	1·95
100—150	0·50	50·0	90	2·0
150—200	0·45	45·5	75	2·2

TABLE 11. REMOVED SALT PER SQUARE METER

	Salt removed per m² from soil depth 0—0·30	0—0·60	0—2·00	Salt removed by drain water in kg./m²	Salt brought in by irrigation water in kg./m²
Initial Salt	(24·7)	(29·2)	(59)	12·5	
After 20 cm. leaching	20	25	—13	12·5	0·7
After 92 cm. leaching	20·5	29	39—1	44	4·5
After 165 cm. leaching	20·5	29	53—7	74	13·75

TABLE 12. EXCHANGEABLE SODIUM AND LEACHING

Period of Leaching and Drainage water	0 — 30		30 — 60		60 — 100		100 — 150 Cm.	
	ECe	ESP	ECe	ESP	ECe	ESP	ECe	ESP
Before Leaching	106	34	37	38	34	44	36	44
After 12 days leaching 15 Cm. drainage	6·5	15	13·5	33	—	—	—	—
After 42 days leaching 52 Cm. drainage	3·0	8	2·6	23	—	—	—	—
After 69 days leaching 84 Cm. drainage	2·6	7	2·2	21	7·5	38	24	43
After 69 days leaching 93 days cropping	3·8	5·5	2	20	—	—	—	—
After 69 days leaching and 3 cropping seasons	3·6	4·2	3·9	10	8·1	19	16	21

about 50 per cent. This would indicate a ratio of ECdw/ECe = 5/3. ... (2)

Substitution of (2) in (1) yields

$$LR = 0{\cdot}36/ECe.$$

The measured and actual LR for plot I is given in Table 13.

DRAIN DISCHARGE AND SALINITY

The measured average drain discharge from plots with different spacing and depth is given in Table 14. Tile drains of 25 m. spacing and 1·20 m. depth were used in Plot I, while open-ditches at 150 m. spacings and 2·00 m. depth were installed in Plot VIII. The average permeability of this particular soil was found to be 0·80 m./day. The calculated drain spacing of 130 m. for an assumed steady discharge of 1 mm./day, drain depth of 2·0 m. and ground-water-table of 1 m. below ground surface, was found to agree with the observed conditions in Plot VIII.

The experiment showed that better drainage was obtained using the narrow spaced drain pipes of Plot I than from the deeper and widely spaced open ditches, reflected in the higher discharges. The difference becomes more significant during leaching with high hydraulic heads. Leaching in Plot I was performed by flooding and in Plot VIII by rice crops.

Although there is no difference in discharge expressed in mm./day during winter and summer cropping periods, considerable difference can be noted when the drainage is expressed as a percentage of irrigation quantities during summer and winter. The percentage in winter is approximately 3 to 4 times that for summer. This difference is attributed to the three following factors :

1. Equal actual discharges during summer and winter cropping periods.
2. Much higher irrigation requirements during summer.
3. Influence of rainfall.

Since the fraction of irrigation water drained determines the salinity of the soil water this means that the solution is less saline during the winter than during summer. Therefore for constant salinity level in the soil during both seasons, a higher discharge during summer is required than during winter. In this experiment if summer discharge is taken to be 1·2 mm./day then winter discharge should be 0·3 mm./day.

In the drainage formula the discharge is roughly inversely proportional to the square root of the drain spacing. This means that summer cropping would require a drain spacing which is half the spacing required for winter cropping only if the salinity of the soil has to be kept on the same level.

INFILTRATION

Tests of infiltration on salty land were performed over periods of one to four weeks. The results are given in Table 15.

The infiltration rate was practically constant over the whole observation period for each location. This indicates that the long period infiltration would not cause a decrease in the soil permeability or deterioration of the soil structure.

HYDRAULIC CONDUCTIVITY AND SOIL TEXTURE.

The soil profile in the experimental area consisted of 4·5 m. stratified silt-loam, clay-loam, and light clay underlain by heavy, dry, dense and impermeable basin clay to a depth of more than 7 m.

Field permeability tests using augerhole pump-out method according to Hooghoudt and Ernest for the upper saturated soil layers below the water-table were conducted, and the results are given in Table 16.

The average K for the soil between 0·60 and 2·0 m. depth is 45 cm./24 hrs. and for the soil between 2·30 and 3·5 m. depth is 93 cm./24 hrs. In view of the similarity in the soil texture below 3·5 m., the hydraulic

TABLE 13. LEACHING RATIO AND SALINITY, PLOT I

ECe	Season	Leaching Percentage	
		Calculated	Measured
2	Winter	18	29
3	Summer	12	25

TABLE 14. DRAIN DISCHARGES AND LEACHING PERCENTAGE

	Leaching		Winter Crop 56/57		Summer Crop 57	
	mm./day	dr./irr.	mm./day	dr./irr.	mm./day.	dr./irr.
Plot I	12	53%	1·2	47%	1·2	12%
Plot VIII	2	14%	0·9	36%	0·9	13%

TABLE 15. RESULTS OF INFILTRATION TESTS

	Location and Number			
	II·3	III·3 B	III·3 D	III·6 B
Duration of Test hours	670	126	178	239
Total infiltration Cm.	882	82	297	396
Average infiltration Cm./24 hrs.	28	16	28	40
Infiltration rate after 24 hrs.	29	12	37	38
Infiltration rate after 36 hrs.	36	19	41	39
Infiltration rate after 108 hrs.	25	19	39	39
Infiltration rate after 156 hrs.	31		32	40

TABLE 16. HYDRAULIC CONDUCTIVITY, (AUGERHOLE METHOD)

Depth in m. from	to	Number of observations	Hydraulic Conductivity (K) in Cm./24 hrs. Minimum	Average	Maximum
0·6	2·0	15	30	45	80
2·3	3·5	20	70	93	150

conductivity can be assumed as 0·93 m./24 hrs. Therefore the total average K becomes 0·77 m./24 hrs. and for simplicity the soil profile up to 4·5 m. depth may be considered to have a K value of 0·70 to 0·80 m./24 hrs., laying on an impermeable layer.

Curves A and B of Figure 11 give the relation of the actual discharges measured at the drain outlet against the corresponding hydraulic heads, which is the difference of the water levels midway between the drains and the level over the drain.

The theoretical curves based on K value of 0·70 and 0·80 m./24 hrs. agree satisfactorily with the actual field observations.

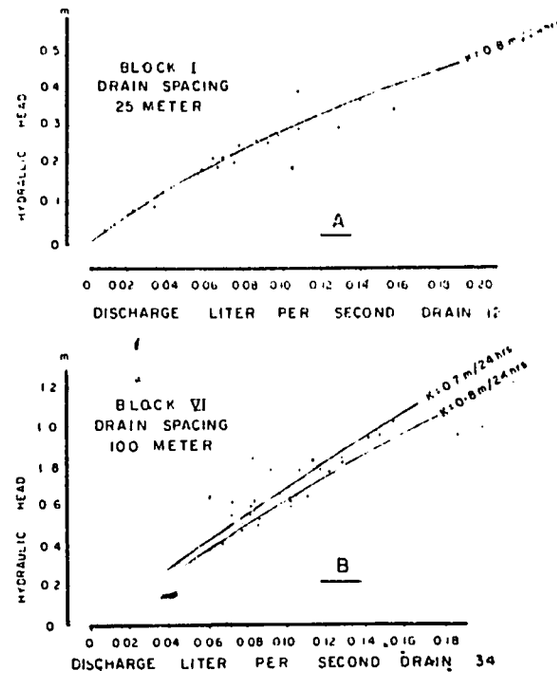

FIG. 11

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MEASURES TAKEN FOR IMPROVING THE SALINITY AND DRAINAGE CONDITIONS IN THE LOWER SEYHAN PROJECT

by

Mufid Kulen and Seref Ozgul*

SUMMARY

Lower Seyhan Plain is one of the largest and most important coastal plains in Turkey. It has an area of 210,000 hectares. The project area consists of alluvial deposits and the climate is arid to semiarid. There are zonal, azonal and interzonal soils in the project area. They are highly calcereous and deep and consist of clays and silts underlain by clay, sand, and gravel.

Hydromorphic soils of the interzonal series are found to be in need of urgent reclamation and improvement. These soils are poorly drained, have heavy texture and sticky and plastic consistency. They cover about 70,000 hectares and have some poor drainge. Many of them are saline and alkaline.

About 85,000 hectares of land have detrimental accumulations of salts. The dominant salt sodium chloride.

According to measurements made by the Augerhole method the mean permeability is estimated to be 4 cm. per hour. No correlation was found between salinity, alkalinity, and permeability nor was there any obvious relationship between soil texture and permeability. The test drilling programme has shown that shallow impervious layers rarely occur. Seyhan River as the main water resource has excellent quality for leaching and improvement and enough quantity for water supply.

Although experience in several countries indicates that the cost of reclamation and development of arid lands composed of heavy soils is seldom justified on the base of direct benefits, this is not true of this plain because of very favourable conditions of climate, rainfall distribution and intensity, irrigation water and chemical contents of soils.

Pond tests made for determining technical feasibility of reclamation and the effect of leaching, showed that prolonged ponding of leaching water on uncropped land tends to reduce the infiltration rate through swelling and dispersion of clay particles.

An extensive review of the results of a sub-surface exploration programme show that the water table is less than 2 meters below the surface in about 60 per cent of irrigable lands and that sub-surface drainage will be required.

The principal sources of ground water recharge are percolation of winter rainfall which is found to average 240 mm. per year and the seepage losses from irrigation, calculated to be average 209 mm. Inspection of well hydrographs show that fluctuations of the water-table vary annually between 1·5 and 2 m. for most of the area and have a direct relation to rainfall distribution over the year.

The most economical system for both irrigation and drainage tertiary canal construction is considered to be alternating irrigation and drainage canals each serving the lands

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on both sides of them. One-hundred hectares was taken as an average service area. Secondary and main drains will be centrally located between secondary and main irrigation canals.

The drainge canals are designed and constructed to accommodate surface flow and also to carry perennial sub-surface flow, whichever is the greater. For the calculation of drain spacing Quasi-Stationary method is used.

INTRODUCTION

Lower Seyhan Plain, the largest and most important coastal plain area in Southern Anatolia is situated on the south flank of the Tauros Mountains. The delta area of the Plain comprises a total of 210,000 hectares. It was formed by deposition of sediments carried by the Berdan, Seyhan and Ceyhan Rivers, and a number of creeks which originate in the Tauros Mountains.

About 85,000 hectares of total area have detrimental accumulation of salts. This accumulation is associated with centuries-old exploitation of soils. Also more than 80,000 hectares need urgent drainage measures.

The investigations for implementation of reclamation measures for the project were made over a period of three years. This study included soils surveys, determinations of salinity and alkalinity, permeability measurements of soil by Augerhole Method, field permeameter tests, ring infiltrometer tests, pond tests, laboratory analyses of soil and water samples, deep borings, ground water observations, studies on artesian pressures, seepage and condition of aquifers.

In this paper the results of these studies are discussed and the plans for improvement of salinity and drainage conditions are presented.

GENERAL DESCRIPTION OF THE REGION

Physical Features

The project area consists mainly of a relatively flat alluvial delta plain. The general slope is southwesterly with grades varying between 1·0 to 0·1 per cent. The shores are low and sandy with inland sand dunes. There are wide stretches of swamplands and lagoons by dunes. The general features of the plain are shown in Fig. 1.

Climate

The climate is arid to semiarid and is characterized by hot summers and mild winters having high relative humidity the year around. Rainfall is concentrated during the winter with a negligible amount in the summer. The area has a year-round growing season and the climate is well suited for a wide variety of crops under irrigation. Freezing temperatures occur during the winter only with a frequency of once in 3 years. The maximum temperature reaches 42·8°C. while the lowest is —7·1°C.

GEOLOGY

Areal Geology

The Tauros Mountains are among the oldest formations of the area. They are composed of thick, regularly layered Cretaceous limestones which have many superficial fractures.

The strata dip in southwesterly direction with a slope of about 30 to 45 degrees. The consolidated Miocene and Pliocene sediments dip beneath the plain with a slope of 3 to 5 degrees. The foothills are mainly marine deposits of Miocene age consisting of interbedded sandstones, shales and marls which are overlain by concordant layers of coarse Pliocene materials such as conglomerate and sandstone.

At the south of the foothills, alluvial deposits of Quaternary age become dominant. In most of the Plain the recent alluvium has a thickness of 25 to 40 m. and is composed of clay, silt, sand and gravel with clay predominating. In the deeper horizons very thick Neogen aged old alluvium is found. On the east and southeast the Plain is bordered by Cretaceos and Miocene hills. On the southwest there are continuous sand dunes along the Mediterranean Sea.

Subsidence of the Delta

The Lower Seyhan deltaic Plain is a subsiding area. The lowering of the low-lying flats as they approach the coast results in a loss of land useful to man if the beneficial effects of alluviation are no longer allowed to compete with the detrimental effects of regional sinking. The subsidence will be further increased by a lowering of artesian pressures and of the water-table in the ow-lands.

The subsidence of the Plain is demonstrated by several lines of evidence. The general dip of older rocks towards the delta indicates a long continuance of the process. The seaward dip of levels from which supplies of ground water are obtained brings the matter into closer perspective ; and also salicornias and other salt-tolerant plants extend inland across depressed areas of various kinds as far as about 15 km. from the sea.

WATER SUPPLY

Surface Water Resources

The water resources for irrigation and land improvement are the Seyhan, Berdan and Ceyhan Rivers. Seyhan River is the most important one. The water stored in the Seyhan Reservoir after the month of April and the high summer base flow provide sufficient water to meet the irrigation demands.

Quality of water

The water quality of Seyhan River is excellent for irrigation and leaching. The extreme chemical characteristics found by monthly sampling from the Seyhan Diversion Dam are as follows :

	Sampling dates	
	May 4, 1959	**January 6, 1960**
Electrical Conductivity (Micromhos/cm. at 25°C.)	355	180
Total Salts (ppm)	227	117
Boron	0.00	0.60
Soluble cations (meq./lt)		
Ca	0.95	1.50
Mg	1.40	0.40
Na	1.18	0.29
K	0	0.25
Sum of cations (meq./lt)	3.53	2.44
Soluble anions (meq/lt)		
CO_3	0.45	0.00
HCO_3	1.80	1.50
SO_4	1.38	0.57
Cl	0.91	0.32
Sodium percentage	0.00	0.00
Residual Na_2CO_3 meq./lt	13	33
Sodium adsorption ratio	1.1	0.4
Water classification	C_2S_1	C_1S_1

The reservoir water will have a beneficial effect on the heavier soils because of its relatively high content of calcium plus magnesium as compared to sodium. The quality of the Seyhan River and the leaching effect due to the winter rains are very favourable for the future irrigation and land improvement of the plain.

SOILS

Soil Groups

All three soil orders of the systematic soil classification are encountered in the project area. There are zonal, interzonal and azonal soils. The approximate location of the principal soil areas are given in Fig. 2. This Fig. shows a generalized cross-section of the plain on which are shown the various levels, subsurface materials and soils according to a broad geologic classification.

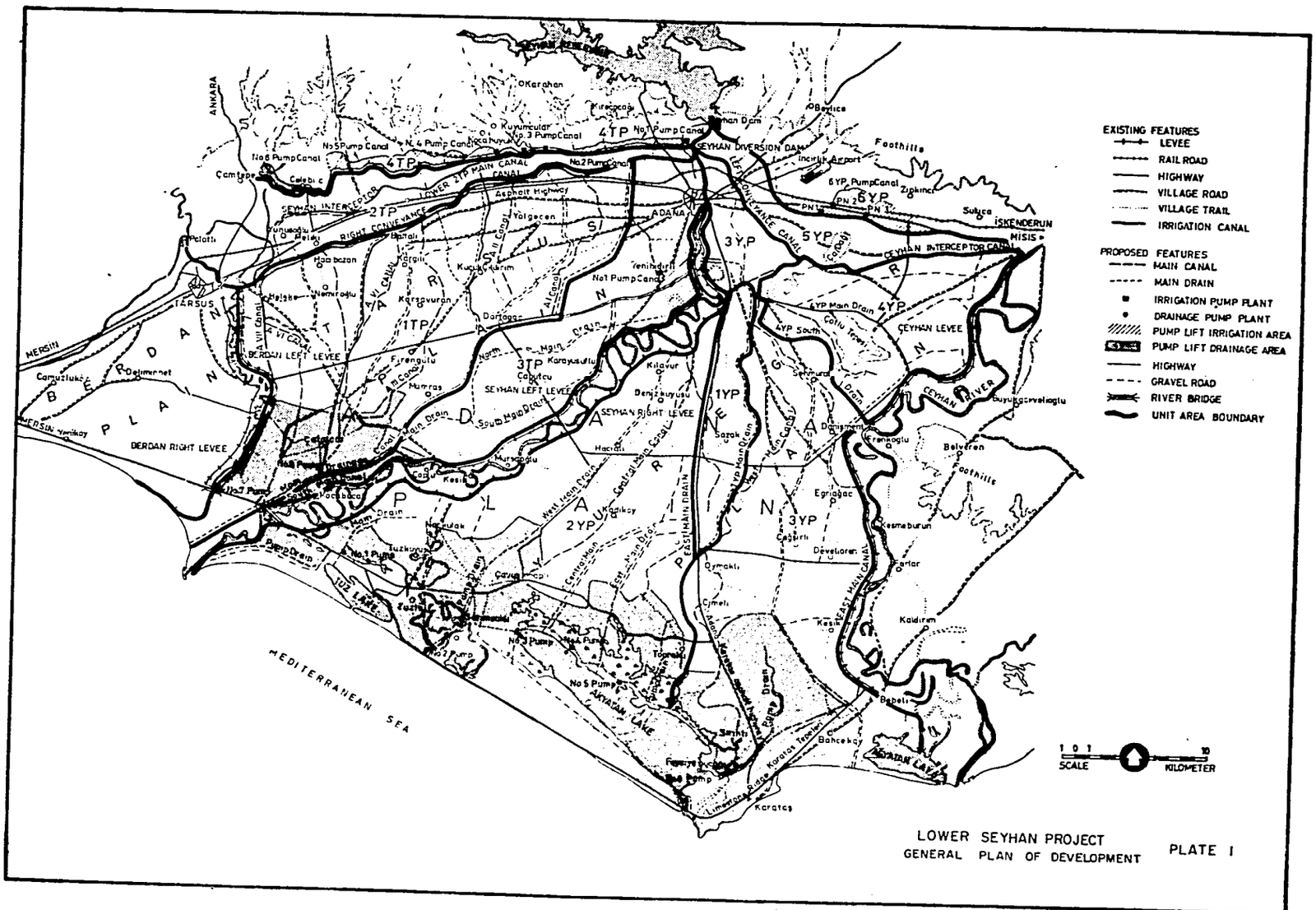

EXISTING FEATURES
LEVEE
RAIL ROAD
HIGHWAY
VILLAGE ROAD
VILLAGE TRAIL
IRRIGATION CANAL
PROPOSED FEATURES
MAIN CANAL
MAIN DRAIN
IRRIGATION PUMP PLANT
DRAINAGE PUMP PLANT
PUMP LIFT IRRIGATION AREA
PUMP LIFT DRAINAGE AREA
HIGHWAY
GRAVEL ROAD
RIVER BRIDGE
UNIT AREA BOUNDARY
SCALE
KILOMETER
SEYHAN DIVERSION DAM
ADANA
TARSUS
MERSIN
ANKARA
ISKENDERUN
MISIS
SEYHAN RIVER
MEDITERRANEAN SEA
BERDAN LEFT LEVEE
BERDAN RIGHT LEVEE
SEYHAN LEFT LEVEE
SEYHAN RIGHT LEVEE
SEYHAN INTERCEPTOR CANAL
LOWER SEYHAN PROJECT
GENERAL PLAN OF DEVELOPMENT
PLATE I

FIG. 1

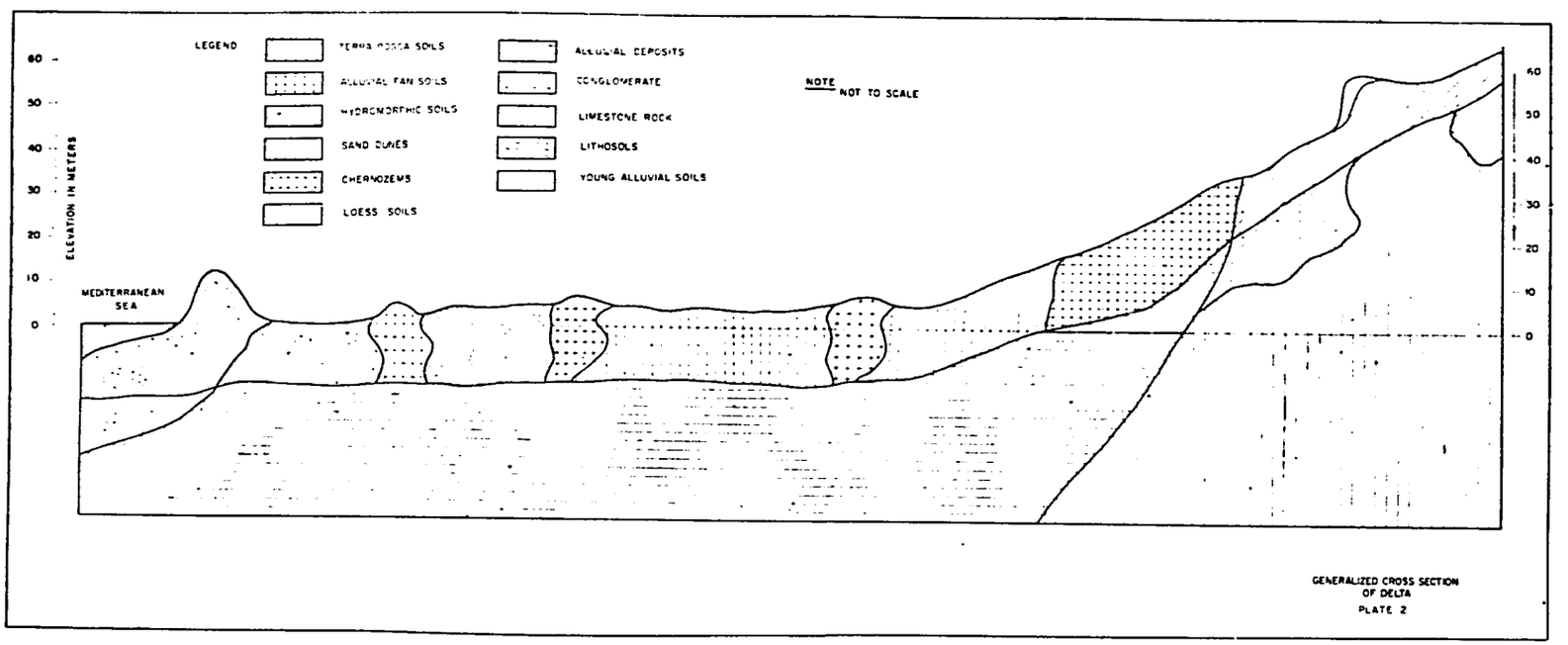

LEGEND
TERRA ROSSA SOILS
ALLUVIAL FAN SOILS
HYDROMORPHIC SOILS
SAND DUNES
CHERNOZEMS
LOESS SOILS
ALLUVIAL DEPOSITS
CONGLOMERATE
LIMESTONE ROCK
LITHOSOLS
YOUNG ALLUVIAL SOILS
NOTE NOT TO SCALE
ELEVATION IN METERS
60
50
40
30
20
10
0
MEDITERRANEAN SEA
GENERALIZED CROSS SECTION OF DELTA
PLATE 2

FIG. 2

The zonal soils are represented by two great soil groups :

(a) Terra Rossas, in the upper undulating parts of the Plain, on and derived from limestone rock ;

(b) Chernozems, on old abandoned streambeds in the main delta.

Interzonal soils are four great soil groups :

(a) Rendzinas Soils
(b) Brumusols Soils
(c) Solonchacks Soils
(d) Solonetzs Soils

Azonal order is represented by 3 great soil groups :

(a) Alluvial Soils
(b) Lithosol Soils
(c) Loess Soils

Physical and Chemical Properties of the Soils

General Features—The soils of the Lower Seyhan Plain consist of the sedimentary deposits derived from the various limestone rocks of the Tauros Mountains. They are highly calcareous ; the lime content varies from 16 to 30 per cent.

The soil located in the higher lands are relatively shallow but in the major area of the Plain the soils are deep. Depths are more than 1,000 m. in many parts of the delta and the soils consist of clays and fine silts underlain by clay, silt, sand and gravel. In Table 1, some basic properties of the delta soils are given. The soils in the various series are grouped according to their parent materials and physiographic positions as follows :

a. **Soils Developed on Calcareous Rock.** The soil in this group are well-drained and no salt or alkali problems have been detected due to the high permeability of the underlying parent (rock) material. The soils in this group are rich in potassium, poor in nitrogen and very poor in phosphorus.

b. **Soils in Alluvial Fan Deposits.** The soils of this group are formed by deposition of the sediments carried by the numerous streams flowing from the Tauros Mountains. The fan deposits are gently sloping and slightly undulating with good internal drainage. Neither alkali nor salts occur in these deposits.

c. **Soils in the Area of Abandoned Natural Levees and Channels.** The abandoned stream channels are generally at higher elevations than the main Plain. The soils are of coarse texture and have relatively high permeability with good internal drainage. Some slight salinity occurs but there are no serious alkalinity problems.

d. **Soils in the Young Alluvial Deposits.** Prior to the construction of the flood protection levees, the plain was flooded by Ceyhan, Seyhan and Berdan Rivers and large quantities of sediment were deposited on the flat delta land. The drainage in these soils varies from good to poor, depending on the depth of the water-table, and slight to severe salinization is experienced depending on proximity to the rivers.

e. **Hydromorphic Soils.** Hydromorphic soils are found in the lower part of the Plain. They are poorly drained, have generally heavy texture and a sticky and plastic consistency. Following wetting they swell, and then shrink and crack when dried, thus forming large blocks. These soils are found in about one third of the Plain and have drainage problems. Many of them are saline, or saline-alkaline, and need to be reclaimed. In several places the water-table rises to land surface at the end of winter as the result of recharge from winter rainfall. The water-table falls 1·5 m. to 2 m.

TABLE 1 : PROPERTIES OF SOILS

Test Pit and Location	Depth of Soil layer (cm)	Sampling Depth (cm)	Mechanical Analysis Sand (per cent)	Silt	Clay	Laboratory Classification	Electrical conductivity (mmhos per cm)	Exch. Sodium (Milliequivalents per 100 gms.)	Lime	Gypsum
41 : N89 E11	20—90	20—70	15·0	60·2	24·8	Silt loam	0·44		>200 ,,	<11·6 ,,
	90—170	110—160	10·0	41·2	48·8	Silty clay	2·30		>200 ,,	<11·6 ,,
	170—290	180—260	5·0	44·2	50·8	Silty clay	2·38		>200 ,,	<11·6 ,,
12 : N82 E06	10—45	20—40	11·6	50·4	38·0	Silty clay loam	0·47		>200 ,,	<11·6 ,,
57 : N73 E09	20—80	30—70	36·0	36·0	28·0	Clay loam	0·90	0·55	267	1·26
	80—100					Very fine sandy loam (F)				
	100—130					Light silty clay (F)				
	160—200	170—190	5·6	89·8	4·6	Silt	12·4	2·46	252	7·78
	200—250	210—240				Silty clay loam (F)	12·0			
	250—330	260—320				Silty clay (F)	5·1			
40 : N87 E10	0—40	0—25	24	42	34	Clay loam	2·40		>200(est)	<11·6(est)
	40—110	95—100	20	30	50	Clay	3·48		>200(est)	<11·6(est)
	110—155	120—140	42	32	16	Loam	3·17		>200(est)	<11·6(est)
64 : N71 E09	20—150	30—140	13·6	56·0	30·4	Silty clay loam	0·80	0·70	417	1·00
	160—190	170—180	17·6	58·0	24·4	Silt loam	0·80	0·85	404	1·64
	190—330	200—330	1·6	34·0	64·4	Clay	1·30	2·87	386	2·36
411 : N95 E21	20—180	20—60	59·4	10·0	30·6	Sandy clay loam	0·31	0·27	276	0·80
		70—160	43·6	23·8	32·6	Clay loam	0·30	0·74	220	1·00
412 : N95 E22	20—140	20—60	35·2	21·0	43·8	Clay	0·40	0·70	124	1·00
		70—130	30·0	23·4	46·6	Clay	0·70	0·98	122	2·20
409 ; N95 E19	20—205	20—60	35·2	26·2	38·6	Clay loam	0·63	0·44	232	1·40
		70—190	18·4	36·6	45·0	Clay	4·00	1·90	304	4·00
402 : N94 E29	20—40	20—40				Clay (F)	0·70	6·36	533	2·80
401 : N94 E27	20—110	30—110	31·2	28·8	40·0	Clay loam	0·40	0·68	136	0·80
399 : N94 E25	20—170	30—90	32·0	31·6	36·4	Clay loam	0·35	0·75	206	1·04
		110—170	20·0	35·2	44·8	Clay	0·50	0·97	220	0·86
257 : N92 E16	20—330	30—90	12·4	28·4	59·2	Clay	1·05	0·78	410	1·80
		110—200	8·4	29·4	62·2	Clay	0·45	1·50	408	2·00
		220—230				Clay (F)	3·20			
276 : N95 E18	20—60	30—60	25·0	22·8	52·2	Clay	0·55	0·53	78	1·80
316 : N87 E16	20—350	20—70	9·0	45·6	45·5	Silty clay	0·50	1·36	437	0·88
		80—160	7·0	47·6	45·4	Silty clay	5·40	8·63	438	2·10
397 : N94 E25	20—150	20—50	37·2	29·4	33·4	Clay loam	0·62	0·73	132	1·00
		60—140	33·0	31·1	35·4	Clay loam	0·32	0·74	230	2·20

ABOVE WATER TABLE

Sodium adsorption ratio (SAR)	Exch sodium percentage (ESP)	Soil structure	Special features	Permeability (cm. per hour) Laboratory	Field permeameter method Ave K_v	Ave K_h
1·8	11 ,,	Subangular blocky	Few roots and root channels	1·30	2·373	8·500
17·0	20 ,,	Angular blocky	Few roots, root channels, light grey mottles	N.D.	1·712	1·557
16·5	20 ,,	Massive	Few roots and root channels grey and y. b. mottles	0·03	0·714	1·020
1·0	0·2 ,,	Angular blocky	Few roots and root channels	0·52	0·724	1·023
1·0	2·1	Subangular blocky	Main and secondary roots	1·68	0·762	0·599
		granular			2·317	0·489
		Subangular blocky	Many lime concretion		1·134	1·00
7·4	9·8	Subangular blocky	Many lime concretion	1·11	0·979	2·307
		granular	Secondary roots	0·15	4·662	2·666
		Platy	Many mottles	0·03	1·633	2·962
9·0	12(est)	Massive	Few vertical cracks some staining, few fine roots	0·44	0·86	0·66
34·0	34(est)	Angular blocky	Few roots and root channels	N.D.	0·034	0·032
27·0	30 ,,	Massive	Roots and root channels	N.D.	0·030	0·027
1·0	2·9	Subangular blocky	Main and secondary roots, Many lime concretions	1·15	2·2	0·7
1·2	4·3	Granular		0·53	5·3	1·0
5·9	9·4	Platy		0·03	2·3	4·0
< 1·0	1		Few roots and lime concretions gravelly with some rock frog.	5·04	0·43	0·32
< 1·0	2			4·08	0·79	0·62
< 1·0	2		Main and secondary roots, root channels	4·90	0·95	2·4
< 1·0	3			5·00	0·37	0·4
> 1·0	2		Very fine roots and root channels, few lime con. some coarse sand	3·26	3·38	0·20
5·19	7			2·07	0·48	0·68
< 1·0	2		Main secondary and fine roots	2·3	2·3	2·3
< 1·0	2		Main secondary and fine roots	4·05	0·63	1·8
< 1·0	2		Main roots	3·09	0·37	0·20
1·0	3	Angular blocky		1·68	0·51	0·47
< 1·0	3		Main secondary and fine roots throughout profile	1·70	0·42	0·43
1·0	5			1·28	0·29	0·20
				0·75	0·33	0·37
< 1·0	1		Main and secondary roots	1·91	0·226	1·390
1·3	4		Main and secondary roots Root channels	1·26	0·757	0·099
12·8	25			0·02	0·360	0·231
2·4	3		Main and secondary roots, root channels, few lime conc., some coarse sand	4·80	0·353	0·445
2·0	3			2·60	0·470	0·457

below the surface after continued evapotranspiration during the summer season, thus increasing salt content.

f. **Soil in the Area of Wind-Blown Coastal Sands and Sand Dunes.** A long, narrow strip of sand dunes parallels the coast of the Mediterranean Sea. The soils are coarse textured and have low water holding capacity.

Texture of Soils. The textures of the project lands are shown in Table 2.

Occurrence of Saline and Alkaline Soils.

Many of the lands are slightly saline or alkaline or both and a large area has highly saline alkaline soils and high water-table. Table 3 gives a summary of the percentage of irrigable lands affected by various degrees of salinity and alkalinity. The alkalinity has been expressed in amounts of exchangeable sodium rather than exchangeable sodium percentage. The dominant salt in the soils is NaCl and Cl — ion usually predominates. Fairly high concentrations SO_4^{--}, Ca^{++}, Mg^{++} ions are also common.

Soil Permeabilities and Infiltration Rates

Soil permeability and rate of infiltration are of primary importance in determining the suitability of lands for irrigation and drainage. Many measurements have therefore been taken in the area to determine these factors.

About 1300 field measurements of horizontal permeability were made by the Augerhole method of the soil layers below the water-table, at depths of 2 to 5 m.

These may be summarized as follows

Permeability (cm. per hour)	Percentage of total tests
0·5 to 1·0	2
1·0 to 3·0	27
Greater than 3·0	71

The mean permeability of the project lands is estimated to be 4 cm. per hour. This value may be used to calculate farm drain spacings for planning purposes.

No correlation was found between salinity or alkalinity and permeability nor was there any obvious relationship between soil texture and permeability.

In order to determine the vertical permeability of low permeability soils about the water-table vertical permeability measurements were made. All of these permeabilities were higher than 0·25 cm. per hour and found to be adequate to transmit water by percolation through the profile. With such permeabilities soil layers above the water-table can dispose of irrigation flows. Inspection of the samples after measurement showed that leaching had no effect on the soil structure, which remained stable.

Ring infiltrometer tests were run. Test results were above the minimum limit of 0·25 cm. per hour, which indicated that special water management problems will not occur for average water uses.

Depth of Impervious Layer

The test drilling programme established that shallow impervious layers occur only rarely in the Adana plain. A decrease of permeability with depth is commonly observed in clay layers, but the permeability survey conducted does not reveal such a decrease down to 6 to 7 meters below ground surface even for soil layers with a high clay content. Decrease in permeability becomes great only below 15 m.

Reclamation Requirements

The heavy-textured lowland soils containing excessive salt accumulations are those most urgently in need of reclamation. Hydromorphic soils will require installation of adequate drainage facilities.

Suitability of Heavy-Soils for Reclamation

The high cost of irrigation development of the heavy soils of the region is justified for the following reasons :

1. A stable sub-surface structure and a relatively high sub-surface permeability make it possible to control the water-table by farm drains at reasonable costs.
2. A high lime content and gypsum occur in many of the saline soils. Both will serve to maintain a favourable exchangeable ion balance, thus preventing permanent deterioration of the soils.
3. Water supply is adequate and of excellent quality.
4. Winter rainfall will enable the cultivation of perennial crops if the land is properly drained.
5. Heavy-textured soils are interspersed with those having lighter-textures, thereby facilitating irrigation and drainage.
6. Soils in the plain are suitable for a number of crops such as pasture, rice, alfalfa, grain and cotton.
7. The year-round growing season makes double-cropping possible.

The climate, rainfall distribution and intensity, and soils are similar to those in the Camarque delta area of the Rhone River, France. These are drained by 2 m. deep open farm drains at 60 m. spacing and pump drainage.

Reclamation Studies

In order to determine the technical feasibility of reclaiming as well as the effect of leaching on the soils under conditions of continuous ponding, pond tests were conducted on hydromorphic soils with and without cropping. The poorest result from the pond tests is given in Table 4. These showed that prolonged

TABLE 2. DISTRIBUTION OF SOIL TEXTURES.

Unit	Soil Texture*								
	H/H	M/M	H/M	M/H	H/L	M/L	C/M	L/L	V/V
	Percentage of Land Area								
1 Y P	43	39	1	9	0	6	2	0	0
2 Y P	41	36	4	6	1	5	1	2	4
3 Y P	55	18	9	5	1	9	1	2	0
4 Y P	62	26	0	8	1	3	0	0	0
5 Y P	76	21	1	1	0	1	0	0	0
6 Y P	81	9	0	0	0	0	0	0	0
1 T P	72	23	1	1	0·5	1	0·5	1	0
2 T P	57	30	6	0	0	7	0	0	0
3 T P	42	43	0	1	1	7	3	3	0
4 T P	55	24	6	9	0	4	0	2	0

* The symbol M/L indicates that the soil has a medium surface and a light subsurface texture. Effective depth of root zone is a assumed as 90 to 120 cm.

TABLE 3. DISTRIBUTION OF SALINITY AND ALKALINITY

Unit	Degree of Salinity and Alkalinity*						
	P_1P_1	P_1S_{2-3}	P_2S_{2-3}	P_2S_{4-5}	P_3S_{1-2-3}	P_3S_{4-5}	P_4S_{4-5}
	Percentage of Land Area						
1 Y P	47	16	37	0	0	0	0
2 Y P	27	13	10	1	0	21	16
3 Y P	33	18	14	0	0	7	28
4 Y P	67	4	6	1	12	0	0
5 Y P	99	0	0	0	1	0	0
6 Y P	50	0	0	6	0	0	0
1 T P	40	3	39	1	0	9	8
2 T P	99	0	1	0	0	0	0
3 T P	21	10	18	0	7	38	6
4 T P	100	0	0	0	0	0	0

* The degree of salinity and alkalinity are indicated by symbols P_1S_2, P_3S_2 etc. The higher the number, the more saline or alkaline the soil.

P_1 = Less than 2 meq. of exch. sodium per 100 grams of soil
P_2 = 2 to 4 meq. of exch. sodium per 100 grams of soil
P_3 = 4 to 6 meq. of exch. sodium per 100 grams of soil
P_4 = More than 6 meq. of exch. sodium per 100 grams of soil
S_1 = Less than 4 mmhos/cm. (ECex10^3) At 25°C
S_2 = 4 to 10 mmhos/cm. (ECex 10^3) at 25°C
S_3 = 10 to 16 mmhos/cm. (ECex 10^3) at 25°C
S_4 = 16 to 30 mmhos/cm. (ECex 10^3) at 25°D
S_5 = More than 30 mmhos/cm. (ECex 10^3) at 25°D

TABLE 4. SALINITY CONDITIONS FOR POND TESTS, UNIT 3 Y P

Depth (cm.)	Electrical Conductivity (mmhos/cm.)	Exch. Sodium (meq./100 gr.)	Exch. Sodium percentage (ESP)	Sodium Adsorption Ratio (SAR)	Soluble Sodium Percentage (SSP)	Boron (ppm.)
0—20	19·3	11·1	19·7	13·8	52·0	0·18
	5·0	5·4	33·2	4·3	4·4	0·21
20—60	22·8	10·2	19·6	18·6	58·0	0·37
	4·5	12·8	31·9	11·7	6·7	0·30
60—100	28·7	10·3	27·7	20·6	53·0	0·18
	20·2	8·6	26·1	26·4	4·8	0·29

Note: For this test 100 cm. of water was applied without gypsum. Conditions before leaching are shown in numerator; conditions after in denominator. Increase in ESP is because lack of soluble calcium available in the soil profile.

ponding of leaching water on uncropped land tends to reduce the infiltration rate through swelling and dispersion of clay particles. Therefore rice is chosen as a first crop for the first 2 years and then irrigated pasture is established. In 3 years, pasture has improved the soil structure to the level of that of a normal soil. The comprehensive reclamation studies conducted by the Tarsus Irrigation Research Station have shown that saline alkaline lowland soils can be restored to normal productivity in a period of 4 to 6 years after sub-surface drainage has been provided.

DRAINAGE

Existing Drainage Conditions

An extensive review of the comprehensive subsurface exploration programme shows that the water-table is 2 m. or less below the ground surface for about 60 per cent of the irrigable lands in the Plain. Table 5 shows the percentages of each unit area affected by ground water.

Most of the Plain is now subjected to waterlogging and salts have accumulated in the upper soil strata where the water-table is shallow for part of the year. Such waterlogging and salinization have significantly reduced the productivity. Extensive areas throughout the Plain are covered with water for prolonged periods after the winter rains commence.

Sources of Ground-Water Recharge

The principal sources of ground-water recharge are :

a. **Percolation of rainfall.** A significant amount of winter rainfall on the Plain recharges the ground-water and in many areas raises the water-table to harmful levels. Summer rainfall on the other hand rarely affects the water-table as it is all used to replenish the soil moisture depleted by evapotranspiration during the hot summer. According to the historic water balance computations (an example given in Table 6) prepared for the years 1935 to 1959, the average annual recharge over the 25-year period amounts to 240 mm.

b. **Seepage Losses under Irrigated Conditions.** Ground-water recharge under irrigated conditions is augmented by seepage losses which may be sub-divided into farm and distribution losses as in Table 6. The average annual recharge during the irrigation season is calculated to be 209 mm.

c. **Inflow from other Areas.** As shown in Fig. 3 the Plain is underlaid by deep aquifers varying in depth from 10 to over 60 m. The subsurface flows originating in the mountains are

TABLE 5. UNIT AREA EXPOSED TO VARIOUS WATER-TABLE DEPTHS

Depth to water-table (m.)	Unit Areas			
	1YP	2YP	3YP	4YP
	Percentage of total unit area			
0—1	61	48	40	25
1—2	0	2	9	29
2—3	11	6	17	19
3—4	28	44	33	12
Over 4	0	0	1	15

TABLE 6 WATER BALANCE COMPUTATIONS

	ALL VALUES IN MM.	1959												
		J O	F S	M M	A N	M M	J H	J T	A A	S E	O E	N K	D A	ANNUAL
1	POTENTIAL EVAPOTRANSPIRATION AS CALCULATED BY THE PENMAN METHOD	7	22	45	74	109	139	162	155	95	39	11	7	865
2	ACTUAL EVAPOTRANSPIRATION	7	22	45	63	93	118	138	132	81	39	11	7	756
3	PRECIPITATION	265	41	6	24	19	63	·	9	13	21	24	137	622
4	EFFECTIVE PRECIPITATION	105	39	6	23	18	57	·	9	13	20	23	99	412
5	RUNOFF [LINE 3 — LINE 4]	160	2	·	1	1	6	·	·	·	1	1	38	210
6	PRECIPITATION DEFICIT [LINE 2-LINE 4]	·	·	39	40	75	61	138	123	68	19	·	·	563
7	SOIL MOISTURE	100	100	100	100	100	100	100	100	100	100	100	100	
8	DEEP PERCOLATION FROM PRECIP [LINE 4 - LINE 2 - REPLENISHED SOIL MOISTURE]	98	17	·	·	·	·	·	·	·	·	12	92	219
9	IRRIG. CONSUMPTIVE USE REQUIREMENT	·	·	39	40	75	61	138	123	68	19	·	·	563
10	FARM DELIVERY REQUIREMENT [LINE 9 X (1/0.70)]	·	·	56	113	107	87	197	176	97	27		·	860
11	DIVERSION REQUIREMENT [LINE 10X(1/0.75)]	·	·	75	151	143	116	263	235	129	36		·	1148
12	TOTAL APPLICATION [LINE 3 + LINE 11]	265	41	81	175	162	179	263	244	142	57	24	137	1770
13	EXCESS OF APP OVER CONS. USE [LINE 12 - LINE 2]	258	19	36	112	69	61	125	112	61	18	13	130	1014
	ESTIMATED DISTRIBUTION OF FARM + CANAL LOSSES													
	A FARM WASTE													
14	SURFACE RUNOFF [10 % OF LINE 10]	·		6	11	11	9	20	18	10	3	·	·	88
15	DEEP PERCOLATION [20 % OF LINE 10]	·	·	11	23	21	17	39	35	19	5	·	·	170
16	TOTAL FARM LOSSES [LINE 14+LINE 15]	·	·	17	34	32	26	59	53	29	8			258
	B DISTRIBUTION LOSSES													
17	DEEP PERC. + EVAPORATION FROM MAIN CANAL [12 % OF LINE 11]	·	·	9	18	17	14	32	28	15	4	·	·	137
18	DEEP PERC FROM SECONDARY AND TERTIARY CANALS [5 % OF LINE 11]			4	8	7	6	13	12	6	2			57
19	OPERATIONAL WASTE [8 % OF LINE 11]	·		6	12	11	9	21	19	10	3	·	·	91
20	TOTAL DISTRIBUTION LOSSES [LINE 11 LINE 10]	·	·	19	38	36	29	66	59	32	9			288
21	TOTAL LOSSES INCLUDING FARM WASTE + DISTRIB LOSSES [LINE 16 + LINE 20]	·		36	72	68	55	125	112	61	17			492
22	DEEP PERC LOSSES FOR FARM DRAINAGE COMPUTATIONS [LINE 15 + LINE 18]			15	31	28	23	52	47	25	7			228
23	TOTAL DEEP PERC EXCEPT FROM MAIN CANALS [LINE 22 + LINE 8]	98	17	15	31	28	23	52	47	25	7	12	92	447

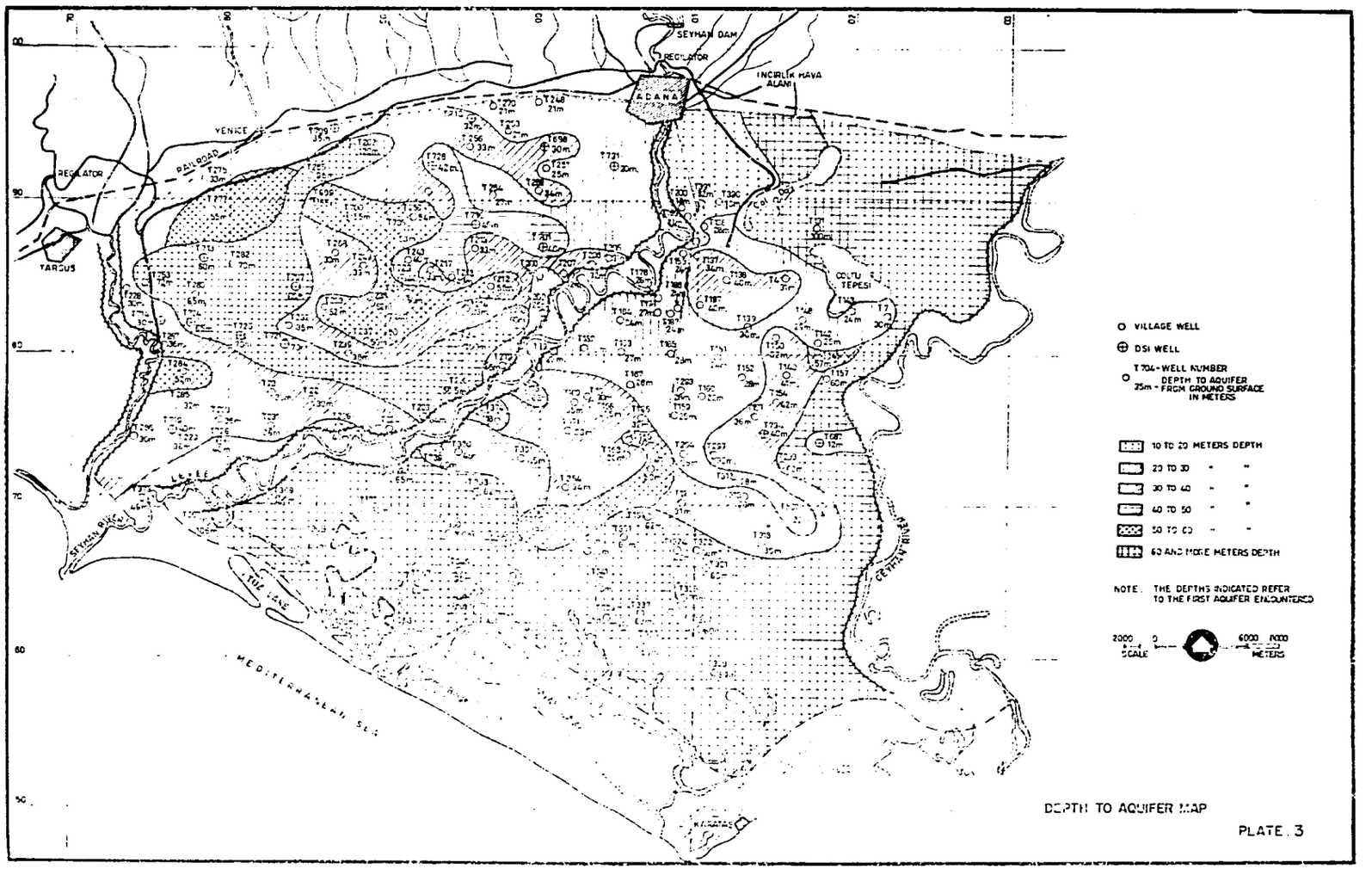

SEYHAN DAM
REGULATOR
INCIRLIK HAVA ALANI
ADANA
VENICE
RAILROAD
REGULATOR
YARGUS
ÖLÜTU TEPESI
SEYHAN RIVER
MEDITERRANEAN SEA
CEYHAN RIVER
O VILLAGE WELL
⊕ DSI WELL
T704 - WELL NUMBER
25m - DEPTH TO AQUIFER FROM GROUND SURFACE IN METERS
10 TO 20 METERS DEPTH
20 TO 30 " "
30 TO 40 " "
40 TO 50 " "
50 TO 60 " "
60 AND MORE METERS DEPTH
NOTE. THE DEPTHS INDICATED REFER TO THE FIRST AQUIFER ENCOUNTERED
2000 0 6000 8000
SCALE
METERS
DEPTH TO AQUIFER MAP
PLATE. 3

FIG. 3

carried to the plain by these deep aquifers. It is also likely that these aquifers are the source of considerable inflow of underground water into the delta area, as supported by the following observations :

1. In most locations ground water pressures increase with depth of each aquifer encountered.
2. The water-table gradient is perpendicular to the general direction of the foothills and steepens somewhat as it approaches them.
3. The water-table is high even in the upper parts of the plain.

Constructions from the River Channels. From the water-table contour maps it is found that all three rivers can account for only a minor portion of ground-water recharge. The hydraulic head differences between the water level of the stream and the surrounding water-table is too small to bring about a significant amount of recharge.

Water Escaping from Artesian Aquifers. Studies on flowing village wells and test drillings have shown that the amount of upward seepage from underlying aquifers is generally low because of the very low permeabilities of compressed clay layers overlying most aquifers. Areas so affected are isolated and of very small extent.

Water-Table Fluctuations

The fluctuations of the water-table are about the same for all wells and vary annually between 1·5 and 2·0 m. for most points of observations. Hydrographs for 33 typical observation wells show no indication flow escaping upward by flattening. The water-table fluctuations have a direct relation to rainfall distribution over the year and are also slightly dependent on average depth below land surface except for very deep water-tables.

Proposed Method of Layout

Existing ground water conditions clearly indicate that almost all of the land of the plain will require deep subsurface drainage. The most economical system for both irrigation and drainage tertiary canal construction is to alternate irrigation and drainage canals, each serving the lands on both sides and therefore giving maximum service with a minimum length of canal. The average service is 100 hectares. Secondary drains and main drains will be centrally located between secondary and main irrigation canals.

Tertiary drainage canals are designed so as to provide an outlet at the nearest low point of each irrigated unit. Layout considered the needs of individual owners. The drainage canals are designed and constructed to accommodate surface flows and also to carry perennial subsurface flows whichever is greater. Temporary submergence of subsurface drainage systems due a storm runoff is accepted, however such submergence should not exceed 3 days in any three week interval. Perennial flow requirements have been calculated from average monthly flow volumes determined from the water balance study.

The drainage system, designed and constructed according to these criteria, will provide an outlet for farm tile systems. Drain spacings are calculated by using the quasi-stationary method.

MARJA IRRIGATION DRAINAGE AND SETTLEMENT PROJECT

by

The Helmand Valley Delegation

INTRODUCTION

The Marja tract is on a typical desert outwash plain lying in the Helmand Valley. It is about 9 kilometers wide, by 19 kilometers long, having an average elevation of 750 meters above sea level and is located about 40 kilometers to the west of Lashkar Gah on a gently sloping terraced bench just below a series of low ridges marking a break in the levels of the older desert benches. (See map, Country Report Afghanistan).

The Marja Wash has brought down large quantities of silts and fine sands which have spread over the general area. The slope is generally to the south with the majority of the land having a grade of one tenth of one per cent. Along the extreme northern edge, there are short reaches which vary from ·03 to ·04 per cent of slope. To the east the tract merges with the low undulating gravely ridges and desert plains which slope to the Helmand River.

The parent material for the soils is the old outwash typical of the great desert plains which extend southward from the foot of the Hindu Kush Mountains into the vast Southwest Afghanistan Desert. The soils are primarily silty to sandy containing varying quantities of gravel. These soils overlay stratified sands, gravels and clays weakly to strongly cemented by lime and salitious materials. Conglomerate underlies the whole area. It is formed by cementation of the gravels and cobbles with a very hard matrix of calcium and other silicates. The conglomerate occurs at depths of 5 to 15 feet in the Marja area and in continuous beds. Stratified with the conglomerate are varied quantities of sands and gravels. Above the conglomerate may be found, in places, hard caliche or strongly cemented gravels.

Fahrenheit temperatures in the area range from a high of a 120 degrees to a low of 12 degrees with an annual mean of 69 degrees. This temperature range compares with continental desert climates at similar latitudes and elevations. The average mean annual rainfall is approximately four inches. The mean annual evaporation is in the range of 111 inches.

PROJECT PLANNING

Marja enjoys a good irrigation water supply from the Boghra Canal and its extension the East Marja Canal. The Boghra diverts from the Helmand River about 70 km. below Kajaki Dam and Reservoir. This reservoir impounds 1,490,000 acre feet of water. The quality of the Helmand River water is good, containing less than 220 parts per million of soluble salts with virtually no toxic ions.

The ground water is poor in quality and is not used for irrigation at the present time. The salt content of the underground water ranges from 2,000 to 3,500 parts per million. This high salt content should eventually decrease through proper irrigation and efficient drainage.

The Marja soils vary widely in depth, gravel content, texture of surface and sub-soil and depth to permeable of semi-permeable

materials. Soils at the lower end of the Marja project have developed from sandy outwash materials and aeoliam sands. These sands have accumulated in an irregular hummocky to dune pattern over the underlying soils. In places where the movement of sands has been both by wind and water sands are stratified with gravel making the entire profile very permeable. In the eastern part of the area, are several isolated low hills (about one meter) with a gravel surface, containing quantities of gypsum beneath a very shallow soil layer. In the extreme western part of the area the soils adjacent to the canal are of steeper slope and very shallow and gravely. In places these soils contain high quantities of gypsum, and because of the wide variety within the entire Marja tract a grouping was first made for the purpose of description. This classification was based on soil texture and chemical analysis rather than on the broader classification presently used as a standard by the U.S. Department of Agriculture which includes drainage characteristics. This grouping is now being reconsidered and re-evaluated in the light of new knowledge and because of the problems arising from inadequate drainage.

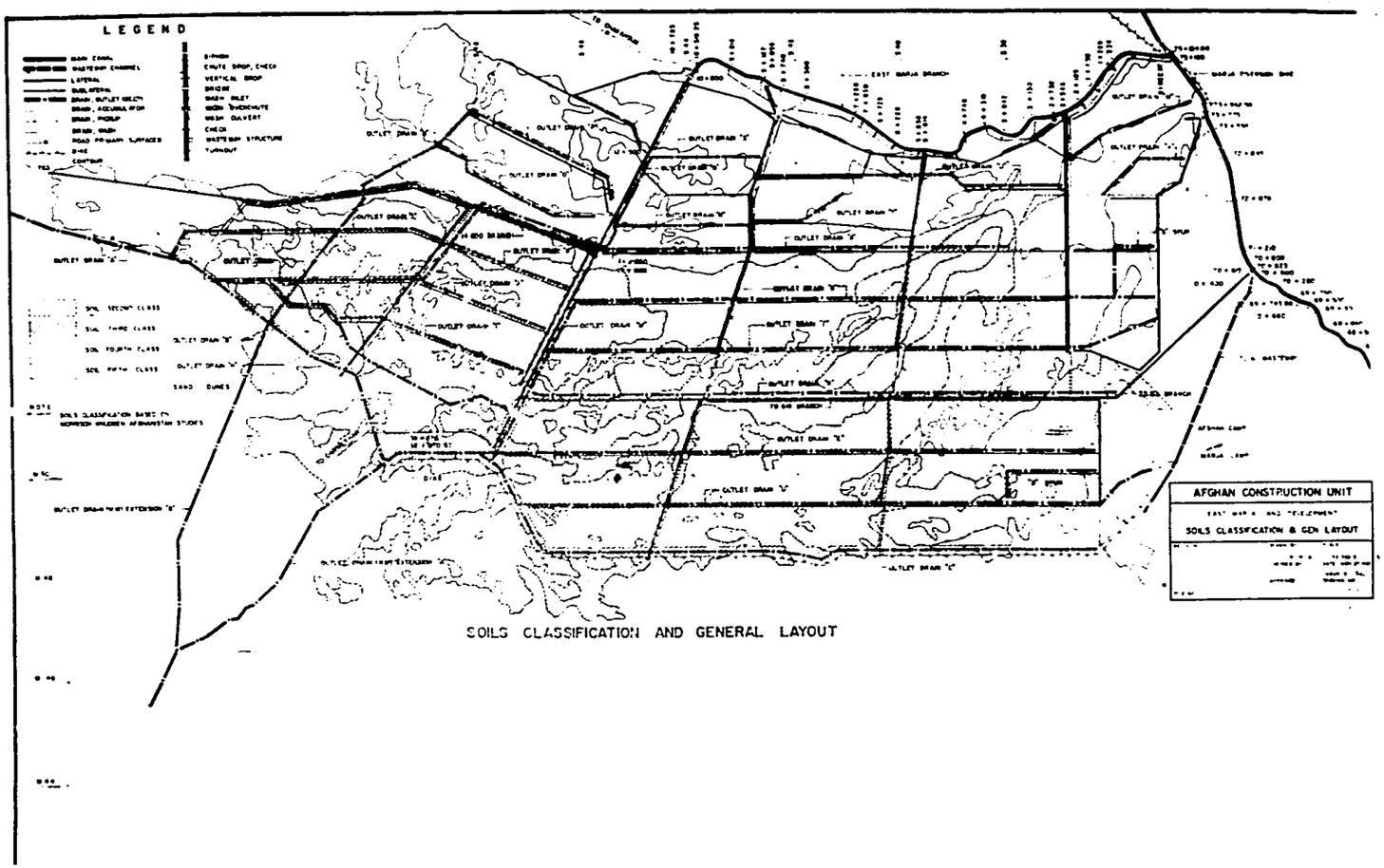
It was originally anticipated that the development of the Marja tract would involve some 45,000 irrigable acres. Subsequent studies eliminated the severely salinized Western tracts. The present area under cultivation is about 21,500 acres.

Acreage to be irrigated, climate, the consumptive use of various crops and a 70 per cent canal efficiency figure were used in computing the total diversion requirement. The canal efficiency factor was due to the length (70 kms.) of the Boghra canal. Also, the effective rainfall and a five per cent reuse of return flow was considered. The gross diversion requirement varies between 1·25 and 10 acre feet per acre for the various crops, which indicates a wide range in crop use and irrigation efficiencies. Hay and pasture crops require irrigation every month of the year and hence are the largest users of water. On the other hand, for annual crops such as summer and winter grains irrigation requirements are considerably less because of the shorter crop year. On this basis the total diversion for the entire Marja area was calculated at close to 180,000 acre feet or approximately 7 acre feet per acre. Farm delivery is 5·3 acre feet per acre. When adjusted to crops the above values amount to a diversion requirement of 4·7 acre feet per acre per crop and 3·5 acre-feet per cropped acre farm delivery.

Soils of the Marja area vary widely in depth, water storage capacity, infiltration rate and initial fertility. Proper land use and irrigation practices are important for each type. There are soils with an intake rate of 1 inch to 2½ inches per hour with but 1 inch of available storage capacity in the soil profile. These soils require a very short run (50 to 100 meters) and a large irrigation head. In contrast there are soils of silty clay loam texture with an infiltration rate of 0·2 inches per hour which with a reasonable length of run would require up to twenty hours for optimum penetration. Since most of the Marja area has a low gradient of 0·001 to 0·0015 it was considered best on the heavier soils to use a check boarder system and larger heads of water. The capacities of irrigation ditches and the size of farm units are based on the soil pattern of the area (Fig. 1).

The natural underground drainability is limited by the rather flat gradient and shallow depth to the impermeable barrier. Such a condition develops a high water-table after a relatively short period of irrigated agriculture. Continued irrigation raises the water-table to critical levels and because of the presence of salts in the profile subsequent salinization results. The need for adequate drainage was realized in the early planning stages of the Marja area.

Preliminary drainage investigations were begun in November, 1952. Some 67 observation wells were located at 2 kilometer intervals over the project. Monthly readings



SOILS CLASSIFICATION AND GENERAL LAYOUT

FIG. 1

were made from December, 1952 through July, 1954. Groundwater elevations and depth to groundwater were plotted and drainage problems reported. During 1956 and 1957 detailed drainage studies were made logging deep open pits on a 200 meter grid over the entire area, and on 50 to 100 meter intervals in selected areas. These pits indicated the presence of a layer of relatively impermeable compacted material consistently undulating at depths ranging from 1·5 to 2·5 meters below the ground surface. The more pronounced ridges and valleys of this compacted material are oriented parallel to the slope in a north/south direction. The soil and sub-strata horizons were logged in each pit to a depth of 12 feet. The texture, structure, consistency and porosity were noted and an evaluation made of the permeability of each horizon or zone. A map classifying the land area as to its relative drainability was prepared. From these studies the need for drainage was recognized and deep major outlet drains were constructed on a 3 km. spacing to an average depth of 2·5 metres. Because of the relatively low water holding capacity of the shallow soils and also because of the gravelly sub-strata underlain with slowly permeable to almost impermeable materials sub-surface drainage was recommended. Drain tile was laid one km. apart in Blocks 1, 2, and 3. Experimental open drains were dug at typical sites to determine proper type, depth and spacing. Recommendations were made to guard against a rise in the water-table where it was likely to reach dangerous levels.

The Marja area was settled by men of the nomadic tribes. Their experience in irrigation farming was nil. The consequent over application of irrigation water, plus the seepage from canals and laterals, made reconsideration and further study of the drainage problem imperative. With the arrival of the Bureau of Reclamation Advisory Team in 1959, investigations and testing were again initiated.

In 1961, auger hole field permeability testing on a kilometer grid was initiated throughout the project area. A grid of test pits was dug on a one kilometer spacing and a two year study of the action of the groundwater was made. Data obtained from these sources indicated that the water-table fluctuated directly with the intensity of irrigation rising to a maximum in July and falling to a low in January. This data also showed a considerable rise in groundwater elevation from 1954 to 1961 (Fig. 2).

From the field permeability tests a drainability map (Fig. 3) and a depth to barrier map, (Fig. 4) were prepared. From a "depth to groundwater" map, the water-table was found to vary between ·60 and 1·50 meters, averaging about 1·0 meter below the ground surface.

Although no piezometers have been installed to study confined groundwater, a review of the fluctuation of the groundwater table shows that artesian pressure is not a problem in the upper drainable strata.

Drainability throughout the project area varys from zero to 60 meters per day. The drainage aquifer of the Marja Wash leading from the northwest into the central part of the project consists of gravel with coarse clean sands having permeabilities ranging from 12 to 60 meters per day. To the North and West the soils become dirtier with permeabilities ranging from 4 to 12 meters per day. On the East and South they range from gravelly sandy loams to gravelly silty clay loams with permeabilities from zero to four meters per day.

Drain depth and spacings were determined by a method developed in 1959 and improved upon since that time by the Denver office of the Bureau of Reclamation. This method takes into consideration the water-table build-up with each irrigation and the drain-out that takes place between irrigations. Farm drain spacing and depth have been determined for about one quarter of the project. Spacings range from 100 meters to 200 meters with depths varying from 1·5 meters to 2·0 meters below ground surface. So far 84 kilometers of properly spaced open farm drains

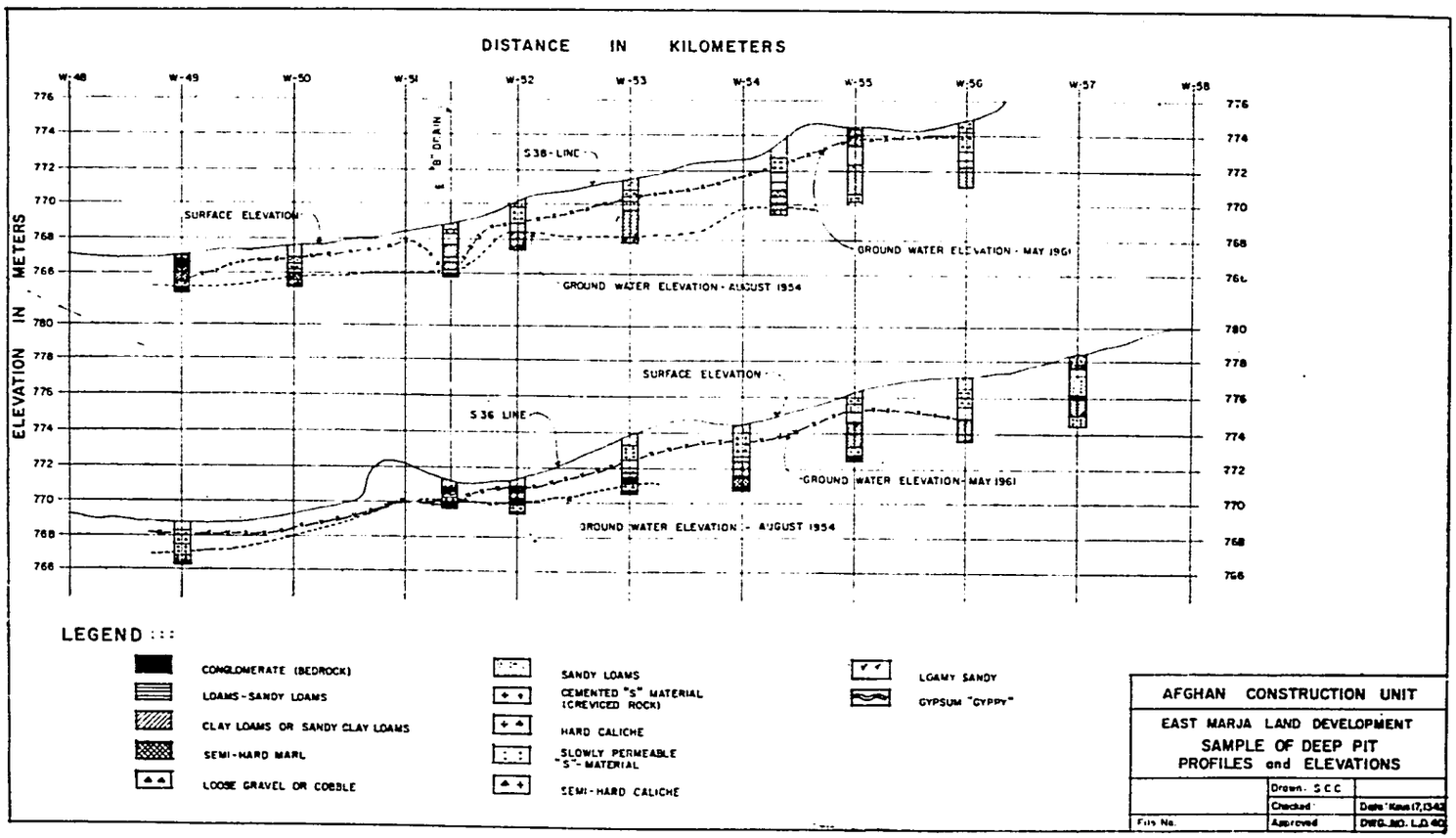
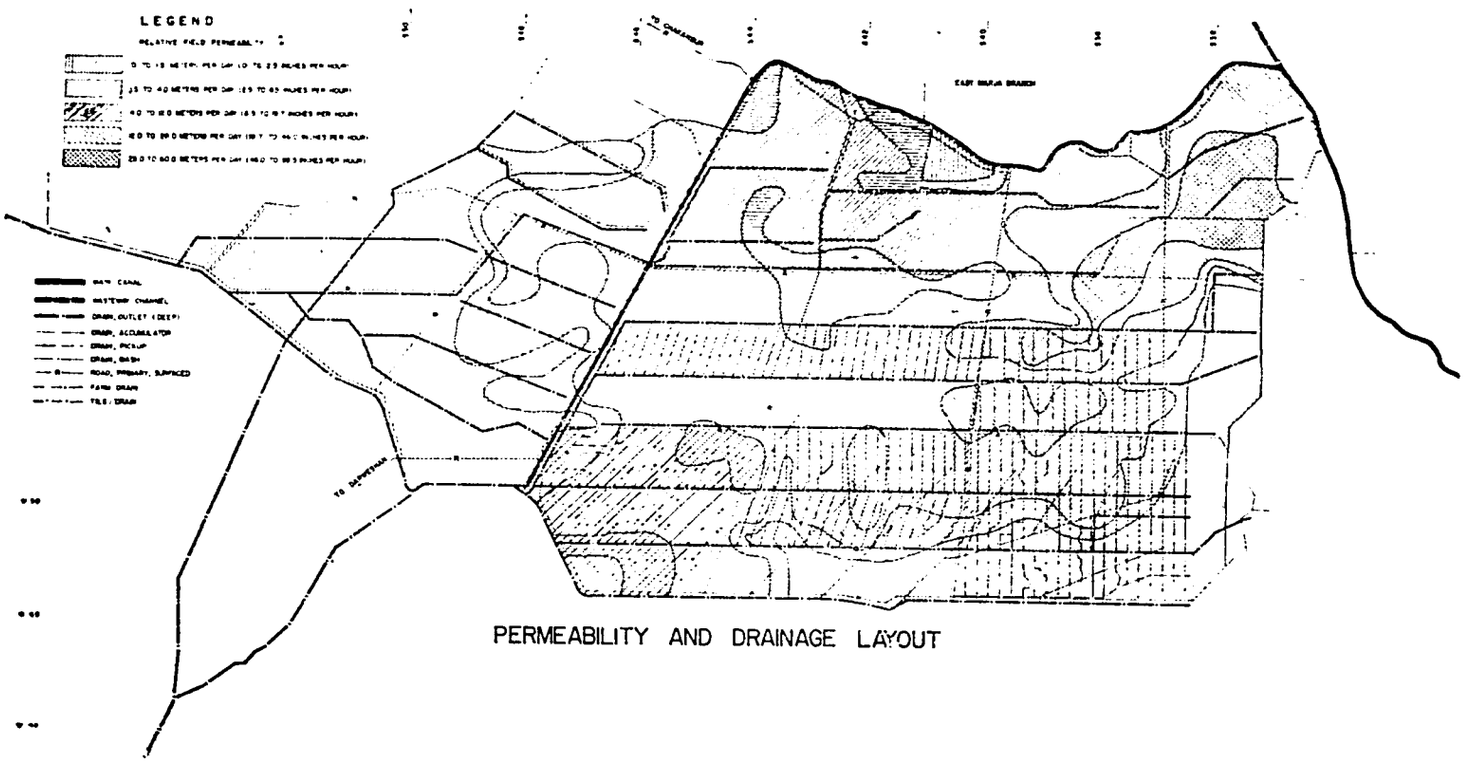
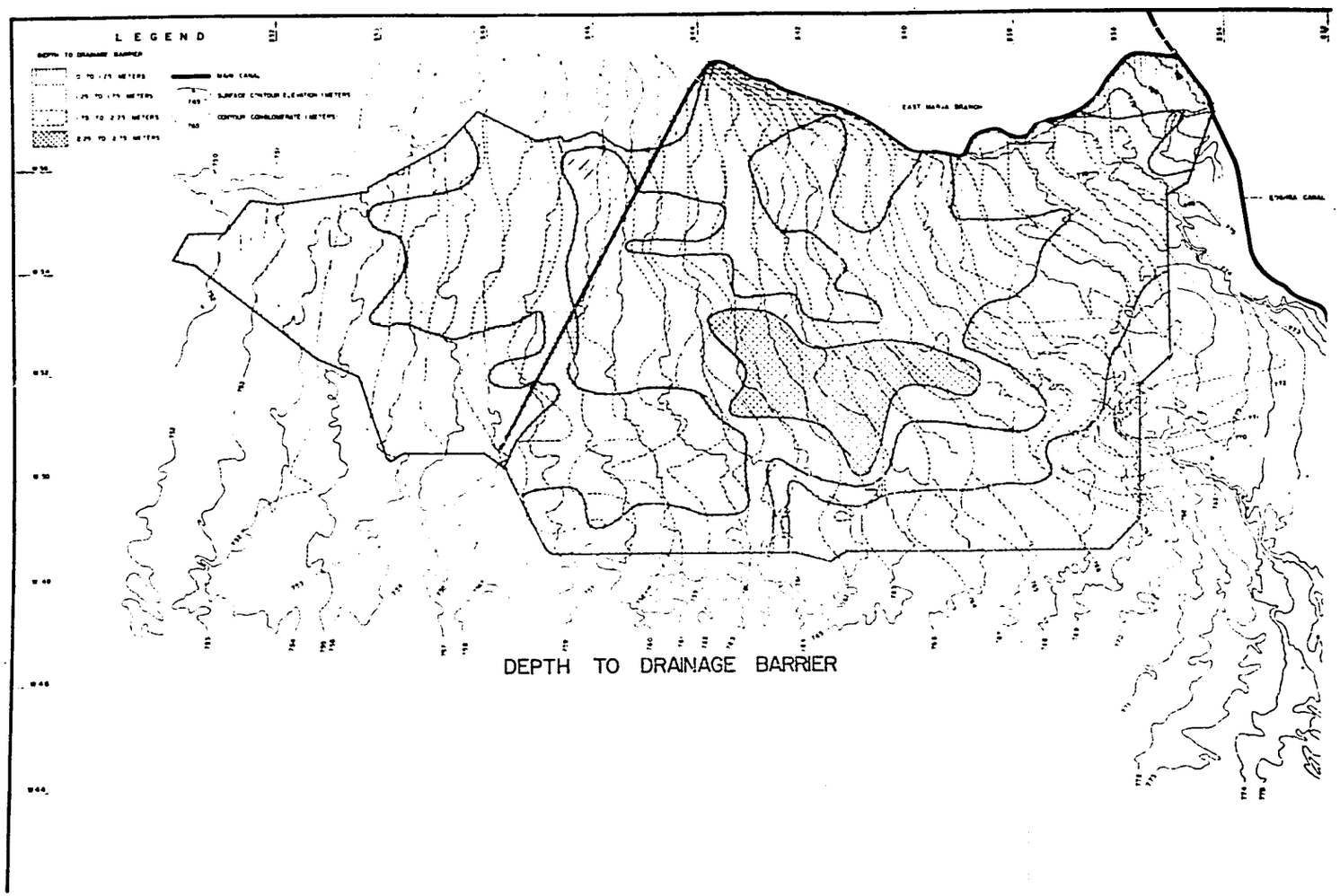

DISTANCE IN KILOMETERS
W-48
W-49
W-50
W-51
W-52
W-53
W-54
W-55
W-56
W-57
W-58
ELEVATION IN METERS
776
774
772
770
768
766
780
778
776
774
772
770
768
766
"B" DRAIN
S38-LINE
SURFACE ELEVATION
GROUND WATER ELEVATION - MAY 1961
GROUND WATER ELEVATION - AUGUST 1954
SURFACE ELEVATION
S36 LINE
GROUND WATER ELEVATION - MAY 1961
GROUND WATER ELEVATION - AUGUST 1954
LEGEND :::
CONGLOMERATE (BEDROCK)
LOAMS-SANDY LOAMS
CLAY LOAMS OR SANDY CLAY LOAMS
SEMI-HARD MARL
LOOSE GRAVEL OR COBBLE
SANDY LOAMS
CEMENTED "S" MATERIAL (CREVICED ROCK)
HARD CALICHE
SLOWLY PERMEABLE "S"-MATERIAL
SEMI-HARD CALICHE
LOAMY SANDY
GYPSUM "GYPPY"
AFGHAN CONSTRUCTION UNIT
EAST MARJA LAND DEVELOPMENT
SAMPLE OF DEEP PIT PROFILES and ELEVATIONS
Drawn. S.C.C.
Checked
Approved
File No.

FIG. 2



PERMEABILITY AND DRAINAGE LAYOUT

FIG 3

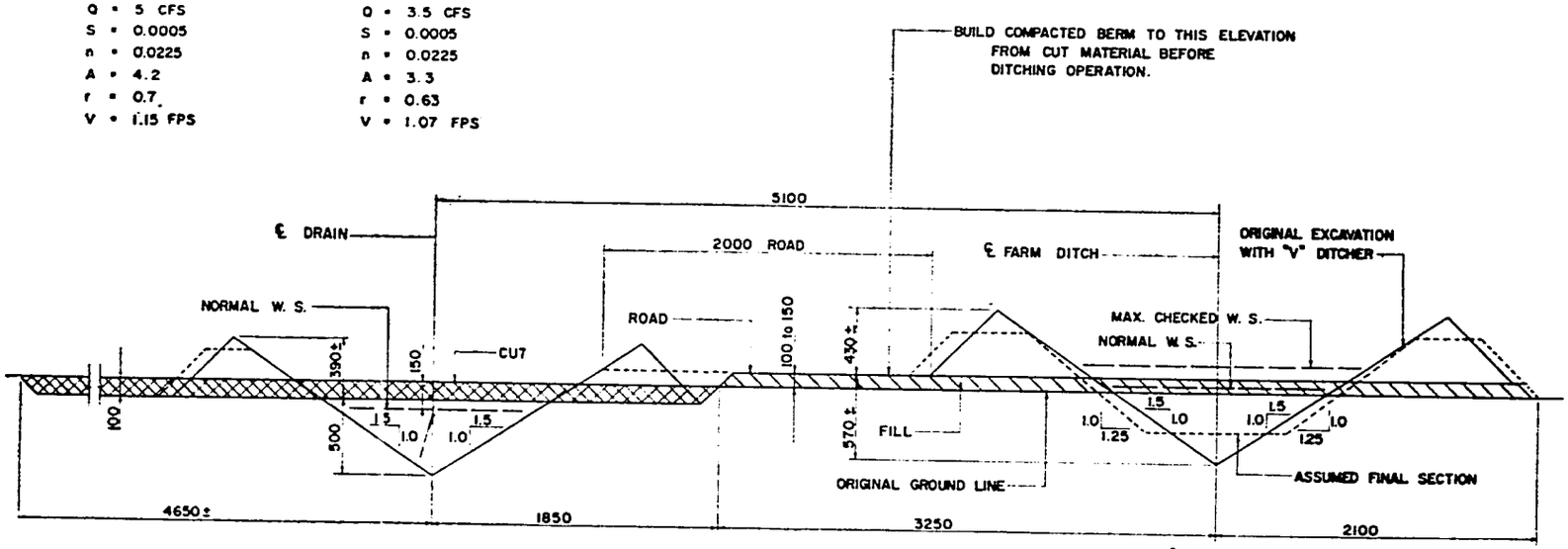


DEPTH TO DRAINAGE BARRIER

FIG. 4

HYDRAULIC CHARACTERISTICS

FARM DITCH	DRAIN
Q = 5 CFS	Q = 3.5 CFS
S = 0.0005	S = 0.0005
n = 0.0225	n = 0.0225
A = 4.2	A = 3.3
r = 0.7	r = 0.63
V = 1.15 FPS	V = 1.07 FPS



NOTES:

ALL DIMENSIONS ARE IN MILLIMETERS.
ALL SIDE SLOPES ARE 1.0:1.0 EXCEPT AS OTHERWISE SHOWN

F IG.5

have been constructed in Marja and the excavation of an additional 138 kilometers is anticipated. Follow-up studies are continually being made of the effectiveness of these newly excavated open farm drains.

CONSTRUCTION

Construction of the project was accomplished in two phases. Morrison Knudson Afghanistan Incorporated (MKA), under contract in 1954 with the Government of Afghanistan, undertook the construction of the major facilities in the Helmand and Arghandab valleys.

The major facilities included dams, main canals appurtenant structures, surface and sub-surface drainage systems and interproject roads. Conventional modern heavy and light machinery was used in all construction. Major canals were constructed with bank slopes of 1·5 : 1·0 to 3·0 : 1·0. Slopes of the major drains were 1·5 to 1·0. Excessive grade dictated the inclusion of numerous concrete drops. All major checks and turnouts including drops were constructed of re-inforced concrete. Large inverted syphons underpass major washes, smaller inverted syphons underpass the main canals at strategic locations. Gravelled roads were constructed along the banks of the canals and major laterals.

The Afghan Construction Unit (ACU) worked concurrently with MKA and installed the necessary sub-laterals and farm ditches and appurtenant structures. ACU did the necessary land levelling, discing, leaching and constructed such sub-surface drains as were subsequently determined to be necessary. In addition ACU assisted the agricultural department of the Helmand Valley Authority in seeding the initial crop on newly developed lands. Farm ditches were constructed both with a motor patrol grader and a winged V-type ditcher. Those constructed with a motor patrol had very flat banks with steep back slopes of dry loose material. When water was turned into them without proper priming the banks above the natural ground line sloughed quite badly. It was necessary for the farmers to raise these ditch banks as much as 30 centimeters to provide for a minimum checkup of water surface elevation. Concrete checks and turnouts were constructed in the farm ditches at selected intervals. Deep drains were constructed by draglines on spacings of approximately one kilometer running in a north/south direction at depths of from 2·5 meters to 3·25 meters. The bank spoil material was levelled and graded to provide access roads. Deep drains intercept hand-dug farm drains which vary in spacing from 100 to 300 meters, and in depth from 1·85 to 2·25 meters.

ACU has completed 160 km. of collector drains at depths of 2·5 to 3 meters, 83·5 km. of open farm drains at depths of 1·5 to 1·8 meters and about 40·5 km. of tile drain has been installed. It is estimated that 138 km. of open farm drain will yet have to be constructed to assure the development of a non-saline soil.

LAND LEVELLING

Land levelling was based on soil classification and the border method of irrigation. The general slope of the land is ·001 to ·0015 which is a minimum for the border method. Effort was made to plan irrigation in the direction of the maximum slope. A detailed topographic map was prepared from a 25-meter by 25-meter grid survey. The soil survey, in detail, was superimposed and the resulting levelling requisites were differentiated by colours showing the good, bad and marginal lands. Consideration was also given to rough topography in shallow soil areas because levelling would be expensive and would result in a spotted soil with alternate pockets of top soil and subsoil. Computations were made by using the average elevation of the field as the elevation of the center of the field and working in all directions. Excessive slopes on slowly permeable soils as well as flat slopes on highly permeable soils were avoided assuring the optimum percolation grade wherever possible.

In general, the investigations on soil and topography revealed three types of levelling

were required. A tolerance of 8 cm. was decided acceptable. First, the area of heavy levelling occurred in the south and included undulating to hummocky fine sands over sandy and sandy clay loams. This area could stand no more than a 15 cm. cut but required spreading of some wind-drift and deep plowing to incorporate the sand into the soil. Second, mixed light, heavy and intermediate levelling was needed on tracts scattered throughout the project. Spreading and plowing sand to incorporate it into the soil was necessary in places. The moderately deep soil could stand a 45 cm. cut. Third, light levelling, requiring only planing or light scraper work occurred throughout the project on the smoother loam and sand soils.

LAND USE

Although Afghanistan is considered to be an agricultural country, the ratio of agricultural land to the number of people deriving a living from farming is very low. If the available farm land were distributed equally among the farmers each would have less than one acre. Since the land is not shared equally, a great number of farmers are without land or with an un-economical unit.

Besides these landless farm tenants there are about 2 million nomadic people in Afghanistan who seasonally migrate in and out of the country and are suffering from restrictions on their migration across international borders. These restrictions have reduced their income from transportation services, seasonal employment and informal trading. Economic and social pressures for several years have led these people to petition the government of Afghanistan for land on which they could settle. The government has felt obligated to provide this. One of the main purposes of the Helmand Valley Project was to provide farms for the above purposes.

More than 600 families, comprizing above 3,000 persons have been settled on the Marja project. Half of these settlers were nomads, and half were landless farmers. The Helmand Valley is sparsely populated due to the shortage of water before completion of the present project.

SETTLEMENT PROGESS

Tribal leaders of the nomadic people and chiefs of the landless farm tenants first petitioned the Government for land through the Ministry of Interior Affairs. The Government, considering the following factors and standards, chooses a number of families that may be granted farms: The amount and class of irrigated land available; the density of the population in the area from which the potential settler is drawn; the character of the tribe from which he comes; his age, health and physical strength. He must be a citizen of Afghanistan and have no property from which a minimum standard of living can be drawn. The individuals chosen are introduced to the Helmand Valley Authority by the Ministry of Interior Affairs which, through its Agricultural Department again screens the applicants and allots farms to those it finds satisfactory. The acreage assigned to each family varies with the land class set up by the Bureau of Lands as follows: class 1, 7½ acres; class 2, 10 acres; class 3, 12½ acres; class 4, 15 acres.

ASSISTANCE RECEIVED BY THE MARJA SETTLERS

The nominal price of the land, Afs. 500 (equivalent to $ 10·00 U.S.) to the settlers may be considered a subsidy or a direct assistance. Each family received an ox, 1,000 pounds of wheat, some basic farm equipment and about Afs. 5,000 worth of building materials such as doors, windows, lumber etc. The wheat is to be paid back at the end of the first year. The cost of the land and the loan for the other agricultural and building materials is to be paid in seventeen years in equal yearly instalments without interest and beginning the fourth year of settlement.

LIVING QUARTERS

Villages in Marja were designed for about thirty families and each house was located so

as to be as near the allotted farm as possible. Some farms are as much as a kilometer away from the house, however, and some of the farmers are becoming concerned about the extra time and transportation this arrangement entails. Some have been granted permission to build homes on their farms. HVA since 1960 has eliminated the establishment of villages as such and has adopted a policy that allows home construction on the farm according to an approved plan. Thirty families have been settled in Marja since the adoption of this new policy.

EDUCATION AND WELFARE

There are six primary schools, up to the sixth grade, with nearly three hundred students in Marja. These schools are so located that all students can reach them on foot. A centrally located high school that will accommodate three hundred students is under construction and is scheduled for completion this year. Adult education courses have also been started for the settlers and about one hundred have attended. School supplies such as books, paper, pencils, etc. are free.

An Agricultural Extension worker is stationed in each village ; his duty is the teaching of better farming through the use of improved seed, fertilizers, adoption of a system of rotation, proper water use, insect control, and vegetable and orchard husbandry. He is also charged with demonstrating the advantages of these better farming practices. Although improvement is sometimes hard to find the Extension programme is proving successful when measured by the increased use of fertilizers and insecticides. These agricultural supplies are available to the settlers through the Agricultural Department at reasonable prices.

The Public Health Department of the HVA has assigned a sanitary advisor to the area and charged him with the improvement of general health and sanitation. The malaria eradication programme has been very successful ; a hospital, staffed by the Public Health Department, is in operation ; houses are dusted once or twice a year with DDT to eliminate harmful insects and the Agricultural Department supplies needed veterinary services.

MECHANIZED FARMING

In 1960, 2,000 acres was set aside as a mechanized farm. The objectives were : to find the economic value of mechanized farming in the newly developed area ; to introduce modern equipment and improved methods of farming and to train some people in the use, operation and maintenance of farm machinery. In 1962, the acreage of the farm was increased to 10,000 acres. A basic rotation of wheat, clover and cotton has been adopted and all possible operations are done mechanically.

As in all newly developed desert soils, it has been found that Marja's are deficient in organic matter and nitrogen. They are also deficient in phosphorous. Thus, green manure, nitrogan and phosphorous fertilizers are basic necessities. Last year's application of 55 pounds of ammonium phosphate and 42 pounds of urea per acre almost doubled the cotton crop and the value of the increased production was three times that of the fertilizer applied. The operation of this farm has demonstrated that if the drainage programme is completed, the required personnel are trained and enough fertilizer applied mechanized farming is feasible.

At the present time the Marja farm population, and the tools to farm with, are insufficient to till the available land. Thus the existing land and water resources are not being used to the extent desired. To fill this need modern machinery and equipment were introduced to the people of the Valley. The mechanized farm has successfully made this introduction.

OPERATION AND MAINTENANCE

The responsibility for delivery of water to the Marja farm laterals was accepted by the

Operation and Maintenance Department (O & M) in 1961. Watermasters and ditch-riders were appointed. Immediate attention was given to controlling water losses, to start water measurement and to keeping water records. A training course was established to teach watermasters and ditch-riders the principals of measurement and water handling. In the preliminary stages of planning the application of sufficient water to the farms was considered most important and hence it was not thought advisable to spend extra money installing measuring devices in the lateral, sub-lateral and farm ditch systems. After a few years of farming, the excessive use of water by the farmers developed waterlogging and salinization. Therefore, drains and a strict control of water application by the installation of water measuring devices and the training of ditch-riders is becoming imperative. Water is not measured to the individual farmer at his turnout, the measurement is made at the lateral and sub-lateral. A programme has been initiated to install metergates in some farm ditches which will make it possible to measure, and therefore control, some of the losses that still exist. Canal and turnout gates are rated to some extent and recently cableways have been installed for current meter measurements of the flow in the canal. Every year during the winter from December 10, to January 20, the water is shut off for 40 days and during this time repairs and improvements such as desilting, cleaning, burning of the weeds that grow on the slopes of the canals and laying of riprap below structures are accomplished. These repairs are done by hand labourers and heavy machinery like draglines, briscoe ditchers, etc. The farmers of the area are also encouraged to clean their farm ditches and drains.

MARJA CANAL

The canal which serves the Marja Development is excavated through materials containing pocketed Gypsum deposits. These "gotch pockets" dissolve slowly and eventually result in leakage and piping through the canal banks. The resulting rise of the groundwater-table in the surrounding areas contributes to the instability of the canal berms and makes their maintenance very difficult ; it also waterloggs the lands for varying distances below the canal.

The first attempt at correcting this serious deficiency was made by hand excavation of a narrow trench. Starting a few inches above the water line on the inside slope of the canal bank, the trench was dug to a depth of 1·75 meters and backfill of impervious material was taken from a borrow area. This method proved ineffective for stopping the seepage as the trenches did not get below the gotch layers, the backfill material was poor and its compaction inadequate.

Lining of the worst sections with a compacted mantel of impervious material was begun. Suitable lining material is scarce in the area, the consequent long haul makes the job very expensive, as does by-passing of the water around the lining operation. However, several kilometers have been lined and the work is continuing. No seepage or other trouble has developed in the lined sections ; the banks are stable and no deterioration has taken place.

A cheaper method of controlling the seepage and piping is being sought. Investigations show that a trench 4 to 5 meters deep in the canal berm will extend below the gotch and reach a comparatively impervious layer. The trench may then be backfilled and puddled with selected fill material. Plans are now complete for a trial run of this method.

The Marja Canal is subject to sand deposition, which is moved by wind-storms from the Margo (Marja Desert) (Desert of Death). The sand is deposited in the canal and the water in turn carries it through the lateral and sub-lateral systems. These sand deposits raise the water level in the canal and ditches, thereby causing excessive seepage into the adjacent lands, as well as a great reduction in capacity of the ditches. Cleaning, sometimes twice or three times a year,

has been necessary. To prevent this sand movement into the canal an experimental dike was built as a sand fence approximately 50 meters up-wind of the canal. The dike has an average height of 1.5 meters, was built by a dozer and extends for several kilometers along the most troublesome sections of the canal. Results have been very beneficial. It is planned that other critical sand-blown sections of the Boghra Canal will be diked in the same way.

GROWTH OF MOSS

High temperature conducive to rapid growth of moss and other water weeds in the canals and ditches. Growth starts early in May continues into December. Moss growth causes increased seepage, leakage, and piping from the canals and laterals ; contributes to the height of the surrounding groundwater-table and results in breaks and washouts. It also reduces the capacity of the ditches to such an extent that definite shortages develop on the downstream farms. De-mossing of the sub-laterals and farm ditches is done by hand ; the larger canals and laterals are de-mossed by dragging a heavy chain along the entire wetted perimeter from one structure to the next. The chain breaks the moss at ground surface and the water carries it down-stream to the next structure where it is removed by hand or a clam-shell bucket on a dragline. The time interval between de-mossings is dependent upon the rate of moss growth and ability of the canal to carry sufficient water despite the moss growth. A two-week interval is average for the system.

The use of aromatic solvents has been studied and recommended but is considered too expensive at this time. Discs have been used to cut the moss in some of the smaller laterals and the results have been satisfactory.

DRAINS

Due to the excessive growth of tules and cattails the outlet drains in the Marja area were not functioning effectively. In early 1961, cleaning of these drains was started and some drains were deepened. Priority was given to those drains serving the areas most heavily irrigated. One hundred thirty-one kilometers of deep drains have now been cleansed. In some places permanent labourers have been hired to keep the drains clean and free of all hydrophyllic growth.

The effectiveness of the cleaning programme is very evident by the noticeable increase in the discharge from the drains and the lowering of the water surface therein. Along with the open drain cleaning programme, 40.5 kilometers of tile drain were cleaned with a small augering machine. Matted ropes of roots, eight inches in diameter and up to ten meters long, were pulled from these sub-surface tiles.

PROBLEMS AND RECOMMENDATIONS

1. **Water Management.** Soil profiles in the Marja area are limited in depth and the permeability of the sub-soil is not high, adequate drainage fecilities were, therefore, mandatory as was pointed up in the previous discussion. But, drains alone do not assure de-salinization. A rising water-table resulting from excessive water application limits the root zone. However, the necessary downward movement of dissolved salts is only accomplished by adequate irrigation. The middle road of enough water to insure downward movement yet not enough to increase the elevation of the water-table must be taught and enforced. Water measurement to the farms is one method of enforcement. Both the HVA Agriculture and O & M Departments concur on the installation of measuring devices, and this work is continuing.

2. **Canal Lining.** Seepage from the canal and lateral system was early recognized as a major contributor to a rising groundwater-table. The problem was attacked some years ago by

the initiation of a lining programme in the Boghra and East Branch Canals. This programme has greatly reduced seepage ; it is in progress now and plans are made for its continuation.

To minimize seepage from the distribution system the following practices have been thought necessary :

1. A canal shut down period of 40 days each year when irrigation demand is at its lowest.
2. Cleaning and straightening of the canals and laterals during this period prevents silt, moss, water weeds, etc. from holding water levels high and thereby increasing seepage.
3. The practice of a rotation system of delivery allows some of the sub-laterals to be dry some of the time. It also reduces waste through over-application and direct dumping into the drains.

3. **Drain Maintenance.** Drainage efficiency is dependent on maintaining designed depth and free flow in the open drains, and free flow in the tile drains. A cleaning programme designed to keep all the drains free and clear of any obstruction is now in operation. Draglines, a Gradall and small augering machines plus a method utilizing hand labour are used for this purpose.

4. **Settlers.** The majority of the settlers are of nomadic tribes, they have experience difficulty in adjusting to this new way of life and their experience in farming was nil. Those who were selected from other regions of the country had some general farming experience but they had not worked in a newly developed area with its inherent problems. Practically all of this latter group came from areas where the soils were fertile, salinity and drainage problems did not exist, and where scarcity of land and water prevailed. Therefore it is not hard to understand that these farmers find themselves facing problems that they alone cannot solve. Their unfamiliarity with proper irrigation methods, crop rotations, the use of green manures and commercial fertilizers etc. are examples. The HVA Agricultural Extension Service has provided advisory help for this farmers and the advantages of these better methods are being demonstrated in the field.

The distance between village and farm has been another disadvantage to the farmers. It causes : (1) Waste of time going back and forth to the farm. (2) Difficulty in moving farm implements and animal manure to the land and farm products back to the village. (3) Sharing of the farm work among all the members of the family is made more difficult. (4) A close watch on the farm to prevent loss of goods, equipment, livestock etc., is harder to maintain. The adoption of the new policy allowing the construction of homes on the farm has alleviated this problem.

To improve the lot of the farmer the Extension programme should be enlarged so as to expedite acquainting the settler with improved agricultural materials and methods. Incentive means could be adopted to speed up the application of such a programme. Also, better seeds, fertilizers, insecticides and improved agricultural implements could be made available to the settler through some form of incentive plan. Arrangements could also be made for the settlers to acquire some of these things through a short term loan. Credit for the purchase of tractors or oxen could also be made

available. The farmer should be encouraged and helped to build better housing for himself and his animals.

5. **Indirect Benefits.** In addition to the direct benefits derived from the Marja project, indirect benefits are of considerable value. Although these indirect benefits cannot be directly valued in Afghani, they are increasing the standard of living of the nation as a whole. Settlers are receiving an education in practical farming and a few attend adult education courses; these efforts make them better producers, more informed citizens and, most beneficial of all, their children are going to school.

The Nomad was not considered an asset to Afghanistan when his movements were international. He paid no taxes, traded illegally, and caused dissension on both sides of the border. As a settler he is contributing to the total agricultural production, paying his legal taxes, educating his children and becoming a solid citizen and an asset to a growing economy.

Costs and benefits of the Marja project are enumerated in Tables I and II.

TABLE 1. DEVELOPMENT COSTS PRESENT AND FUTURE, MARJA PROJECT.

	Previous Costs Afs.	Estimated Cost of Proposed Drainage and Canal Rehab. Afs.	Total Costs Afs.
Land Development (Project Irrigation System and Drainage)	211,001,918	68,181,981	279,183,899
Building Construction	14,884,277		14,884,277
Kajakai Dam	22,630,500		22,630,500
Diversion Dam	23,476,500		23,476,500
Boghra Canal	115,690,500	63,711,958	179,402,458
Roads	1,163,250		1,163,250
Surveys and Studies	5,499,000		5,499,000
TOTAL COST	394,345,945	131,893,939	526,239,884

Note: The previous costs include 30,000 acres. Later investigations showed about 8,500 acres were not suitable for continued irrigation development. For this reason the future costs include only 21,500 acres.

TABLE 2. COSTS AND REVENUE PER ACRE PRESENT AND FUTURE, MARJA PROJECT.

	Present Afs.	After Completion of Proposed Improvement Afs.
Development Cost	13,144	19,279
Production Cost	146	258
O & M Cost	50	50
Gross Revenue	456	1,036
Net Revenue	260	728
Ratio of Development Cost to Yearly Net Income	51[1]	27[1]

* The original development cost of the 8,500 acres not considered suitable for farming is not included in this figure.

STANDARDS FOR RECLAMATION OF SALINE AND ALKALI SOILS

PART I

by

Dr. N. D. Rege* and Dr. R. V. Tamhane*

SYNOPSIS

Saline, alkaline and waterlogged soils are problem soils all over the world. In India, approximately 6 million hectares of saline-alkaline soils and about 1·2 million hectares of waterlogged soils are reported mainly in the States of Punjab, Uttar Pradesh, Delhi, Rajasthan, Gujarat and Maharashtra. Different local names have been assigned to such soils in different parts of India.

The causes of saline and alkali soils are many and varied. The main ones are arid climate, saline nature of parent materials, salty irrigation waters, high subsoil water-table, poor drainage, seepage from canals and over-flow from sea-water.

Reclamation methods primarily depend major causes leading to saline-alkali and upon waterlogged conditions and the nature and extent of the problem. They deal with leaching out of excessive salts, improvement of drainage, use of inorganic and organic amendments, following suitable cropping systems, etc. Areas that cannot be economically reclaimed could be used for grasses, bushes and trees and a list of salt tolerant plants has been given.

Salient points for future investigations and development of saline-alkali reclamation approach and programme have been outlined under major groups of studies, such as (1) soils in relation to irrigation, drainage and salinity development, (2) water quality, (3) water-plant relationships, (4) reclamation methods and economic evaluation.

INTRODUCTION

Saline, alkaline and waterlogged areas are found in almost all countries, where the climate differs widely. Irrigation is resorted on extensive scale without proper facilities for drainage and where proper utilisation of land presents many difficulties such as small land holdings and subsistence level of agriculture. India is no exception to this. There are about 6 million hectares of saline and alkaline soils whereas, on a conservative estimate, there are over 1·2 million hectares waterlogged. The states which are badly affected are Punjab, Uttar Pradesh, Delhi, Rajasthan, Maharashtra and Gujarat.

These areas are so badly affected that most have gone out of production. At present, over 40 per cent of the total area is already under cultivation in India and there is not much left for further development. It has become imperative to think seriously in terms of reclaiming some of the affected areas and also to take care that more and more areas do not become affected.

SALINE AND ALKALINE SOILS

Saline and alkali soils are known in different region in India by different local names. They are called **thur** in Punjab, **reb**

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or **rebels** in Uttar Pradesh, **Kari** in Kerala, **Karl** in Maharashtra and so on, whereas alkaline soils are known as **rakkar** in Punjab, **usar** in Uttar Pradesh and **chopan** in Maharashtra.

In Punjab, there are over 2·4 lakh (0·24 million) hectares which have been very badly affected by salinity. Out of these, nearly 1·6 lakhs (0·16 million) are in the canal irrigated areas. In all about 0·12 million hectares have gone bad enough to reduce the crop yields considerably.

In Uttar Pradesh, there are 0·12 million hectares which have been so badly affected by salinity that they are lying waste. Another 0·12 million hectares of cultivated land have also been affected in comparatively more arid parts of Uttar Pradesh and on the left bank of the river Ganga.

In Rajasthan, there are about 0·04 million hectares and about 0·12 million hectares in Maharashtra, Gujarat, West Bengal and Kerala.

WATERLOGGING

Very little information is available concerning these areas in different States but about 1 million hectares in Punjab alone, and about 28,000 hectares in Maharashtra have been affected.

Causes of Salinity and Alkalinity

The main causes responsible salinity and alkalinity are :—

(1) Arid climate.
(2) Saline nature of parent rock.
(3) Use of irrigation water containing soluble salts.
(4) High sub-soil water-table.
(5) Poor drainage.
(6) Seepage from canals.
(7) Overflow of sea water on land.

As early as 1876, Uttar Pradesh Government (then United Province) appointed Reh Committee to investigate the causes leading to soil salinity. It expressed that the major cause for the deterioration of the fertile lands was the general aridity, the scanty rainfall not being able to leach out the undesirable salts formed through weathering processes.

Lather observed that the salts found in saline and alkaline soils are the decomposition products of igneous rocks during the formation of the profile and they make their appearance on the surface under certain conditions, such as (i) arid or semi-arid climate, (ii) an impervious sub-soil or hard pan, and (iii) a temporary high humidity in the soil with intermittent dry periods. Under this category fall the saline and alkali soils for Uttar Pradesh, Punjab, Maharashtra and Gujarat.

Mann and Tamhane (1910) and Tamhane (1920) attributed the salt accumulation due to poor drainage of the soil and downward and outward movement of irrigation water as well as the evaporation in the soils of Maharashtra State and Sind (now in Pakistan).

Wadia (1936) indicated that the development of salty areas was due to rise in the sub-soil water caused by improper irrigation, addition of salts by salt laden rivers and canals, and possible existence of salt bed below.

Basu and Tagare (1943) attributed the saturation of sodium salts in the soils of Deccan canal area to great aridity of the tract, nearness of saline sub-soil water and topographic situation affecting surface soils through washing from surrounding catchment areas. They expressed that these soils very much resemble "Solonetz" and worst type of alkali soils having impervious "B" horizon.

Krishnamoorti (1962) attributed the salinity of the soil in the Tungabhadra irrigation area to high salt content in the lower depths of the soil and presence of impermeable layer.

In case of such soils along the coastal belts, flooding of these areas very often with sea water can be considered as the primary cause.

Reclamation

Reclamation methods for different categories of saline and alkaline soils depend mostly on the causes leading to these conditions. A number of investigations have been carried out in the past and are being conducted at present in India. These mainly deal with :—

(1) Washing of the salts.

(2) Opening of feeder drains.

(3) Using soil amendments such as gypsum, sulphur, etc.

(4) Using suitable cropping systems.

Mann and Tamhane (1910) suggested deepening of the *nalas* and opening of feeder drains to overcome waterlogged conditions and salt accumulation. Nasir (1923), Dilip Singh and Nijhawan (1932) and Uppal (1961) and Prof. Kaul (1961) observed that such salty soils could be reclaimed by using gypsum, calcium chloride combined with green manuring, such as, "Dhaincha" (Susbania sp.), Farm Yard manure, Argimone Mexicana powder etc.

Inglis (1927) Gokhale (1928) and Krishnamoorti (1962) found that adequate drainage could reclaim these soils and also lower subsoil water-table. Leaching of soil also helped in lowering down the salt content in these areas.

Mc Kenzie Taylor and Mehta (1941) used rice instead of cotton to leach the Punjab soils of the injurious salts and Kanwar (1962) adopted paddy-barley rotation successfully to reclaim the saline alkali soils.

Basu and Tagare (1943) have observed beneficial effects of Farm Yard Manure and Gypsum and have also suggested the use of molasses for reclaiming the saline alkaline soils.

In addition to these methods, growing salt loving plants—grasses, trees and bushes have been found to be useful to some extent in reclaiming such areas.

Thus it can be seen that the methods of reclamation are varied depending upon the nature and extent of the problem. As such, it becomes imperative that there should be a complete inventory regarding the causes that lead to the problem so as to arrive at specific methods to be adopted for its solution. Such an inventory will also give information on whether a particular area can be economically reclaimed and if not, to what useful purpose it can be put thereby preventing it from being further deteriorated.

Based on the information so far obtained, the following methods can be considered as general recommendations :

Saline soils

(1) Putting the drains perpendicular to the slope of the land and connecting it to the main drain. This would help in leaching of salts below root zone and also lowering down the water-table below 6 ft. (even in monsoon).

(2) Irrigating the land directly from the source (not through other fields) and adding gypsum at 2·5 ton per hectare.

Alkaline soils

(1) Using gypsum at a rate of 1·20 tons per hectare.

(2) Using farm yard manure (50,000 lbs. or more per hectare) and sulphur at a rate of 1,200-2,500 lbs. per hectare.

(3) Using press mud or lime sludge at a rate of 10 to 15 tons along with 3 to 5 tons per hectare of molasses.

Areas which cannot be economically reclaimed for agricultural purposes can be put to grasses, bushes and trees (for fuel) so that they do not get further deteriorated as well as eroded.

Some of the useful salt tolerant grasses and trees are given below :

Grasses

Highly tolerant :

1. *Chloris gayna* (Rhodes grass)
2. *Cynodon dactylon* (Bermuda)

3. *Paspalam notatum*
4. *Sporobolus arabious*
5. *Sporobolus pallidus*

Fairly tolerant :

1. *Aristida histrix*
2. *Bracharia mutica* (Para)
3. *Cynodon plactosty achyum* (Giant Star)
4. *Echinocles colona*
5. *Elyonurus suidicus*

Less tolerant :

1. *Aristida funiculata*
2. *Cenchrus ciliaris*
3. *Cenchrus setigerus*
4. *Dicanthium annulatum*
5. *Erogrostis tremula*

Trees (for fuel)

Highly Tolerant :

1. *Acacia arabica*
2. *Acacia spirocarpa*
3. *Cassia articulata*
4. *Dalbergia sisoo*
5. *Morus alba*
6. *Prosopis juliflora*
7. *Salvadora persica*
8. *Tamarix articulata*

Fairly tolerant :

1. *Azadirachta indica*
2. *Cassia fistula*
3. *Delonix regia*
4. *Zizyphus nummularia*
5. *Zizyphus jujuba*

Less tolerant :

1. *Acacia senegal*
2. *Butea monospherma*
3. *Prosopis monosperma*
4. *Tamarindus indica*

NEED FOR FURTHER INVESTIGATION AND DEVELOPMENT

Most of the work done so far in connection with the reclamation of saline and alkaline soils is on a very limited scale, namely on pot-culture and small plot field trials. Further these investigations are mostly exploratory in character. There has not been so far in India any concerted effort to investigate this problem on sound technical procedure. As such, though some of the observations so far obtained are useful, these are yet to be confirmed before these can be recommended for use on large scale. Further in the absence of large-scale studies economics of the different reclamation methods is yet to be worked out.

It has, therefore, become an absolute necessity to work out a procedure for investigating, developing and evaluating the technique of reclamation. An attempt is made here to line out some of the salient points which need to be considered while formulating the future programme in this connection.

Salient points :

1. Studies on soils in relation to irrigation, drainage conditions and salinity development.

(a) Texture } With special reference to infiltration and permeability.
(b) Structure }
(c) Formation of compact layers and their causes.
(d) Field capacity (water)
(e) Ground water relationship to internal drainage.
(f) Water potential of different crops.
(g) Seasonal cycles of water balance.
(h) Salt content at different levels in profile.
(i) Salt balance—seasonal cycle.

Water quality

(a) Analysis of irrigation water from all sources.
(b) Classification in relation to salt content.
(c) Suitability of grouping of water for leaching.

Water Plant Relationship.

(a) Water requirement of crops.
(b) Moisture status in root zone.
(c) Influence of irrigation efficiency.
(d) Salt tolerance of plant.
(e) Plants as indicators of salinity and alkalinity.

Reclamation methods

(a) Choice of methods in relation to origin and type of soils.
(b) Classification of reclamation procedure.
(c) Sequence of reclamation procedure.
(d) Crop selection.
(e) Post reclamation programme.
(f) Economics—evaluation.

It would be worthwhile to consider taking up projects on similar lines in different countries to evaluate the effect of soil climate, crops etc. on reclamation measures—their efficacy and economics.

PART II

by

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SYNOPSIS

India is faced with shortage of food which is likely to go up with increase in population. It is very necessary, therefore, that all out efforts be made to step up food production in the country. For this purpose, sizeable areas of land affected with saline and alkali conditions need to be taken up for reclamation on priority basis. The work has already been initiated on a sizeable scale in Punjab State.

This paper describes in detail : (a) the formation of saline and alkali soils due to such factors, as rise of water-table in irrigated tracts, irrigation from wells containing saline water, flooding of areas and infiltration of sea water into the coastal areas ; (b) diagnosis of saline and alkali lands by visual soil survey and scientific soil and water surveys ; (c) prerequisite for reclamations ; namely, adequate water-supply and drainage ; and (d) techniques of reclaiming saline soils, alkali soils and alkali-cum-saline soils.

The paper concludes with a detailed account of how reclamation is being carried out in the Punjab (India). A land reclamation organisation has been set up in the State and the Land Reclamation Act has been passed by the State Legislature. Crops worth about Rs. 5 million are being produced on lands which did not bear a blade of grass before. It is hoped that 100 thousand acres of land will be under reclamation at an early date. Already about 1,000 cusecs of water is being used for reclamation purposes and this quantity is likely to be doubled next year.

INTRODUCTION

It is well known that in high rainfall areas, due to leaching of bases, acidic soils are formed, while in low rainfall regions, on account of arid or semi-arid conditions, saline and alkali soils occur. Since approximately one third of the land surface of the world is arid or semi-arid (Fig. 1), the incidence of saline and alkali soils is very common.

Saline soils contain varying percentages of soluble salts which affect productivity. "Alkali soils" may or may not contain soluble salts. They possess high pH value, high degree of alkalisation and high dispersion factor. These also affect the productivity of soils.

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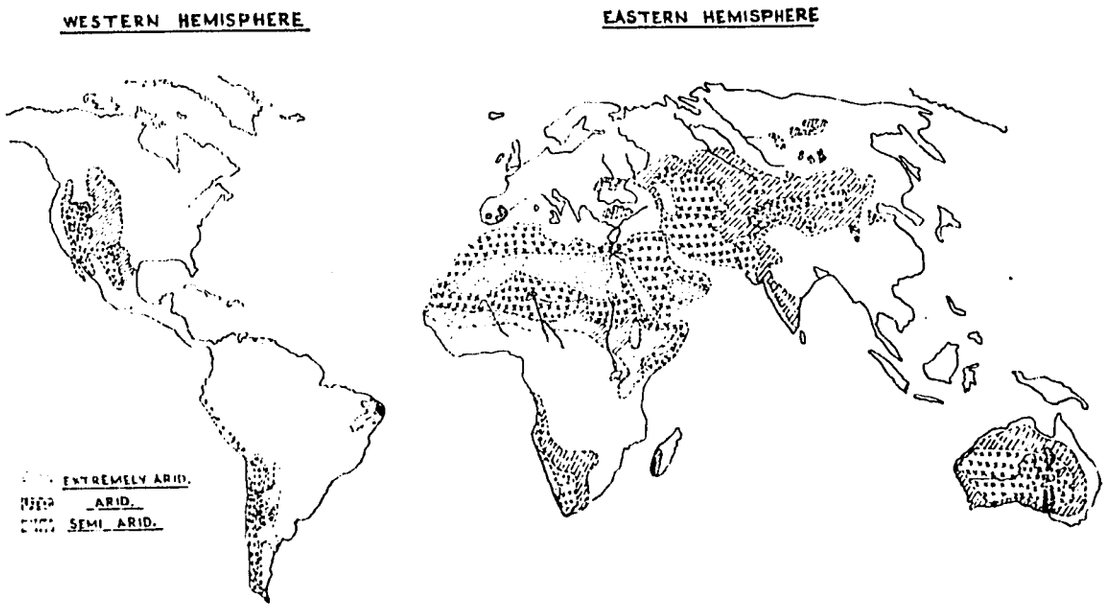

FIG. 1. ARID HOMOCLIMATES

Hilgard divided alkali soils into two types, white alkali and black alkali. Sodium sulphate and sodium chloride form white alkali and sodium carbonate and sodium bi-carbonate produce black alkali.

Salinisation is a process of accumulation of salts at the surface or at some depth below the surface. In the Indo-gangetic plain it has been observed that the presence of salt bearing layers at certain depths in the soil profiles is a common feature.

Millions of acres of land that were once productive have been abandoned on account of accumulation of salts in the soil. It has been the major cause of the collapse of ancient empires in Mesopotamia. About 100,000 acres of productive land in the Indus Basin is going out of cultivation per year because of salinisation. It is in fact a major problem wherever irrigation is not accompanied by proper drainage.

In India, since the advent of canal irrigation, salinity has extended over large areas of fertile land. In the Central and North Western districts of Uttar Pradesh on the left bank of Ganga River, about two million acres of good land have become saline or alkaline. The total area damaged by salts and alkalinity in Uttar Pradesh is about five million acres. Along the East Coast of Madras in the Deccan Plateau especially in Tapti, Godawari and Bhima basins and in the States of Bihar and Orissa, there are vast areas of saline and alkali soils. In Punjab (India) three million acres of land are affected by salts. Out of about 15 million acres of saline or alkali land in India, about half of the area is found in Punjab and Uttar Pradesh.

Further large acres are getting saline every year on account of adoption of certain faulty irrigation and agricultural practices and absence of effective drainage. Lands once fertile are lying barren to-day. Unable to obtain food and fodder from their land, the farmers shift to other places. Abandoning the land in this way causes further deterioration of soil. In an agricultural country like India, especially with food deficit, it is essential to check this menace and to restore the productivity of such lands. As a rule, the saline and alkali soils are

potentially fertile and once reclaimed, they are a valuable asset both to the tiller of the land and to the nation. The production from fifteen million acres of land, after reclamation can make the country self-sufficient in food.

Efficient methods of reclamation based on research work in the laboratories and on large scale experimental farms in the Irrigation and Power Research Institute, have been developed and applied in the field. Forty to fifty thousand acres of saline and alkali land in Punjab are under reclamation. The work is being extended to undertake reclamation of much larger areas.

FORMATION OF SALINE AND ALKALI SOILS

Salinisation due to rise to water-table. The salts contained in the soil are either distributed evenly in the soil profile or accumulated well below the root zone. In the Indo-Gangetic alluvium the common salts are sodium sulphate, sodium chloride and sodium carbonate. Sodium sulphate being a hygroscopic salt, can absorb, under certain conditions of humidity and temperature, a considerable amount of moisture from the atmosphere. When evaporation takes place a moisture gradient is established in the soil column and there is a tendency of the salts to move upwards towards the surface. With rainfall, a cycle of movement of water, first downward on account of gravity and then upward due to capillarity and evaporation, is set up. The water which percolates into the underground comes in contact with the salts present in the soil, dissolves them and evaporation brings these to the surface in the form of solution. The water evaporates and salts are left behind.

Low precipitation combined with certain irrigation and agricultural practices induces upward movement of moisture which brings salts to the surface. Rain or well water does not penetrate deep enough into the subsurface. In canal irrigation, however, large depths of water are applied to the field and the percolation into the underground is considerable. With the percolation of water, the salts, which are distributed in the soil profile or are lying in pockets or scattered, depending upon the deposits of the alluvium, are washed down to the lower layer and form a zone of salt accumulation. With subsequent irrigation, rainfall or evaporation, the salts move downward or upward, the resultant movement depending upon the difference between the irrigation-cum-rainfall and evaporation-cum-transpiration.

The crop pattern being followed in a tract has a pronounced influence on the movement of salts. Where rice, sugar-cane or berseem are grown, the movement is downward but in the case of other crops, the movement of moisture and salts is upward.

The tendency of the cultivator has always been to raise crops on a greater area than that for which water is allowed. The lowering of the "delta" on account of increase in the cultivated area with the same supply of water results in the movement of moisture and salts in the upward direction. The salts first appear in patches and in the course of years, affect the whole field. This is due to the formation or presence of salt infested layers at different depths of clay bearing strata. The upward movement of water is slowed down by the presence of soil crust whose depth varies from place to place. If the crust is either shallow or absent, the water-table rises generally and salts go on depositing at the surface.

With the accumulation of harmful salts in the root zone, a toxic limit is reached which eliminates plant life. The sodium salt enters the clay complex and replaces the calcium which is present in the normal soil. The soil becomes alkaline. These changes may be represented as below :—

(i) Calcium Clay
$+ NaCl = Na$ clay $+ CaCl_2$
(leached down)

(ii) Calcium Clay
$+ Na_2SO_4 = Na$ Clay $+ CaSO_4$

(iii) Calcium Clay
$+ Na_2CO_3 = Na$ Clay $+ CaCO_3$

"Delta" means depth of water allowance.

Irrigation from wells containing saline water. The canal water generally contains a small quantity of salts and it fit for irrigation. It has also been shown that continuous irrigation by canal water over a long period has had no effect on the normal soil. The underground water, however, in certain tracts is brackish and its use for irrigation causes salinity and alkalinity. Certain ground waters have a very high salt content. Ground waters, before use for irrigation, should be analysed for salt content and if high, the water should be diluted with canal water, where available. In order to prevent salinisation of soil, ground water surveys for the quality of water should be carried out when irrigation is to be done by underground waters.

Salinisation of soil by flooding. Wherever spills from rivers, rivulets and *choes* inundate the land, erosion of the top fertile soil occurs. In course of time, large areas on both sides of the streams become saline and alkali. Nothing but dab grass grows there. In certain cases, even grass is absent. With continuous rise of salts, the soil becomes fluffy. In certain areas, frequent inundations convert the land into hard alkali soil.

The concentration of salts in the top layer in such areas becomes as high as 2 to 3 per cent. The salt present is mostly sodium sulphate. Sodium carbonate and bi-carbonate are also present to a small extent. The pH value of these saline soils is about 8·5 to 9. The infiltration rate is fairly good. For alkali or rakkar soils, salts content is low but pH value is above 9·5. These soils are, practically impervious. In a comparatively dry hydrological cycle, when the rainfall is not heavy and run off is confined to the bed of the natural *nallah*, stream inundation is occasional. Consequently, the land does not exhibit heavy salinization, but in a wet cycle this salinization takes place. There are large areas now on practically every rivulet and *nallah* on both the sides, which are saline and alkali.

In Punjab (India) saline areas exist on the left bank of the Ravi and Beas rivers and on both banks of the West Bein, East Bein, Sakki, Kasur and Hudhiara nallahs, Ghaggar river and various *choes* and *khads*. This has taken place particularly in the semi-arid areas where the rainfall is between 10" to 25". The areas affected by salinisation and alkalization on some of the natural drainage choes are given below :—

Sakki	=	60,000	acres
Western Bein	=	50,000	,,
Jhambowali choe	=	60,000	,,
Sirhind choe	=	60,000	,,
Saraswati river	=	30,000	,,
Chutang Nadi	=	15,000	,,
Hudhiara Nallah	=	13,000	,,
Total	=	2,88,000	,,

It will thus be observed that large areas have been rendered barren due to salinity caused by flooding. The area affected by these streams only comes to three lakh acres and the loss of food production in money is roughly of the order of Rs. 3·5 crores.

Salinisation by infiltration of sea water into the coastal areas. Intrusion of sea water causes the formation of saline and alkali soils. The soil of little and Great Rann of Kutch have been rendered saline on account of the continuous action of sea water. The salts present are generally sodium chloride and some sodium sulphate. Similarly, vast areas in the erstwhile Saurashtra State are also saline. Bhal area near Bhavnagar is an example of the vast tracts which have been rendered saline by the effect of sea water. Artesian waters in the State of Gujarat are highly charged with salts such as sodium chloride. Irrigation by this water renders the soil saline in course of years.

DIAGNOSIS OF SALINE AND ALKALI SOILS.

For the diagnosis of saline and alkali soils, *thur* and *sem* girdawaries (Visual Soil Survey) and also scientific soil and water surveys are carried out.

Thur and sem girdawaries (Visual Soil Survey). In order to estimate the extent of damage on account of waterlogging, salts and alkalinity, *thur* girdawaries are carried out by the village revenue officials (Patwaries). The girdawaries have been in progress since 1927 by the Civil Department. In this case the survey has been confined to certain villages and selected estates only. No notice was taken of land deterioration until the damage to the land exceeded 75 per cent. In 1944 the definition for the classification of the damage to the land was changed and work of survey of areas in the canal irrigated tracts was undertaken by the Irrigation Department. According to Irrigation Department standard the land was recorded as *thur* when the damage to land was more than 20 per cent. The classification is (i) Uncultivated thur (Thur Kohna) (ii) Ex-cultivated thur (Thur Nau), (iii) Cultivated thur (Thur Juzvi).

In winter when the salts are conspicuous at the surface, staff comprised of Booking Clerks, inspect the fields and record the different categories of *thur*. The *sem* (waterlogged) land is also recorded as cultivated, ex-cultivated and uncultivated. All the canal irrigated tracts are surveyed in this way every year. The staff of the Land Reclamation, Irrigation and Power Research Institute, such as Supervisors, Assistant Land Reclamation and Land Reclamation Officers exercise an independent check of the *thur* area. Similarly, the officers of the Irrigation Branch such as Zilladars, Deputy Collectors, Sub-Divisional Officers and also Executive Engineers check a certain percentage of the girdawaries recorded by the Booking Clerks. The record is compiled and examined in the Statistical Division of the Research Institute. An Annual Report is prepared and submitted to the Government. The increase or decrease of *thur* and *sem* is worked out and recorded in a special proforma (Statement No. 1). For areas outside the irrigation boundary the data is collected by the Civil Department and is reported on a proforma specified for the purpose. The accumulation of salts in the soil below the natural surface cannot, however, be determined by visual *thur* girdawaries, for these Scientific Soil Surveys carried out.

Scientific Soil Surveys. Soil surveys afford information about the general features of the area and properties of different types of soil not only unto plough depth but of subsoil to a reasonable depth. A consideration of variations of soil characteristics such as texture, soluble salt content, pH, etc., seem necessary for reclaiming deteriorated soils. Without the basic information about soil of any area made available from the soil survey the work on essential development of land is hampered to a great extent. In carrying out the soil surveys, the sampling sites are made on grid system and field notes with respect to natural flora, soil colour, soil crust, etc., are recorded. Soil sampling is done by auger and at times from pits. Soil samples are collected at each foot depth along the profile or by separate horizons, upto a depth of 10 feet or water-table or hard strata whichever is nearer from the surface. All changes of soil strata while sampling are noted. The soil samples are analysed for their total soluble salt content and pH. Representative samples are, in addition, tested for mechanical analysis, water holding capacity, contents of exchangeable bases, calcium carbonate manurial constituents, etc. The soils are categorised with respect to their salient physical and chemical characteristics. The soil surveys thus help in bringing out to light those portions of the command area which require special attention, e.g. waterlogged, deteriorated lands needing reclamation, etc., and in fa[illegible]ing a phased development programme.

The soil surveys are either pre-irrigation or post-irrigation. The purposes of the pre-irrigation soil surveys are :

a. to determine the character of the soil,

b. allocation of areas fit for cultivation as soon as water becomes available,

c. identification of lands which can be reclaimed and determination of the amount of water required for reclamation,

d. determination of the prospects of rise in water-table and waterlogging.

The objects of post-irrigation soil surveys on the other hand, are :

i. to locate the areas that have already deteriorated or are in the process of deterioration,

ii. to formulate methods for the reclamation of deteriorated areas, and the saving of those which are likely to deteriorate,

iii. to determine the type of drainage required for reclamation or precaution of deterioration.

Soil Crust Survey. Over-lying the sandy strata of the Indo-Gangetic alluvium, is a clay crust on the top. The depth of the crust varies from place to place. Certain areas may have no soil crust at all. The presence of the crust helps in retarding the rise of water-table and also checks salination. The greater the depth of crust, the greater is its effect in delaying the rise of water-table. A knowledge of soil crust of an irrigated area is essential. A detailed survey was carried out of the Punjab State regarding the depth of soil crust. Most of the areas in Gurdaspur, Amritsar, Hoshiarpur and Karnal districts in the Punjab, have a fairly deep soil crust varying from 15 to 20 feet. However, in Ferozepur, Sangrur and Hissar districts, the soil crust is shallow. Once the water-table has risen in the deep soil crust and it is charged with salts, it takes a long time to lower the water-table and remove salinity. On the other hand, where the soil crust is absent or present in a shallow depth only, water-table can be lowered easily and the salts can be removed.

Survey for Quality of Water. A knowledge of the quality of water used for irrigation is very essential along with information regarding the quality of soil. The river water generally contains a small percentage of dissolved salts. Therefore, the canal water which comes from river being low in salt content is fit for irrigation. It has been shown that continuous use of canal water does not bring out deterioration of soil.

Where ground water is used for irrigation, it is necessary that the water should be analysed for suitability. As survey for the quality of ground water for Punjab and certain parts of Rajasthan and Gujarat States was cartied out. The result revealed that deep water-tables are brackish, while high water-tables are sweet. The north-west part of the Punjab State have sweet ground water while the South East part possess highly brackish ground water. In certain tracts, such as Riwari, Bhiwani, Hansi, Sirsa and Hissar, the salt content of ground water is very high. Even reasonable dilution with canal water will not make it fit for irrigation. Chemical treatment in such cases have to be resorted if ground waters are to be used for irrigation. In sweet water areas also, pockets of highly brackish water occur. In Rajasthan the water-table is generally deep and saline. The artesian wells of Gujarat State contain very large quantity of salts mostly sodium chloride. The results of analysis of the water samples are examined with reference to the standards fixed for declaring the suitability, or otherwise, of water.

There are a number of ways by which the quality of water is designated. According to the practice in the Punjab the criterion adopted is as follows :

i. Below 60 parts per 100,000 the water samples are fit for irrigation provided they do not contain harmful limits of sodium carbonate or sodium bicarbonate. which produce gradual deterioration.

ii. Between 60 to 120 parts per 100,000 the salt index is considered first. Salt index-total Na—24·5 (total Ca in $CaCO_3$) × 4·85.

The salt index is negative for all good waters and positive for water unsuitable for irrigation.

iii. Beyond 120 parts per 100,000 the water are not fit for irrigation.

The quality of ground water has to be considered in conjunction with the quality of the soil to be irrigated, the nature of salts and its distribution in the soil profile. The texture of soil also determines the suitability of water for irrigation purposes.

The U.S. Salinity laboratory, on the basis of the analysis of a very large number of irrigation waters has laid down the following limits of conductivities for safe and un-safe water.

Conductivity (Microhms)	Suitability or otherwise for irrigation
1. Below 250	Entirely safe.
2. 250 to 750 (moderately saline)	Safe under practically all conditions.
3. 750 to 2,250 (medium to high salinity)	Safe only with permeable soils and moderate leaching.
4. Above 2,250 (for areas where saline waters are important)	
i. 2,250 to 5,000 (high salinity)	
ii. 4,000 to 6,000 (very high salinity)	Unsafe for irrigation.
iii. Above 6,000 (excessive salinity)	

Ground Water-Table Surveys. Variation in water-table is determined from observations made on a series of wells or pipes sunk in the underground. A regular record of these observations is essential for determining the rise or fall of water-table. Variation in water-table can only be studied with the data extending over a large number of years. In the canal irrigated tracts of Punjab, observations of water levels in open wells were initiated by Colonel Higham as far back as 1892. These observations were made twice a year, in June and October, i.e. just before and after monsoons. Later on, these well lines were extended to non-irrigated tracts also. Now there are several thousand open wells and pipes in the State along the provincial as well as Circle lines, which are regularly observed and data so obtained compiled. Subsoil water depth maps showing the depth of water from the natural surface both for June and October separately, for the whole of the State are prepared and printed by the Research Institute. Similar maps are also prepared for different canal tracts. Different maps and water-table contour maps are also prepared between two specific periods for purposes of comparison. Intimately connected with the ground water-table observations is the rainfall data.

REQUIREMENTS OF LAND RECLAMATION — WATER SUPPLY AND DRAINAGE.

Amongst others, the two most important requisites in the land reclamation procedure are sufficient water for leaching down the salts and proper drainage especially in the case of high water-table areas.

Water Supply for Reclamation. The reclamation water supply is one cusec for every 45 acres of saline land. It may, however, slightly vary with the nature of the soil. Working out the water requirements for say one hundred thousand acres, it will amount to 2,000 cusecs. This requirement is during the reclamation period only. As soon as the land is reclaimed, and becomes normal, the water supply is reduced to the normal water

allowance as for good land which is about one cusec for every 400 acres.

The water required is indeed large but the task of reclaiming saline lands is equally great. This has to be taken up at a high priority, concentrating all attention and resources. Even if it requires withdrawing partial supplies from good land, it should be done in view of the return that is expected from these lands and also to save the land from further deterioration. In normal land, other resources of water supply such as tubewells percolation wells, etc. can be explored to replace the canal supply withdrawn.

A total of 2,200 cusecs of water supply in States where canal irrigation exists is not a very big quantity. In the prepartition Punjab, a discharge of 2,500 cusecs was being utilised for reclaiming saline lands. It must have increased now. During the Kharif season in Punjab (India), it is not difficult to spare 2,200 cusecs from various canal systems for land reclamation purposes. The difficulty arises after the middle of September when the river falls and the supply in the canals decreases. It is hardly sufficient even for the requirements of normal irrigation and, therefore, extra supply of land reclamation cannot be made available. To overcome this difficulty, an early maturing variety of rice has been developed so that by the end of August or early September the crop matures, and is harvested. This incidentally also saves the crops against damage due to flood inundation.

A well planned and efficient drainage system is a pre-requisite to the successful implementation of any reclamation operation to be undertaken for amelioration of saline and alkali infested soils. Water-table must not be very high and stagnant. The drainage system normally comprises of main drain, link drains, subsidiary drains and the field drains, all connected to each other. The responsibility of execution and maintenance of the main drain, link drains, and the subsidiary drains rests with the State Government while that of the field drains is with the people themselves. By draining out excessive water from the deteriorated lands in the form of seepage, the field and link drains help to keep the water-table low, which is essential for the growth and maturity of crops. A huge programme of drainage has been launched by the Punjab Government on war basis and it is contemplated that the same will be completed by 1964-65. Out of the eight Drainage Circles, three Circles have been attached with the Research Institute. This is a very important feature from the point of view of efficiency of work. The Land Reclamation and the Drainage Departments working together under one and the same organisation, are of immense advantage for expeditious working. The total expenditure contemplated to be incurred on drainage for the two years, i.e. 1963 and 1964 is of the order of several crores in each Circle. With the completion of the drainage programme, waterlogging in the State will be considerably reduced. With the lowering of the water-table saline areas would also appreciably decrease.

TECHNIQUES OF RECLAMATION.

Efforts have been made to develop measure to reclaim saline soils. Gedroiz in Russia; Desigmond in Hungary; Hissink in Holland; Gosparini and Alinari in Italy. Hume in Egypt; Rei Ferberg in Palestine; Smith in Iraq; Asghar in Pakistan and Hauser in Afghanistan, Pendelaton in Java, Treakle in Australia; Sack Ville in Canada, Kelley Worston and Poweris Overstreetetal in America, Uppal Ray Chaudhri, Taylor Hoon and Dhawan in India have studied this problem in detail with specific reference to Indian conditions. Uppal has carried out intensive semi-field experiments on the efficiency of Jantar (Sesbania aculeata) green manuring for the reclamation of alkali salts. The problem of salinity-cum-alkalinity has assumed a very grave picture, which is adversely affecting the agricultural production of every country. In view of the increasing

menace, further experiments were undertaken on the basis of the data collected from thur-cum-general soil and sub-soil water survey, soil crust survey, etc., etc., of the State of Punjab. These experiments were conducted on semi-field and field scale so that the results of these experiments could be applied directly to the field. The comparative efficiency of the different treatments as compared in relation to the varying agricultural practices.

As a result of the investigations made in the Punjab Irrigation Research Institute, extending over a number of years, an efficient method of reclamation of saline soils has been developed and thousands of acres of land have been reclaimed by this method.

The method developed briefly is as follows :—

The bunds (Watts) of an affected field are raised, levelling done and flooding is started at the end of April and leaching continued to the middle of June, for a period of about two months. With this flooding operation, the excessive salts lying at the surface or in the top foot are dissolved and leached from the top few inches of the soil. After leaching rice (mostly Jhona 349 or Sathra 273) is transplanted. The heavy water requirements of rice keep the process of movement of salt downward and the Carbon dioxide (CO_2) given by the plant roots reduces the pH value of the soil. In the following Rabi season, depending upon the conditions of the lands, and available water supply, leguminous crops like Berseem, Senji and Gram are sown. It is advisable to sow Berseem, if the salt content is still high at the surface (first root) because due to greater requirements of water for this crop, the movement of the salts continues downward. This also improves the nitrogen balance of the soil. The next best crop is Senji but in areas where Rabi water is not available gram sown in *wadh* water after rice is also very helpful.

The soil samples are taken after every reclamation cycle and analysed for salt content and alkalinity and the rotation Rice-Berseem, Senji/Gram is continued for a number of years till the time the salts are washed down from the top 10 feet of the soil. The reclamation is generally completed within three to five years. It has been observed that if the salt are leached down to 10 ft. depth below the surface, the salts do not rise again to the surface. It has also been observed that land once reclaimed in this way is capable of bearing normal crops with average yields on usual water supply. At the time of partition in 1947 about 2,500 cusecs were being utilised in the reclamation of about 100,000 acres of saline lands. These reclamation measures brought back to cultivation about 25,000 acres of saline land each year and were instrumental in reducing the annual rate of damage to half which was approximately of the order of 50,000 acres per annum.

The water used for reclamation of saline land in the Punjab is at the rate of one cusec for about 50 acres based on a reclamation *wari* of 7 days.

It is considered, however, that this water allowance could be reduced especially in the high water-table areas.

'Hill' has recently worked out the leaching requirement. This is usually explained as percentage of the volume of water applied to the surface of the land but sometimes expressed in terms of the ratio of the quantity of applied water to the consumptive use. Formulae have been developed by him for leaching requirements related to the functions to be performed and the salinity of the applied water.

Reclamation of Alkali Soils. In Punjab (India) large blocks of alkali soil exist. For allotment of land to the displaced persons from Pakistan, it was considered essential to assess correctly the value of the land. A scientific soil survey spread over 184 villages of Karnal district was carried out with a view to determining the extent of deterioration of soil on account of alkalinity and the extent to which reclamation was required.

The area surveyed was of alluvial origin over-lying sand layers. It contained high percentage of clay and also *kankar* (calcium carbonate nodules) at varying depths and also in the form of belt of different thickness. A hard pan at some depth below the surface also existed in the profile. The profiles examined showed excess of salts and high alkalinity.

Sodium carbonate being a strong alkali, destroys the normal structure of soil and the bacterial activities therein. When soil containing sodium carbonate comes in contact with water, deflocculation of clay occurs and with the downward movement of water, fine clay particles in suspension travel downward and choke the pore space in the soil at some depth below the surface. In this way a hard impervious stratum is created in the profile and due to base exchange, rise in pH takes place. The existence of hard pan in the Nardak tract of Karnal District appears to have taken place in this way. The existence of hard pan and high pH create difficulties in the reclamation of alkali land.

In order to determine a suitable and economical technique of reclamation of black alkali soils, research work was undertaken in 1950 and continued for a number of years in the laboratory on semi-field and field scale.

Detailed results of these tests may be obtained by applying to the Land Reclamation, Irrigation and Power Research Institute, Amritsar (Punjab), India.

Reclamation of alkali-cum-saline soils. The reclamation of alkali-cum-saline soil is comparatively easier than that of reclamation of alkali soils. The presence of salts makes the soil more permeable and thus it is easier to carry out the leaching operations.

In order to study how reclamation of black alkali soil would proceed when sodium sulphate and sodium chloride are also present along with Na_2CO_3, (even though the quantity of total salts is the same) 30 plots of size 11′ × 15′ in three groups each were taken and salts 1 per cent by weight up to a depth of two feet were added in the following proportions :—

1. Group 'A' salt mixture containing 0·66 per cent Na_2CO_3 and 0·16 per cent each of Na_2SO_4 and NaCl (Total salt content 1 per cent).
2. Group 'B' salt mixture containing 0·5 per cent Na_2CO_3 and 0·25 per cent each of Na_2SO_4 and NaCl (Total salt content 1 per cent).
3. Group 'C' a salt mixture containing 0·333 per cent each of Na_2CO_3, Na_2SO_4 and NaCl (Total salt content 1 per cent).

Out of each of the above three groups nine plots were sown and one was kept fallow for a study of the physico-chemical changes which take place after the addition of salts. The first crop after leaching was senji following by sugarcane in Kharif 1955. Sugarcane was ratooned in Kharif 1956. The yield showed that increase of Na_2CO_3 retards the speed of reclamation and also decreases the yield. The average yield for each group (nine plots average per acre) of salts obtained is given in Table 1.

The point worthy of note is that sugarcane within the above limits of salt mixture can be straightway tried as a reclamation crop. Its irrigation requirements are well spread out on 10 months of its growing period. One cusec of water can raise easily 80 acres of sugarcane whereas in case of rice one cusec is required for 45 acres.

As regards washing of salts and reduction of pH analysis of a typical plot from group after sugarcane (1956) are given in Table 2.

MANAGEMENT OF SALINE AND ALKALI LANDS—LAND RECLAMATION OPERATION IN THE FIELD.

Preparation of Scheme. First of all people of the State are informed of the land reclamation work to be undertaken and they are asked to submit their applications if they

TABLE 1.

S. No.	Group	Senji 1954-55	Sugarcane variety Co 455 mds	1955 variety Co 290 mds	Sugarcane variety Co 453 mds	1956 Ratooned variety Co 290 mds
1	A	18·55	1188·88	957·0	1191·63	1463·43
2	B	39·50	1614·03	1374·45	2311·88	1903·2
3	C	80·80	2093·75	1181·35	2152·72	1646·6

TABLE 2.

Depth of sample	Group A		Group B		Group C	
	pH	T.S.	pH	T.S.	pH	T.S.
0"— 6"	9·58	·11	9·66	·14	0·58	·128
6"—12"	10·11	·153	9·92	·205	9·73	·130
12"—24"	10·30	·242	10·08	·228	9·96	·177
24"—36"	10·43	·273	10·05	·146	9·85	·147

want to have their lands reclaimed. On the receipt of their applications, detailed thur girdawaries of their land are carried out and maps are prepared on which thur area and the type of thur are marked. The land reclamation schemes are then prepared, detailing the arrangement of the water supply, the canal from which it is to be obtained the alignment of the minor, sub-minor, etc. When the schemes are approved the local Superintending Engineers are requested to make the supply available and the people concerned are informed to dig their water courses and get ready to receive the supply. Where new channels are required, the engineering staff constructs these channels. Where no other arrangements can be made excepting the lift, pumps are installed on the canals to obtain water from distributaries.

(b) **Application by persons desirous of taking up Reclamation work.** The owners of the thur land apply to the Director, Land Reclamation, Irrigation and Power Research Institute, Punjab, stating that their land is barren on account of salinity and alkali requesting extra water. After the receipt of the application, the Assistant Land Reclamation Officer inspects the site and carries out a survey of the area and prepares a scheme for reclamation and makes arrangement of water supply, etc., from suitable channels. On approval of the scheme by the competent authority, the owners are required to execute an agreement that, "They would carry out all land reclamation operations as instructed by the Department, utilise the supply in the thur area proposed for reclamation and grow the crops according

to the cropping scheme approved by the Reclamation Department."

(c) **Reclamation Supplies.** The reclamation supply is about six times the normal supply given to the zamindar for food lands, but at the same water rates. Further if the land fails to produce normal crop, remissions in water rates are granted. If the crops are less than 25 per cent, full remission is granted. If the crops are between 25 per cent and 50 per cent, the water rates are reduced to half. This is to give incentive to the owners of the *thur* land to take up land reclamation work.

(d) **Booking of Irrigation.** During the reclamation season, the field staff visit the areas regularly, supervises the work and advises the zamindars regarding the correct procedures to be adopted. The Booking Clerks keep a record of leaching sowing, appraisement of crops and harvesting, etc. It is also the responsibility of the Booking Clerk to see that every acre of land receives irrigation according to its turn (*Wari*). The appraisal of the crop made by the Booking Clerk is checked 100 per cent by the Zilladar and all the fields where crop has failed, by the Deputy Collector and the Assistant Land Reclamation Officer. Land Reclamation Officer checks 25 per cent of the area under the failed crops (*Kharaba*). The Research Assistant independently studies the soil and the crop and compares his results with the yields obtained, etc.

A handicap frequently experienced is the shortage of irrigation supply at the time of maturity of paddy crop on account of sudden drop in river discharge. During September-October, the supply in Kharif channels stops altogether, and that affects the crop yield very much. It is essential that Jhona 349 should be grown in the *thur* land brought under reclamation. This variety of rice matures in 85 days, much earlier than the finer varieties of rice and is harvested by the end of September. The trans-planting is done by the middle of July. As an alternative for augmenting the canal supplies, a scheme is being taken up for installation of large number of shallow tubewells where the underground strata is suitable. Alternatively water from the drainage channels is being arranged to be used for irrigation.

Land Reclamation Act. Considering the great importance of the problem of Land Reclamation, the Punjab Government has enacted 'The Punjab Thur and Sem Lands (Reclamation) Bill, 1962'. It was passed in March, 1963.

The Bill empowers the Director and his authorised agents to undertake survey for the purpose of preparation of *thur* schemes and after hearing objections, declare areas as reclaimable. In the event of owners not taking up reclamation in accordance with the directions of the Land Reclamation Officer, the Director can take temporary possession of the land for the purpose of reclamation for a period of five years and then lease it to willing tenants on suitable terms. Any expenditure incurred by the Director for the reclamation of this land is recoverable from the owners of the land as arrears of land revenue. The advantage to the owners of reclaimable areas is that after the reclamation of their *thur* lands they have the right to increase rent.

LAND RECLAMATION WORK IN PUNJAB.

In the Punjab, a scheme of land reclamation has been taken up from Kharif 1961. An area of at least 70,000 acres of saline land is to be brought under reclamation operations by the end of March 1966; 35,000 acres would become fit with normal crops by that time and the remainder will be reclaimed in the next three or four years. In this way, areas under reclamation would increase progressively from year to year and ultimately most of the saline land in the State will be reclaimed. Every effort is, however, being made to bring at least one lakh acres of saline land under reclamation as early as possible.

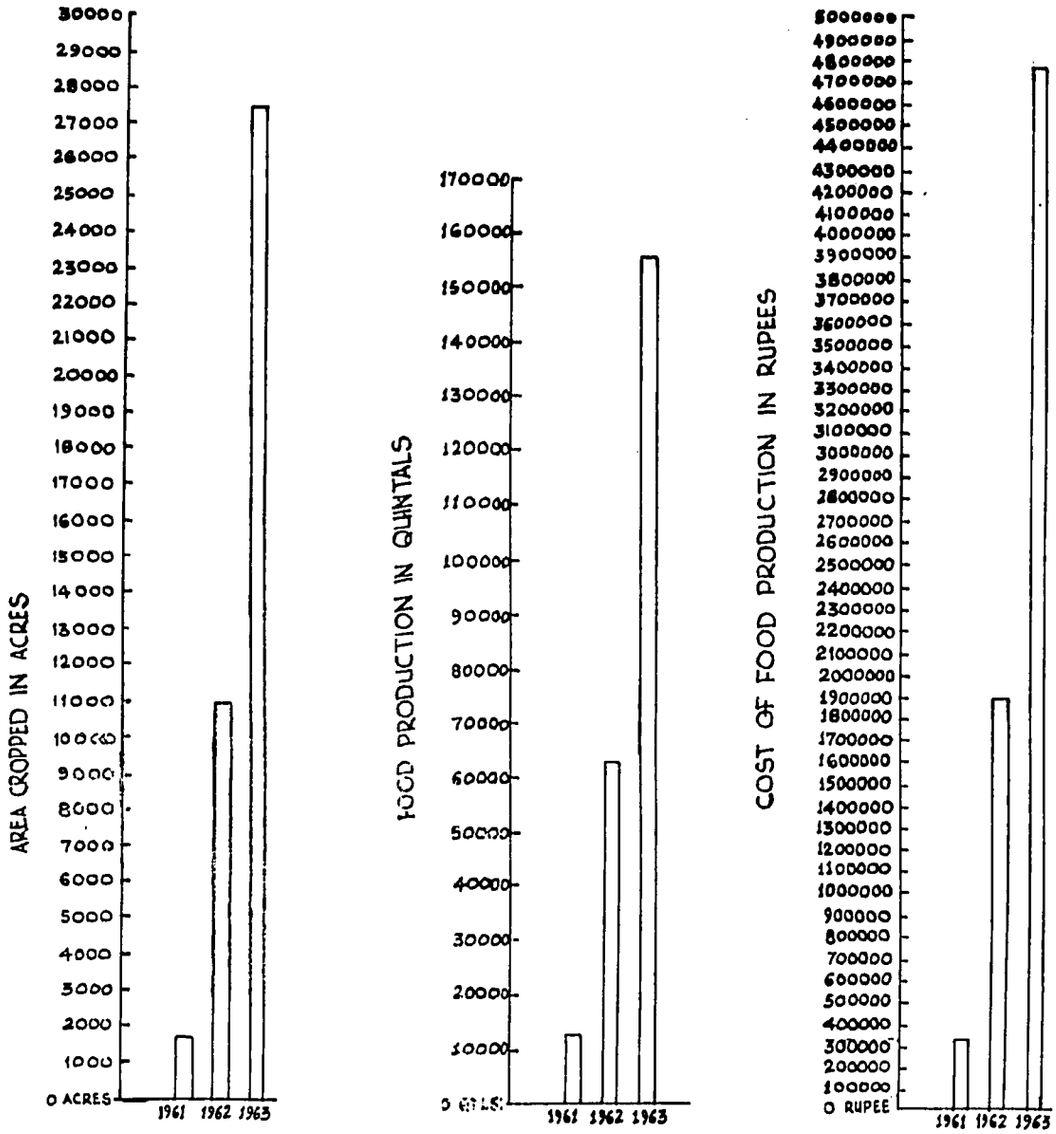

FIG. 2. FOOD PRODUCTION IN VARIOUS YEARS AS A RESULT OF RECLAMATION OF *THUR* LAND IN PUNJAB.

At the moment, *thur* is about fifty thousand acres. So far the reclamation work is being carried out by the zamindars themselves under the guidance of the Directorate. Besides reclamation by the zamindars, reclamation of Government and Panchayat land is also being done at Basdhara (Karnal) and Shahpur Piran (Kapurthala). Huge areas belonging to Panchayats will be subsequently taken up for reclamation.

Land Reclamation Organisation.

For taking up land reclamation work, additional staff in the Directorate had to be employed. Deputy Director (Land Reclamation), Land Reclamation Officers, Assistant Land Reclamation Officers, Deputy Collector, Sub-Divisional Officer, Research Assistants, Sectional Officers, Zilladars and other auxiliary staff have been recruited. There are

FIG. 5. GOOD CROP OF BERSEEM RABI 1962-63 ALONG AMRITSAR—ATTARI ROAD.

about 120 Field Assistants for reclamation. The State has been demarcated into zones and each zone consists of the folllowing canal circles :—

North Zone

1. Upper Bari Doab Canal Circle.
2. Ferozepur Canal Circle.
3. Sirhind Canal Circle.
4. Patiala Circle.

South Zone

1. Western Yamuna Canal Circle (East)
2. Western Yamuna Canal Circle (West)
3. 1st Bhakra Main Line Circle.
4. 2nd Bhakra Main Line Circle.

Crop Production.

Food production from saline and alkali lands under reclamation has been increasing speedily. Crops worth several lakhs of rupees have been grown on lands which once not yielded a blade of grass. Net income from these lands in 1963 was of the order of about Rs. 50 lakhs (Tables I and II). In 1962, it was Rs. 17 lakhs, and in 1961 it was about Rs. 2½ lakhs (Fig. 2).

IMPORTANCE OF RESEARCH IN LAND RECLAMATION.

Research work both in the laboratories and in the field is most essential for a systematic approach towards the problem of land reclamation. A Study of various methods and their improvement should continue in the laboratories. Long range effect of various

amendments already in use and new ameliorative measures should be examined. This work can be efficiently carried out by the cooperative efforts of a Physical Chemist, Soil Physicist, Agronomist, Hydraulician and a Mathematician. Incidentally, this combination exists in the Land Reclamation, Irrigation and Power Research Institute and has been working for a large number of years. Further intensification of research work in the laboratory as well as in the field is, however, badly required. The laboratories should be provided with up-to-date apparatus and latest equipment and should have the latest literature of all the countries engaged in work on this subject.

THE ROLE OF TILE DRAINAGE IN LAND DEVELOPMENT IN THE UNITED ARAB REPUBLIC

by

Mohamed El-Madany*

THE NEED FOR DRAINAGE

In order to study the need for drainage to increase the crop production of the cultivated soils in the United Arab Republic, the deposits of the Nile soils alluvium and their hydrological properties have been considered.

The soil profile consists of a very thick layer of highly permeable sandy and gravelly material, overlain by a cap of heavy clay from 8 to 25 m. thick. In Table 1 some results of the analysis of a sample of the heavy clay are shown.

During thousands of years these soils have been under basin irrigation, which allowed for the cultivation of one winter crop only. During the rest of the year the river water levels were too low to allow irrigation and the land was left fallow. Owing of the flooding of the basins before showing the winter crop a high ground water level was built up in most areas, which, however, would drain away during the rest of the year through the clay cap to the highly permeable aquifer in the sub-soil.

With a careful management of the flood irrigation water no permanent high water-table occurred during basin irrigation in the main part of th ecultivated soils.

The problem of drainage became serious due to the introduction of perennial irrigation, mainly at dawn of the present century. By the continuous winter and summer irrigation a higher water-table was gradually built up. In some areas, in particular in the northern part of the Delta, a waterlogged surface soil developed. Still, in the main part of the Delta the water-table varies between 0·50 and 2·00 m. below surface level and neither waterlogging of surface soils nor extreme salt contents occur over large areas. In Table 2 the depth to ground water-table, as observed in some localities of the Delta is shown. Table 3 shows the salt content of the surface soil (0—50 cm.) of the same areas. This relatively favourable situation is due to hydrological properties of the soil profile, in particular the presence of the highly permeable aquifer. The irrigation losses in the heavy clay are relatively low, while the aquifer allows for evacuation of drainage water percolating downward through the clay cap. In other deltaic areas, where this condition of natural drainage does not exist, permanent irrigation leads to immediate waterlogging of the surface soil and extremely saline topsoils.

Although, as explained, no extremely high soil water-table resulted immediately after the introduction of perennial irrigation, it was observed that the yield of certain crops (Fig. 1) have decreased in recent years. The loss of production was attributed to a gradual rise of the water-table into the root-zone of the crops and a slight increase of the soil salinity. Preliminary drainage experiments showed a favourable response and the need was felt to provide the lands with field drainage systems which could be connected with the existing network of main drains.

From the beginning preference was given to tile drainge over open drainage for field drainage systems, since open drainage would cause the loss of at least 12 per cent of the

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TABLE 1. MECHANICAL ANALYSIS OF NILE DELTA SOILS.

Location	Depth cm.	Clay 2 mu.	Silt 2–20 mu.	Sand 20 mu.
Embabi	0—30	53	29	18
	50—60	55	28	17
Bilbeis	0—30	73	2	25
	50—60	77	2	21

TABLE 2. DEPTH OF GROUND WATER LEVEL

Depth of Ground water below surface in cm.	Percentage of total areas			
	Embabi	Bilbeis	Kafr Sakr	Kafr-El-Sheikh
0—50	8	2	10	5
50—100	48	46	60	74
100—150	20	44	18	20
More than 150	24	8	12	1

TABLE 3. AVERAGE SALINITY, EXPRESSED AS ELECTRICAL CONDUCTIVITY IN MMHOS/CM. OF THE SATURATION EXTRACT, OF THE SURFACE SOIL.

EC_e in mmhos/cm.	Percentage of total area			
	Embabi	Bilbeis	Kafr Sakr	Kafr-El-Sheikh
Less than 2	70	21	45	45
2—4	22	25	41	32
4—8	8	31	37	20
More than 8	0	23	7	3

cultivated area in addition to difficulties encountered in connecting these field drains with the main drains through the small holdings as well as the difficulties involved in their clearance and maintenance.

Up to 1952, 50,000 feddans (acres) were supplied with tile drains in lower Egypt. Since satisfactory results were obtained this has lead to the following decisions :

1. In 1956 a law was passed giving responsibility of executing field drainage to the Government.
2. A long-term drainage project programme of at least 30 years was planned to cover gradually all areas under perennial irrigation. The capital cost of this scheme is estimated at L.E. 210 million of which L.E. 10 millions are being spent in the current five years' plan 1960-65.
3. In cooperation with the United Nations Special Fund and the Food and Agriculture Organization, Netherlands Engineering Consultants (NEDECO) as a sub-contractor, a project was started to test and demonstrate tile drainage methods.

DRAINAGE AS A DEVELOPMENT FACTOR

According to the latest census the population of Egypt is estimated at about 27 millions, of which 66 per cent represent the rural, 33 per cent the urban and 1 per cent the desert population. About two-thirds of the economically active part of the population is engaged in agriculture directly, while the average density of the population is 770 persons to the square kilometer in the Nile valley and Delta. Moreover an appreciable part of the urban population depends indirectly on agriculture through employment in manufacturing and processing industries that depend on agricultural raw material. Thus actually a much greater part than two-thirds of the population depends on agriculture.

This means that development now and for many years to come, means mainly agricultural development, if the aim of development is defined as increasing the standard of living of the greatest part of the population. One of the indicators to judge the growing development of a country is the decrease in percentage of the population economically engaged in agriculture. Such a decrease results from a gradual change of agricultural population to other activities, generally industry. Thus agricultural and industrial development can be considered as complementary to each other. The creation of employment possibilities in industries is viewed as a major factor in agricultural development and thus for the raising of the standard of living for the largest profession group in the country.

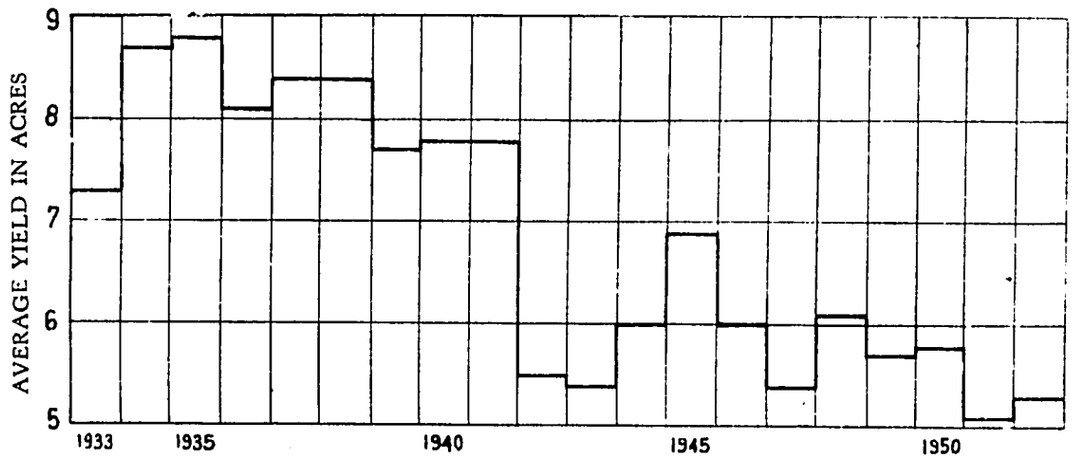


FIG. 1. GRADUAL DROP IN MAIZE YIELD BEFORE TILE DRAINAGE (MIDDLE DELTA)

Apart from providing other means of employment to agricultural workers, there are two alternative solutions to encounter the excessive pressure of population, which is the main problem to which the UAR is confronted :

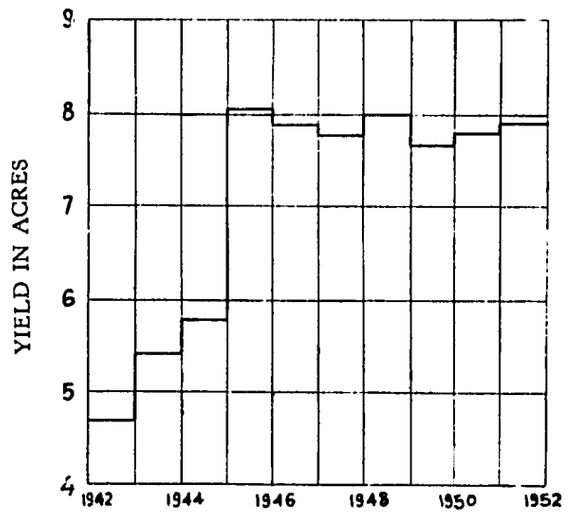
i. To make the cultivated land more productive.

ii. To make more land available.

Making more land available, through either reclamation activities or measurements to increase and regulate the water supply for irrigation, although of extreme importance is mentioned in the second place, owing to its natural limits.

The present cultivated area in the United Arab Republic (Egypt) is estimated at about 6,100,000 acres. It is already arranged that the irrigated area within the Nile Valley will gradually increase on the High Dam water and other sources until it reaches, by 1971, to about 7,800,000 acres, all perennially irrigated. Further agriculture expansion will be possible on the upper Nile projects. Aside of these areas, a reclamation programme in about 3,000,000 acres in the oasis is under execution on ground water.

The highest possibilities for agricultural development result from improving the productivity of already cultivated land. Present production can be greatly improved by introduction of new, high-yielding varieties, better crop protection, higher use of fertilizers, development of animal husbandry and dairy farming, better marketing facilities etc. but a basic requirement for all agricultural development is the regulation of the ground water regime of the soil. Agricultural drainage, aiming to bring the ground water at an optimum depth, is considered the most important single factor for improving production under present Egyptian conditions. Some researches have indicated that over large areas immediately after drainage an average yield increase of 50 per cent was obtained. In Fig. 2 the average yield increase for maize measured in a large area in the middle of the Delta is shown. However, this picture will probably show a Figure too favourable for a country-wide average increase due to drainage. But, if only a 10 per cent increase is effectuated, this means an extra production equivalent to the production of more than 1,00,000 acres, since the total yearly cropped area is around 11 million acres, (average 1·75 crops per year). Thus, if the average yield increase after drainage is only 10 per cent, it will have very nearly the same impact on agricultural production as the High Dam.



One Ardeb = 150 Kgs.

FIG. 2. AVERAGE YIELD OF MAIZE CROP BEFORE AND AFTER TILE DRAINAGE AREA 18,500 ACRES.

PROGRESS MADE WITH TILE DRAINAGE PROGRAMME

The Executive Project

Considerable progress has been made with the first large scale execution of the tile drainage. In the scope of the first 5 years' plan around 350,000 acres will be provided with tile drains, of which now nearly 200,000 acres have been completed. Although experiments have indicated a spacing between the laterals varying between 20 m. and 60 m., yet it was found practicable to adopt 60 m. throughout the project, having the depth 1·25 m. below ground surface. If later investigations revealed, in some area, the inadequacy of that

maximum, it can be intensified by adding more laterals. Such procedure was considered as a suitable measure that can allow both the executive project and research work to proceed together.

The Experimental Works

The study of the tile drainage required detailed hydrological researches in small scale areas and extensive investigations in larger areas. The demonstration of execution methods, selection of suitable machinery and economic appraisal of tile drainage required execution on a larger scale than is needed for hydrological studies. Therefore, 6-representative pilot areas, between 1,000 and 2,000 acres, have been selected in different parts of the country. In these areas pre-drainage investigations were carried out and suitable designs were prepared and executed.

During an extensive field survey the following data were collected in an observational grid-system: ground water depth, ground water salinity, hydraulic conductivity of soil, ground levels, irrigation and cropping pattern. The data are usually collected on special field logs and necessary computations were considerably simplified by use of nomograms (see Appendix I). Soil conductivity or permeability is the main single factor to be determined for the establishment of an effective drainage system.

It should be noted that the cost of investigations are small as compared with the capital cost of the drainage systems. It varies between LE 0·5 and 1·0 per acre or approximately 2 to 3 per cent of the capital cost.

Design procedure

Based on the data collected a design procedure has been developed. For each collector unit all data are averaged and only if appreciable difference in the measured permeabilities or salinities occur a subdivision is made. To eliminate as much as possible extreme values of permeability and salinity, due to local effects over small areas, the geometric average method is adopted.

Drainage discharge

The average rate of deep-percolation losses of water below the root zone towards the ground water is estimated at 1 mm. per day for a normal irrigation rotation. To obtain the design rate of discharge, which is the amount of water to be removed by the drainage system, this rate has to be corrected with the already accruing rate of natural drainage. Since direct measurement of the existing rate of natural drainage is impossible and it can not be calculated by means of Darcy's law as the vertical transmissibility is essentially unknown, a salt balance method is adopted for its estimation. By this method the average rate of natural drainage is calculated as :

$$D_n = \frac{\text{Average depth of watering} \times \text{salt content of Irr. water}}{\text{Salt content of drain water}}$$

The salt balance calculation method is based on the assumption that an equilibrium condition occurs and that all salts brought in by irrigation water are removed by drainage water in the cultivated soils.

TILE SPACING

The steady state formula of Hooghoudt has been selected as one of the more reliable for the calculation of the required drain spacing, being preferred over the known unsteady state formula's which have not yet yielded satisfactory results. Hooghoudts' equation should be considered as a "calculation analogue", since the results actually obtained in the field mainly depend on the selected drainage design criteria used in the formula, *viz.* the depth of the dewatering zone and the rate of discharge. Both are essentially unsteady and a time factor has to be selected and tested. Generally it is estimated that adequate drainage is obtained if the water level is at least 1 m. below surface 4 to 6 days after irrigation. In Appendix 2 a culculation example with the Hooghoudt formula is given.

In the six selected pilot areas the drain spacings to vary between 20 and 60 m. at a depth of 1·50 m. It may be concluded from the results that soils vary widely even in pilot areas of about 1,500 acres, therefore, reasonably conservative averages should be adopted on the basis that future additions will be possible. To make this feasible the behaviour of all affecting factors should be carefully studied for many years after execution.

MECHANICAL EXECUTION

Trenching and pipe laying machines should be suitable for the soils in which they have to work. Knowing that the soils to be drained are generally of heavy clay and that the drain depth would be greater than usual in temperate climates, heavy machines with 100-hp meters and provided with an automatic hydraulic depth regulation of the trench bottom were selected. With these machines the drainage system in two pilot areas, comprising a total length of more than 300 km. laterals, has now been completed. It was proved that mechanical execution by means of these machines is very well possible in the Egyptian heavy clays.

The capacity of the machines was, during the precalculation of the project, estimated at 1000 m. per day of 8 working hours. In the first pilot area, however, the production was 750 m. per machine per day, while in the second area productions of 1,100 m. have been obtained.

In the set-up of the project no provisions were made for experimenting with equipment for digging collector drains. It is assumed however that future developments in which collector trenches are dug with a dragline provided with a medium-sized specially designed bucket, can be expected.

The second major advantage of mechanical lateral tile laying, is the high quality which can be obtained which is potentially higher than that of hand laying. This advantage has important repercussions, since few or no silt will enter the pipes through the joints. Pipes have been dug up two years after laying and no silt whatsoever was found. This means that the customary 4" diameters can be decreased as no overdiameter to take account of a decreasing hydraulic cross-section due to silting-in will be required.

ECONOMIC APPRAISAL

It has been explained before that drainage is considered as the most important single factor in agricultural development. Though the increase in yield is due to many interacting factors, it is proved that drainage is the most effective and essential factor for maintaining and improving the fertility and productivity of the land. Moreover, drainage has important side effects. By removing excess water, health conditions will be improved through a decrease of the causes of parasitic diseases spread among farmers, who represent more than two-thirds of the inhabitants, thus increasing their productivity. An economic analysis of tile drainage in the UAR showed that the capital cost of a tile drainage system is expected to be recovered, through increase of production, within a period of approximately 5 years. The estimation has been made according to results obtained from the last 5 years work. It is expected that in the scope of the long term drainage programme, mechanically installed drainage will play an increasingly important role.

TILE AND PIPE MAKING

Under the provisions in the plan of operation for the tile drainage project machineries for making tiles for lateral drains and pipes for collectors have been erected at a central area in the Delta, near Tanta. The tile making machine is fully automatic with a capacity of 15,000 tiles or 5,000 m. per working day of 8 hours. The collector pipe machine can make pipes with diameter 20 and 25 cm. at a capacity of 100 m. a day.

APPENDIX 1
DETERMINATION OF PERMEABILITY

The permeability is measured in the field by the Augerhole method as developed by Hooghoudt and simplified by Ernst. This requires a hole augered at least 0·30 m. below the ground water-table. The permeability is calculated from the rate of rise of water in the hole, the depth of the hole, its diameter and the depth of the water-table.

The results are based on the soil layer extending from the water-table to approximately 15 cm. below the bottom of the hole, or to the impervious stratum if the hole penetrates through such a stratum. The field data are collected for every hole on a special field log (Fig. 1).

The calculations are made by means of the two graphs Ernst has constructed from a large number of relaxation studies. Graph 1 is to be used for S larger than or equal to $\frac{1}{2}$H where S = depth of impervious layer below the bottom of the Augerhole. Graph 2 is for the case S = 0.

The nomographs are based on the equation

$k = c \frac{\Delta y}{\Delta t}$ where c is a function of y and H.

Both nomographs are made for r = 4 cm. If Augerholes of other diameters are used, the nomogram can be adopted by multiplying the measured values of y and H by the ratio :

$$\frac{\text{radius of augerhole in nomogram (4 cm.)}}{\text{radius of the augerhole in the field}}$$

The converted values are then entered in the nomogram, r = 4 cm., and the corresponding permeability is obtained.

Ernst has also deduced the following aproximate formula's

$$k = \frac{3600\ r^2}{(H + 1 \text{ or})\left(2 - \frac{y}{H}\right)y} \frac{\Delta y}{\Delta t} \quad \text{for } S = 0 \quad \ldots (1)$$

$$k = \frac{4000\ r^2}{(H + 2 \text{ or})\left(2 - \frac{y}{H}\right)y} \frac{\Delta y}{\Delta t} \quad \text{for S greater than } 0{\cdot}5\ H \quad \ldots (2)$$

Example :

r = 4 cm. ; y = 33 cm. ; H = 40 cm. ;
Δy = 4 cm. ; t = 80 sec. = 0·0222 hrs.
S = 20 cm.

As S = $\frac{1}{2}$H then Nomogram I should be used from which C = 15, then

$$k = c \frac{\Delta y}{\Delta t} = 14{\cdot}8 \times 4/80 = 0{\cdot}74 \text{ m. per day.}$$

The corresponding value of k as computed from formula 2 is 0·70 m. per day.

APPENDIX 2

The Hooghoudt equation used for the calculation of the drain spacings is :

$$L^2 = \frac{8\ k_2\ dm + 4\ k_1\ m^2}{S}$$

in which : L = distance between drains in meters

k_1 = permeability of the soil above drain level in m/day

k_2 = permeability of the soil below drain level in m/day

d = depth of the equivalent layer in meters (to be read from special tables, given by Hooghoudt)

m = hydraulic head in meters

s = quantity of water to be drained in m/day.

In deriving his formula Hooghoudt assumed that the stationary flow at some distance from the tiles is horizontal, while around the tiles a radial flow occurs. The resistance for vertical flow is neglected. The resistance for radial flow is accounted for by introducing an equivalent layer in which the same flow occurs as the actual flow, but in horizontal direction only with the same hydraulic head as required for the actual horizontal plus radial flow. The equivalent depth (d) has to be used in the formula instead of the depth to the impervious layer

FIG. 1. FORM FOR K-MEASUREMENT IN DEEP AUGERHOLES

BORING ---- A1 ------- DATE - 26/1/'64

LOGGED BY - John Auger

SITUATION - 50 m. East of Canal

LANDUSE ----- Cotton

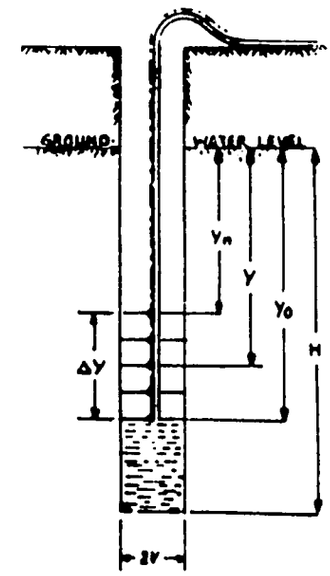
DEPTH AUGERHOLE	200 cm
DEPTH GROUNDWATER	160 cm
DEPTH 1 CONTACT POINT	195 cm
RADIUS AUGERHOLE	4 cm
DISTANCE BETWEEN 2 CONTACTS	1 cm

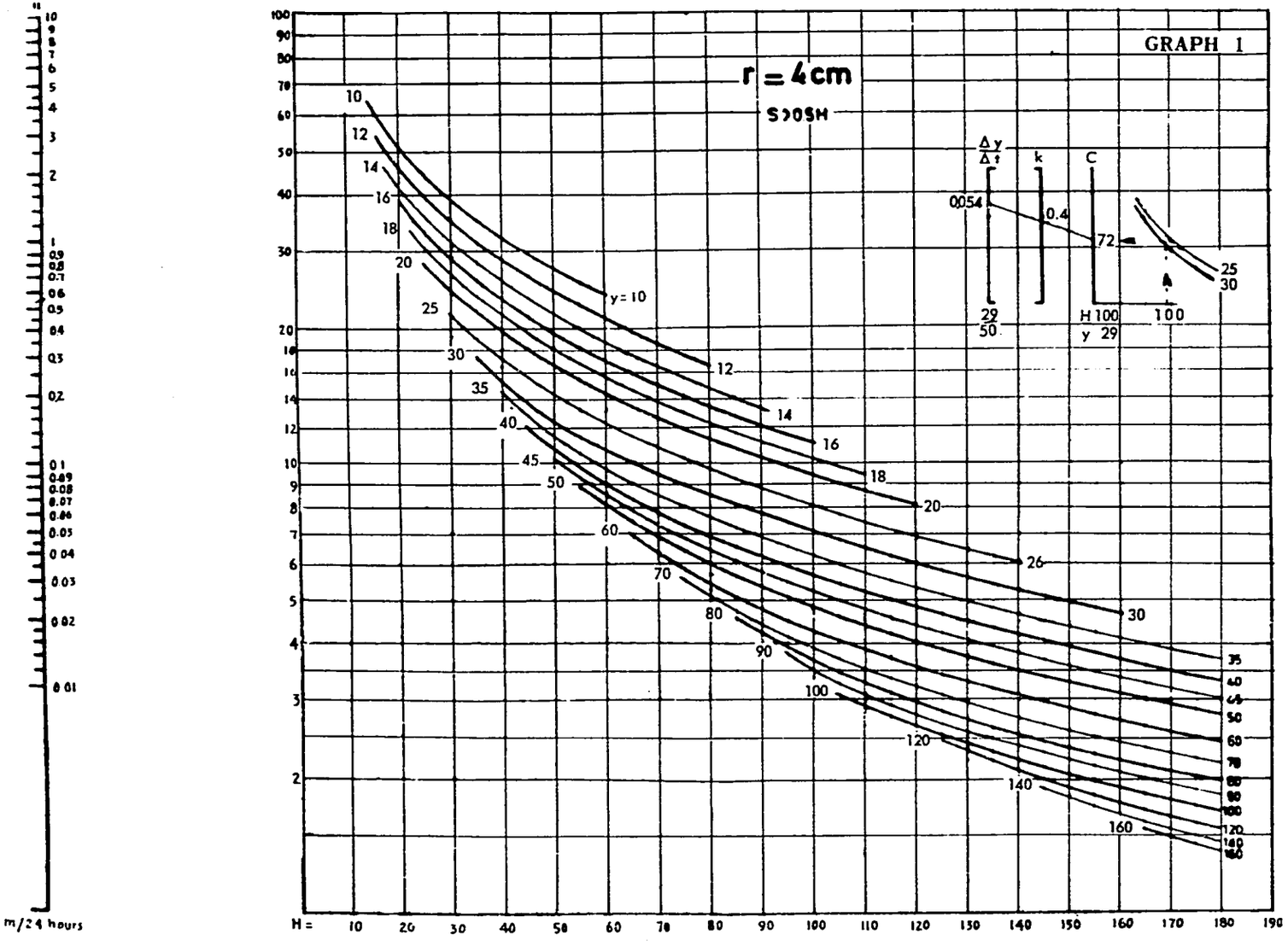
H	40	
Y_0	35	
Y_n	31	
ΔY	4	
Y	33	
Δt	80	
$\Delta Y'$		
Y'		

FORMULA ACCORDING TO ERNST - $K = \frac{4000\, r^2}{(H+20r)(2-\frac{Y'}{H})Y'} \times \frac{\Delta Y'}{\Delta t}$

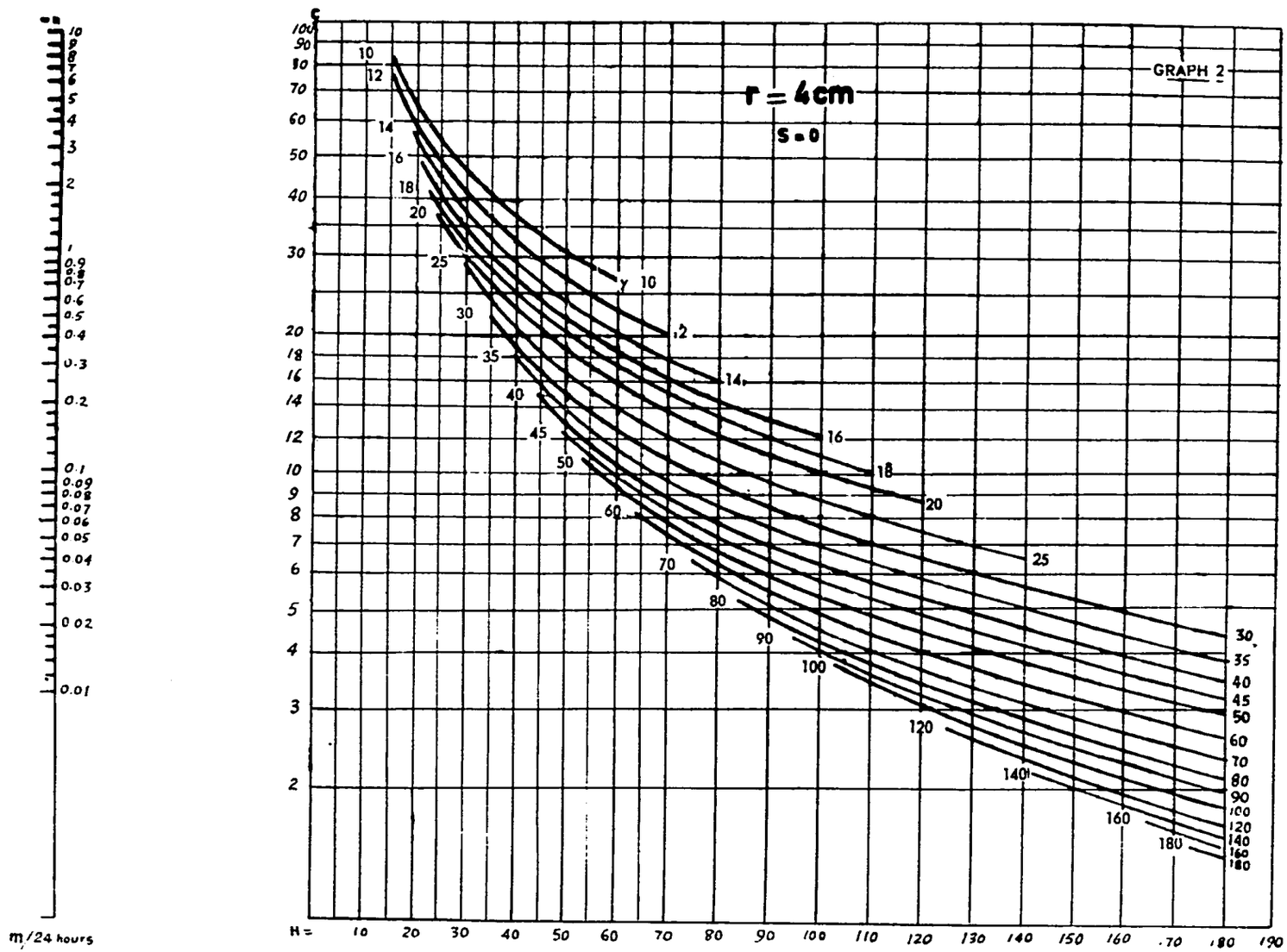
DEPTH TO 1st CONTACT	IN cm 195	IN SECONDS			
		FIRST READING		SECOND READING	
		t	Δt	t	Δt
1st CONTACT		0			
			19		
2nd CONTACT		19			
			20		
3rd CONTACT		39			
			21		
4th CONTACT		60			
			20		
5th CONTACT		80			
K IN m/DAY		0.69			

LEGEND




GRAPH 1
r = 4cm
S>0SH
Δy/Δt
k
C
0054
0.4
72
29/50
H 100
y 29
100
25
30
y = 10
12
14
16
18
20
26
30
35
40
45
50
60
70
80
90
100
120
140
160
m/24 hours
H =

GRAPH 1.



GRAPH 2.

(H). This equivalent depth (d) depends on the wet circumference of the drain πr_0 (r_0 being the outside diameter of the tile, the drain spacing L and the depth of the impervious layer (H). As an example, one of the Hooghoudt tables valid for the tile diameter used in the tile drainage projects as summarised in Report 5. "Drainage of Bilbeis and Sindabis areas*" is given below :—

L in m. / H in m.	15	20	25	30	40	50	75
1·00	0·82	0·86	0·89	0·90	0·93	0·94	0·96
2·00	1·18	1·32	1·43	1·50	1·61	1·76	1·76
3·00	1·34	1·56	1·71	1·86	2·07	2·19	2·41
4·00	1·39	1·67	1·87	2·08	2·37	2·59	2·93
5·00		1·73	1·99	2·22	2·59	2·87	3·34
6·00			2·05	2·31	2·74	3·07	3·67
7·00				2·36	2·84	3·23	3·93
8·00				2·39	2·91	3·35	4·15
9·00					2·97	3·43	4·32
10·00					3·01	3·50	4·46
15·00							4·88
	1·04	1·74	2·07	2·40	3·02	3·62	5·03

According to Hooghoudt, the use of the tables for d, results in an error of less than 10 per cent.

Example : $s = 0{\cdot}001$ m. per day
$k_1 = 0{\cdot}25$ m. per day
$k_2 = 0{\cdot}05$ m. per day
$H = 6$ m., $r_0 = 0{\cdot}07$ m.
$m = 0{\cdot}9$ m.

As a first appropriation assume a value for L say 40 m., the corresponding value of d as obtained from Hooghoudt tables is 2·74 m., thus :

$$L^2 = \frac{8 \times 0{\cdot}05 \times 2{\cdot}74 \times 0{\cdot}9 + 4 \times 0{\cdot}25 \times 0{\cdot}9^2}{0{\cdot}001}$$

$$= 1800,$$

$$L = 42 \text{ m.}$$

* Both Sindabis and Bilbeis are in the east of the Nile Delta.

CHAPTER X

FARM LAYOUT AND DISTRIBUTION SYSTEMS

CUMRA-KARKIN IRRIGATION DEVELOPMENT PROJECT

by

Ragip Boyaci and Cemal Savaskan*

SUMMARY

The Country Progress Reports submitted in the previous NESA Seminars contain information concerning the large irrigation projects which have been undertaken by Turkey in its programme to increase agricultural production. However, anticipated agricultural production goals are not being attained and on some project yields which initially tended to rise, have decreased below their original level. This is due to various reasons. Some of the most important are :

1. Inadequate water supply to all parcels of an area.
2. Lack or inadequacy of proper farm irrigation and drainage systems.
3. Lack of efficient drainage systems.
4. Inadequate farm planning and land preparation.
5. Farmers lack of knowledge of good irrigated agriculture.
6. Excessive fragmentation and dispersion of farms.
7. Inadequate source of credit to meet the farmers needs.
8. Inadequate use of fertilizers by the farmers.
9. Inefficient pest and insect control.

Prior to the establishment in 1960 of TOPRAKSU (Soil Conservation and Farm Irrigation Directorate in the Ministry of Agriculture), assistance to farmers in irrigation development was mainly confined to farm planning and development work on individual farms. After 1960 Topraksu embarked on a programme which included major irrigation development of groups of farms mutually commanded by a single canal, i.e., the tertiary canals serving large project areas.

In this paper is given basic information concerning the Cumra-Karkin Irrigation Development Pilot Project undertaken in 1961 and 1962 on a total area of 320 hectares commanded by tertiaries 5-6-7, located within the Konya-Cumra Irrigation Project of the Central Anatolia.

The Government of Turkey has been gravely concerned by the fact that extremely fragmented and scattered farms have created various economic and social problems along with a decrease in national production. In developing this project land consolidation was attempted for the first time in Turkey. A total of 233 irregular shaped parcels belonging to 191 farmers were re-grouped, into 191 rectangular parcels and provided with access roads and the facilities to properly apply irrigation water and drainage outlets.

* Agricultural Engineer, Deputy Head, Investigation and Planning Division and Agricultural Engineer. Chief Engineer Sixth Regional Directorate, respectively. General Directorate of Soil Conservation and Farm Irrigation, Turkey.

All farmers were provided with title-deeds, including those who had neglected to register their lands in the past.

By improving and expanding the old irrigation system all new parcels were supplied water directly from tertiary or quaternary canals. Previously, only 60 per cent of the total area could be irrigated with any degree of efficiency. Main project works delivering water to the area have been renovated by DSI (State Hydraulic Works in the Ministry of Public Works). Canal sections have been restored to designed capacity and lined with concrete. Measurement of irrigation water has been provided through the installation of Parshall flumes in all tertiary and quaternary canals. A surface drainage system provides for discharge of waste water into the main drainage channel. Wherever possible the borrow pits of the service road network were utilized as surface drains.

Farmers land area was reduced at the rate of 4 per cent to provide rights-of-way for these new facilities.

All lands between canals were levelled, properly graded for irrigation, and each parcel was provided with a head ditch and drainage outlet. As an assistance to farmers in carrying out farm plans the government granted all the seedling, seeds and fertilizers required for the first year of operation. The area is subject to high winds during the fall, winter and spring seasons. In addition to wind erosion control measures considered and provided in the farm plans, the government supplied wild olives (Russian olives) which are planted on the boundaries of all parcels.

It appears that the most of the project which costs 260 dollars (2,617 TL.) per hectare is excessively high for a project in this arid region of Central Anatolia which has a comparatively low production potential. However, the benefit-cost ratio, computed on the basis of proposed cropping pattern is 4·4. It is interesting to note that, although only wheat was planted the first year, the income realized produced a benefit-cost ratio of 3. Farmers from the balance of the Cumra Project are greatly impressed with the high yields produced on the demonstration area. Many have requested similar project for their farming area while others have directed requests to the Cumra Regional Irrigation Experiment Station for assistance in procuring and utilizing fertilizers.

Consideration must be given to the fact that this demonstration was undertaken without the benefit of the legal authority expected to be provided in a new land reform law proposal. Greater participation by farmers in development activities can be expected on future projects undertaken under the new law. It must be noted also that some of the many government services rendered on this project were required as incentives to farmers in inducing them to agree to farm boundary revisions.

The project was prepared and implemented by the VI Regional Directorate of TOPRAKSU, at Konya. Permanent structures were constructed by constructor in accordance with project specifications. Land preparation, farm irrigation and drainage systems and other agricultural works were completed by the Revolving Fund Operation of the Cumra Regional Irrigation Experiment Station. The project was initiated and carried out the first year under a project agreement with the U.S. Agency for International Development.

INTRODUCTION

The Cumra-Karkin Irrigation Development Project is an area of 320 hectares located within the boundaries of the old Cumra Irrigation Project. It has been developed to demonstrate the irrigation works, land development and land consolidation with farm boundary revisions needed in the programme to rehabilitate the entire Cumra Project.

CUMRA IRRIGATION PROJECT

Cumra Irrigation Project is located in the southern part of the Konya Plain in Central

Turkey. The plain situated at an elevation of 1,000 meters is a closed basin surrounded by high mountains.

An irrigation system serving an area of 35,000 hectares was established in 1912 by a German company. The principal water resource of the project is Beysehir Lake with a total storage capacity of $1,870 \times 10^6$ cubic meter. Water diverted from Beysehir Lake is conveyed to the irrigable area through Carsamba Creek which has been improved to provide a channel 192 kilometers long, (Fig. 1).

During the last ten years the State Hydraulic Works (DSI) has constructed four dams in streams discharging into the basin. (Apa Dam, Sille Dam, May Dam, Altinapa Dam). Apa Dam provides additional storage for the Cumra Project and also serves as a regulator in Carsamba Creek. Sille, May and Altinapa dams will provide storage to bring in an additional 3,500 hectares new irrigated land.

Underground water exploration undertaken by DSI has indicated that a usable supply of ground water is available from deep aquifers. Drilling to date has indicated that supplies exceeding 144×10^6 cubic meters per year can be economically pumped and used for irrigation. All the shallow aquifers encountered have yielded salty water unfit for irrigation purposes.

Renovation of main irrigation canals, drainage outlets and appurtenant control structures is in progress by DSI. TOPRAKSU is proceeding with reconstruction of existing tertiary canals and construction of new tertiaries and quaternary canals required to serve the entire irrigable area.

Technical assistance in farm planning and land development is provided to project farmers by TOPRAKSU. A loan fund, maintained in the Agricultural Bank, is available to farmers for implementation of farm plans prepared and approved by TOPRAKSU.

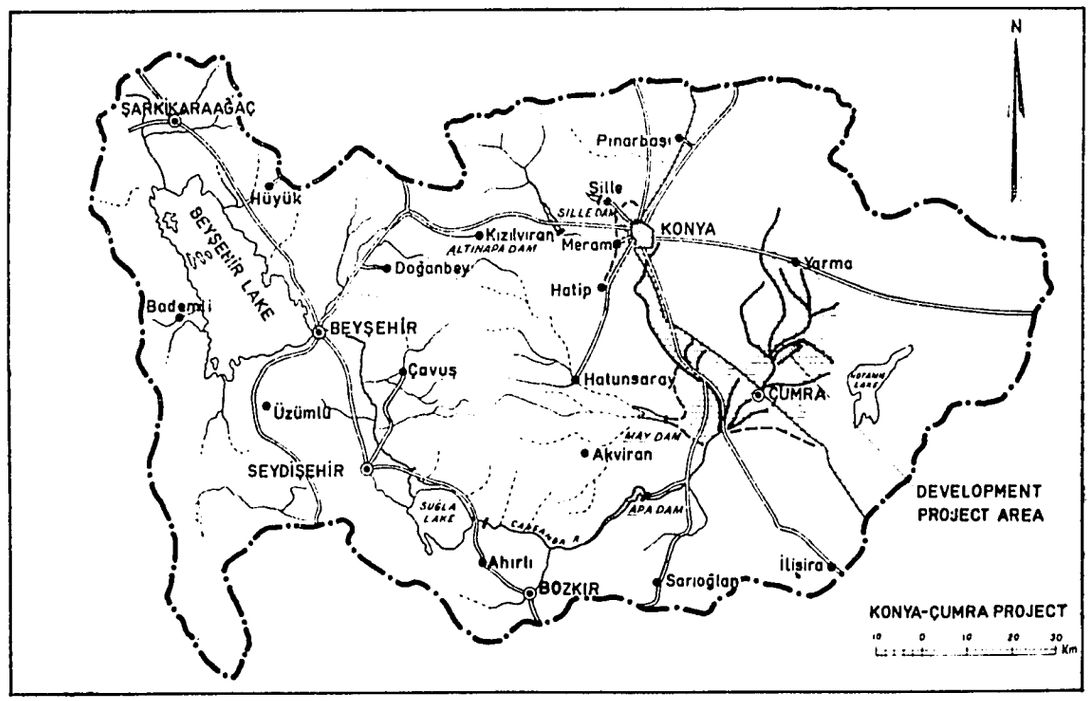


FIG. 1

DESCRIPTION OF THE PROJECT AREA

Location

The project area which covers 320 Ha. was developed primarily as a pilot scheme for both irrigation and land consolidation demonstration. This project includes areas served by the main canal II and by the tertiary canals T-5, T-6, T-7 supplied by secondary canal I.

The project area is located 50 kilometers south-east of Konya City, at a distance of 7 kilometers north of the Cumra Regional Irrigation Experiment Station. A gravelled road extends through the project from Cumra Town where both a railroad and a paved highway serves the area.

Climate

This region where continental climate predominates, is the most arid region of Turkey. Meteorological data obtained from the nearest weather station located at the Cumra Irrigation Experiment Station during last 7 years follow :

Average annual precipitation : 216.3 mm.

Seasonal distribution of precipitation :

Spring	:	35 per cent of total
Summer	:	7 per cent of total
Fall	:	20 per cent of total
Winter	:	38 per cent of total (mostly snow)

Average annual temperature :	11°C.
Maximum temperature	37°C.
Minimum temperature	—26°C.

Average monthly temperatures ;

January	:	1·6°C.	February	:	2·2°C.
March	:	5·9°C.	April	:	11·1°C.
May	:	16·0°C.	June	:	20·0°C.
July	:	23·6°C.	August	:	22·8°C.
September	:	18·0°C.	October	:	13·0°C.
November	:	7·0°C.	December	:	2·7°C.

The average number of days with frost occuring between December and March, is 26. Winds of critical velocities inducing serious wind erosion in the area prevail in the fall, winter and spring. Records show that the south winds in winter reach velocities of 35 and even 40 meters per second. It is recorded that the average annual evaporation amounts to 1380 mm.

Topography

Generally the relief of the project area is fairly flat. The east-west gradient varies between 0·0 per cent to 0·2 per cent. However, there are some undulations in the topography and elevation differences between are often 1·5 to 2 meters. Generally barriers to surface drainage have developed along field boundaries as a result of poor plowing practices and the deposition of wind blown material. Drainage problems have been created and irrigation efficiencies are low.

Soils

Soils are generally brown and gray, developed from alluvial parent material. They are deep, clay and clay loam textured lacking organic matter and phosphorus, abounding with lime. Permeability is medium to slow. About 25 per cent of the top soil has been eroded by wind. Water-table is rising due to deep percolation and seepage from earth irrigation canals and improper and excessive irrigation. Salinity is becoming a serious problem.

Land use capability classes determined in the project area follow :

Class	Area (Ha)	Percentage
I	130·1	40
II	160·4	50
III	12·6	4
V	3·6	1·5
VI	12·0	4
VII	1·3	0·5
Total	320·0	100

Water Supply

Water is supplied by the secondary canal I of 2·5 m^3/s capacity within Cumra Irrigation System built by the German company in 1912. The irrigation water quality is second class.

PROBLEMS OF PROJECT AREA

Irrigation

Both gravity and pump irrigation is practised to irrigate 60 per cent of the project area. Irrigation efficiency are only 20 per cent due to the following factors :

1. The secondary and tertiary canals of the irrigation system which were built over 50 years ago have lost their original capacities. There are badly eroded ditchbanks and siltation caused by wind and water erosion and uncontrolled weed growths. The majority of water control structures and gates have ceased to work properly or are partly demolished. During tests to determine velocities in the old canals it was observed that, it took 3 days for a 2,500 meters long canals to head up. From measurements made on various canals the seepage loss was estimated at 40 per cent.

2. Lack of permanent type (quaternary) canals to serve other areas far from the tertiary canals. Farmers have been required to make mutual agreements for rights-of-way to supply water through primitive type temporary (seasonal) channels.

3. Lack of an efficient main drainage system.

4. Lack of farm irrigation and drainage systems.

5. Lack of land levelling desirable to irrigate uneven lands.

6. Farmers lack practical knowledge of good irrigation practices and methods. The wild flooding methods used are causing waste of water and loss of soil nutrients, damaging vegetation in low spots, and creating waterlogged areas. Crop production is reduced because high spots do not receive sufficient water. Damages to neighbouring fields by flooding and seepage has caused disputes and litigations.

Waterlogging and Salinity

Deep percolation due to poor irrigation applications and excessive seepage from earth irrigation canals in the absence of an adequate drainage system has contributed greatly to the rising water-table. Records are available for certain areas showing that during irrigation season, the water-table is at about one meter from the surface, but after the irrigation season ends it drops approximately two meters.

The salinity problem becomes more serious each year as the salts from deep layers are brought to the surface by capillary action and the evaporation process.

Present Agricultural Aspect

Farmers, in general, are notoriously conservative and slow to adopt now ideas and practices. They know very little about irrigated agriculture. Chemical fertilizers are not used and the importance of pest and insect control is not fully recognised. Although an adequate supply of irrigation water is available, summer fallowing is practiced, generally in accordance with the following system :

1st year :	Winter wheat	75% of total area
	Spring wheat	25% of total area
2nd year :	Summer fallow	50% of total area
	Melons	50% of total area
3rd year :	Winter wheat	75% of total area
	Spring wheat	25% of total area
4th year :	Melons	50% of total area
	Summer fallow	50% of total area

Land Ownership Pattern

There is a total number of 233 parcels belonging to 191 farmers in the project area.

The largest parcel is 7 hectares while the smallest is 0·08 hectares. The average size is 1·7 hectares. Farms averaging 1 to 2 hectares comprise 40 per cent of the project area. The greatest number of parcels in the project area owned by a single farmer is five parcels. Parcels are generally irregular and of various forms. Many of the project farmers own other land located outside of the project area (Fig. 2).

Sub-division as a result of inheritance is the main reason for land fragmentation on this project as well as other areas of Turkey. Most of the farms are small and production income is insufficient to provide a family of 3 members with a decent living.

Generally, the required cadastral survey of the project area has not been completed and the majority of the farmers do not have title-deeds. The litigation required for right-of-way acquisition and settlement of disputes over indefinite boundary lines is becoming a serious hindrance to agricultural development. Undersized, and dispersed plots along with the legal problems and other structural deficiencies associated with inadequate canal, drain and road systems do not provide the means for an adequate income and fulltime employment to farm families.

MEASURES AND PRACTICE FOR SOLVING PROBLEMS

Planning and project preparation including policy and procedure determinations extended over a two-year period. Project implementation of T-5 canal serving a total of 131 Ha. was completed in 1961, while T-5, and T-7 canals serving 189 Ha. were completed in 1962.

The project was carried out with close cooperation between the farmers, the Registry and Cadastral Survey Department, the Regional Office of DSI, the Cumra Regional Irrigation Experiment Station of TOPRAKSU and the Agricultural Extension Service.

Water Requirement

Water requirement of crops was estimated by using Blaney-Criddle formula, according to a crop rotation plan based on the recommendation made by the Irrigation Experiment Station. Monthly and seasonal consumptive uses estimated by the Blaney-Criddle method are shown in Table 1.

Table 2 shows water requirements number of irrigations and irrigation frequency of certain crops in rotation.

Land Consolidation

The important role of land consolidation in the improvement of the agrarian structure in areas where holdings are excessively subdivided and fragmented is well known and needs no further explanation concerning its agricultural, economic and social advantages. Land consolidation will be of utmost benefit to this region, as well as all Turkey for the average farm size in only 8·5 Ha. and average number of plots per farming family is 7 on the national level.

However, the land consolidation scheme implemented in this region, is not consolidation in the broad sense i.e. a comprehensive scheme of integrated reorganization of the whole region including road and water course construction, resettlement, demolition of old farms, reclamation and land improvement, but rather a pilot scheme aimed at the reallocation of scattered plots without expanding the size of the individual farms, and provision for good irrigation without major construction works. Enabling legislation is required to permit implementation of the integrated type of land consolidation.

This scheme of small size which involves only a limited number of land owners has been accomplished under mutual agreements. It has served at a demonstration of the benefits to be derived through land consolidation and has pointed up the need for additional legislation in this field.

The first step was to accomplish the cadastral survey of the project area in

cooperation with the General Directorate of Registry and Cadastral Survey. Ownership maps and the owners were determined to existing registers. The next step was to publish the ownership situation, hear claims of land owners and make appropriate adjustments in accordance with such claims. All ownership disputes were settled legally by mutual agreements signed by the land owners.

TABLE 1.

	f	Cereals (k = 0·75) mm.	Melons (k = 0·75) mm.	Alfalfa (k = 0·85) mm.	S. beets (k = 0·80) mm.
April	111·5	83·6	—	94·7	89·2
May	152·9	114·6	114·6	130·0	122·3
June	174·4	130·8	130·9	148·2	139·5
July	190·0	95·0	142·5	161·5	152·0
August	178·0	—	134·5	151·3	142·4
September	131·5	—	—	114·9	108·1
October	101·6	—	—	86·4	40·6
Seasonal Total mm.	—	424·0	522·5	887·0	794·1

$$f = \frac{P}{100} (1{\cdot}8\, f + 32)\, 25{\cdot}4$$

TABLE 2.

Crops	Cereals	Melons	Alfalfa	S. beets
Seasonal consumptive use mm.	424·0	522·5	887·0	794·1
Seasonal effective precipitation mm.	65·7	47·7	86·7	79·6
Seasonal water deficit mm.	358·3	474·8	800·3	114·5
Seasonal water requirement mm. (Ea = 0·70)	512	678	1,143	1,021
Irrigation frequency (days)	30	24	21	25
Number of irrigations	3	3	6	5
Daily peak consumptive use in the most critical month mm.	4·3	4·7	5·4	5·0

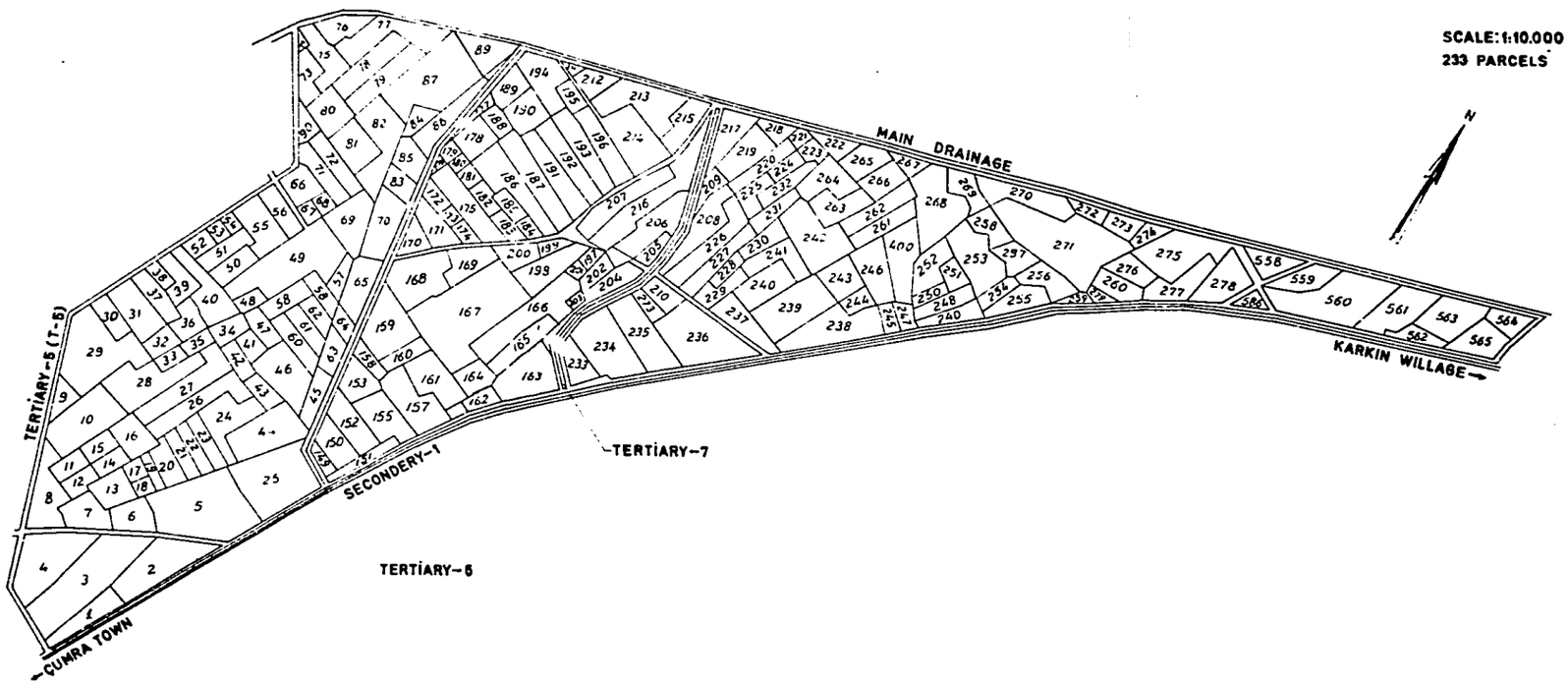


FIG. 2. BEFORE CONSOLIDATION

The land consolidation plan was carried out in consideration of a lay-out of quaternary canals according to topography and the following essential points :

1. Consolidation of scattered and fragmented holdings of individual farmers, into a single tract of land located to the greatest extent possible in the same area of his holdings held before consolidation.
2. Provision for a road system to serve every tract ;
3. Alignment of all tract boundaries during the consolidation process to create rectangular shaped parcels ;
4. Regrouping parcels in consideration of a four per cent reduction acreage to cover land losses due to road and canal right-of-way requirements.

Figure 3 shows the adjusted land pattern in the project area. During the consolidation process, scattered parcels belonging to one farmer, were re-grouped around the largest plot held by the owner, regardless of its land use class. No payment was made for the four per cent reduction in area required to provide roads and canals.

A total of 233 parcels belonging to 191 farmers were re-grouped into 191 larger, rectangular shaped tracts. The largest new parcel, after consolidation was 7 Ha. while the smallest is only 0·2 Ha. prior to consolidation while the greatest number of fragmented parcels held in one ownership was 5.

The ownership pattern after land consolidation is as follows :

Size of Parcel Ha.	Number of parcels	Percentage
0·0 — 0·5	23	12·0
0·5 — 1·0	50	26·2
1·0 — 2·0	65	34.1
2·0 — 3·0	36	18·8
3·0 — 5·0	12	6.3
5·0 — 10·0	5	2·6
	191	100·0

After demarcation of boundaries, land registration was completed and title-deeds were given to owners, by the General Directorate of Registry and Cadastral Survey.

Improvement and Enlargement of Irrigation System

The following principles were taken into consideration during the improvement and enlargement of the existing irrigation system in the project area :

1. Improvement of the existing water control structures and canals in the project area ;
2. Construction of quaternary canals and related structures to supply water to new parcels created according to the consolidation plan ;
3. Construction of surface drainage system for waste water disposal ;
4. Construction of a suitable road system to serve each parcel.

Deepening of main drainage outlet and concrete lining of the secondary canal through a distance of 12 kilometers was completed in cooperation with DSI. The daily peak consumptive use and a 70 per cent irrigation efficiency were considered in determining the capacity of canals.

All tertiary and quaternary canals were constructed with side slopes of 1/1 and lined with concrete 0·08 to 0·10 m. thick. A proper Parshall flume was provided at the beginning of each canal. A total of 4,740 meters of tertiary canal (5, 6, 7) was constructed to improve the irrigation system.

Figure 4 shows the quaternary and additional tertiary (8, 9, 10) for enlargement of the existing irrigation system to supply water to all new parcels in the project area. The total length of concrete lined quaternary and new tertiary canals, the design flow capacities of which vary between 14 to 90 liters per sec. is 10,040 meters. A total of 98 wooden head gates and 23 water distribution boxes were constructed in the canals to provide delivery of water to the parcels in addition to 21 siphons built for road crossings.

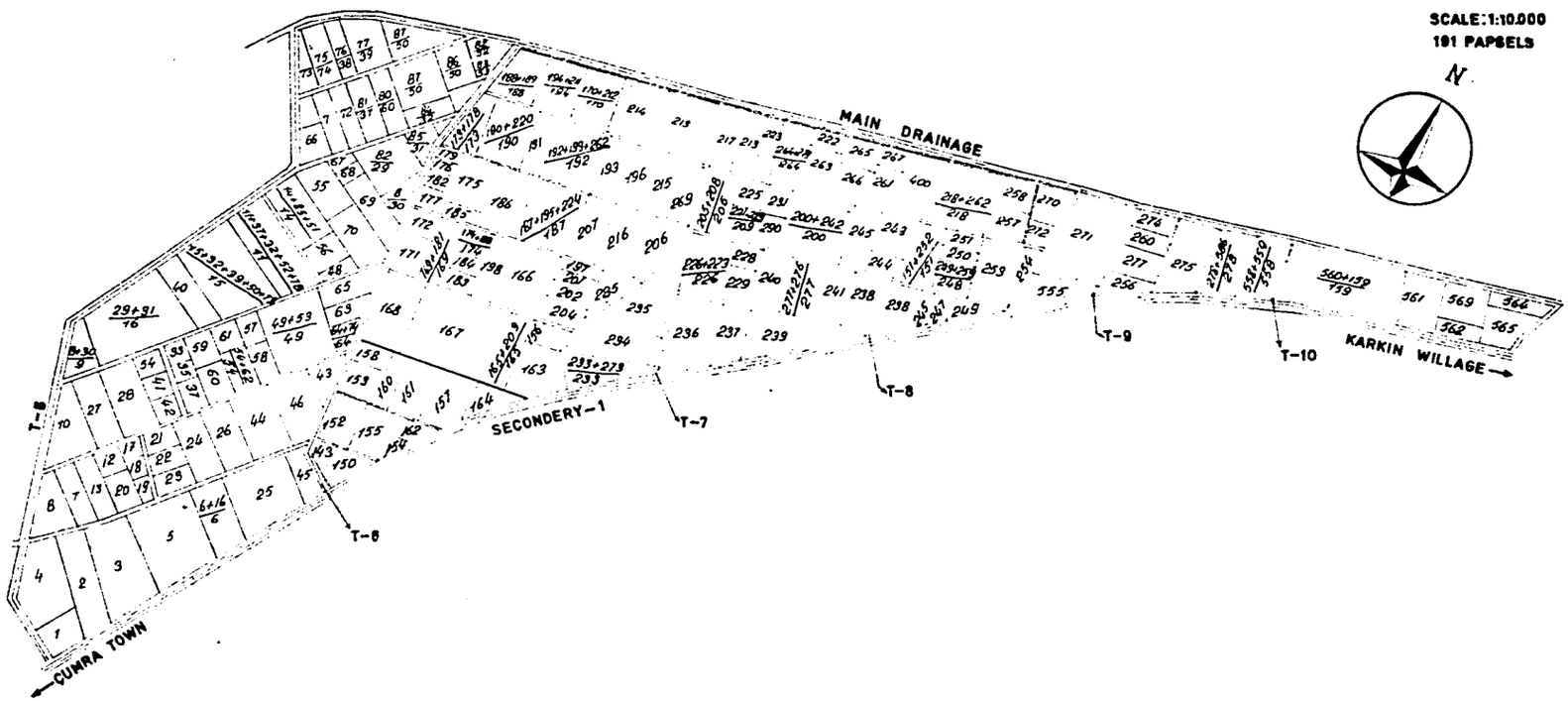


FIG. 3. AFTER CONSOLIDATION

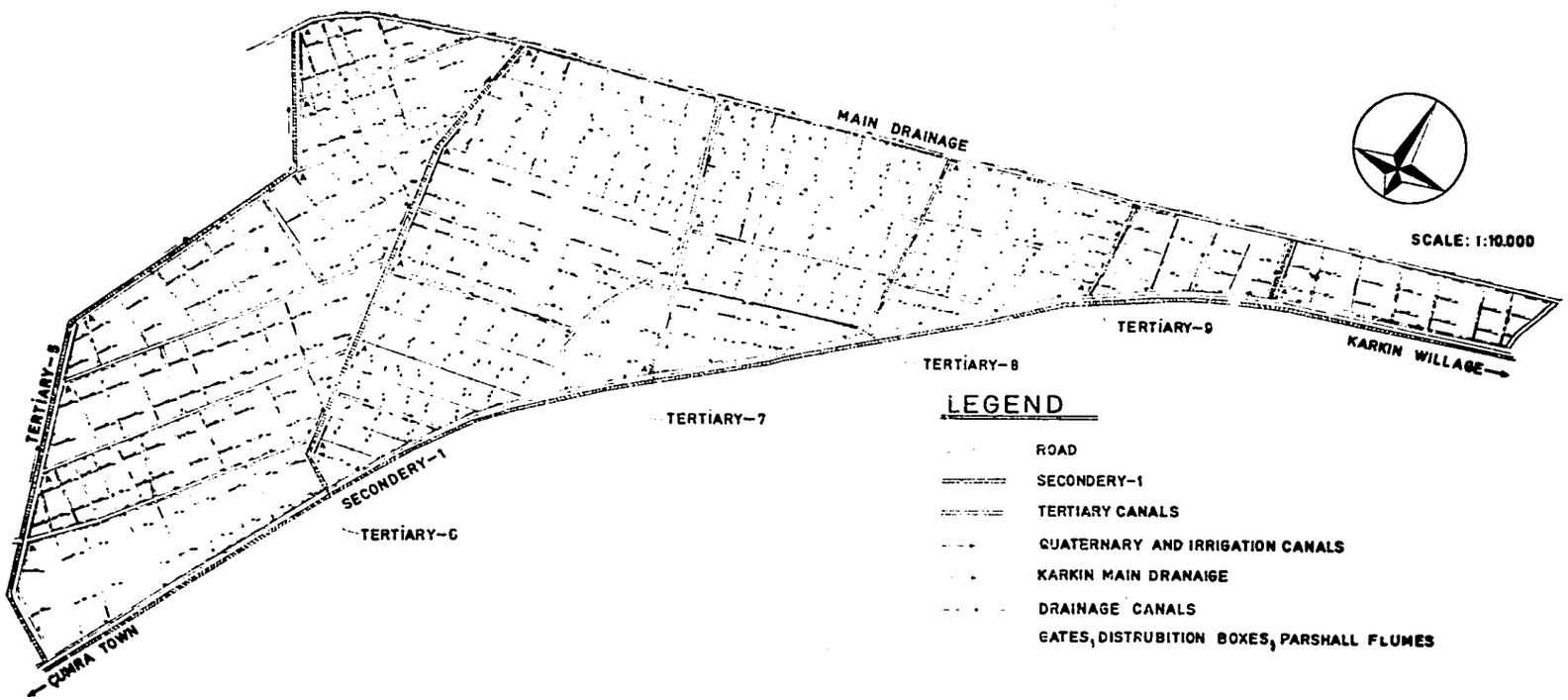


FIG. 4. IRRIGATION LAY-OUT OF THE PROJECT AREA

Surface drainage canals which are parallel to the service roads discharge into the main drainage canal. Service roads, constructed five meters wide, totalled 22 kilometers in length.

Farm Irrigation System

Land levelling was carried out on all parcels without regard to boundaries. Each parcel was levelled to provide gravity irrigation based on a proper land gradient.

Tractor drawn scrapers were used for land levelling. At a rate of 0·3 Ha/day for heavy levelling and 0·6 Ha/day for medium levelling, the average cost for land levelling was 100 dollars per hectare.

Boundary demarcation of new parcels was completed with fixed cornerstones after land levelling. Farm plans were prepared for each farm and assistance rendered in establishment of the farm irrigation and drainage systems. A total of 31·5 kilometers of farm irrigation canal and 35·5 kilometers of surface drainage canal were constructed in accordance with the farm plans.

Wild olives (Russian olive) were planted on the boundaries of parcels to control wind erosion in the project area. In addition, the rotation system for winter-summer-winter crops was planned to provide crop strips laid out perpendicular to the prevailing wind direction. To promote application of rotation systems, farmers were given the seeds and fertilizers necessary for the first year operation. As an on-the-job training measure, project farmers were given preference in employment as labourers during construction and implementation of the project.

ECONOMIC ANALYSIS OF THE PROJECT

Future Agricultural Aspect

A five-year crop rotation system was recommended for the project area and summer fallow is completely eliminated. Irrigated pasture was recommended for the lands of capability classes VI and VII.

To minimize wind erosion damages during the implementation of the crop rotation system in the area, each parcel served by the tertiary canals was subdivided into 5 contour strip blocks. The following crop rotation was recommended and will be carried out :

Block No.	First year	Second year	Third year	Fourth year	Fifth year
1	Cereals	Melons	Alfalfa	Alfalfa	S. beets
2	Melons	Alfalfa	Alfalfa	S. beets	Cereals
3	Alfalfa	Alfalfa	S. beets	Cereals	Melons
4	Alfalfa	Cereals	Cereals	Melons	Alfalfa
5	S. beets	Cereals	Melons	Alfalfa	Alfalfa

The cropping pattern provides a distribution of 20 per cent cereals, 20 per cent melons, 40 per cent alfalfa and 20 per cent sugar beets.

Increased Yield and Net Income

Income estimated based on the rotation applied before and after the project implementation, cultivated area, yields obtained, cost of production, selling prices were considered in the economic analysis of the prepared project.

	Before	After
Gross annual income per Ha.	878 TL.	2,056 TL.
Gross annual income in the project area	263,543 TL.	616,876 TL.
Net annual income per Ha.	405 TL.	1,273 TL.
Net annual income in the project area	121,510 TL.	381,857 TL.

The income increases based on the preceding data follow :

Gross annual income increase/Ha.	1,178 TL.
Gross annual income increase total project area	353,333 TL.
Net annual income increase/Ha.	868 TL.
Net annual income increase total project area	260,155 TL.

Cost of the Project

The costs involved in the implementation of the project follow :

Service road and permanent irrigation and water control structures	306,000 TL.
Land levelling	331,000 TL.
Farm irrigation and drainage system	36,000 TL.
Wind break	9,480 TL.
Investigation, planning, project design, controlling and other costs	102,750 TL.
Total cost	785,230 TL.
Cost of project per hectare :	2,617 TL.
The annual cost of the project is :	59,677 TL.

which is obtained by applying a coefficient of 0·076 to the total cost. The coefficient is obtained in consideration of the following factors :

1.	Annual interest rate	5 per cent
2.	Amortization period	50 years
3.	Replacement period	25 years
4.	Replacement rate	10 per cent
5.	Annual operation and maintenance	2 per cent

$(0{\cdot}05 + 0{\cdot}006 + 0{\cdot}02 = 0{\cdot}076)$

Economic analysis

(a) **The Output--Capital Ratio**—This ratio was obtained by dividing the total annual net increased benefits of the project by investment for the project :

1. Based on expected results :

$$\frac{260{,}155}{785{,}230} = 0{\cdot}33$$

2. Based on the first year cropping :

$$\frac{177{,}000}{785{,}230} = 0{\cdot}22$$

This ratio indicate that the total cost of the project can be recovered within three to five years.

(b) **The Benefit—Cost Ratio.** This ratio was obtained by dividing the total annual net increased benefit of the project by the total annual cost.

1. Based on expected results :

$$\frac{260{,}155}{59{,}677} = 4{\cdot}4$$

2. Based on the first year cropping :

$$\frac{177{,}000}{59{,}677} = 3$$

The resulting ratio of benefit to cost are 3 to 4·4 which as a measure of economic feasibility, shows that the project is economically justified.

Evaluation of the project based on the first year cropping.

Project implementation was first started on the area served by Tertiary 5 on August 1961 and completed on May 1962. Yield increases and income were calculated on the basis of the first year experience following the implementation of the project.

Where heavy levelling was carried out a total amount of 30 tons of manure was applied per hectare, while 300 kg. per hectare of ammonium sulphate (21 per cent N) and 560 kg. per hectare superphosphate (16 to 18 per cent P_2O_5) were applied to all cropfields. The total area was Grahamploughed to maintain land levelling and all fields sown to winter wheat. The land preparation work was completed late in May which precluded planting of the crops recommended in the rotation plan.

Three irrigations were applied. A net amount of 113 mm. of water was applied to the field each irrigation. It was estimated, on the basis of measurement made at the main head gate, that the total of 159 mm. of water was applied during 6-day period required to irrigate the entire area.

It took only 10 hours to irrigate one hectare after project implementation, compared to 40 hours before implementation.

Yields and costs involved determined locally, before and after project implementation are shown below :

	Before	After
Length of stem	80—100	130—160
Number of heads/m²	280—350	470—700
Grain yield	1,400 Kg.	2,500 Kg.
Straw yield/Ha.	2,500 Kg.	5,000 Kg.
Gross annual income per Ha.	1,300 TL.	2,375 TL.
Prices : Grain 0·75 TL./Kg. Straw 0·10 TL./Kg.		
Production cost/Ha.	230 TL.	715 TL.
Net annual income/Ha.	1,070 TL.	1,660 TL.

The following figures are based on the total cultivated area of 300 Ha. :

Gross annual income increase/Ha.	1,075 TL.
Net annual income increase/Ha.	590 TL.
Gross annual income increase in the project area	322,500 TL.
Net annual income increase in the project area	177,000 TL.

One of the main objectives of this project was to demonstrate effectiveness of land consolidation in programmes for land development an areas composed of small irregular tracts. In this respect, it has been most successful.

Administrators and technicians associated with the project have become cognizant of the many benefits resulting through adjustment of farm and field boundaries to fit existing to topography, i.e., reduced costs for levelling and farm ditch and drain construction and, more important, the establishment of condition which permit efficient application and control of irrigation water. The many problems that arose during the time consuming negotiation with land-owners in correction with farm boundary adjustments and acquisition of right-of-way indicated the need for new legislation to enable this phase of development to proceed in an expeditious manner. The knowledge gained in carrying out this project, especially in the field of land consolidation has been invaluable to the officials responsible for drafting the proposed land reform law which was submitted to the Turkish Grand National Assembly during the current session.

DETERMINATION OF COMMAND AREA OF OUTLETS BASED ON SUPPLY, TIME AVAILABLE AND DEVELOPMENT OF CROPPING SYSTEMS BY INDIA

PART I

CRITERIA FOR FIXING OUTLETS AND THEIR COMMANDS OF PERENNIAL IRRIGATION SYSTEMS IN NORTHERN INDIA

by

Baleshwar Nath*

SYNOPSIS

The paper outlines the practices followed on perennial irrigation systems in northern India for fixing outlets and their commands. It shows the limitations of the different systems and elaborates how ventage tables are laid down in Uttar Pradesh for outlets of different sizes in relation to regulation of channels running on a roster-basis for a limited number of days during irrigating seasons.

The paper also brings out how the existing criterion is governed by an over-all broad-based experience, and how its application is extended even to State tubewells irrigating units.

Steps to be taken for improving outlets factors have been indicated in the paper, which lays stress more on observance of a water users etiquette than on imposition of rules and regulations through legislation or administrative orders.

The outlet is a term used to designate the work which passes water from an irrigation canal to water-courses or field channels. From the point of view of practical field operation, an outlet forms the dividing line between the State control and that of the beneficiaries themselves on irrigation supplies.

It is of crucial importance how the ventages and commands of outlets are fixed, how their irrigating potentialities are determined and how they are correlated with cropping system actually practised in their commanded area or advocated for different agricultural tracts.

Criteria and standards in this respect vary considerably from area to area and from region to region, depending upon a large number of governing factors, more important of which are :

I. **Natural Factors :**

a. Topographical features of individual outlet commands.

b. Soil characteristics of commanded areas.

c. State of sub-soil drainage including groundwater-table behaviour.

d. Climatic conditions including rainfall pattern.

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II. **Agronomic Considerations.**

a. Kinds of crops to be catered for.

b. Length of growing periods of different crops.

c. Time and frequency of tilling and watering.

III. **Irrigational aspects :**

a. Availability of supplies along with their qualitative and quantitative distribution across the year.

b. Critical watering periods of different crops.

c. Keenness of cultivators to irrigate their fields.

d. Mode of applying water.

IV. **Institutional Factors :**

a. Roster of channel running.

b. Water rate structure.

c. Methods of assessment and distribution of water including Warabandis and Osrabandis and imposition of punitive rates for misuse of supplies.

Delineation of Commands

For demarcating commands on individual outlets, a contour map of the area to be served by the canal is the first requisite. Before individual outlets can be delineated, the position of distributory channels, subsidiary drainages, village boundaries and roads are marked out. Maps are prepared either on a scale of 4 inches to a mile as in the Punjab or 16 inches to a mile as in Uttar Pradesh.

Limits of individual outlets commands then become more or less self-evident from natural local drainage system, which roughly indicate ridges and depressions. These are sometimes subjected to further limitations on account of political (administrative) and other operational, technical or even non-technical considerations.

From the gross commanded areas of individual outlets so determined, deductions are made for such areas as are unculturable waste or lie on high contours, tanks and low depressions, habitation and hamlets, village tracks, roads and pathways, areas already protected with wells and tanks, areas with very high ground water-table and such other land blocks, as cannot be brought under the plough.

Culturable Commanded Area (C.C.A.)

The resulting figure is culturable commanded area of the outlet, commonly called as C.C.A. This is further divided into two parts, viz., flow and lift.

But, physical considerations outlined above do not alone decide the position and ventage of an outlet. Actual areas to be irrigated and crops to be catered for are of equal importance, if not more, in this connection. Practices on that account vary considerably from region to region.

Departmental experience on open canals in the Punjab indicates that minimum intensity of irrigation should not be less than 40 per cent of the C.C.A. If, however, supplies on any project are likely to fall short so as not to suffice for such proportion, irrigation limits could be contracted. In other words, the scope of project could be reduced. There is, therefore, to be a compromise between dispersal of benefits of irrigation over the project service area and keeping up percentage level of intensity of irrigation in the area commanded by individual outlets.

Where, however, a high percentage of irrigation intensity is likely to cause waterlogging, as has happened in many irrigation tracts in the Punjab, limitation has to be imposed on location and size of outlets, so as to restrict the area irrigated season after season.

Where, however, supplies are ample and there is no fear of waterlogging, intensity of irrigation could be increased to the mutual benefit of irrigators and the State.

Controlling Factors

Before actual outletting of any scheme can be designed, it is necessary to accept one or other season, viz., kharif or rabi as the controlling factor in determining water allowances for individual outlets and eventually for channels. In other words, channels in their design concept have either to be kharif channels or rabi channels.

In northern India most of the rivers from which major irrigation schemes off-take are snow-fed, these rivers during hot weather due to melting of snow. Demand for water is also keenest and irrigation can be done very profitably at that time, as canals can be run to their full authorised discharge. Where, kharif crops need extensive irrigation, kharif, season becomes the controlling factor.

Actual performance or experience on irrigation systems in the areas or adjoining areas leads to an estimate of kharif 'full-supply factor' i.e. F.S.F. at outlet. This factor means the average acreage to be irrigated by one cusec of outlet capacity. For example, on two important irrigation systems in the Punjab this factor is taken as :

i.	Western Yamuna Canal	75 to 115
ii.	Sirhind Canal	80

Working out from this the full supply factor at channel head and taking into consideration the C.C.A., kharif intensities can be calculated. In the case of two systems mentioned above kharif intensity for perennial areas works out in the neighbourhood of 16 per cent.

From these factors, outlet capacity i.e. water allowance per 1,000 areas of C.C.A. can be determined as shown below :

$$\frac{1000}{D} \times \frac{I}{100}$$

where D is the kharif full supply factor

I is the kharif intensity

where outletting is done on consideration of kharif, rabi season is let to develop as it may. But, criteria in these respects are modified to correspond with the economic development of the tracts. Sometimes large scale remodelling of outletting and even of channels has to be carried out to meet the changing socio-economic conditions.

In Uttar Pradesh, where rainfall is generally heavier than in the Punjab, kharif-rabi ratio is more in favour of rabi irrigation. Percentage of canal irrigation to culturable commanded areas in some divisions of Upper Ganga Canal worked out to :

Rabi	34%
Sugarcane	12%
Rabi plus sugarcane	40%
Other Kharif	17%
Annual total irrigation.	63%

This percentage is undergoing a change because of increasing sugarcane areas. On that account some channels needed to be remodelled to function as kharif channels instead of rabi channels as originally designed.

While crop ratio between kharif and rabi on Western Yamuna Canal in the Punjab works out to about 1 : 1 ; that for Kanpur District, in Central Uttar Pradesh, is 1 : 2 Rabi season is therefore, generally the controlling season in Uttar Pradesh. The percentage of culturable commanded area is based on experiences gained on old systems.

Critical Watering Period

River supply in rabi season generally falls abruptly after the monsoon season. Channels cannot be run either constantly or even alternatively. Supply of irrigation water to different canals, distributories and minors has, therefore, to be determined mostly on the basis of the so-called critical watering period.

In the western districts of Ganga Canal in the absence of winter rain, wheat would be watered every 40 days, sugarcane every 21 days. The first watering of wheat, which is commonly called 'Kor' is needed shortly after

germination and is ordinarily completed within 5 to 6 weeks, usually between the middle of November and the end of December. This requirement has an important bearing on the design of outletting system on open canals. If, however, the monsoon season continues late, this period is shifted by a fortnight or so, i.e. from 1st December to about 10th January.

Experience on old Ganga Canal showed that while rabi irrigation extended over a period of 140 days or 20 weeks only, smaller channels were run for 70 days, i.e., 10 weeks, longer channels actually designed for alternate running had to be kept running for 84 days, i.e., 12 weeks, so that the minors taking off from them could be fed with sufficient water. Some alternative channels actually ran for 90 days, while some channels intended to be run constant could run for 112 days only.

A Rationalised Approach

On the Sarda Canal System in Uttar Pradesh, which was built between 1921 and 1928, a rationalised criterian was developed for fixing outlet ventages. This was not applied rigorously, but generally. Assuming a depth of 0·885 ft. required for maturing rabi crops including waterings needed for sugarcane areas 'outlet factors' were assumed corresponding to the number of running days of channels given below :

How run	No. of running days in Rabi	Outlet factor i.e. acres/cusec
Constant	140	300
4 weeks in 5 weeks	112	250
2 weeks in 3 weeks	91	200
3 weeks in 5 weeks	84	190
1 week in 2 weeks	70	160
112 days channels	56	125

Ventage Tables

Actual outlet sizes were worked out from the ventages table outlined for ordinary metal or reinforced concrete pipes of commercial sizes fixed with their central axis 1·5 ft. below full supply level of the channel or at bed level, if water depth was less. On main canals, however, where fluctuations in water level are faced frequently, outlets were fixed generally 2 ft. below rabi full supply level, ventage table adopted is given in Table 1.

To start with, however, 80 per cent ventages were allowed on new channels. When, on development of irrigation the ventages proved to be insufficient they could be increased. Corresponding to 80 per cent is depicted in Table 2.

Special Cases

Where rice areas exist outlets therefore are provided separately. These are fixed on Fasli basis i.e. for the season only. They are not used during the rabi season, when supplies in canals are hardly sufficient to cope with the demand. Sometimes special outlets are required for specific seasonal blocks of crops like sugarcane.

Criteria outlined above are based on overall broadbased field experience. On close field level examination of soil types considerable improvements are possible. Agricultural Extension Services now coming into action can take up such examinations with great advantage.

State Tubewell Commands

Extensive State tubewells commands have been fixed on the analogy of open canal outlet commands reckoning 1,000 acres for 1½ cusecs. Intensities of irrigation have mostly been assumed on the same basis. But, State tubewells afford a distinct field for practising intensive pattern of irrigated agriculture, as supplies from tubewells are firm and perennial and there is no fear of waterlogging. A revision of policy in this respect is urgently needed.

Though Punjab and Uttar Pradesh are contiguous States and have major irrigation schemes off-taking from perennial rivers, there still exists considerable variation in practices with regard to fixing of ventages. Part of this difference is inescapable because of variation in rainfall patterns of the two areas. But, there are many features of which a rationalised uniform approach could be adopted.

TABLE 1

Ventage allotted (inches diameter)	Area of rabi plus sugarcane in acres for running days of channel of				Remarks
	70 alternate	84 or 91, 3 in 5, 2 in 3*	112 4 in 5	140 constant	
	under acres	under acres	under acres	under acres	
3 inches	25	30	40	45	
4½ inches	40	50	65	75	100 per cent
5 inches	60	75	95	110	ventage
6 inches	85	105	135	150	table.
6 inches × 4½ inches	125	155	200	225	
2 inches × 6 inches	175	220	280	300	

* Nominal roster.

TABLE 2

Ventage allotted (inches diameter)	Area of rabi plus sugarcane in acres for running days of channel of				Remarks
	70 alternate	84 to 91, 3 in 5, 2 in 3*	112 4 in 5	140 constant	
	under acres	under acres	under acres	under acres	
3 inches	31	38	50	56	80 per cent
4 inches	50	63	81	94	ventage
5 inches	75	94	119	138	table
6 inches	106	131	169	188	
6 inches × 4¼ inches	156	194	250	281	
2 inches × 6 inches	219	275	350	375	

* Nominal roster.

Another important factor which hinders fixing of outlets on a rationalised optimum utilisation basis is the size of holdings in most of the irrigated areas. Sizes being irregular and small, considerable wastage of water occurs in providing field channels to serve them. Rectangulation has been done in most of the Punjab. Consolidation being done in many other areas is not adequately orientated to take care of this important aspect of irrigated agriculture.

Improving Outlet Factor

Levelling of fields is, by and large, not attempted in a scientific manner. This forestalls the very purpose of economising on outlet supplies which are otherwise fixed after considerable thought and calculation. Outlet factors can be improved if levelling of fields is done and wastage of water reduced at field level in all other respects too.

There exists consciousness on the part of Irrigation Engineers in fixing up outlets, their commands and their ventages on the basis of requirements of the areas served, but there is no equal degree of consciousness on the part of irrigators to economise irrigation supplies and use water on an economic basis. Imposition of punitive rates, Warabandis and Osrabandis do have a chastising effect. What is required at present is strict control on the use of irrigation supplies so that no water is wasted through uneven fields and ill-kept water channels.

Where surface water channels lead to wastage through evaporation and percolation, it may seem prudent to adopt sub-surface distribution using polythene or other cheap type of pipes. This is a measure which has to be examined in respect to its economic and financial implications as indigenous production of cheap pipe is very limited at present.

Considerable difference of opinion exists between Irrigation Engineers on the question of splitting up of outlets. Some Irrigation Engineers have felt that outlets should not be given so as to deliver a friction of a cusec, others feel that small outlets should be used. There are merits and demerits in both the view points. A mean has to be struck between the two concepts so as to enable the best use of supplies available. Some actual field research may yield helpful criteria in this respect.

While flow irrigation is a very easy process of applying water to the crops, it leads to over-irrigation generally. In many areas waterlogging conditions have appeared because of over-irrigation, season after season. A light lift is considered preferable by many Irrigation Engineers from a water economy point of view. In fact, where manual lift is allowed for irrigation from open canal, water rates are only half those for flow irrigation.

Water Users Etiquette

What is required is to revise the existing code of practice of water utilisation from our outlets with the application of new techniques of water distribution and field water management. The existing rules and regulations with regard to irrigation supplies need to be amended so as to invoke a sense of cooperative responsibility for enforcement of water users etiquette among the users instead of punitive rates now in vogue.

It is also essential to devise ways and means to tone up the moral fibre of the users so as to enable them to appreciate the moral responsibility with regard to proper and economic use of water.

Users also need to be made familiar with the latest agronomic practices so as to enable them to apply only necessary quantity of water and to plan the rotation of crops to yield maximum agricultural production from the supplies available.

Our outlets will continue to be fixed on a liberal basis so long as the end-use-set up of irrigation supplies is not efficient. It is therefore, necessary to provide a sound socio-economic basis for coordinating aspects of irrigated agriculture into a well planned development programme. A practical field demonstration approach will go a long way to achieve the desired results.

Outletting on irrigation canals is not a theoretical problem. It is a subject in which many disciplines come into operation. These are problems of rural India. They cannot be tackled merely through academic or legislative approaches.

PART II

DETERMINATION OF COMMAND AREA OF OUTLETS

by

S. S. Lamba and A. N. Murthy*

SYNOPSIS

Outlets are devices to supply water from the irrigation supply system to the water courses (field channels). These are located at the boundary of the irrigation supply system at which the State's responsibility for supply of water ceases and that of the cultivator begins.

The purpose of this note is to bring out in a general way the object of providing outlets, methods of determining their capacities in consideration of area command, the cropping pattern proposed, water requirements of various crops proposed and water supply periods, and different types of devices in general use in India.

The command is extent of land to be served by an outlet. In fixing the outlet command, considerations of gross command area, culturable command area and the irrigable area based on the intensity of irrigation admissible, are taken into account. The design criteria are briefly dealt with under the important factors like (i) natural factors, (ii) agronomy considerations, (iii) Irrigational aspects and (iv) institutional factors. The water requirements of crops which determine the discharge required are dealt with at some length.

In the design of the outlets, the prevailing systems of irrigation in Northern India and the Deccan are briefly dealt with. The essential difference is that while in Punjab water is supplied on the basis of a fixed water allowance and the farmer is free to grow any crop he considers most profitable, in the Deccan there are two seasonal blocks and sugarcane blocks to which supply of water is agreed upon, depending on the types of crops to be grown, for terms of about 6 years at the end of which they are to be renewed.

The different types of outlets, classified as Non-Modular or Semi-Modular and Modular, in common use are dealt with briefly. The details of design are not presented.

Water requirements

The work on water requirements of crops was started as early as 1850 but the term was actually defined by Hellriegal, who conducted investigations in pots in 1883. Systematic investigations were undertaken in the first decade of the century, simultaneously, in the great plains in the U.S.A. and the Indo-Gangetic Plain of India.

Initial investigations were conducted in pots, but it was soon realised that the information thus made available was not, in toto, applicable to field conditions and thereafter the investigators resorted to investigations conducted in the field.

The water requirements of crops vary widely with the crops. The water requirement, usually expressed in acre-inches per

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Editor's Note : The introductory portion of this paper is essentially a restatement of the first 6 paragraphs of the preceding one so it has been omitted.

acre, varies for different crops in the same area depending on the duration of crop growth, the size of the plant and the degree of wetness of the soil required to mature the crop.

Critical periods

For proper appreciation of discussion on water requirements, it is necessary to know about the plant growth. The following are different stages of a growing plant area :

(a) The formative stage or early stage of growth.

(b) The grand growth stage or period of rapid growth.

(c) The differentiation stage or flower and fruit setting period, and

(d) The maturation stage or period of ripening.

The growth of a plant plotted against time is represents a sigmoid curve as shown in Fig. 1.

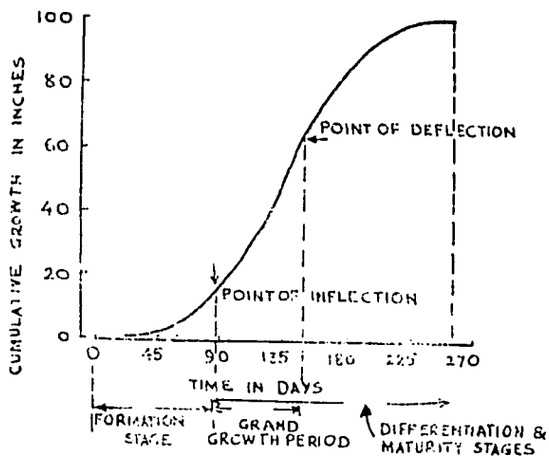

FIG. 1. S-SHAPED CURVE OF SUGARCANE CROP

The points of inflection and deflection of the curve indicate the critical periods during the life of a plant, because any stress of soil-moisture or shortage of water in the soil adversely affects crop yield. Shortage of water during the grand growth period reduces the size of the crop, the plants remain stunted and in some crops the tiller mortality is very high. For most crops, an irrigation at this stage keeps up the tempo of growth and normal development ensures.

The stage at which the curve indicates decline is critical because here flower, fruit and seed formation sets in. Stress of soil-moisture at this stage results in poor size of fruit or seed and consequent poorer size of harvest. Keeping up the soil-moisture at this stage is essential for getting proper out-turn of the crop.

The moisture in the soil is critical when the soil fails to give up sufficient water to the plant, and this stage of soil-moisture is called the wilting percentage. Thus, between the point the soil is fully wet and the point of wilting percentage is the range of available soil-moisture that meets the requirements of crops. Most crops require adequate water supply within the first nine inches of soil and as such it is essential to keep the surface layers of the soil always sufficiently moist*.

For some crops, however, it is essential to provide a short period of stress which enables the plant to develop an extensive root system. For instance, in the case of cotton, it is essential to allow top soil to dry up for a while after a good initial start so that it extends its root system deep down and if after this stage—say after 40 days, the soil is irrigated, the crop develops in a normal manner.

Similarly, in the case of sugarcane, a similar stress at the maturation stage is helpful in the accumulation of sugar in the plant, therefore immediately after monsoon, irrigation at long intervels is desirable.

Some important Indian crops and their water requirements are given in Appendix I. Appendix II gives the sowing and harvesting seasons of principal crops in different States in India.

* Roots zones normally extend much deeper than 9 inches. I do not understand the reference to "the first nine inches". Editor.

CROPPING PATTERN

Besides the water requirements of different crops, the other factor affecting the discharges is the cropping pattern adopted. This depends on the existing crop pattern, suitability of soil conditions for proposed new cropping pattern, the response of the villagers and the economic conditions for betterment of the people in the area of command. Besides these, the cropping has an important relation to the irrigation supply.

It is of paramount importance to fit the crops in the cropping scheme so that the maximum requirements of water do not clash with one another ; otherwise either the carrier channels will be of uneconomic design or water will not be available as required and one or more crops will suffer from shortage of water in the soil. Peak demand and comparative duration of water needs are important. These are shown graphically for different crops as observed at Delhi in Fig. 2

The suggestions on cropping scheme in relation to irrigation supply as suggested in the Indian Council of Agricultural Research's Research Series No. 28 are :

"Since the demands and the peak requirements vary, we have to fix rotation of crops accordingly. During the summer months of April-June, minimum area should be put under short duration crops of which the peak water requirements correspond with the peak of the monsoon rains. This should be from the last week of July to second week of September. These crops have low requirements after September. The important crops which have such a character are *jowar*, maize, cotton, groundnut, *mung*, *urid*, cowpeas and sannhemp. In assured rainfall areas (precipitation above 30") these are the principal crops grown, except in very clayey soils of Madhya Pradesh in Narbada Valley region which are difficult to work in the rainy season. There wheat, linseed and gram are grown. The general sequence of cropping of such areas is *jowar*-groundnut-cotton. Here the rainfall does not exceed 40 inches per annum".

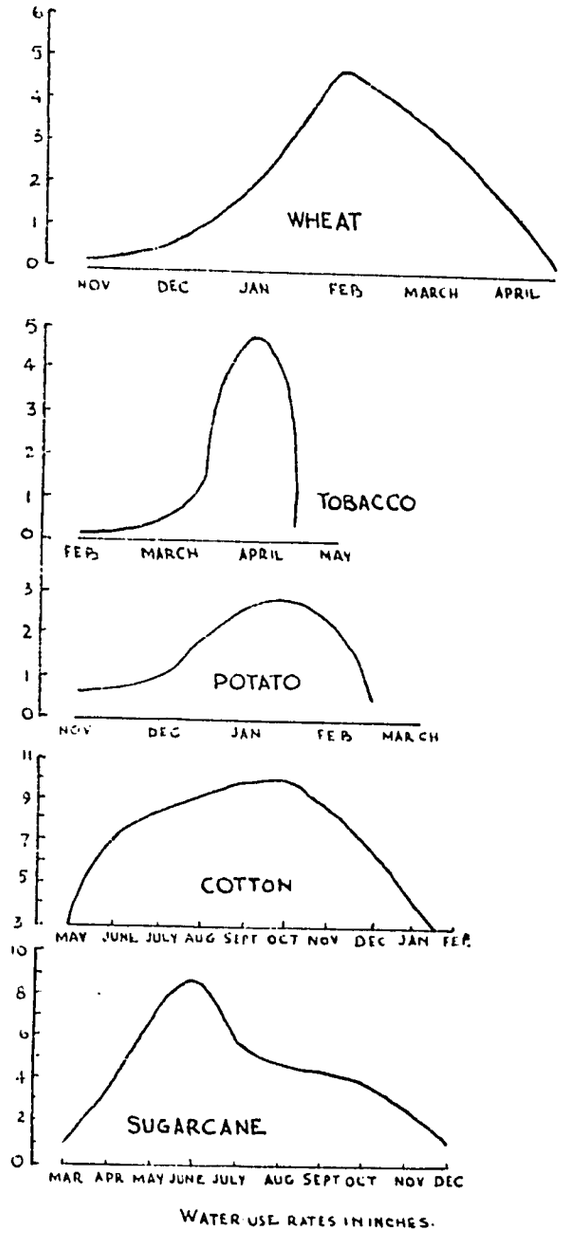

FIG. 2

"In irrigated areas, it is customary to crop more area in the winter when temperatures are low than in the summer. Crop requirements are spread over a longer interval and water can be equitably

distributed over a larger area. In the north-western irrigated areas and the Indus Basin Plains, the general sequence of cropping consists of wheat-sarson or *toria*-cotton-gram. This area is comparatively more dry than other areas of the country. In holdings where water supply is more restricted, gram may be mixed with wheat. In areas commanded by percolation wells, the sequence of cropping varies and may be represented as follows :

wheat-cotton-senji-maize

jowar (fodder)-senji-sugarcane-wheat"

"Several variations are made in these established sequences, dependent upon labour supply, manurial resources, capital availability, etc".

"In the northern Gangetic Plains, cotton is largely replaced by sugarcane and peas by gram in the irrigated sections. The sequence of cropping thus is wheat-sarson-sugarcane-peas. There are several variations of this sequence adopted by farmers of this tract. On the same land, sugarcane is often rationed for one or more seasons. The intervening fallows are used for sannhemp green manure or for fibre or kharif pulses".

"In coastal areas of West Bengal, Orissa, Andhra Pradesh, Madras and Kerala, two successive crops of paddy are taken, for the water requirements of both the crops are met by south-west and north-east monsoon rains. The second crop of paddy does require some supplemental irrigation to mature the crop. In the uplands, the farmers take red gram, black gram or horse gram and gingelli as alternative crops to the second crop of rice."

"Thus, we see that water requirements of crops, particularly from the points of view of peak requirements and comparative duration of the water needs are important considerations in adopting a sequence of cropping and the area put under crops in the holding. With rainfall exceeding 55 inches, with irrigation or rains from the north-east monsoon, the intensity of cropping is about 200 per cent. It falls off as the rainfall decreases and may be as low as 50 per cent where rainfall is below 20 inches, without protective irrigation. Secondly, the crops of high water needs are commonly fitted in the areas of about 30 inches rainfall together with irrigation. Even up to rainfall of 45 inches, some 'rabi' crops of low water requirements are included in cropping programmes of farmers".

DESIGN OF OUTLETS

Command and discharge. The crop pattern, crop rotation and water requirements being determined the discharge requirement for the irrigation of a particular crop after the area contemplated is arrived at and thus the discharge for which the outlet is to be designed is also determined.

Full supply factor. In the design of outlets, whether 'kharif' or 'rabi' the controlling factor has to be decided. Where 'kharif' crop requires extensive irrigation, 'kharif' it controls. In U.P., where the rainfall is heavier than in the Punjab, 'kharif'—'rabi' ratio is more in favour of 'rabi' and hence it controls.

The percentage of cultivable commanded area to be supplied with water is determined, based on experience in the area or neighbouring ones. Thereafter, the full supply factor (F.S.F. at outlet) is estimated, based on experience. It is the average acreage to be irrigated by one cusec of outlet capacity. It is also the average water allowance on the basis of commanded culturable area. This factor and the culturable commanded area to be served being known the discharge required to be passed through the outlet is determined.

The same method of determining the discharge capacity of the canal has also been in practice in the Deccan for a long time. In the Nira Right Bank Canal (which was nearing completion in 1926) the distributaries and

outlets were designed accurately to the crops likely to be grown.

Outlet capacities. The system adopted in design of outlets for the Nira Right Bank Canal (Bombay-Deccan) is explained below as an example :—

For the perennial section the assumption that a concentration of 100 per cent of crops must be allowed for, and that those crops, for which the land was suitable (based on the soil classification of the Special Irrigation Division) would be grown. For cane, the "capacity coefficient" of the channel was taken as 50 (i. e. the distributary head duty generally assumed for cane) whereas for other crops the "capacity coefficient" was assumed as 100. This was based on past experience.

Practice in Northern India. In Northern India, the principle followed is that the available supplies should be distributed to each outlet in proportion to the area of culturable land commanded, and it is left to each cultivator to irrigate with his share of the outlet supply whatever area he considers will bring him maximum profit. So far as this is possible, the water is distributed on a time-basis in proportion to the various cultivators holdings, the assumption made being that the supply drawn off by an outlet will be constant for the period of flow. The system followed, therefore, for this and other reasons is to run the distributaries with full supply (or keep them closed) and to distribute the water proportionately by using semi-modular outlets, which are sufficiently elastic to dispose of small fluctuations.

Practice in the Deccan. While in the Punjab water is supplied on the basis of a fixed water allowance and the farmer is free to grow any crop he considers most profitable to him, in Maharashtra the big sugar factories are supplied water on volumetric basis. Though the volumetric method of supply is a rational one, there are difficulties in its adoption to large number of small holdings. Making the measurements and keeping of their accounts is cumbersome. Suitable device for measuring small quantities of water supplied to individual farmers, lack of physical control over the supplies in the field channels which pass through fields of more than one farmer, etc., are some of the problems encountered.

In the areas of erstwhile Bombay State, the so-called block system is prevalent. These are in the form of permits for a term of years and guarantee to supply water in the various seasons. The two prominent type of blocks are as under :—

(1) **Two Seasonal Blocks.** In this pattern, water is guaranteed for the two seasons of 'kharif' and 'rabi'. These are eight-monthly blocks. The usual practice is to allow water for equal areas in both seasons and the irrigators are charged on the sanctioned areas whether water is taken or not. The usual term is six years and the agreements are renewed after this term. There are variations to these permits. e.g., pre-seasonal watering for 'kharif' may be given to a block-holder for crops like long-staple cotton. Similarly, post-seasonal watering may also be allowed for the standing 'kharif' crop. Pre-seasonal and post-seasonal rates are levied in such cases. Similarly, a crop which may be considered a hot-weather crop like extra long-staple cotton may be permitted to continue during the 'kharif' season against the two seasonal block permit.

(2) **Sugarcane Blocks.** These also have a term of six years. Before the sanction of these blocks, soil surveys are carried out to assure the drainability of the soil and the limits of acreages to be allowed for cane are fixed usually at about 1/6 and 1/10 of the suitable area. Sugarcane is allowed on the basis of one acre in a command of three acres, the other two acres being meant for dry crops. Since sugarcane crops of maturing periods from 12 to 18 months have now been introduced,

overlapping sugarcane is also allowed in the sugarcane block to a limit of about 60 per cent. Thus, in a command of 3 acres, there may be one acre of basic cane and up to 0·6 acres of overlapping cane during the overlap season, the balance being under dry crops.

The lands under sugarcane are carefully watched for damage which may occur by water-logging or salinity, and damage registers are compiled from year to year. The blocks are renewed after taking into account the damage that may have occurred which may justify reduction of the sugarcane area in any particular command. These long-term commitments facilitate sanctions and reduce the clerical annual applications and disposals.

The requirements of water are expressed in terms of 'duty'. This varies with the crops and the seasons the latter considered being Hot Weather, Monsoon and Rabi, each of 4 months duration starting with 15th February. The duties at the head of the canals are

Sugarcane or rice	40 to 45 acre per cusec.
Cotton	80 to 85 acre per cusec.
Eight months	120 to 150 acre per cusec.
Hot Weather	45 to 50 acre per cusec.
Monsoon	180 to 200 acre per cusec.

The usual number of irrigations required for different crops on the average are as follows :—

Sugarcane	30 to 35 waterings
'Bajra' and other monsoon crops	2 to 3 waterings
'Jowari' and other 'rabi' crops	3 to 4 waterings
Eight months crop	10 to 13 waterings

The water turn for the different seasonal perennial crops are as follows :—

Hot weather crops	15 to 20 days
Monsoon crop	20 to 30 days
Rabi crops	20 to 30 days
Eight months crop	10 to 12 days
Perennial crops	10 to 12 days.

The various crops irrigated are reduced to a common basis. On the larger Deccan canals, the hot weather duty is calculated on the sugarcane basis and the monsoon or rabi crops on a seasonal basis. One and one-half acre hot weather or standing perennial is equal to 1 acre of sugarcane for 4 months, and in the case of monsoon and rabi duties, 1 acre sugarcane 1½ acres of seasonal crops, and a single watering is equal to 1/3 of seasonal crop.

In Maharashtra, 1 to 1½ cusecs is considered as suitable discharge for water courses. This has been fixed keeping in view the topography of the country, the ease of construction and maintenance, the ease of handling the small discharge and minimum losses entailed in the field channels. The lengths of the water courses are generally kept ½ to 1 mile to minimise losses. With 1 cusec discharge, 4" water in about 6 hours could be supplied at the field over 1 acre which roughly corresponds to need of dry cropping. With 2 cusecs, this period of supply could be reduced to 3 hours which is a reasonable period. For paddy, the time taken may be almost double. However, higher discharge capacity of outlet is considered if all the command is under heavy perennial or cane crop.

DIFFERENT TYPES OF OUTLETS

The earliest type of outlets were open cuts in the banks of irrigation channels and were gradually replaced by some form of pipe or barrel outlet. These suffered from the serious disadvantage of the cultivators easily increasing the discharge through the outlet. Since the beginning of the twentieth century, various problems connected with irrigation outlets have been studied in great detail and improved devices have been evolved. The first of the numerous attempts was the Kennedy Cill outlet followed by Kennedy Gauge outlet and Gibb's Module. These were followed by the Harvey outlet—forerunner of open flume type and another known as Stoddard—Harvey which is a combination of a pipe and an open flume.

The most important land mark in the history of irrigation outlets was the publication in 1922 of paper No. 26 of the Pubjab Irrigation Branch on the Moduling of Irrigation Channels by E.S. Crump. Thereafter, several improvements have been attempted by Punjab Irrigation Engineers from time to time.

The outlets in general may be divided into these classes, viz., (i) Non-Modular outlets, (ii) Semi-Modular outlets and (iii) Modular outlets.

(i) **Non-Modular outlets.** These are outlets whose discharge varies with the difference in the water level between the distributing channel and the water course. There are two types of these outlets, viz ,

(a) Pipe outlets, and
(b) Scratchley outlets.

(a) **Pipe outlets.** These simplest and oldest type of outlets originally consisted of earthenware pipes, replaced in time by steel or cast iron pipes, and lately by hume or concrete pipes.

The simple formula used in practice for the discharge through a pipe outlet is

$q = CA_p\sqrt{2gH}$

where C=co-efficient of discharge.

Ap=Area of the orifice.

If the outlet has a free fall, H should be measured from the Centre of the pipe or barrel to the full supply level in the distributary, and if it is drowned, H is the difference in the water level in the water course and the distributary. If the outlet has a free fall, the discharge through it is independent of the water level in the water course, and under these conditions it is semi-modular. The co-efficients of discharge vary with sizes of pipes as well their material and lengths. It is, therefore, usual to have approved discharge tables.

(b) **The Scartchley Outlet.** This is a pipe outlet with the downstream pipes end in a cistern, two or three feet square, opposite is fixed a cast-iron or stone office to give the authorised discharge, while the pipe is laid at the bed level of the cistern, the office is fixed at a higher level to ensure semi-modularity.

If the orifice is submerged, it functions as a non-modular pipe outlet.

Semi-Modular outlets. These, also called semi-modules, are outlets whose discharge is independent of the water level in the water course, so long as the minimum working head required for the working of the semi-module is available.

There are many different types of semi-modular outlets, but those commonly in use in the Punjab are the Crump's open flume and the adjustable proportional module.

Crump's open Flume Outlet.

This was first introduced in 1922 and was subsequently standardised throughout the Punjab. The discharge is given by the formula.

$q = K.\ Bt.\ G^{\frac{3}{2}}$

Where Bt. is the width, and G the depth of upstream water in the channel above the Cill level, K being a constant.

The following values of K are adopted for different widths of flumes :

Bt.	K
0·2 to 0·29 ft.	2·90
0·3 to 0·39 ft.	2·95
Over 0·4 ft.	3·00

The minimum value of Bt. adopted in practice is 0·2 ft. and the minimum modular head adopted is 0·2 of G. When designing, it is necessary to assume Bt. or G and calculate the other.

The type of open flume outlet as in common use in Punjab is given in Fig. 3.

Adjustabic Proportional Module : (A.P.M.)

Structurally, this is a long throated flume

with a roof block, capable of vertical adjustment. With the roof block removed, the A.P.M. differs from the flume module only in regard to the length of the throat. This, however, is an orifice type of flexible module. The upstream and downstream approaches of the A.P.M. are exactly similar to those of Crump's open flume outlet described above. The length of the crest is G+1·0 ft. for the cast iron block comprised of

(a) A base plate

(b) Two check plates

(c) A roof block which slides between the check plates and can be fixed in any position.

The formula for discharge is

$q = 7{\cdot}3\ Bt.\ Y \sqrt{H_s}$

where q = discharge in cusecs through the outlet.

Bt. = Width of the throat

Y = The elevation of the roof block above the crest.

H_s = The head equivalent to the velocity of approach.

The modularity in the A.P.M. is ensured by the introduction of the standing wave.

Crump's Adjustable Proportional Module is shown in Fig. 4.

Adjustable Orifice Semi-Module

From experience it was found that channels fitted with the Adjustable Proportional Modules silted badly. The same device was, therefore, used with the crest lowered to 8/10th setting or to bed level to improve the silt draw. This arrangement continued to be called the A.P.M., but more appropriately it is Adjustable Orifice Semi-Module (A.O.S.M.). Standard design of A.O.S.M. as used in the Punjab is given in Fig. 5.

The discharge calculation for the A.O.S.M. is the same as in the case of A.P.M., described above.

Module-Outlet or "Modules"

These are outlets whose discharge is independent of the water levels in the distributary and the water course, within reasonable working limits.

Among modules there are two distinct types :

(a) with moving parts, and

(b) without moving parts.

Modules with or without moving parts. There are various types of Modules with moving parts like Henares Canal Type, Visvesvaraya Self-Acting Modules, Kennedy's Outlet Module, Wilkin's Module, Joshi's Module, Khanna's Auto-Adjustable Orifice Distributor, etc., and those without moving parts are Gibb's Module, Khanna's Rigid Orifice and Gaffoor's Rigid flume Module.

All these modules are expensive in cost and not simple to design or construct. They are liable to go out of order on account of silt and weeds, and rusting of the moving parts, and as such they are of little practical value.

Timely Construction

To achieve early and satisfactory use of water, it is necessary to properly plan and construct outlets and to make adjustments as may be necessary. The recommendations made by the Planning Commission to the State Governments in this behalf merit repetition and are reproduced below :

> "The project authorities should mark the position of outlets and also the alignment of the water courses and field channels, at the time of marking the alignment of distributaries and minors. The cultivators whose area lies in the command of those outlets should then be given notice that they should complete the construction of the field channels within a specified time. This specified time should be such that it gives liberal opportunity to the cultivators to complete the construction of the field channels. At the same time, it should leave sufficient

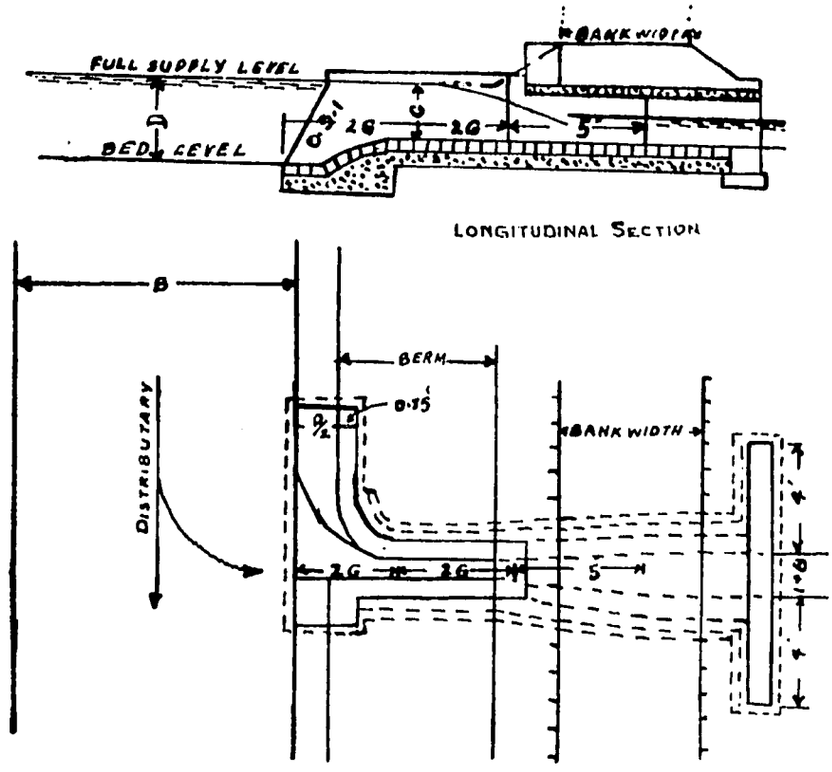

FIG. 3. TYPE DESIGN OF OPEN FLUME OUTLETS AS IN USE IN THE PUNJAB

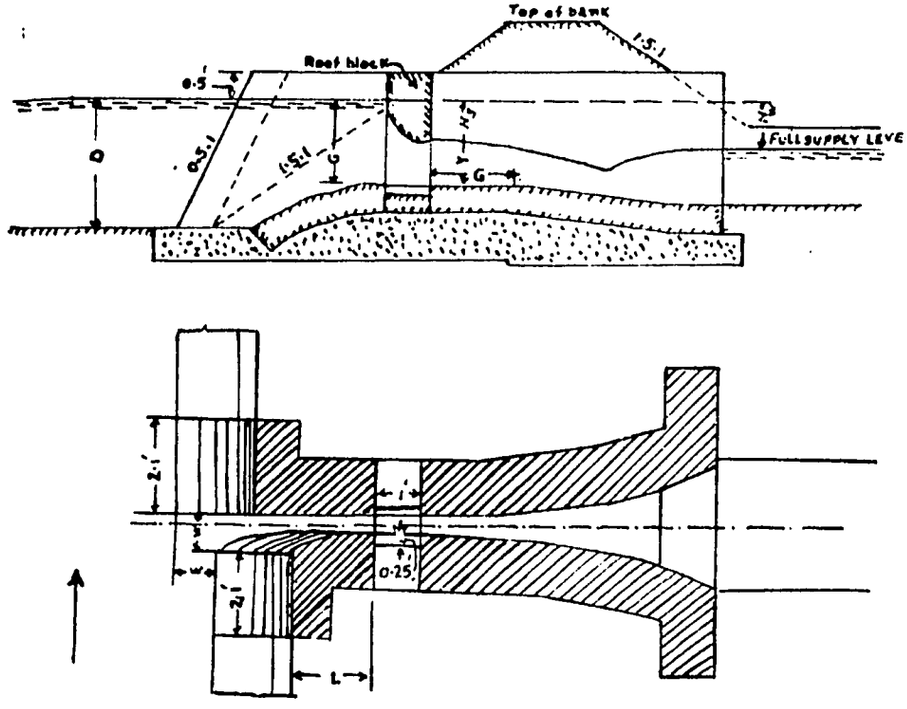

FIG. 4. CRUMP'S ADJUSTABLE PROPORTIONAL MODULE

margin for the project authorities to do the construction in time to synchronise with the creation of the irrigation potential at these outlets, should the cultivators fail to construct the field channels themselves. It sometimes happens that the position of outlets has to be changed for securing better command of the area. This may become necessary in spite of detailed levelling and contour mapping carried out by the project authorities. The project authorities should give an assurance to the cultivators that if it becomes necessary to change the position of an outlet after the field channels have been constructed by the cultivators on the alignment marked out by the project authorities, then any channel necessary to connect the field channel to the new location of the outlet would be constructed at project cost".

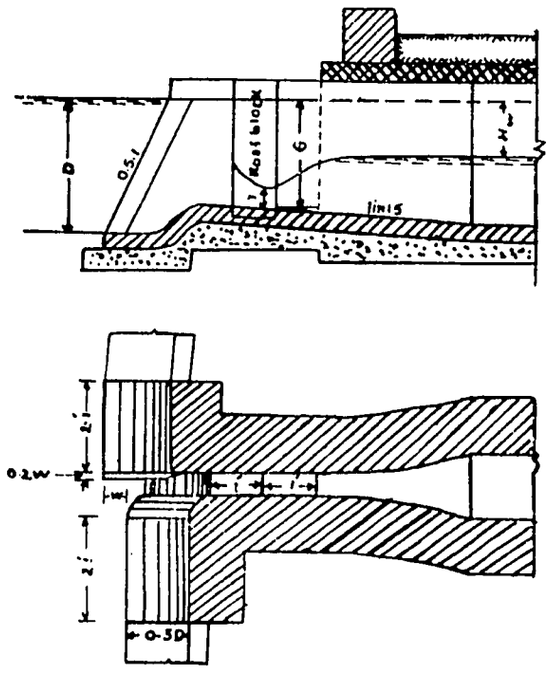

FIG. 5. STANDARD DESIGN OF A.O.S.M. AS USED IN THE PUNJAB

CONCLUSION

It is essential that water resources developed are quickly and usefully utilised to derive maximum benefit. In order to supply water to the field in a properly regulated manner, to minimise losses and wastage in water courses and to secure a constant discharge, suitable devices for outlets have to be employed. In determining the capacity of the same, area under command, crop pattern, water requirements of crops and other governing factors will have to be considered carefully and it should also be borne in mind that the discharge for which the outlet and hence the water course taking off from it is designed is neither too low to be lost in absorption nor too high to be unmanageable.

While the State undertakes its responsibility for the supply of water for irrigation up to the field, proper utilisation of the same to derive the maximum benefit unto himself and to the State is the responsibility of the water user who has to be educated to play his part.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the very valuable guidance and material given by Shri D.B. Anand, I.S.E., M.I.E., Member (Water Resources), Central Water and Power Commission, New Delhi, in the preparation of this paper.

The authors also gratefully acknowledge the material freely drawn upon in the preparation of this paper from the book "Irrigation Outlets" revised and enlarged by Shri N.D. Gulhati, I.S E , M.I.E. (India).

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APPENDIX 1

SOME IMPORTANT INDIAN CROPS AND THEIR WATER REQUIREMENTS.

S. No.	Name of crop	Water requirements (in inches)	Remarks
1	Sugarcane	50	Northern India
		115	Southern India
2	Paddy	Av. 55	
3	Cotton	30	
4	Maize	30	
5	Jowar	30 (Grain Jowar)	
		12 to 15 (Fodder Jowar)	
6	Bajra	20	
	(Winter Bajra)	15	
7	Ragi	20	
	(Kar Ragi)	24	
8	Wheat and Barley (Winter Cereals)	13	
9	Potato	25	
10	Tobacco	25	
	(Cigar Tobacco)	30	
11	Jute	24	
12	Oilseeds		
	(i) Groundnuts	25	
	(ii) Sesamum	...	
	(iii) Linseed	12	
	(iv) Brassica	10	
	(v) Castor	30	
13	Pulses	...	

SOWING AND HARVESTING SEASONS OF

		Winter Rice	Autumn Rice	Summer Rice	Wheat	Barley	Ragi	Jowar
		1	2	3	4	5	6	7
Assam	Sowing	—	—	—	—	—	—	—
	Harvesting	—	—	—	—	—	—	—
Bihar	Sowing	June-Aug	May-July	Sept-Nov	Oct-Nov	Oct-Nov	June	May-July
	Harvesting	Nov-Dec	Aug-Oct	Feb-Mar	Mar-Apr	Mar-Apr	Sept	Oct-Nov
Bombay	Sowing	June-July	—	—	Oct-Nov	Oct-Nov	June-July	June-July (K) Sept-Oct (R)
	Harvesting	Oct-Nov	—	—	Mar	Feb-Mar	Oct-Nov	Nov-Dec (K) Jan-Feb (R)
M.P.	Sowing	June	—	—	Oct-Nov	—	—	June-July (K) Oct-Nov (R)
	Harvesting	Oct-Nov	—	—	Feb-Mar	—	—	Nov-Dec (K) Feb-Mar (R)
Madras	Sowing	June-Oct	—	Dec-Mar	—	—	June-Sep	June-July (K) Apr-Nov (R)
	Harvesting	Dec-Mar	—	Apr-May	—	—	Sep-Jan	Oct-Nov (K) Jan-Feb (R)
Orissa	Sowing	—	—	—	—	Oct-Nov	—	—
	Harvesting	—	—	—	—	Mar-Apr	—	—
Punjab	Sowing	Mar-Aug	—	—	Oct-Dec	Oct-Dec	—	June-July
	Harvesting	Sep-Nov	—	—	Mar-May	Mar-Apr	—	Oct-Nov
U.P.	Sowing	June-Aug	—	—	Oct	Oct	June	—
	Harvesting	Sept-Dec	—	—	Mar-Apr	March	Sep	—
W.B.	Sowing	May-July	Mar-July	Oct-Jan	Nov-Dec	Oct-Jan	—	—
	Harvesting	Oct-Jan	June-Sep	Feb-Apr	Feb-Apr	Feb-Apr	—	—
Ajmer	Sowing	—	—	—	Nov-Dec	—	—	—
	Harvesting	—	—	—	Mar-Apr	—	—	—
Coorg	Sowing	June-July	—	—	—	—	May-June	—
	Harvesting	Dec-Feb	—	—	—	—	Oct-Nov	—
Delhi	Sowing	—	—	—	—	—	—	—
	Harvesting	—	—	—	—	—	—	—

(K) Kharif (R) Rabi (I) Irrigated (D) Dry

II

PRINCIPAL CROPS IN INDIA (STATE WISE)

Bajra	Maize	Sugarcane	Groundnut	Castorseed	Cotton	Jute	Tobacco
8	9	10	11	12	13	14	15
—	—	Apr-May	—	—	—	Mar-Apr	—
—	—	Dec-Feb	—	—	—	July-Aug	—
May-July	May-July	Feb-April	—	Sep-Oct	Jan-Feb	Mid Mar-Apr	Nov.
Oct-Nov	Sep-Oct	Dec-Apr	—	Mar-Apr	Aug-Apr	Aug-Mid Sept	Feb-Apr
June-July	June-July	Jan-Mar	June-July	June-July	June-July	—	Aug-Oct
Oct-Nov	Sep-Oct	Nov-Apr	Sep-Dec	Dec-Feb	Jan-Apr	—	Jan-May
—	—	—	June-July	—	May-June	—	—
—	—	—	Sep-Nov	—	Nov-Mar	—	—
June-Sep	July-Oct	Jan-May	Feb-Mar (I) Apr-Aug (D)	June-July	May-July Sep-Nov	—	Oct-Dec
Sep-Feb	Sep-Feb	Oct-Apr	May-July (I) Aug-Jan (D)	Nov-Feb	Jan-Aug	—	Jan-Mar
—	—	Feb-May	—	—	—	May-June	Nov
—	—	Nov-Feb	—	—	—	Sep-Mid Oct	Feb-Apr
June-July	June-July	Feb-Apr	—	—	Mar-July	—	March
Oct-Nov	Oct-Nov	Nov-Mar	—	—	Nov-Jan	—	May-June
Aug.	June	Feb-Apr	June-July	June-July	June	—	June-Feb
Oct-Nov	Aug-Sep	Nov-Apr	Nov-Dec	Feb-Apr	Oct-Jan	—	Sep-Apr
—	—	Feb-May	—	—	—	Apr-May	Sep-Dec
—	—	Dec-Mar	—	—	—	Mid-Aug Sep	Feb-Apr
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—

PART III

IRRIGATION PRACTICE IN SOUTH INDIA

by

K. V. Ekambaram*

INTRODUCTORY

Rice and Sugarcane are the main irrigated crops of South India. Other crops such as millets, groundnut. cotton and oil seeds depend practically on rains. There are even some varieties of rice that come up with the help of rain and a successful crop is raised if the rainfall is sufficient and timely. The annual rainfall if the southern states of India, is about 40 inches in the east coast region and about 120 inches in the west coast but in the interior of the peninsula it drops down to as low as about 20 inches. In the Western Ghats it can be as high as 250 inches. The succeeding paragraphs deal with the irrigation of rice which is the major irrigated crop in South India.

Irrigation Season for Rice

Over most of South India, the main crops of rice is generally grown from July to December. It gets the benefit of North-east monsoon which is the predominant monsoon in the Central and Eastern parts of South India. Where the supply of water is plentiful ; a second crop, the duration of which is short, is also grown. In Madras State. this generally precedes the main crop but in the Coastal tracts of Andhra it succeeds the main crop.

Irrigation Sources.

Vast extents of rice fields are irrigated in the deltas of the Mahanadhi, Godavari, Krishna and Cauvery. There are structures across these rivers which divert water into the canals and their various branches. Rice is also irrigated over sizeable extents with the help of the minor rivers and numerous streams that traverse the country.

Another important source of irrigation in South India are the numerous tanks that dot the countryside. They have been formed over many centuries by just a simple earthern bund across a valley. An idea of their numbers can be had from the fact that in Madras State alone, which comprises an area of 50,000 sq. miles (130,360 sq. kms.), there are as many as 37,000 tanks. These sources represent a real decentralisation in irrigation, each village having at least one tank if not more. Tanks are of various sizes, some irrigating areas as small as 5 and 10 acres. The biggest, namely, Chembarampakkam. near Madras City, has a capacity of 3,120 m. c. ft., and irrigates about 13,000 acres. Rajasingamangalam tank in Ramanathapuram District has an embankment about 14 miles in length.

A third important source are the numerous wells dotted all over the country. They are very often shallow. One of the important advantages of rural electrification has been the fitting up of electric motors and pumps in these wells and irrigation of small areas by means of these.

Irrigation Practice

Rice needs profuse irrigation. To prepare the field a large quantity of water has to be

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let in. This is allowed to soak, and the field is ploughed which is known as puddling. Then the rice seedlings, prepared in separate beds, are transplanted. Subsequently, water has to be continuously retained in the field which is very rarely allowed to go dry. Only when the crop is getting ready for harvest, water is drained and the field allowed to become dry.

DUTY

In the Canal systems, duty is expressed in terms of the number of acres that can be successfully raised for a continuous flow of one cusec of water right through the season. In North India, the general practice is to express duty in terms of depth of water required to bring the crop to maturity. In storage works as in irrigation tanks, the number of acres that can be raised with a million cubic feet of water is the duty.

The duty will vary with the nature of the soil and the extent of rainfall during the season. The duty for which the Godavari and Krishna delta systems are designed is 70 acres per cusec. In the Cauvery Delta, the designed duties vary from 45 to 73 acres per cusec. There are some systems which work at a low duty of even 25 acres per cusec. The Periar System works at a high duty of 90 acres per cusec. This is partly due to the fact that there are a number of storage tanks in the system, which supplement the canal supply. In any case, this varying duty indicates how flexible the irrigation needs of a rice crop are. It also indicates that in such of these systems where a liberal supply is at present allowed, there is a possibility of economising supplies by improving distribution methods.

Design Principles

Because of the profuse irrigation allowed for rice, generally the whole of the cultivable commanded areas has to be irrigated simultaneously. The drainage and seepage from the irrigated fields, prevent any non-irrigated crop being raised in the same area. In a few cases, where the irrigated area was limited by political boundaries, the irrigation extended beyond this till a natural boundary such as a valley prevented further extension. So, a canal design should take into account the above fact and should be able to serve the whole of the cultivable commanded area.

The area under each outlet is again bounded by natural features such as minor valleys or uncommanded land.

Irrigation Methods

From the outlets, water courses take the water to the land to be irrigated. In Madras State, the practice is to align the water course and acquire land at the Government's expense till a 25-acre limit is reached. In the Plan Projects, water courses are even formed at Government cost up to a limit of 50 acres to enable speedy development. Below 25 acres the cultivators are expected to provide land and to form their own water courses. Very often irrigation is carried on from field to field.

Drainage

In the areas where rice is irrigated in South India, this is not a very serious problem for two reasons, namely that the rice crop can stand a submersion for even about seven days and the country in general has a good slope to facilitate easy drainage. No doubt very near the coast the country is flat and here in years of heavy rainfall the crop suffers due to prolonged submersion.

Some Impressions

A brief review of the irrigation of rice in South India has been given above. Rice is a crop that needs abundant water for growth ; about 60 inches or so. So, it can be attempted only in the regions where rainfall is profuse or the river carries a good deal of water during the irrigation season. At other places, a wise way of using water may be to raise crops that may not be so exacting in the use of water.

Deltas of rivers go on expanding gradually. The soil with which they are formed is alluvial and is ideal for the growth of rice. But, the land is flat and drainage is not easy. Consequently, the crop becomes liable to submersion. There is need here to maintain efficient drains. There are certain varieties of rice which can stand submersion. Most probably, better types are yet to be evolved.

On the irrigation side, there is a good bit that can be done to economise the use of water. Lining of canals and their branches to prevent loss by seepage, proper design of canals and outlets, lying out of water courses so as to enable each field to be irrigated directly are some of the methods.

Though duty experiments have been carried out in the various Agriculture Farms, no conclusive answers have been found for the optimum use of water for the growth of rice. There is scope for a good deal of study in this direction. Presumably, some varieties of rice can also be evolved that will need a smaller quantity of water. Water resources are also getting used up. Deficiency is felt in Madras State. It will perhaps be felt in other places in due course. It is high time scientific studies were made with regard to an optimum use of water.

CHAPTER XI

MINOR IRRIGATION SYSTEMS BY INDIA

PART I

MINOR IRRIGATION PROGRAMME AND WELL CONSTRUCTION IN INDIA

by

Jagat Kishore Jain*

SUMMARY

Irrigation systems costing individually less than Rs. 1 million are classified as minor irrigation works in India. These works are responsible for more than 60 per cent of the total irrigated area in the country. They can be completed promptly and yield quicker results than major ones. Great emphasis is being given to development of minor irrigation sources under the country's Five-Year Plans. The minor irrigation includes works, such as open wells (dug wells), tubewells (deep wells), small storage and diversion works and pumping installations on rivers and streams for lift irrigation.

Open wells form an important item of minor irrigation contributing more than 1/3rd of the total irrigation in the country. They are scattered in almost all parts of the country and additional wells are being constructed at an increasing rate which has presently reached a figure of about 80,000 per annum.

The paper describes different types of open wells in irrigation use and also how application of modern technology by way of deep boring and deepening of wells and installation of power pumps in place of age-old devices for water lifting has resulted in considerable improvement of their performance. Great priority is being accorded in India on boring and deepening of wells in order to augment their discharges. The indigenous old methods of lifting water from open wells are being replaced at a fast rate by power pumps run on diesel or electricity. Power pumps including diesel engine as well as electric motors are being manufactured in the country in sufficient numbers and are available at reasonable cost. Efforts are also being made to make the electric power available to the cultivators at a rate not exceeding 9 nP per unit. This rate is considered to provide sufficient incentive to the cultivator for using electrical pumping.

The performance of irrigation wells varies in India from region to region depending upon the availability of ground water, cropping patterns and other climatic and soil factors. The regional average of the gross

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area irrigated per well ranges from 2 acres in the South to 12 acres in the North. Taking an average performance on All-India basis, economies of lift irrigation from wells has been analysed for three different typical cases. The analysis shows that economics of wells is very much improved by boring and installation of electrical pumpsets.

Well irrigation has advantages over other systems of irrigation. These have been described. Well irrigation stimulates and mobilises efforts of the individual cultivators to the maximum extent in making full and economic use of irrigation water and obtaining maximum results. The Standard of levelling and preparing fields and other irrigation and agriculture techniques adopted in case of well irrigation is better than in other systems of irrigation.

The paper concludes with a brief mention of the measures that are being undertaken in India in planning and implementation of the large sclae well construction programme to ensure that wells are located and designed properly and there are no failures due to over-draft from the local groundwater formations.

INTRODUCTION

The term minor Irrigation was used for the first time in India by the Irrigation Commission (1903) to include small irrigation works, such as open wells, tanks and others, too small to be classified under canals. According to the criterian now in vogue all irrigation works costing individually less than Rs. 1 million are classified as minor irrigation.

Minor irrigation works have been playing a significant role in the development of irrigation in the country. They are responsible for more than 60 per cent of the total irrigated area. These works have many inherent advantages ; they can be completed quickly with lesser outlay and also yield quicker results. The works, being owned by the cultivators themselves, bring about greater satisfaction of the psychological as well as physical need of the cultivators. As the cultivator knows fully the capability of his work, he can plan his cropping strictly according to the water output ; also he can operate his work and get the water at his will and convenience. Moreover, as the utilisation of water from minor irrigation sources is usually confined to the area very near the source, loss of water in conveyance and distribution is very much reduced.

Recognising these advantages, great emphasis is being laid on minor irrigation systems in the present efforts that are being made for development of irrigated agriculture in the country. More than Rs. 5,000 million will have been spent on these works in the first three Five Year Plans from 1951 to 1966. The works completed would benefit an additional area of about 20 million acres. Another sum of similar order is proposed for the Fourth Five Year Plan alone from 1966 to 1971.

According to the current classification, minor irrigation includes mainly the following categories of works :—

A. GROUNDWATER SCHEMES

(i) Open wells (dug wells)

(ii) Tubewells (deep wells)

B. SURFACE WATER SCHEME

(i) Diversion schemes,

(ii) Storage schemes,

(iii) Pump installations on rivers and streams for lift irrigation.

OPEN WELL CONSTRUCTION

Open wells are the most important means of arranging groundwater utilisation in India. As distinguished from tubewells, open wells comprise ordinary surface wells of varying dimensions, dug or sunk from the ground surface into the water bearing stratum to extract water for irrigation. Individually, they are very small works but collectively, they contribute to nearly 1/3rd of the total

irrigation in the country. Their popularity has been referred to in history since the earliest recorded time and at present the total number of functioning wells in the country exceeds 5 million. They are scattered in almost all parts of the country although their concentration naturally varies from region to region according to the rainfall, the geological sub-strata and groundwater availability. Their regional concentration is shown in Fig. 1 which is the Isohyetal Map of India. Well irrigation is, by and large, confined within the region with normal annual rainfall of less than 45 inches (1,125 mm). In humid areas with more than 45 inches rainfall, well irrigation is not popular to meet irrigation requirements which are usually of occasional and supplemental nature in such areas. The number of open wells is greatest in the Indo-Gangetic alluvium of Punjab and Uttar Pradesh. Wells also exist in large numbers in alluvial pockets and coastal fringes in other States. There are many areas in the Deccan Trap where, though groundwater availability is chequered due to presence of rock in the sub-stratum, open wells provide the only convenient means of irrigation. Application of modern technology has enabled many improvements in design, construction and performance.

Open wells form a most important category of minor irrigation. Recognising their popularity and advantages (described later in this paper), additional well are being constructed at an increasing rate which has presently reached a figure of about 80,000 per annum. The wells belong to the individual cultivators and their construction is arranged by the cultivators themselves. Under the Five Year Plans, the Government has been extending financial assistance to the cultivators in the form of long-term loans (15 years) and subsidy. The subsidy usually is subject to a maximum of 25 per cent of the total cost. Loan usually covers the entire cost and varies from region to region depending upon the nature of the sub-stratum and the depth of static water-table.

Types of Wells and their Construction Features.

There are four principal classes of open wells in irrigation use :

1. Masonry wells
   (a) Masonry wells without boring.
   (b) Masonry wells with boring.
2. Wells with pervious lining.
3. Katcha wells.
4. Wells with rocky sub-strata.

1. **Masonry Wells.**

These wells have masonry steining wall usually sunk in sub-soil by applying static weight of sand bags and simultaneously scooping out earth from inside. In locations, where it is not possible to sink masonry steining by ordinary methods due to present of hard clays, boulders, etc., it is built up in a dug pit from the bottom upwards. For sinking, the masonry steining is supported on a well curb, which may be of wood, iron or reinforced concrete. The curb is of the same width as the bottom section of the steining and its depth is also nearly the same. The wooden curb is made of hard wood, such as kikar, shisham or sal. The thickness of masonry steining is so arranged while sinking that for the completed well, it increases with its depth below the ground surface to withstand increasing earth pressure. The thickness it usually regulated according to the following table :

Depth of steining section below ground level	Thickness	
	Brick masonry	Stone masonry
10 ft.	13 inches	12 inches
10—33 ft.	18 inches	15 inches
33—40 ft.	21 inches	18 inches
40—47 ft.	24 inches	21 inches

The above method of well sinking has been in vogue in India for thousands of years and wells as deep as 150 and greater have

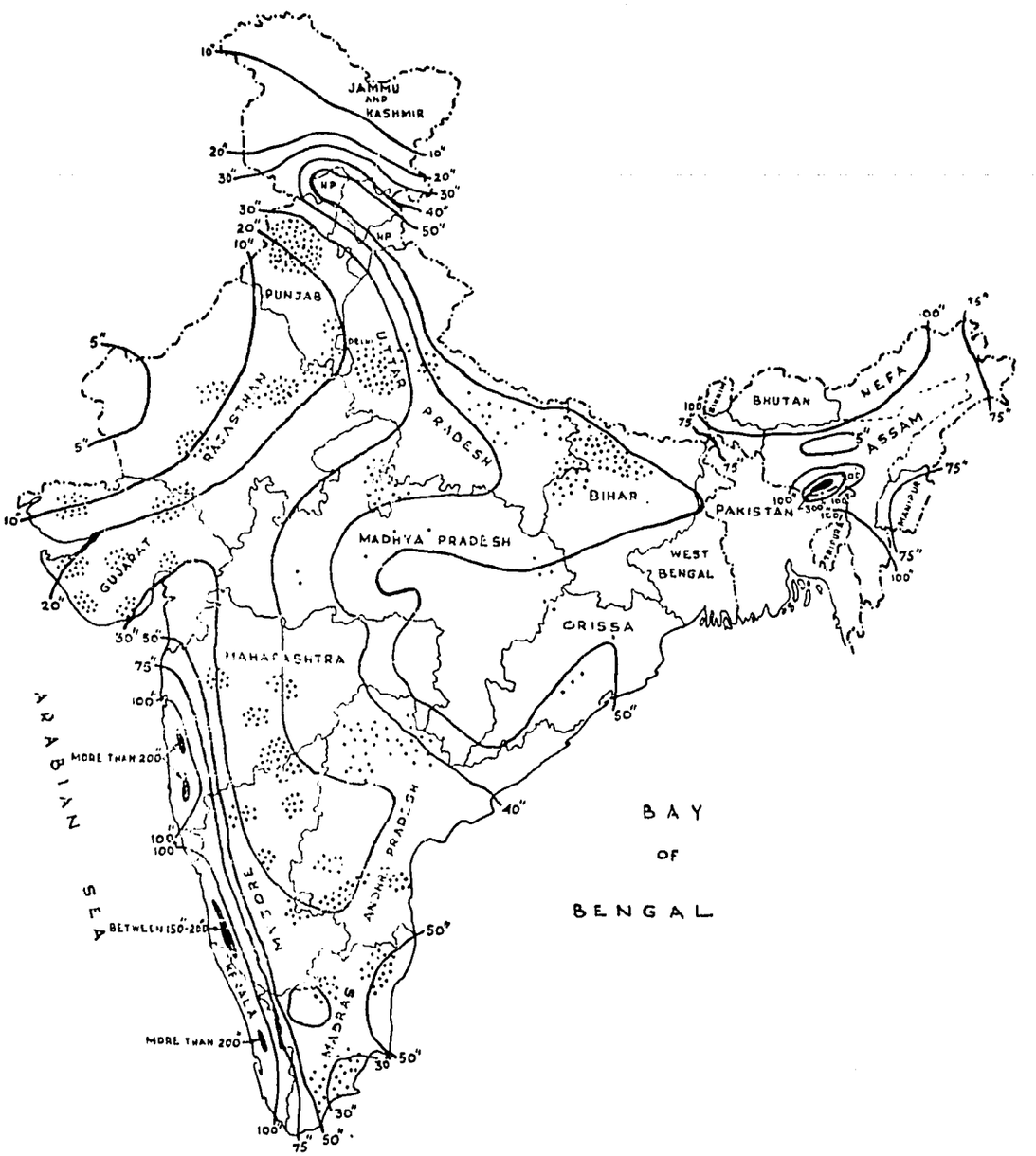

FIG. 1. LOCATION OF WELL DEVELOPMENTS

been constructed by this method. The diameter of masonry wells constructed for irrigation purposes usually ranges from about 8 to 20 ft.

(a) **Masonry wells without boring (Fig. 2)**

Fig. 2 shows a well of this type. These wells draw water from their previous bottom. The arrangement is feasible for tapping thin aquifer available near the water-table. Streamlines entering the well have to deflect and converge upward. Due to this pattern of flow, the loss of head in transmission is of a higher order than that in the other types of wells which draw water from their peripheries.

Only very small discharges, usually under 500 gallons per hour, may be drawn from such wells. If the velocity of flow exceeds the critical velocity the velocity at which the sand particles just begin to move, the sand particles will be lifted up with the water and there will be danger that the steining wall to settle down, and get damaged. The drawdown and therefore, the discharge of these wells has to be restricted in order to avoid any movement of sand. To minimise this handicap, the practice of filling up the bottom of the well with 2 to 3 ft. of graded brick or stone ballast or shingle with fine grade of material at the bottom and coarse at the top has been found quite effective and is being encouraged.

Masonry wells with boring

Boring of a well essentially consists of drilling a small sized bore through the bottom of the well and extending the bore to a layer or layers of good groundwater bearing medium lying underneath the well. Boring thus helps to augment the well discharge : it also enables utilisation of the part of the local groundwater source which would have otherwise remained uptapped.

The size of borings in open wells usually ranges from 3 to 6 inches and the depth from about 10 to 150 ft. depending upon the strata available and the manner of tapping. Basically there are two types of tappings : (a) cavity, and (b) strainer. In the first, the boring taps the water bearing medium just below a thick impervious bed. As the water is raised, a cavity is gradually formed in the water bearing medium below the bore due to the uplifting of finer soil particles. There is no subsistence due to roof action of the impervious layer. The cavity increases the flow in the well by increasing the percolation area and reducing congestion of streamlines and resistance to flow at the entrance of the well. In the second type, the water is tapped through strainer screens provided opposite the vertical depths of the water bearing stratum strata. The cavity bore is to be preferred only where there is available a hard, thick and extensive layer of impervious stratum immediately over-lying a comparatively thin bed of good water bearing medium. In case the water bearing strata available below impervious layer is thick, a more suitable arrangement for tapping the aquifer fully may be to have a bore fitted with screens almost the entire thickness of the water bearing medium.

Figs. 3 and 4 show cavity type of bored wells. In the formation depicted by Fig. 3, a good water bearing stratum of relatively small thickness is available immediately under the layer of thick clay in which the steining wall of the well is bottommed. The impervious layer is bored in the centre in order to draw water from the medium below through a cavity formed in due course. As the stratum bored is firm, no casing pipe is necessary in the bore. Bored masonry wells of this type have been in existence in India for a long time. Fig. 4 shows a formation in which the medium tapped below the impervious layer through cavity in many strata below the bottom of the well.

Bores of the second type are depicted by Figs. 5 and 6. Fig. 5 shows only one water bearing medium tapped through the strainer. In Fig. 6, two non-contiguous water bearing aquifers are tapped by providing screens for the water bearing strata and blind pipe in the

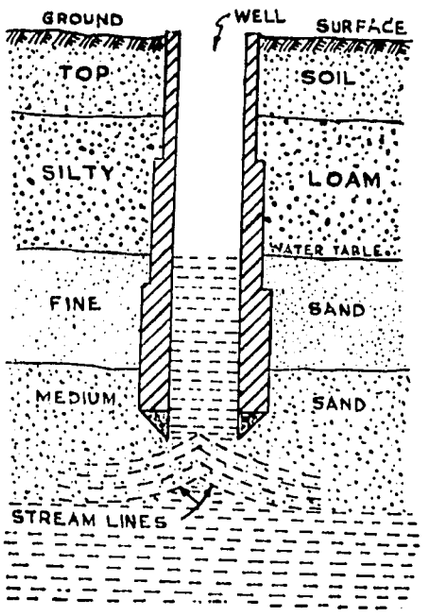

FIG. 2. MASONRY WELL WITHOUT BORING

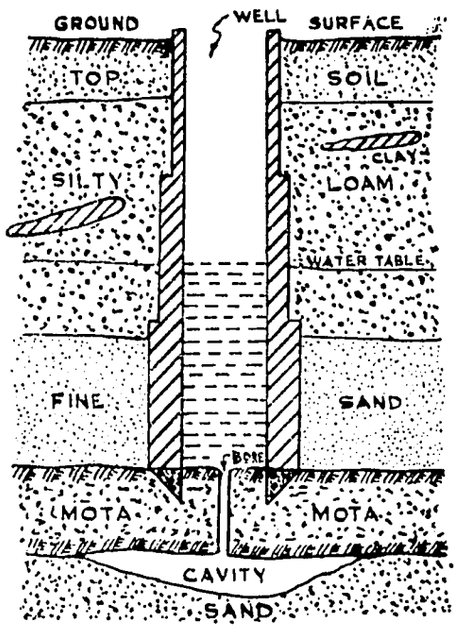

FIG. 3. MASONRY WELL WITH CAVITY TYPE BORING
(Cavity immediately below the well)

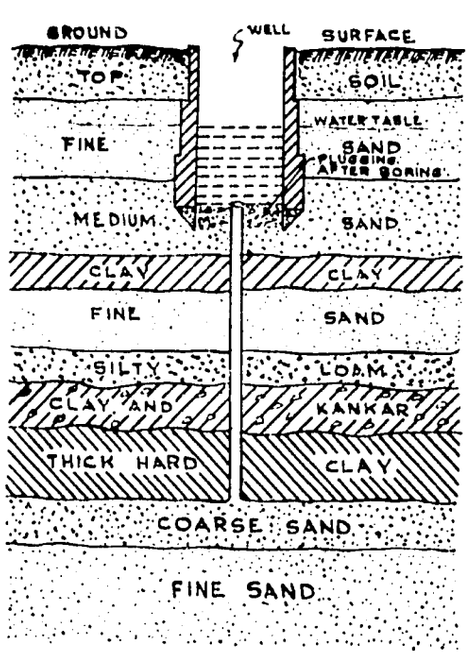

FIG. 4. MASONRY WELL WITH CAVITY TYPE BORING
(Cavity available at deeper depth)

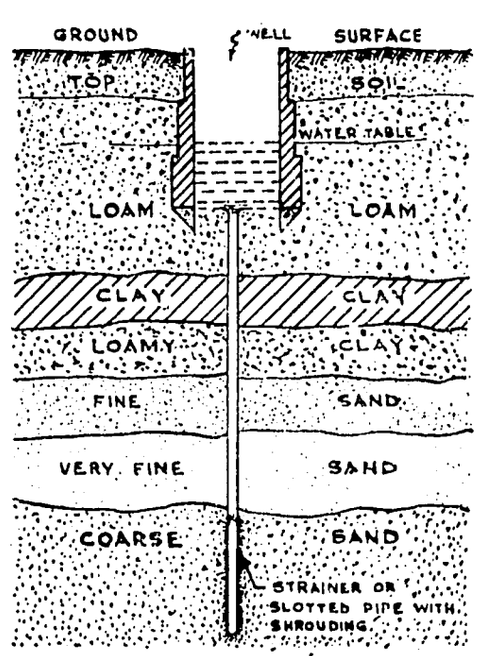

FIG. 5. MASONRY WELL WITH STRAINER TYPE BORING
(One length of strainer only)

poor water bearing stratum. By alternating blind pipe and strainer in this manner, a number of water bearing media can be tapped according to availability and requirement.

Deep borings of the type depicted in Figs. 4, 5 and 6 are a recent development.

Boring in open wells is usually carried out by the percussion method, using power percussion rigs or handboring sets. As holes drilled are neither very big nor very deep, percussion drilling is found to be more feasible and convenient than rotary drilling. Percussion drilling outfits are simple in operation and being comparatively lighter can be moved from well to well. The method is satisfactory from the point of view of cost and also enables fairly accurate logs which are essential for proper setting of screens in the bore holes. When power rigs are used, boring work is done more quickly. However, the advantage of the handboring sets is that the whole equipment is locally made and can be operated, maintained and repaired with ease by the local artisans.

The cost of cavity boring usually ranges from Rs. 5 to Rs. 25 per foot and that of strainer boring from Rs. 20 to Rs. 50 per foot.

Wells with pervious lining (Fig. 7)

Some wells as shown in Fig. 7 are lined with cylinders of inter-twined brush-wood or bricks laid dry. In between dry masonry, some bands of pucca masonry are provided for stability. The wells are plugged at the bottom by concrete. These wells are usually constructed in areas where no layer of water bearing strata is available within a reasonable depth from the ground surface. Through their pervious periphery, they draw whatever discharge can be obtained from the poor type of strata available. These wells often draw in sand which has to be removed periodically.

Kutcha Wells (Fig. 8)

Wells for temporary use or those owned by small cultivators are frequently left unlined. Such wells (Fig. 8) are dug usually in the harder soils, which can stand vertically without lining. A relatively wider pit is dug to just above the water-table below which it is considerably narrowed down and usually lined with woven fabric of hemp stems or matting, etc., through which the water oozes into the pit. As these wells usually extend only a few feet below the water-table due to difficulties of underwater excavation, the draw-down to which they may be subjected is limited. They can, therefore, yield only a small discharge which may be within the lifting capability of 'Dhenkli' or 'Piccottah' (counterpoise lift).

Wells in Rocky Sub-strata (Fig. 9)

In spite of rocky sub-stratum, well construction is undertaken in the Deccan Trap and in many other areas, as they provide the only convenient local source of irrigation. These wells are usually open excavated pits through top soil mantle and soft rock. For their water supply they usually depend on joints, cracks, fissures, embedded layers of unconsolidated material, etc., which exist in rocks and serve as passages and receptacles for water. They are generally constructed in large sizes to provide storage and also in order to tap more joints and cracks or water bearing pits, if possible. The top portion above the rock is usually lined with masonry.

The discharge of the wells in rocky sub-stratum is increased by boring or deepening. The boring helps to tap the embedded beds of water bearing material, if existing underneath. Rock boring, however, is costly and is encouraged only if no alternative means of cheaper irrigation is available. Deepening of wells is comparatively cheap and is very popular in the States of Andhra Pradesh, Gujarat, Maharashtra and Rajasthan. Deepening of wells consists of blasting the bottom of the wells by dynamite in stages to the desired depths. The objective of deepening is two-fold : (a) to expose additional water bearing joints, cracks, crevices, etc., and (b) to increase the storage capacity of the well.

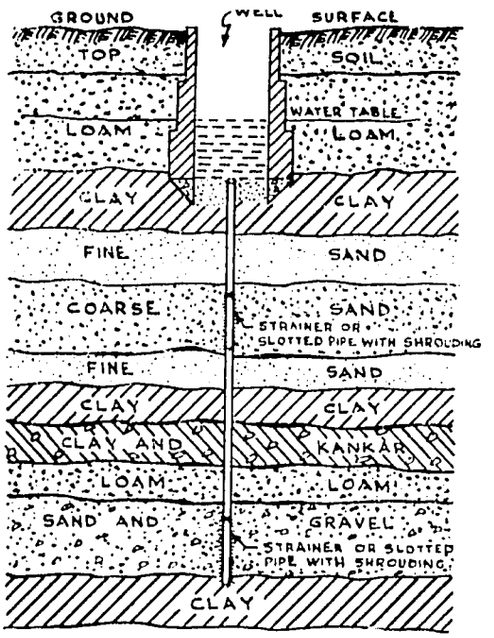

FIG. 6. MASONRY WELL WITH STRAINER TYPE BORING

(Two lengths of strainers with blind pipe in between)

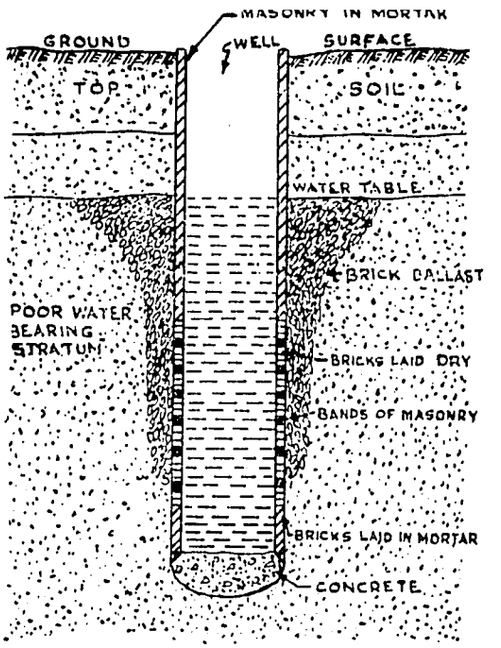

FIG. 7. WELL WITH PERVIOUS LINING

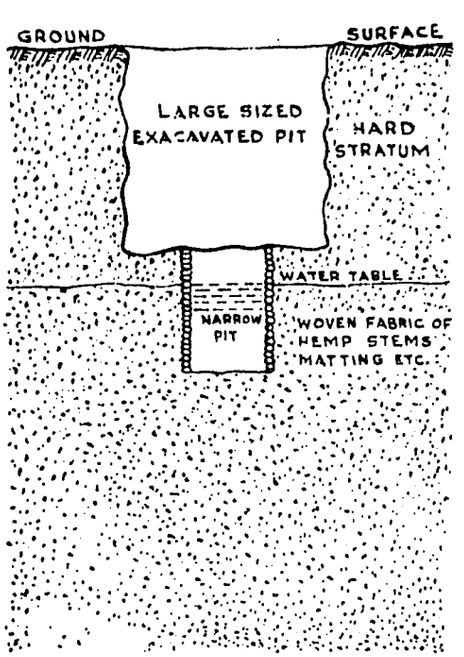

FIG. 8. KUTCHA WELL

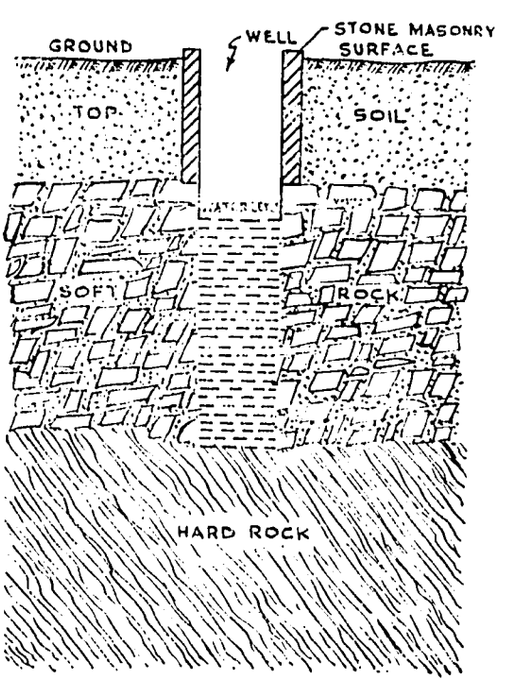

FIG. 9. WELL IN ROCKY SUB-STRATA

Air compressors are commonly used for drilling holes required for blasting. Usually in a 10 ft. diameter well 6 to 8 holes at a time each about 2½ ft. in depth are drilled. The holes are loaded with geligenite cartridges and detonators. The cartridges are then ignited by exploders to set off the blast. The debris of the shattered rock is removed and the process is repeated till the desire depth of deepening is reached. The cost of deepening by this method averages about Rs. 50 per foot depth for a 10 ft. diameter well.

Lift Appliances

The indigenous methods of lifting water from open wells, making use of man or animal power, are being replaced rapidly by power pumps run on diesel or electricity. The number of power pump installations increased from 107, 355 in 1951 to 390, 108 in 1961. The latter figure comprised 229, 944 diesel engine pumpsets and the remaining 160, 164 electric driven pumpsets. Power pumpsets including electric motors and diesel engines are being manufactured in the country in sufficient number and at reasonable rates.

Power pumps are becoming increasingly popular as they not only draw more fully on the supplies available in the well, but they also to release the bullock power of the cultivator which when it is vitally needed by him for other agricultural operations during the irrigation period. Under the minor irrigation programme, installation of pumpsets is being encouraged on all wells which have been bored or sufficiently deepened or otherwise have adequate water supply for 4 to 5 hours continuous running of the pumpset. Governmental financial assistance in the form of long-term loan is made available to the cultivators to meet the entire cost of pump installations. A diesel engine pumpset installation usually costs about Rs. 3,000 and an electrical pumpset installation about Rs. 2,000. The H.P. of the diesel engines used usually ranges from 5 to 10 and those of electric motors from 3 to 5.

Diesel engines, as a source of power for running of pumps are more expensive not only in initial investment but also in operation and maintenance, than electric motors. They also require frequent repairs which become tedious if repairing facilities are not available within a reasonable distance. Electric motors are superior in these respects but they are dependent on availability of electric power. With the development of power in the country and extension of rural electrification, increasing emphasis is being laid on installation of electric pumpsets. In order to promote them efforts are being made to make available electric power to the cultivators at a rate not exceeding 9 nP. per unit. This rate is considered to provide sufficient incentive to the cultivator for using electrical pumping to meet his irrigation requirements.

The popular old types of water lifting appliances used on wells are (a) counterpoise lift, (b) piccottah, (c) rope and bucket lift, and (d) persian wheel. The piccottah works on the same principle as the counterpoise lift with a difference that the function of the counter-weight is performed by one or more persons walking to and fro on the lever or holding the lever by hand and then jumping in a pit. The piccottah is usually larger than the counterpoise lift and is more massively built. An innovation that has been made in the conventional rope and bucket lift and is very popular in the South is that the bucket is provided with a spout. The spout enables the bucket in its final position to empty by itself. This does away the necessity of man at the well to control the bucket.

Wind mills which involve little expenditure in operation are also being encouraged for the lifting water in areas where sufficient wind velocity is available for their successful running. Attempts are being made to improve the design of wind mills. According to the present development, the minimum velocity required for operation of the wind mills is of the order of 8 miles per hour. In general, there are very few areas which have wind velocity of this order throughout the major portion of the year thus the scope for installation is limited.

Water Output

Water output which may be obtained from an open well depends upon the yield of the well and its storage capacity. When water is lifted from an open well after a spell of closure, the water output will be mostly obtained from storage ; later as water lifting continues, deliveries from the well will be contributed more and more by the yield of the well. The yield depends primarily on the quality of water bearing strata tapped and increases with the draw-down in the well. It also varies from season to season, increasing appreciably during the rainy season.

The average yield of wells which have not been bored to tap deeper aquifers is rather limited, usually ranging between 100 to 1,000 gallons per hour. These wells would accordingly provide a daily water output varying from 1/10 to 1 acre inch. Because of meagre discharge, storage available inside such wells often becomes an important factor in order to sustain continuous operation of even the smallest capacity water lifting appliance for a minimum reasonable period of say 4 to 5 hours per day. For arranging this sufficient storage, wells in the rocky sub-stratum where it is usually not possible to augment the discharge by boring, are generally constructed in large diameters up to 20 to 30 ft. or even more.

The discharge of bored wells is considerably higher depending upon the depth and the quality of water bearing media tapped and the size of the bore. It is quite normal to obtain a water output of about 2 acre inches from bored wells in the alluvial tracts of the Uttar Pradesh and Punjab. Quite a number of bored wells yield much higher discharges.

Irrigation Performance and Cropping Pattern

There are some open wells which irrigate a crop area of only 1/3rd to 1/2 acre per annum ; there are also those on the other extreme which irrigate up to 25 acres or even more in a year. The average gross area irrigated by wells per annum varies widely from region to region as the following table shows :

Name of State	Gross area irrigated per year (in thousand acres)	Number of open wells in use (in thousands)	Average gross area irrigated per well (in acres)
Andhra Pradesh	920	430	About 2·1
Bihar	736	150	About 4·9
Gujarat	1,604	425	About 3·7
Madhya Pradesh	915	310	About 3·0
Madras	1,660	825	About 2·0
Maharashtra	1,650	780	About 2·1
Mysore	375	105	About 3·5
Punjab	2,815	235	About 12·0
Rajasthan	2,225	515	About 4·3
Uttar Pradesh	6,720	790	About 8·5

Note : (1) There is no well irrigation in the other six States.
(2) Figures are approximate computations.

A well in the Punjab irrigates on an average as many as 12 crop acres in a year against only 2.0 crop acres in Madras. Apart from differences in groundwater availability and discharge of wells, this big variation in irrigation performance of wells is due to such factors as cropping pattern, soil, climate, quantity and pattern of rainfall, static water lift and size and strength of the draft animals which differ widely from region to region. In the northern States of Punjab, Uttar Pradesh and Rajasthan, wheat is the predominant irrigated crop. The wheat, growing during the cold season, requires irrigation applications at comparatively longer intervals and also gets considerable support from the winter rainfall. The rich loamy soil in the region is also retentive of moisture. The average area irrigated per well is, therefore, considerably higher. The area irrigated per well in Rajasthan is low (compared to other Northern States) because the water output of the wells is limited due to excessive depth of the Static water-table. In the southern States and also in Maharashtra and Gujarat, conditions are very different. The climate is warm throughout the year and, therefore, frequent waterings are necessary. Predominant cereal crop in southern States is paddy which requires heavy irrigation applications. The cropping pattern includes an appreciable percentage of cash crops including garden crops, vegetables, chillies, etc., which require frequent waterings. In areas comprising red soils in the southern States, irrigation requirements are high because of the porous nature of the soil. In the Deccan Trap, the performance of wells is low because of the rocky sub-stratum, which yields meagre order of supplies.

In wells which are located near the cities and towns, generally a more intensive all-the-year-round use of the water is made to raise cash crops, mainly vegetables, which have a ready market in the urban areas. Besides, on such wells, the irrigation, manurial and other agricultural, practices followed are also comparatively of a very much higher standard.

Land Preparation and Irrigation Methods.

The standard for field preparation and levelling for well irrigation is usually better than that for canal irrigation. In case of well irrigation, the cultivator is directly aware of the cost and labour involved in lift irrigation and, therefore, caters for its more economical use.

There are mainly two irrigation methods adopted in well irrigation : (a) the flat bed or check-basin system ; and (b) the ridge and furrow system. Cereal crops like wheat, barley, paddy, ragi, sorghum, etc., are usually raised in flat beds which vary in size and arrangement according to the nature of the crop ; type of soil and topography. The field is divided into a number of small plots (beds) with temporary bunds, providing an irrigation channel for every two rows of beds for irrigation. When slope is greater, each row of beds is provided with an irrigation channel. Usually beds are smaller in size for vegetables and larger for wheat. The beds are locally formed with manual labour. The course of bunds is demarcated by running the plough length-wise and breadth-wise at required distances and bunds are formed manually using local spades for the purpose.

For crops, such as cotton, sugarcane, tobacco, chillies and vegetables, like potatoes, onions, etc., the ridge and furrow method is usually adopted. The fields are laid into ridges and furrow after the preparatory tillage is over. The furrows are longer in level beds and shorter in sloping ones. They are wider and deeper for some crops as sugarcane and shallow for others as cotten, vegetables, etc., which require light irrigations. The furrows are usually opened by manual labour with the aid of local spades. Progressive farmers, however, are gradually making increasing use of bullock-drawn ridgers for the purpose.

Sometimes, a combination of furrows and bed system is used as for example onions raised during the monsoon period.

Depth of Irrigation

The following table gives the number of irrigation applications and also the total depth of irrigation worked out on average basis, in a study carried out for principal crops in the Punjab :

Crop	Average number of waterings	Average total depth of irrigation (in ft.)
Wheat	4	·80
Cotton	5 to 6	1·00
Vegetables	6	1·20
Potatoes	8	1·60
Sugarcane	8 to 10	1·80
Maize	5 to 6	1·00

It has generally been observed that the total depth of irrigation required to mature a crop on well irrigation is about 3/4th of the depth required on canal irrigation. The reasons for this are :

(a) Economical use of water by preparing and levelling the fields more carefully and adopting improved irrigation and agricultural practices.

(b) Smaller length of water courses and their better maintenance resulting in smaller order of losses,

(c) Water channels are frequently well-consolidated and are also plastered with mud in some cases to reduce the seepage losses, and

(d) Correct timing of each watering according to the requirements of crops is at the will of the cultivator.

Economics of Well Irrigation

Economics of well irrigation differs widely from region to region depending upon a number of variable factors, such as (a) initial investment, (b) static water lift, (c) source and cost of power, (d) water output, (e) cropping pattern, (f) local conditions of climate, soil, etc., which influence irrigation requirements and the yield of the crops, and (g) agro-economic status of the farmers.

An attempt has been made in the following paragraphs to work out the economics of three typical cases of well irrigation on an average basis representative of the country as a whole. The three cases are (i) unbored masonry well fitted with persian wheel ; (ii) bored masonry well fitted with electrical pumpset ; and (iii) bored masonry well fitted with a diesel driven pumpset. For each of these cases, two economic parameters, namely, cost per acre and cost of water lifting per unit have been worked out.

	Case (i)	Case (ii)	Case (iii)
Initial Investment (in Rs.)			
(i) Well	2,250	2,000	2,000
(ii) Boring	...	1,000	1,000
(iii) Persian wheel/power pump	600	2,000	3,000
Total	2,850	5,000	6,000
Working Expenses (per annum)			
(i) Depreciation			
(a) 1 per cent for (i) above	22·50	20	20
(b) 3 per cent for (ii) above	...	30	30
(c) 5 per cent for electrical pumpset : 10 per cent for persian wheel and diesel run pumpset	60·00	100	300
Total depreciation	82·50	150	350

(Contd.)

	Case (i)	Case (ii)	Case (iii)
(ii) Cost of power			
(a) Maintaining pair of bullocks (proportionate cost only as bullocks would be used for other purposes during the year)	500·00	...	...
(b) Electric charges at 3·5 units per hour for 700 hours @ 10 nP. per unit	...	245	...
(c) Diesel oil @ 0·3 gln. per hour for 700 hours @ 1·85 per gln.	...	...	388·50
(iii) Oil and lubricant L.S.	20	30	80
(iv) Maintenance and repairs	40	50	150
(v) Interest on capital outlay @ 4½ per cent	128·25	225	270
Total working expenses	770·75	700	1,238·50
Water output			
(per annum in acres inches)	110	250	250
Area irrigated			
(per annum in crop acres)	6	12·5	12·5
Economic parameters			
(i) Cost per acre (in Rs.)	475	400	480
(ii) Cost of water lifting (in Rs.)			
(a) per acre inch	7	2·80	4·75
(b) per acre	128	56	99

It would appear from above that the economics of well irrigation is very much improved by boring and installation of electrical pumpsets.

Advantageous role of wells in irrigated agriculture

Apart from the fact that open wells are the only possible means of irrigation in many tracts, open well irrigation has definite advantages over canal to tubewell irrigation. These are :—

1. Open wells invariably belong to the individual cultivators. Catering for a small order of discharges and irrigated areas they are well suited to meet the requirements of small land holdings of individual farmers. They provide a greater degree of flexibility to the cultivator in planning his cropping and timing his irrigation applications. The cultivator can operate the well and get the water at his will and convenience. Well irrigation thus brings about better satisfaction of the psychological as well as physical needs of the cultivator.
2. Since the cultivator makes his own financial investment in the well, he is very prompt in making full use of its water potential. Hence well irrigation results in much quicker accruing of irrigation benefits.
3. The commanded area of an open well is limited ; hence the losses in conveyance and distribution of water are usually of low order.
4. The cultivator fully appreciates the value of the water lifted from his well

as he himself meets all the expenditure and labour involved. He has thus sufficient incentive to use this water as economically as possible by proper preparation of fields in small level beds and taking other improved irrigation and agriculture techniques.

5. From well water, the cultivator can time his irrigation applications at smaller intervals. He is, therefore, able to make his cropping pattern more intensive and productive by including crops like vegetables, tobacco, etc., which require irrigation at frequent intervals.

6. On many diversion canal systems, the supplies dwindle down considerably during the crucial periods of crop growth in the hot weather as well as in the cold weather when there is keen demand of irrigation water. Open wells existing in the canal command play the important role of supplementary canal irrigation during such critical periods.

7. Open well irrigation in the canal commanded area helps to control the water-table at a safe level below the ground surface and thus to avoid the hazards of waterlogging.

8. The supply from wells has immense value in years of drought, when it is less liable to failure than surface water sources.

Planning and Implementation of a large scale well construction programme.

Following are some of the technical considerations which experience in India has shown are important from the point of view of planning and implementation of a large scale well construction programme :

1. Construction of new wells should be taken up in a region after careful surveys of the groundwater potentialities. New wells should not be permitted if the groundwater recharge is precarious and the water-table has a tendency to go down. Groundwater extraction should not be allowed to reach a stage which results in overdraft from the local groundwater formation. The behaviour of the water-table in every region where groundwater extraction is in vogue should be carefully and regularly watched with a view to timely detecting if there is any sustained lowering of water-table.

2. If water-table is observed to be lowering gradually in groundwater irrigated tracts, prompt measures should be taken to arrest this tendency. Feasibility of undertaking groundwater recharge schemes should be explored.

3. Programme for construction of wells should be linked up as far as possible with soil conservation activities. like contour bunding, gully plugging and other water conservation and groundwater recharge schemes like head-water tanks, percolation tanks, field embankments, etc., in order to improve the supplies and performance of wells.

4. While encouraging construction of wells in a region, due attention should be paid to the location, spacing and the size of the wells. Too near spacing of wells is known to result in interference and depletion of supplies in existing wells in some regions. This should be avoided. It would be desirable to determine the near-safe range of spacing of wells in each region.

5. In case the bottom of the well is left in sandy strata, it is highly desirable that it be filled with a thick layer of graded brick or stone ballast as explained earlier. This would ensure the stability of the well by filling up the cavity, formed below the steining due to lifting of sand particles.

CONCLUSION

Although open wells are small works catering for meagre order of irrigation supplies ; collectively they play an important role in the country's irrigated agriculture. In many dry tracts, they provide the only possible means of irrigation. Application of modern technology by way of deep boring, deepening of wells and installation of power pumps in place of age-old devices for lifting water, has resulted in considerable improvement of performance. They may not be as efficient or economic in the long run as tubewells (deep wells) in tracts where large scale groundwater extraction is possible, but with modern improvements their economics is reasonably satisfactory ; while they are more suited for irrigation of small land holdings and yield much quicker and better results than larger, more complicated schemes.

Well irrigation has many advantages over other systems of irrigation. It stimulates and mobilises efforts of the individual cultivators to the maximum extent in making full and economic use of irrigation water and obtaining maximum production. The standard of levelling and preparing fields and other irrigation and agriculture techniques adopted in case of well irrigation is better than in other systems of irrigation.

Recognising these advantages, well construction is being encouraged in India under the minor irrigation programme in the country's Five Year Plans. Adequate measures are being undertaken in planning and implementation of the large scale well construction programme to ensure that wells are located and designed properly and that there are no failures due to over-draft from a local groundwater formation.

PART II

GROUNDWATER DEVELOPMENT IN INDIA THROUGH IRRIGATION TUBEWELLS

by

M. P. Pandey and K. V. Raghava Rao*

SYNOPSIS

The system of tubewell (deep well) irrigation has been in practice in India since the early thirties. The first tubewells were constructed by the (now) Uttar Pradesh Government in the Indo-Gangetic alluvium. These tubewells were operated by the State Electric Grid. In view of the advantages of tubewell irrigation, the system spared to the neighbouring States of Bihar, Punjab and now West Bengal. Prior to undertaking extensive tubewell projects, field tests were conducted in Uttar Pradesh in order to standardise the capacity of wells and their constructional and operational features. It is established that in the Indo-Gangetic alluvium, tubewells of 1·5 cusecs capacity spaced a mile to a mile and a half apart can safely be operated without any appreciable depletion in the water-table. Such tubewells are found to irrigate about 400 acres in a command area of about

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800 acres. Gravel shrouded slotted tubes have been preferred to strainer type in consideration of more efficient operation and longer life.

Five thousand State tubewells were constructed in the First Two Five-Year Plans. 2,500 more are being constructed in the Third Plan. Besides, there are many private tubewells.

With a view to extending tubewell irrigation schemes to the other parts of the country, a Groundwater Exploration Project was started on a nation-wide scale in 1954 under the Indo-American Technical Collaboration Agreement No. 12. Since than the Exploratory Tubewells Organisation under the Ministry of Food and Agriculture, Government of India has been drilling deep bores all over the country and conducting geo-hydrological tests. These explorations have revealed vast potentialities in coastal alluvial tracts inland river basins and notably in the arid areas of Rajasthan desert. Production tubewells schemes have been taken up in these proven areas.

In order to derive lasting benefits the water-table behaviour in the tubewell irrigated areas is being closely watched. Emphasis has been laid on coordinated conjunctive use of groundwater with surface water. Volumetric system for sale of water is in vogue as a measure of economical use of groundwater.

INTRODUCTION

India took to tubewell (deep well) irrigation in the thirties of this century when the first wells were constructed in the Indo-Gangetic plains of Uttar Pradesh. These plains are rich in groundwater supplies and to a large measure are recharged by the rivers debauching from Himalayas and draining the alluvial tracts. The advantage of tubewells over canals lies in the fact that they can be constructed right in the centre of the places where irrigation is needed or is proposed. The flow from the pumps outlet to the different fields is by gravity over a relatively short distance ; and there is no need to construct an extensive system of distributaries. Tubewells are a boon in an area where irrigation requirement is keen but no surface water irrigation is possible.

In Uttar Pradesh, the primary consideration in tubewells construction has been to provide irrigation in those tracts where it has been possible to extend any canal irrigation. While this is a determining factor in Punjab also, some shallow tubewells have recently been constructed there as an experimental measure under the anti-waterlogging programme. In Bihar, the tubewell programme was taken up as an insurance against the vagaries of the monsoon. In spite of about 50 inches of rainfall, crops have failed in Bihar once in every 3 to 4 years because of erratic and untimely rains. The same consideration has now governed the undertaking of tubewell construction programme in the West Bengal.

Before starting tubewell projects on a large scale, the Uttar Pradesh Irrigation Department conducted field experiments in the thirties with a view to investigating the following aspects :—

(a) What is the most efficient spacing for a system of tubewells ? Is it better to locate a large number of small tubewells closely spaced over a given area, or a smaller number of larger units spaced further apart ?

(b) What is the maximum abstraction which the local sub-soil will withstand at one night and what is the danger inherent in over-straining the capacity of the soil ?

(c) What is likely to be the most economic spacing of tubewells in regard to loss of water by percolation from the distributing channels ?

(d) What is the largest unit of water which a single cutltivator can conveniently handle in irrigating small holdings ?

(e) For what number of hours in a year of average rainfall is a tubewell likely to work, having regard to the crops in a given tract ?

(f) What is the probable life of a tubewell, (i) its strainer, and (ii) the rest of the equipment, having regard to chemical or other corrosive elements present in the soil ?

(g) What are the sources of replenishment of the underground reservoir and what is the probable effect on the latter of pumping at the rate proposed for prolonged periods of the year ?

After examining the various factors and conditions in Uttar Pradesh, it was considered that the most economical size for a tubewell would be outlet of 1·5 cusecs with '*Pucca*' channels of one mile length. Separate tubewells, each selling water by volume to individual cultivators at the source, were preferred to an arrangement under which a battery of wells would feed minor distributaries constructed by the Government.

Since the inception of tubewell projects in Uttar Pradesh up till 1951, there were about 4,000 State owned tubewells in Uttar Pradesh, Bihar and Punjab. The construction of tubewells received an impetus in the National Planning under the Grow More Food Programme. In each of the first two plan about 2,500 State owned tubewells of 1·5 cusecs capacity were constructed. The current Third Plan has also a programme of about 2,500 tubewells State owned. This rate is proposed to be maintained in the future Plan periods also. This system of irrigation is now being extended from Indo-Gangetic alluvium to other areas as a result of the groundwater project described later in this paper.

In addition to the large sized State owned and operated tubewells, private owned tubewells also are now being constructed in large numbers. The capacity of the private tubewells usually ranges from about 0·25 cusec to 1 cusec. It is anticipated that about 15,000 private tubewells will be completed during the Third Five-Year Plan. With the increased generation of electric power and extension of power lines in rural areas, it is expected that the number of additional tubewells installed during the Fourth Five-Year Plan will be of the order of 35,000.

GROUNDWATER EXPLORATION

As mentioned earlier, tubewells construction in the initial stages was mainly confined to the Indo-gangetic alluvium. With increased emphasis on irrigation, after Independence, it was felt that a systematic exploration of tubewell possibilities in other parts of the country where geo-hydrological conditions were apparently favourable. should be carried out. With this end in view, the Government of India decided to start an exploratory drilling project on a scientific basis in order to establish the groundwater resources of the country available for agricultural purposes. This led to the Indo-American Cooperation Agreement No. 12 for a nation-wide survey which envisaged drilling over 300 experimental bore holes in 16 different regions covering alluvial basins of the larger rivers and the soft rock areas. To carry out this pioneering job, the Exploratory Tubewells Organisation was created in the Ministry of Food and Agriculture. The areas were selected for exploration on the basis of the earlier investigations carried out by the Geological Survey of India. The exploration aimed at collection of subsurface data, testing of aquifers and delineation of productive areas for development of groundwater resources for irrigation purposes. The techniques involved are drilling of pilot holes to 1,500 ft. depth, electrical logging of the bore holes, and conducting individual aquifer tests for quality of water and yield capacity test in fully developed wells and determining some of the aquifer constants.

The first phase of the project was successfully completed in August, 1959. The Government of India. thereupon sanctioned

continuation of the groundwater exploration till the end of the Third Plan period, (March 1966) to cover further areas and carry out intensive work in promising areas. It is proposed to extend the valuable work in the Fourth Plan period.

The large scale groundwater exploration completed has proved over 15,000 sq. miles as worthy for future groundwater development for irrigational purposes and has created a potential for over 8,000 irrigation tubewells in the following States :

	State	Area explored (sq. miles.)	Extent proved groundwater worthy (sq. miles.)	Average discharge in (I.G.P.H.)	No. of production tubewell feasible
1.	Uttar Pradesh	8,800	1,320	36,000	900
2.	Madhya Pradesh	5,000	1,218	29,900	600
3.	Maharashtra				
	(a) Purna valley	1,440	600	6,500	300
	(b) Tapti valley	4,000	80	33,600	40
4.	Gujarat				
	(a) Saurashtra	1,900	135	2,000	30
	(b) Kutch	5,760	500	30,000	250
5.	Rajasthan	11,000	600	30,000	100
6.	Bihar	7,000	992	38,000	400
7.	Kerala	500	104	11,000	40
8.	Andhra Pradesh	404	125	31,000	80
9.	Orissa	1,800	1,327	22,000	250
10.	Madras	2,600	1,396	26,000	400
11.	Punjab	6,800	356	34,000	100
12.	Assam	1,500	780	35,000	500
13.	West Bengal	9,000	5,468	40,000	4,000

Technical features of existing tubewells

Generally, irrigation tubewells constructed in India are of two types : (*i*) Strainer wells with no gravel packing, (*ii*) Gravel packed wells with slotted tubes against aquifer zones.

In the first category the screen size is chosen in relation to the effective size of the formation materials so as to prevent sand from entering into the well while pumping. In the second category the gradation curve of the aquifer materials is used to establish the limit of gradation of the artificial gravel pack which will stabilise aquifer materials and give reasonable improvement in the well efficiency. In view of the diverse textures of the aquifers sands generally met within the alluvial formations of the country, it is not possible to adopt a specified screen opening for tapping the water bearing horizons in the construction of irrigation tubewells all over the country.

The gravel shrouded tubewells have the following advantages over the strainer type :

1. By gravel treating a well, provision is

possible for larger openings in the screen or slotted pipe than in the well screen when not gravel treated.

2. Gravel treatment also increases the effective diameter of the well. The yield is proportional to the logarithms of the diameters.
3. The gravel treatment controls the entrance of the fine sand from the formation into the well.
4. The application of correct size graded gravel against the screen will help increase the transmission constant and reduce entrance velocity.

Gravel treated wells have longer life compared to strainer wells. In view of these advantages there is a tendency in recent years to construct more artificially gravel-packed tubewells. However, if the quantity of water needed is less than the maximum and can be obtained by using ordinary straight screening methods, the gravel treated wells are not constructed in view of the initial costs involved.

Pumping equipment

In the early stages, centrifugal pumps driven by horizontal motors were in use. These sets were lowered below ground level to ensure that the suction limit did not exceed 25 feet.

With the development of turbine pumps now being manufactured in India, the use of old type pump sets has been given up, except in small private tubewells. The present tubewells are installed with deep well pumps (oil lubricated) driven by hollow shaft vertical electric motors. In the tubewell kiosk are housed the panel of electrical instruments, T.P.I.C. switch and air-break star-delta starter. The efficiency of the combined unit is of the order of 80 to 90 per cent. Submersible pumps are also being manufactured in India now and their use is on the increase in view of their advantageous constructional features.

Size of tubewell standardisation

An attempt at standardisation was first made in the Gangetic alluvium as a pre-requisite for the implementation of the large tubewell scheme for irrigation in the Ganga Valley in the early thirties. From field investigation, it was found that a tubewell drilled to an average depth of 240 ft. tapping a total thickness of 80 to 100 ft. course water bearing strata and installed with a 6 inch diameter strainer, would deliver a discharge of about 1·5 cusecs. The radius of influence was found to be 1,000 ft. It was further considered that; (a) the course sand strata below the water-table in the Ganga Valley is widespread and continuous ; (b) each tubewell could command about 1,000 acres of cultivable land ; and (c) 1·5 cusecs was about the largest unit of water which a single cultivator could conveniently handle in irrigating his small holding. The field investigations led to the adoption of a tubewell yielding on an average 1·5 cusecs with a local depression of 16 to 22 ft. as a standard well. The spacing of the 'standard wells' was fixed at 1 to 1½ mile apart.

In recent years, considerable knowledge has been gained after operating additional wells in the Ganga Valley and by drilling and testing exploratory wells in the arid, semi-arid, coastal and river alluvial tracts. The information gathered confirms that in view of the diverse conditions prevailing in the individual groundwater basins all over the country, the optimum size of tubewells should vary from basin to basin and a standard arrived at for one basin may not necessarily be applicable to other basins. Even in the heavily tubewell irrigated tracts it has been observed that no appreciable permanent depletion in the originally observed water-table has taken place after continuous pumping over the last several years. The standards for optimum pumpage from an individual well and their spacings are being reviewed.

Siting of tubewells and fixation of commands

Tubewells are normally located at the intersection of water sheds in the commanded area so that advantage is taken of natural gravitation in distributing the irrigation

water. For actual location of individual wells, water sheds and drainage lines are first marked out in the entire area to be covered by tubewell irrigation. Possible sites of individual wells thus are indicated primarily at intersection of watersheds, the off-taking ridge lines from the point of intersection serving as alignment for distribution channels. Irrigation commands of individual wells are formed by the natural local drainage lines besides considerations like village border, railway lines, important roads and other barriers.

The commanded area of a tubewell is related to the irrigation capacity of the well and the proposed intensity of irrigation in the tract. Tubewells in North India usually have a commanded area ranging from 800 to 1,000 acres with an expectation of irrigating about 40 to 60 per cent of the commanded area. The latest thinking, however, is that commanded areas of this order are on the high side. It is felt that tubewells afford a distinct field for practising intensive pattern on irrigated agriculture as supplies from tubewells are firm and perennial and there is no fear of waterlogging. Hence the recent trend is to fix the commanded area of tubewells so as to cater for 70 to 80 per cent intensity of irrigation.

Operation and maintenance

The organisational set up varies from State to State. The general pattern for the operation and maintenance of State tubewells is described as follows :

State tubewells are under the general technical and administrative control of the Chief Engineer, Irrigation Department. They are jurisdictionally divided into administrative units, known as Tubewell Circles, each circle being under the charge of a Superintending Engineer. The Superintending Engineers are responsible for the construction, maintenance and upkeep of tubewells and their appurtenant works including preparation of revenue accounts in their respective circles. A tubewell division is under the charge of an Executive Engineer, with three or more subdivisions attached to it. To each division is attached a Deputy Revenue Officer, who supervises the work of the revenue staff and exercises magisterial powers under the Canal Act.

The actual field operation staff works under the Sub-divisional Officer or Assistant Engineer. The field staff in a sub-division consists of three to four overseers, three to four electrical and mechanical supervisors and other subordinate staff on regular pay-rolls or on works charged basis. Normally each overseer and each supervisor looks after 50 to 60 tubewells with regard to civil and mechanical works respectively. On the revenue side, there is one Zilladar along with 'Amins' and tubewell operators in each sub-division. A tubewell operator is parallel to Patrol or Patwari and is the pedestal of official set-up of tubewell organisation. He runs the tubewells. He keeps accounts of irrigated areas, field by field and also of the charges levied thereon. Besides, he keeps a watch on the demand for irrigation and advises cultivators on matters pertaining to use of tubewell water.

During the season and at the end of the 'Fasal' field-wise records maintained by the operators, are checked by 'Amins' and 'Zilladars' and individual demand slips are prepared. On the basis of these records Jamabandies (consolidated account of assessment) are prepared in the office of the Executive Engineer under supervision of the Deputy Revenue Officer are forwarded to the Revenue authorities for collection of charges. Finally, the performance of a tubewell is judged by the gross receipts indicated by the Jamabandi.

The above set-up related to the construction and maintenance of tubewells and distribution of tubewell water. The utilisation aspect of tubewells primarily is the responsibility of the cultivators who are advised, in the technical aspects of management of farming, by the Agriculture Department of the State. The advice tendered by the Agriculture Department at the level of the cultivators is being increasingly made available

through the machinery of Community Blocks. The organisational problem is, therefore, one of combining into an efficient team the officials of the Engineering Department and the Agriculture Department, and the cultivators themselves.

The Mechnical Sub-Divisional Officer attached to the Division is in-charge of drilling rigs, development of wells, pump testing units, well site electrical installation. etc., and the Civil Sub-Divisional Officer is in-charge of lay-out and upkeep of the houses, distribution tanks, water coarses, etc. Every division is equipped with a mechanical workshop and spare parts store for quick repair of equipment including pumping sets.

Irrigation Performance and Cropping Pattern

Irrigation performance of a tubewall varies from region to region depending upon the discharge of the well, cropping pattern and the local rainfall, climatic and soil conditions. A tubewell in the semi-arid regions of North India where the predominant irrigated crop is wheat, irrigates on an average about 400 acres. A tubewell with equivalent discharge in the South where the main crop is paddy hardly irrigates 100 acres. In order to ensure that these tubewells are occupied all the year round for full utilisation of available water, it is necessary that the cropping pattern adopted should be as intensive as possible. The cropping pattern suggested in some areas for optimum utilisation of tubewell water are :

ACRES

	Early Kharif (hot weather April to May-June)				Late Kharif (July to September)			Rabi (October to March)		
	Sugar cane	Orchard and vegetable	Fodder	Other crops	Cotton and maize	Sugar cane	Paddy	Other crops	Sugar cane	Wheat
1. Punjab and West U.P. (out side sugar factory area)	20	25	15	15	75	20	10	20	20	225
2. Punjab and West U.P. (sugar factory area)	100	10	15	...	...	100	15	35	100	175
3. East U.P. and Bihar (sugar factory area)	100	10	15	25	...	100	15	10	100	200
4. East U.P. and Bihar (outside sugar factory area)	...	10	25	65	15	...	100	10	...	250
5. North Gujarat	20	25	15	15	75	20	10	20	20	225

Steps are being taken to demonstrate the improvement of cropping patterns in actual cultivators plots in order to convince the cultivators of the advantages in the form of increased produce and income that accrues from such cropping patterns.

Usually it takes a period of 4 to 5 years before irrigation is fully developed around a tubewell. This period is considered too high and steps are being taken to cut it down by taking advance measures for (a) timely construction of field channels, (b) levelling and preparation of fields, (c) evolving and demonstrating improved cropping pattern, (d) making available timely supplies of improved seeds, fertilizers, etc.

The hours run by a tubewell during a year give an idea of the irrigation development under it. In full development, tubewells in West Uttar Pradesh, are found to run on an average 4,500 hours in a year.

Distribution of Water

The tubewell water is delivered to the fields by means of small irrigation channels called water courses or field channels. The first 1 to 2 miles of the channels are lined with masonry at Government cost, the rest being earthen. Attempts are being made to evolve a cheap affective lining which may be adopted on a wider scale.

The area which receives water from a tubewell belongs to a number of cultivators. As every cultivator is naturally anxious to obtain the maximum quantity of water at the earliest possible opportunity, it becomes necessary to fix the schedule for the distribution of available supplies between the various shareholders indicating their time and turn. This turn system is called 'osrabandi' in Uttar Pradesh and 'warabandi' in the Punjab and is governed by the rules under the Irrigation Enactment in force. The turn system for each tubewell may either be agreed upon mutually among the shareholders themselves of the Irrigation Officer in charge of tubewells may frame the schedule for them. The commanded area is divided into 8 to 12 'thokes' (blocks of areas) and for each 'thoke' a man of influence and integrity is nominated as 'thokedar' with the consent of the concerned cultivators. The turn generally begins with the first holding at the head of the water course and ends with the one at the tail end. The time of each farmer's turn is proportionate to the area in the command of the tubewell. The 'thokedar' is responsible for the distribution of water among the cultivators within his 'thoke'.

Sale of Water

Unlike the canal system in India where the water rate is usually charged from the cultivators on crop area basis or the commanded area basis irrespective of the actual area irrigated, the water rate on tubewell is generally charged on volumetric basis. The volumetric sale of water is not only convenient and highly equitable but also provides incentive to the farmers for economic use of water. There are usually two systems in vogue for assessing charges on volumetric basis :

1. The discharge of the tubewell is measured over the V-notch from time to time and then is calculated by multiplying the discharge with the time interval for which the discharge is passed in the field.
2. The quantity of water delivered is correlated with the electrical energy consumption. In this way the units of electricity consumed provide the direct volumetric measure of water delivered. The discharge of the tubewell is checked from time to time and the correlating factor between the discharge and the electrical consumption is adjusted accordingly.

Efforts are being made to introduce a two part tarift which would comprise a fixed compulsory charge for the entire commanded area irrespective of the area actually irrigated and a second charge based on the volume of water actually consumed. It is expected that this basis would provide greater incentive to the cultivators to make fuller use of available

irrigation water and bring maximum area under irrigation all the year round.

OBSERVATION ON WATER TABLE BEHAVIOUR

In heavily (tubewell) irrigated tracts there is imperative need to observe the behaviour of the regional water table as a help in planning additional wells in the area and to aim at safe extraction of ground water from the basin or region by putting a ceiling on pumpage from the groundwater reservoir. In addition, such observations facilitate delineation and control of water-logged areas in the irrigated tracts.

With this objective in view, the rise and fall of spring levels in 700 wells spread out all over the heavily tubewell irrigated tracts lying between the major river courses (Ganga and Yamuna) have been under observation (Semi-annual) in Western Uttar Pradesh for the last forty years. The results show that no appreciable change in groundwater table has taken place in the tubewell pumped areas, except in a few localities to a limited areal extent. Even in the latter case, the depletion is of the order of 2 to 3 feet only. The study also proves that Ganga and Yamuna rivers are effluent during the month of May. In selected regions these rivers recharge the groundwater table during and after the flood stage. In the same tract, some parts are irrigated (e.g. Hindan-Yamuna, Arind-Pandu, Isan-Kali etc.) simultaneously by canal systems as well as by tubewells. The study of water table behaviour shows that the water table has attained more or less an equilibrium stage and there is no appreciable rise or fall to continuous pumping.

The Government of India has plans to bring out a water table map of the country by setting up permanent observation wells all over the country. This is of special significance in States where tubewell irrigation is gaining importance. The processing of data regarding fluctuations in the water table is undertaken by the Geological Survey of India as the coordinating body.

CONCLUSION

Tubewells are playing a significant role in the country's agricultural development especially in raising cash-crops. With the experience gained in running them for over three decades, new designs are being evolved with a view to tapping groundwater sources on an economic scale. This system of irrigation is spreading from the Gangetic alluvium to coastal and other alluvial areas. Side by side close study is being made of inherent geohydrological problems. The indications are that groundwater development be accelerated in the very near future. The groundwater development is now being coordinated with surface water development in order to derive full benefits of conjunctive use.

PART III

SMALL STORAGE AND DIVERSION SCHEME IN SOUTH INDIA

(With particular reference to Andhra Pradesh)

by

M. A. Rahman*

SYNOPSIS

Most irrigation in southern states of India is provided by small storage works (tanks) and diversion schemes. There are more than 125 thousand tanks in the region. Quite a large number had been lying in a state of dis-repair due to long neglect by the erstwhile zamindars and jagirdars (landlords) who owned them. With the recent land reforms, great headway is now being made towards speedy restoration of these derelict tanks under the minor irrigation programme. A large number of additional works are also being constructed.

This paper describes in detail the main design and construction features adopted generally in the southern states (particularly in the State of Andhra Pradesh) for execution of small storage and diversion schemes. Background information in regard to the land resources, water resources, rainfall pattern, type of soils and cropping pattern in the southern states has also been furnished.

INTRODUCTION

The system of tank irrigation has been traced back too well before Christian era in South India and it forms the back-bone of the economy. These tanks are found in large numbers in almost all districts. Most of them are ancient works brought into being by benevolent rulers of the past. Ramappa and Lakhnawaram lakes in Warangal District of Andhra Pradesh, constructed during the rule of Kakatia Dynasty, stand as living examples of unparallelled skill in planning and execution of irrigation tanks. Some of the existing anicuts across Musi river in Andhra Pradesh date back to Khutub Shahi period. Andhra Pradesh, Mysore and Madras have comparatively more minor tanks than other States.

Land Resources

The four southern states, Andhra Pradesh, Madras, Mysore and Kerala have a total geographical area of 245.380 thousand square miles. The total irrigated area is 15·243 million acres. Out of this 5·997 million acres is cultivated under tanks which is 39·20 per cent of the gross irrigated area. The areas irrigated in different states under different sources in 1956-57 is given in Table 1.

Andhra Pradesh has geographical area of 106 thousand square miles and a total cultivated area of 27·90 million acres which is 42 per cent of the gross area. The irrigated area is 6·78 million acres. Out of this roughly 2·64 million acres are being irrigated by minor tanks and 4·14 million acres by wells and other minor sources. Thus the area of 2·64 million acres irrigated under the tanks which is 39 per cent of the gross irrigated area, speaks for the importance of tank irrigation.

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TABLE 1. AREA IRRIGATED BY STATES IN SOUTH INDIA 1956-57

State	Geographical area in sq. miles	Canals	Tanks	Wells	Other sources	Total
		(Thousands of Acres)				
Andhra Pradesh	1,06,052	3,149	2,916	793	210	7,068
Madras	50,132	1,997	2,195	1,236	89	5,517
Mysore	74,191	408	809	320	292	1,829
Kerala	15,005	414	77	29	309	829
	2,45,380	5,968	5,997	2,378	890	15,243

Note : (1) Column 2—From Indian Year Book, 1962.
(2) Columns 3 to 7—Hand Book of Irrigation and Power published by the Central Board of Irrigation and Power, 1962.

The total number of tanks in the area is as high as 58,500 and many more will be added in due course. The district-wise distribution of tanks and area irrigated in 1955-56 is shown in Table 2.

Rainfall

Almost all the entire rainfall in South India is received due to the South West monsoon from June to October. The coastal districts also receive rainfall from the North East monsoon, which is from October to December. Besides there are cyclonic storms such as have occurred in years of 1928, 1948, etc., in the coastal districts of Krishna, Godavari and Vizag which result in extensive damages to all the tanks and other irrigation works in these areas.

Andhra Pradesh can be divided into three regions with respect to the rainfall :

1. North Coastal Andhra and Northern Telengana where the rainfall varies from 110 to 120 centimeters (43·50 to 47·50 inches).
2. Mid Telengana and South Coastal Andhra where the rainfall varies from 80 to 90 centimeters (31·50 to 35·50 inches), and
3. Rayalseema and Mahboobnagar district of Telengana where the rainfall varies from 55 to 70 cm. (21·50 to 27·50 inches). The distribution and incidence of rainfall is so uncertain and variable that it is essential to assure supply, by storing in periods of excessive rainfall. Rainfall district-wise in Andhra Pradesh is shown by Table 3. Fig. 1 is an isohytel map of Andhra Pradesh. The Rayalseema region is more effected by famine due to the meagre and uncertain rainfall.

Soils

The soils of South India can be classified into 4 major types :

1. **Alluvial Soils** are found in the coastal areas of South India particularly in Deltic regions.
2. **Black Cotton Soils** are the typical soils of Deccan trap extending over Andhra Pradesh, Mysore and some parts of Madras.
3. **Red Soils** are found in eastern Andhra Pradesh, Mysore and major parts of Madras.
4. **Latterite Soils** are a soil type peculiar to India existing in Mysore and Kerala States.

TABLE 2. DISTRICTWISE DISTRIBUTION OF TANKS AND AREA IRRIGATED IN 1955-56

Sl. No.	Name of District	Below 10 Acres	11-50 Acres	51-100 Acres	101-200 Acres	Above 200 Acres	Total No. of Tanks	Settled Ayacut under the tank	Actual Irrigation under tank during 1955-56	Gap columns (9-10) Acres
	Telangana Region									
1.	Warangal	1,585	1,594	633	317	288	4,357	2,21,784	1,99,786	21,998
2.	Khammam	531	798	210	97	66	1,702	93,186	90,222	2,964
3.	Karimnagar	3,080	2,827	648	263	176	6,994	2,69,554	1,92,554	77,309
4.	Adilabad	335	568	130	254	34	1,161	42,760	44,382	—
5.	Nalgonda	1,599	1,409	617	215	114	3,954	1,25,460	1,10,441	15,019
6.	Medak	2,817	2,605	910	544	64	6,940	1,93,395	1,93,628	67,473
7.	Hyderabad	498	1,211	306	149	10	2,174	61,706		
8.	Nizamabad	300	547	304	162	102	1,415	1,09,863	1,07,449	2,414
9.	Mahboobnagar	1,653	1,660	534	277	159	4,283	1,83,280	1,66,966	16,314
	Total	12,438	13,219	4,292	2,078	935	32,980	13,00,988	11,05,119	1,97,791
	Andhra Region									
10.	Srikakulam	—	7,324	—	1,914	78	9,316	2,44,950	2,77,692	—
11.	Visakhapatnam	—	2,394	—	118	106	2,618	3,25,420	1,35,567	1,89,853
12.	East Godavari	—	627	—	520	49	1,196	—	1,33,594	—
13.	West Godavari	—	302	—	116	27	445	4,13,561	2,31,750	1,81,811
14.	Krishna	—	456	—	107	37	600			
15.	Guntur	—	179	—	98	8	285	1,39,770	45,166	94,604
16.	Nellore	—	238	—	69	215	522	2,42,146	3,09,034	—
17.	Kurnool	—	426	—	51	41	518	49,284	59,956	—
18.	Anantpur	—	1,497	—	628	112	2,236	1,08,305	1,91,273	17,032
19.	Cuddapah	—	1,029	—	106	49	1,184	31,580	73,025	—
20.	Chittoor	—	5,290	—	1,307	299	6,626	1,30,882	1,76,460	—
	Total	—	19,762	—	5,034	751	25,547	16,85,898	15,33,517	4,83,300
	Grand Total	—	49,711	—	7,112	1,704	58,527	29,86,886	26,38,636	6,82,091

TABLE 3. RAINFALL BY DISTRICTS IN ANDHRA PRADESH

		Cm.	Inches	Basin
I. Northern Coastal Andhra and Northern Telangana (Average rainfall 40" to 50").				
1.	Srikakulam	120	47·5	(c)
2.	Visakhapatnam	120	47·5	(f)
3.	East Godavari	120	47·5	(a)
4.	West Godavari	105	41·5	(a)
5.	Adilabad	116	43·5	(a)
6.	Nizambad	105	41·5	(a)
7.	Karimnagar	115	45	(a)
8.	Warangal	110	43·5	(a) (b)
9.	Khammam	115	45	(a) (b)
II. Mid Telangana and South Coastal Andhra (Average Rainfall 30" to 40").				
10.	Medak	90	35·5	(a) (b)
11.	Hyderabad	80	31·5	(b)
12.	Nalgonda	80	31·5	(b) (a)
13.	Krishna	90	35·5	(b)
14.	Guntur	80	31·5	(b) (d)
15.	Nellore	90	35·5	(c) (d)
16.	Chittoor	85	35·5	(c) (d) (e)
III. Rayal-Seema and Mahaboobnagar District of Telangana (Average Rainfall 20" to 30").				
17.	Mahaboobnagar	65	25·5	(b)
18.	Kurnool	60	23·5	(b) (c)
19.	Ananthapur	55	21·5	(b) (c)
20.	Cuddapah	70	27·5	(c)

The main drainage basins in the State are those of rivers (a) Godavari (b) Krishna (c) Vansadara (d) Nagavalli (e) Pennar (f) Coastal rivers (g) Palar.

Water Resources

The main drainage basins in South India are: 1. Godavri, 2. Krishna, 3. Cavery, 4. Vamshadhara, 5. Nagavally, 6. Pannar, 7. Other Coastal rivers such as Upputeru, Gundlakamma, etc., 8. Palar.

Crops and Cropping Seasons

The main irrigated crops in Andhra Pradesh are (1) Paddy, (2) Sugar-cane, (3) Garden crops, (a statement showing the area irrigated under the above crops in Andhra Pradesh is enclosed). Paddy is grown generally in 2 seasons i.e. in Abi, which is from June to December and Tabi which is from January to May. Occasionally a third crop of paddy is also grown which is for a shorter duration of about 2 to 3 months.

Catchment, Yield, etc.

Most of the tanks in South India form part of groups of tanks and either receive the surplus of the upper tanks or feed surplus into lower tanks or do both. Any tank that neither receives water from an upper one nor

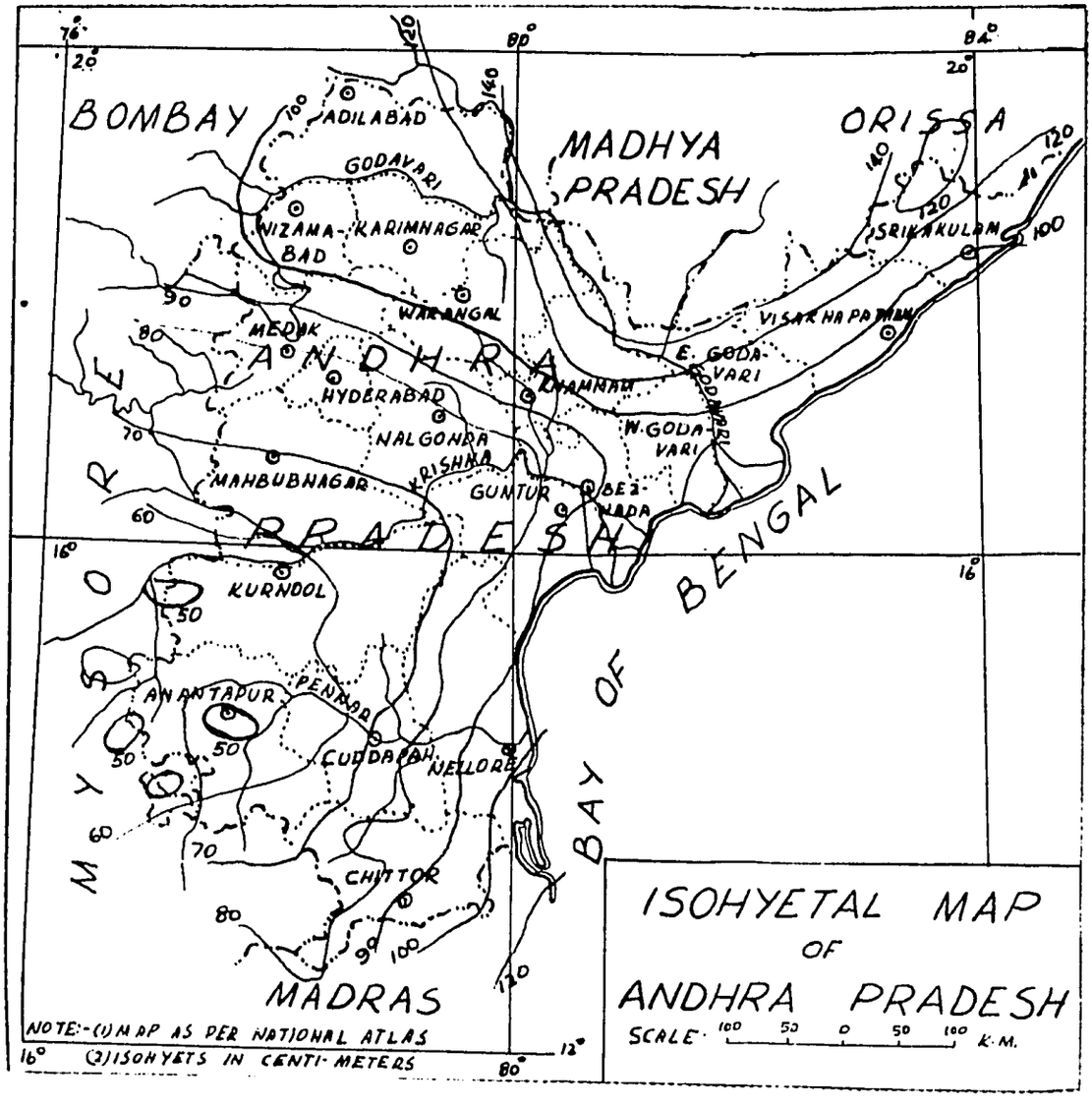

BOMBAY
MADHYA PRADESH
ORISSA
ADILABAD
GODAVARI
NIZAMABAD
KARIMNAGAR
WARANGAL
MEDAK
ANDHRA
HYDERABAD
NALGONDA
KHAMMAM
E. GODAVARI
W. GODAVARI
VISAKHAPATNAM
SRIKAKULAM
MAHBUBNAGAR
KRISHNA
GUNTUR
BEZWADA
KURNOOL
ANANTAPUR
PENNAR
CUDDAPAH
NELLORE
CHITTOR
MADRAS
MYSORE
BAY OF BENGAL
ISOHYETAL MAP OF ANDHRA PRADESH
SCALE 100 50 0 50 100 K.M.
NOTE:-(1) MAP AS PER NATIONAL ATLAS
(2) ISOHYETS IN CENTI-METERS

FIG. 1

discharges surplus into lower tanks is termed as an isolated tank. In a group system considerable economy is achieved and the surplus water of each tank and also the return drainage of its cultivation is caught by the next lower tank. Each tank takes a share of the yield of the whole catchment above it which is classified as follows :

1. **Free Catchment** is the catchment area which drains into tank only under consideration, and
2. **Combined Catchment Area** is the area of the whole catchment above the tank. The difference between combined and free catchment area gives the area of the intercepted catchment by the upper tank. For calculation of yield purposes 1/5 to 1/7 of the intercepted catchment area is considered as equivalent free catchment. The catchment is classified as, good, average or bad depending upon the nature of the country, nature and quantity of vegetation, humidity, distribution of rainfall, geological formation of soils, wind temperature and humidity of air. Depending upon the nature of catchment and the average monsoon rainfall, the yield from the catchment area is calculated from Strange's table. To ensure more assured supply the rainfall at particular stations is considered for a period of 40 years and arranged in a descending order and the rainfall figure at 76 per cent C.L. is taken for calculating yield based on Strange's table.

Duties

The duty for paddy crop varies with the incidence of rainfall in a particular area. For rice, in terms of depth of water over the ayacut this is 62 inches excluding the rainfall. So the net duty varies from 4 acres/Mcft. to 8 acres/Mcft. where the average monsoon rainfall is up to 25 inches and more than 35 inches respectively. Duty in Abi period is obviously less and is approximately half of the duty in Tabi period as there will be natural rainfall for the area irrigated in Abi season.

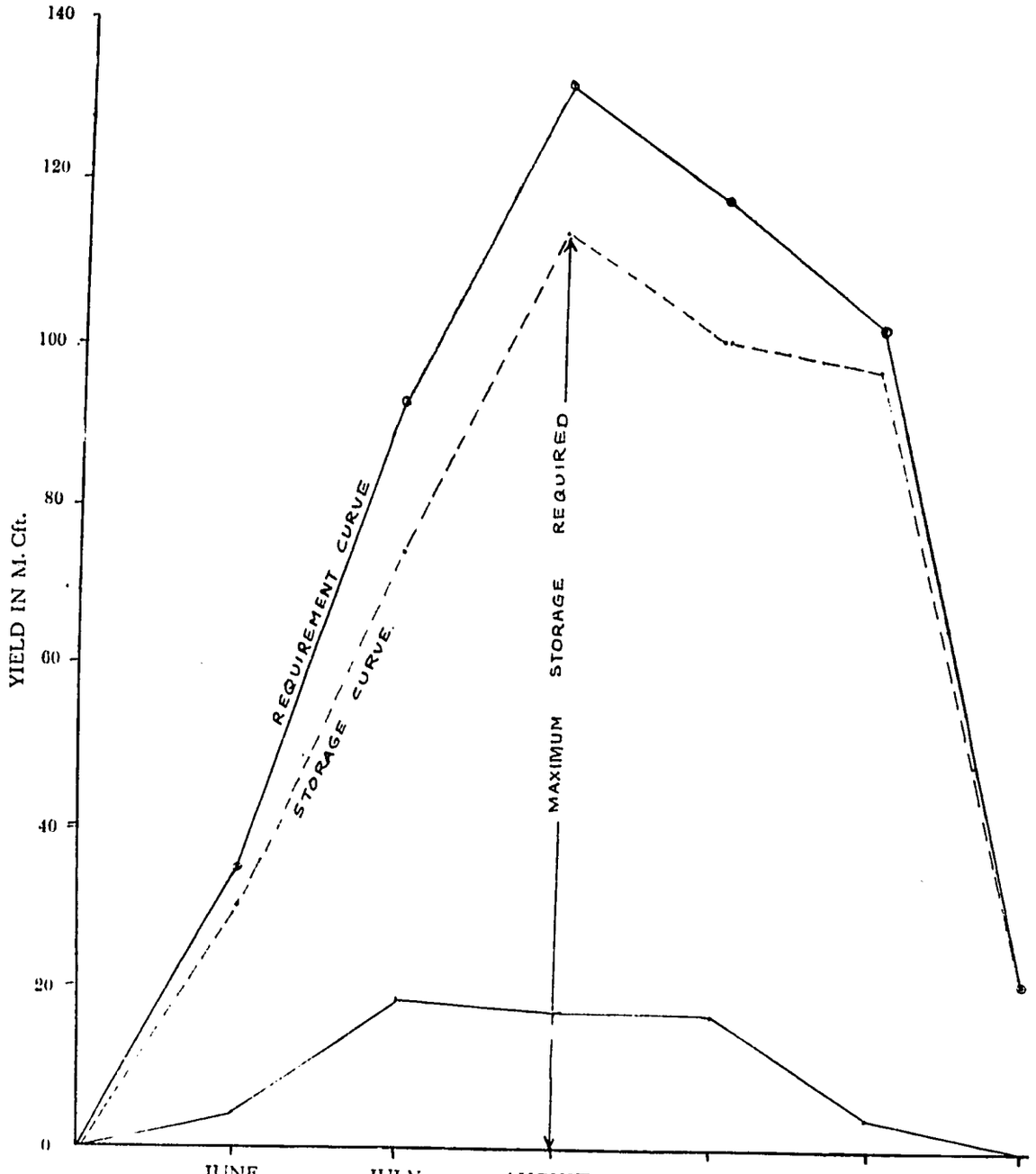
Design Criteria of Tanks and Minor Storage Schemes

The monthly monsoon rainfall of a particular station which influences the catchment (sometimes when the catchment area is large it is influenced by number of raingauge stations. The catchment influenced by each raingauge station is determined by Thyeson's Polygon method), is taken at 75 per cent C.L. and the monthly yield available is calculated by means of Strange's table, depending upon the nature of the catchment. The cropping pattern under any particular project is determined keeping in view the soils available, the existing habits of the villagers and the climatic conditions. The monthly requirements of the cropping patterns proposed are calculated with the duties of different crops. The net requirements are arrived at by deducting the rainfall in the corresponding months. To these net requirements the losses due to evaporation, transmission and percolation are added and the requirement at head works is calculated. Fig. 2 shows the monthly yield available and the total requirements of crop for a particular case, "Sarpanapally Project", Vikarabad, Hyderabad District. The maximum ordinate between the line of yield and demand line indicates the storage needed. The full tank level of the reservoir is fixed at such a level where this capacity is available. The number of fillings are thus deduced by dividing the total net demand by the capacity thus fixed.

Bund Design

The top width and free board of the earthen bund are fixed depending upon the depth of standing water, the fetch of water spread, catchment area and the nature of soils available. The top width varies from 4 to 25 ft. and free board varies from 3 to 10 ft. Table 4 shows the different free board and top widths generally adopted with respect to depth of standing water is enclosed.

FIG. 2. SHOWING MONTHLY YIELDS-REQUIREMENTS AND NET STORAGE OF PRO : SARPANPALLY PROJECT, VICARABAD TALUQ, HYDERABAD DISTRICT, A.P.



	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.
Monsoon Rainfall	1·94"-4·48"	8·15"-18·82"	7·73"-17·85"	7·65"-17·51"	2·12"-4·89"	0·00
Net requirements (including losses)	30·59	74·57	114·15	100·79	97·55	21·55

HYDRAULIC DETAILS

Catchment area	... 27·44 sq. miles	Pro: Capacity	... 190·97"
Nature of C.A.	... Good	Net requirement excluding losses	... 322·84 M. Cft.
F.R.L.	... + 1848·00	Number of fillings excluding losses	... 2·83 or 3.
Ayacut proposed	... 2700 acres	Number of fillings including losses	... 3·85 or 4.
Net requirement including losses	... 439·20 M. Cft.		
Max. storage as per ordinate	... 114·15 M. Cft.		
Add storage at starting level	... 71·62 M. Cft.		
	185·77 M. Cft.		

TABLE 4. STANDARDS FOR TANKS WITH RESPECT TO DEPTH OF STANDING WATER

Depth of water in ft.	Free board in ft.	Top width in ft.	Remarks
5 to 10	3	4	
10 to 15	4	5	
15 to 20	5	6	The slopes generally vary from 1½ : 1 to 3 : 1 depending upon depth of water.
20 to 40	6	15	
40 to 60	8	20	
Over 60	10	25	

Generally for tanks having depth of water at maximum water level upto 15 ft. a homogeneous section is adopted. For tanks holding more than 15 ft. depth of water a zonal section is adopted with a hearting of impervious materials supported by a casing of more pervious or semi-pervious material containing a larger quantity of grit.

Filter

In deep portions of the river and where the depth of water against the section is more than 40 ft. filters could be continuous and in other portions longitudinal filters with cross filters at 30 ft. intervals are generally provided. A layer of sand gravel 3 ft. or more in thickness will be provided between the filter and the embankment material of pervious zone in sections for water depth more than 40 ft. The layer will have down grade of 2 per cent towards the cross filter.

Upstream Blanket

A clay blanket is provided on the upstream side of the embankment when the section has to retain water more than 40 ft. deep and the foundations are relatively pervious. The length of the blanket u/s is determined by the desired length percolation gradient of 10 times height of bund.

Cutoffs Trench

Cutoffs are provided primarily with the object of increasing the creep length. They are generally located in the upstream portion of hearting having a minimum cover of 5 ft. The side slope of trench depends upon the nature of the soil in which it is to be excavated. The depth will be restricted to either half of the depth of the storage or to hard strata whichever is less. The bottom width is generally ¼ of the depth water, subject to a minimum of 10 ft.

Hearting and Casing Zones

The top of hearting zone is generally kept midway between maximum water level and top of bank level and top width will be 6 to 8 ft. or more according as the depth of water is 40 ft. between 40 to 60 ft. or more respectively. The side slopes will be generally 1 : 1. A typical section for a depth of 20 ft. standing water and more is shown in Fig. 3.

Rock-Toe

When the height of bund is more than 20 ft. rock-toe is generally provided. The height or rock toe varies from 1/5 of bund height to 1/6 of bund height for sections to hold water upto 40 ft. and more respectively.

The top width of rock-toe, varies from 3 to 10 ft. depending upon the depth of water and the side slopes will generally be 1 : 1.

Toe-Drain

A toe-drain with 3 ft. bed width and 1 : 1 slopes will generally be provided for drainage. The bottom width is generally increased to suit the drainage to be conveyed. In the stream or river portions the rock-toe will be protected by means of a stone-pitched revetment.

Anicuts

In addition to the 58,500 small tanks, there are innumerable diversion works in Andhra Pradesh. The anicuts across Godavari at Dowlaiswaram and across Krishna at Vijayawada were constructed under the eminent guidance of late Sir Arthur Cotton and irrigate the fertile delta lands.

There are various small Kacha anicuts which are often called "Katwas" made up of mud and rubble by the ryots themselves in almost all of the villages. They can be classified as :

1. Direct Irrigation.
2. Indirect Irrigation.

Direct Irrigation

This is used when the incidence of rainfall is uniform and when there is perennial flow in the stream.

Indirect Irrigation

This is used when the flow in the stream is occasional. The flood water in the rainy season is diverted to storage works through which irrigation is carried out.

The percentage of diversion for direct and for indirect irrigation varies with the equivalent free catchment area and the average monsoon rainfall. Table 4 showing the various diversion percentages adopted with respect to the above factors.

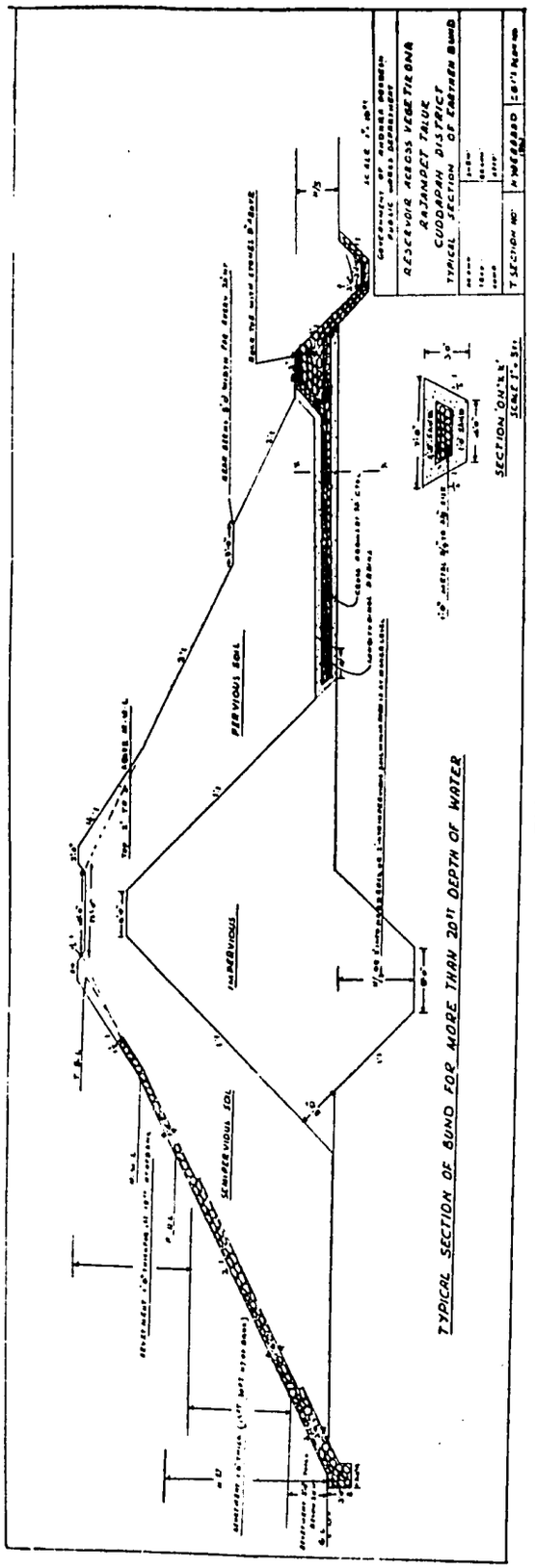


FIG. 3

TABLE 5. PER CENT DIVERSION FOR DIRECT AND INDIRECT IRRIGATION

Catchment area in sq. miles. (Equivalent C.A.)	Monsoon Rainfall in inches	Diversion for direct irrigation (%)	Diversion for filling tanks (%)
1—5	(a) upto 25	10	15
	(b) 25—35	12½	20
	(c) 35—50	15	25
5—15	(a) upto 25	12½	20
	(b) 25—35	15	25
	(c) 35—50	20	30
15—50	(a) upto 25	15	25
	(b) 25—35	20	30
	(c) 35—50	25	35
50—100	(a) upto 25	20	30
	(b) 25—35	25	35
	(c) 35—50	30	40
100—150	(a) upto 25	25	35
	(b) 25—35	30	40
	(c) 35—50	35	45

Duty in Ac/Mcft. (a) : 4 : (b) : 6 : (c) : 8.

Direct diversion schemes are preferred, where conditions permit as there will be practically little foreshore submergence and these are cheaper than storage works.

DESIGN CRITERIA OF ANICUTS

Fixation of Crest.

The crest of the shutters, or where there are no shutters, crest of the solid weir is fixed at such a height as to secure adequate command, i.e. to enable a sufficiently high water level to be maintained in the canal to irrigate the required area by flow. The anicut also must be high enough to ensure passing into the canal adequate quantities of water to supply the seasonal requirements of the crops up to the limit of the full flow of the river. The crest of the anicut is fixed at least 0·5 to 1 ft. more than the full supply level in the channel and the margin between the full supply level and crest is known as driving head.

Location and Design of Anicut

Anicuts are located where the rivers have a straight course, narrow gorge, and where the full command can be obtained by a weir of reasonable height so that the combined cost of construction of the head works and of

cutting the canal from the anicut to where irrigation commences can be as small as is consistent with the efficiency of the works.

Foundations

The foundations of anicuts are generally taken to the hard strata or rock with an intention of saving of huge cost involved in the protective works which are otherwise needed. When it is not possible at reasonable cost to reach hard foundations the anicuts are designed based on Bligh's theory for permeable foundation. Suitable cut-off walls of R.C.C. piles are taken to 1½ to 2 times the scour depth when hard foundations are not available. The aprons are designed based on the straight drop spillway method.

Supply Channel

The supply channel can be classified into two types (a) for direct irrigation, (b) for feeding the tanks.

(a) **Supply channel for direct irrigation.** Direct irrigation under the anicut is generally practiced when the incidence of rainfall over the area is uniform, when the stream is perennial and the flow in the stream is at least equal to the requirements of the ayacut even in the dry months. The channels are designed with a duty of 60 acres per cusec.

(b) **Supply channel for feeding tanks.** These channels are generally intended to carry the total supplies required for the ayacut from the stream when it is in floods. The wet days in a particular area are obtained by means of rainfall atlas and vary from 10 to 30 days a year. The channel is designed to carry the full requirements of the ayacut during the above wet days. Thus the requirements are diverted from the stream which is non-perennial during the wet days stored in the tanks and supplied as per the needs of the ayacut.

Opinion of the Revenue Department

Whenever a new scheme is investigated by the Public Works Department, the Revenue Department is informed of the details regarding the proposed ayacut, the submergency and the probable financial return with a request to furnish the opinion of the Revenue Department on the financial and administrative aspects of the scheme especially with respect to (1) water rate, (2) betterment levy, (3) compensation for the submergible lands, (4) abatement of a land revenue and lower riparian rights. After receipt of the Collector's opinion, the scheme is referred to Board of Revenue if the cost exceeds Rs. 250,000 before giving administrative sanction. For scheme costing less the Chief Engineer is competent to accord administrative sanction based on Collector's approval without referring it to Board of Revenue.

Betterment Levy

When the proposed irrigation projects materialise, the value of dry lands coming under the command of the project, increases many-fold. The Government have felt it appropriate to collect a part of the increased value of the lands from the ryots. They have accordingly enacted legislation called "Andhra Irrigation (Levy of Betterment Contribution) Act, 1955" according to which betterment charges are leviable for providing assured supplies to the ayacut if the cost of the scheme exceeds Rs. 100,000 as given below. As per the practice followed the following are the rates of betterment levy.

1. Betterment contribution in respect of conversion of dry lands to wet. Rs. 200/acre
2. Betterment contribution in respect of precarious wet to wet. Rs. 100/acre
3. Betterment contribution in respect of conversion of registered wet to wet. Rs. 50/acre

Reference to Forest Department

Generally, while starting investigation of any new project care is taken to see that no reserved and rich forest comes under foreshore submergency. It is also very rare that deforestation is needed for developing the

ayacut. In spite of the above if some forest area comes under submergency the Chief Conservator of Forest will be supplied with the relevant maps showing the proposed project, foreshore submergency, etc , and he will be requested to accord permission. The Forest Department generally transfers the area, to be deforested, free of cost to the Public Works Department. After the concurrence of the Forest Department the scheme is sanctioned.

TABLE 5. AREA IRRIGATED UNDER RICE, SUGARCANE AND WHEAT, ANDHRA PRADESH, 1960-61

S.No.	District	Rice		Sugarcane		Wheat	
		Area (acres)	Outturn (tons)	Area (acres)	Outturn (tons)	Area (acres)	Outturn (tons)
1.	Anantapur	1,38,647	79,638	9,068	28,639	2,421	320
2.	Chittoor	3,20,330	1,90,604	24,439	76,890	393	50
3.	Cuddapah	1,59,410	97,174	1,324	6,457	428	50
4.	East Godavari	7,33,944	4,16,972	28,345	90,055	...	...
5.	Guntur	5,50,939	3,84,538	2,057	7,282	576	80
6.	Krishna	8,85,860	5,08,689	17,106	67,136	37	...
7.	Kurnool	1,39,044	45,106	1,216	4,305	2,963	420
8.	Nellore	5,30,806	2,57,017	40	142	...	...
9.	Srikakulam	6,60,908	2,81,429	22,774	52,413	...	...
10.	Visakhapatnam	3,52,880	1,17,457	31,289	82,213	...	...
11.	West Godavari	8,87,088	4,66,719	30,672	1,09,692	411	10
12.	Adilabad	1,28,047	38,957	189	669	11,666	960
13.	Hyderabad	1,07,857	42,091	1,136	4,022	1,845	110
14.	Karimnagar	2,36,932	74,238	94	333	1,247	90
15.	Khammam	2,85,819	52,036	...	...	60	...
16.	Mahboobnagar	2,11,545	1,01,432	111	393	4,790	280
17.	Medak	2,17,036	65,736	10,552	37,371	11,902	970
18.	Nalgonda	3,69,657	1,46,776	7	25	99	...
19.	Nizambad	2,94,605	1,64,818	45,073	2,32,042	6,325	470
20.	Warangal	2,35,854	71,269	3	11	545	30
	Total	73,17,208	36,02,696	2,25,995	8,00,090	45,350	3,840

Cost

A major portion of small tanks were under the control of the Zamindari system till recently. These tanks after their initial construction were not properly looked after and maintained during the jageer days. As a result, they are in state of dis-repair and the ayacut under them was gradually diminishing. On abolition of the Zamindari system the Government have taken over all such tanks, and much headway is being made towards restoring these long neglected sources. The cost of restoration generally works out to Rs. 250 to Rs. 350 per acre of irrigated area. The cost of constructing new sources already under execution and those already sanctioned is generally working out to an acreage figure of Rs. 800. The cost of diversion schemes is working out to Rs. 350 per acre.

Maintenance of Minor Irrigation Works

The tanks, numbering 58,500 which from the bulk of minor irrigation work in Andhra Pradesh, pose the main problem of maintenance. The initial restoration of tanks having more than 25 acres of ayacut is done by Public Works Department and the tanks are maintained by the State Public Works Department or are handed over to Zilla Parishad for maintenance depending upon the ayacut limit as detailed below. There are different practices in the State for maintaining these tanks. In Andhra region tanks having ayacut 200 acres and more are looked after by the State Public Works Department and the rest by Zilla Parishads. In Telangana area, the tanks having ayacut of more than 100 acres are looked after by the State Public Works Department and the rest by Zilla Parishads.

DEVELOPMENT OF SMALL IRRIGATION PROJECTS IN TURKEY—HACILAR PROJECT

by

Lutfi Dincer*

INTRODUCTION

Development of water resources in Turkey is carried out by following river basin development plans in which projects are recommended for implementation according to results of investigations on interrelated land and water resources in each river basin. However, in the river basins there are some projects, which are called "small water projects", that can be undertaken individually and independently from the river basin development. Such projects are implemented under a programme which is separate from the programme for the development of the river basins.

Investigations and planning work involving these projects is not as involved as required for river basins. Small projects require smaller investments and can be implemented and start producing benefits within a shorter time. Through small water development projects it becomes possible to produce benefits in many places and attain the aims of social justice throughout to country. It is also possible to obtain the participation of the local people in these projects.

In Turkey there are two agencies which deal with small water projects. The General Directorate of Soil Conservation and Farm Irrigation (TOPRAKSU) handles projects which require water with a discharge of under 500 lt./sec., and the General Directorate of State Hydraulic Works (DSI) handles projects requiring larger discharges.

In accordance with a protocol between those two agencies, the division of projects involving water storage is made on the basis of the heights of the storage facilities. (TOPRAKSU) performs the studies and construction work for small dams up to 10 meters in height, and the studies and construction work for larger dams are performed by DSI.

Procedures

Transmittal of small water resources development projects to either DSI or TOPRAKSU and the later stages such projects go through to consist of the following :

The Request. In most cases requests concerning small water projects are made verbally or in writing by the local people, by administrative officials, or members of the Parliament on behalf of the people. Such requests concern the improvement of an existing irrigation project, remedying of water shortages, or providing irrigation water to the lands of villagers who realize that water is needed for the development of their existing land resources.

Small water projects may also be determined by the local organizations of the two agencies without such a request.

Preliminary Investigations. Preliminary investigations are carried out in the field using maps of 1 : 25,000 scale. The irrigability of the area, the availability of water, and the relationship of the project with the river basin development plan are determined. Approximate cost and the benefit-cost ratio are calculated, and the participation of the

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people in the investment, in the form of labour and funds, is indicated.

Planning Studies. Planning studies are carried out for projects which are found suitable among those for which the preliminary investigations are completed. Water analyses are made during this stage. Evaluations are made of the records of gaging stations which may have been installed after preliminary investigations or of the records made during independent observations made during various seasons where stations were not established. Maps of 1 : 5,000 scale are made for the irrigation area and, if the project contains storage works, maps for the dam-site (1 : 1,000) and for the reservoir area (1 : 5,000) are prepared. Studies in lands classification and agricultural economy are conducted. For the storage works, detailed geologic investigations, exploratory drilling for foundations, and studies of construction materials are performed. In the light of the data thus obtained, new determinations of the estimated cost and the cost-benefit ratio of the project are made.

Construction Programmes. Projects to be included in construction programmes are selected mainly on the basis of the following criteria :

1. Estimated cost and benefit-cost ratio,
2. Difference between annual benefits and annual costs,
3. Participation of the local people in the investment by contributing funds and labour,
4. Undertaking of the local people to pay the amortization of the investment and to provide the operation and maintenance of the project,
5. The location of the project in the country and considerations of social justice.

Design and Construction. Projects are built either by force-account or by contractors. Inexpensive and simple projects, and especially these projects in which local people are participating, are built by force-account. The construction drawings for such projects are prepared by DSI or TOPRAKSU. The local people provide active help in canal excavation and transportation of materials, and they guarantee that rights-of-way shall be provided for the works without any problem of expropriation. The agencies build diversion works and structures.

The projects where local people participate by providing funds only and the larger projects are built through contract awards. Awards are made on the basis of preliminary designs prepared by the agencies. Construction drawings are prepared by the contractor and become effective when approved by the agencies. Construction work is supervised by these agencies.

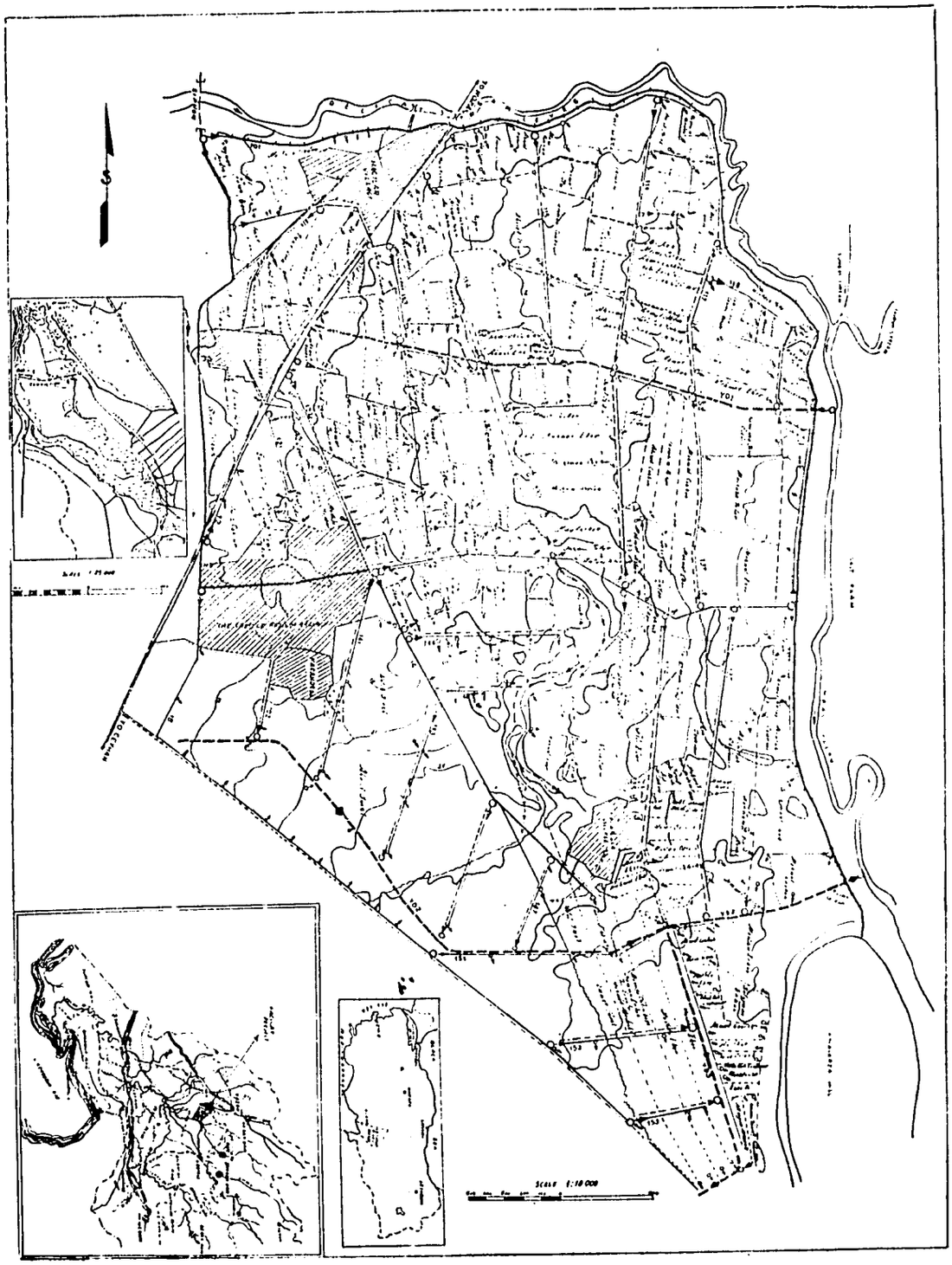
Operation and Maintenance. When the construction of a project is completed, it is transferred to the village, municipality, or a Committee of Village Elders concerned, or, if there exists one, to an irrigation district. Operation, maintenance and repair, etc., are performed by the above parties in accordance with contracts which they sign with the agencies.

THE HACILAR VILLAGE

The Hacilar Village is located in the Kozan plain, in Ceyhan River Basin. The population of the village is 1,600. Total land is 1,534 Ha. and gross irrigable area is 1406 Ha.

There are two springs which have permanent discharge for irrigation in the project area. One, Bekirce Spring has a 930 lt./sec. discharge, and other, Alapinar Spring discharges 270 lt./sec.

The village people have sold their water rights for 270,000 T.L. annually. With this money, they built a primary school, a village administration building, a library, a mosque, an auditoruim, roads in the village and a levee along the Dolicay Stream in order to protect their land from flood damages.



LCCATION

The Ceyhan River Basin is located in the South of Anatolia. It is surrounded by Euphrates, Seyhan, Asi Basins and the Mediterrenean Sea. The drainage is 22,000 Km.², which is 2·9 per cent of the area of Turkey. The population of this area is 775,000 which is 2·75 per cent of population of Turkey.

The annual average water potential of the Ceyhan River is 6,810 billion m³. 300,000 Ha. out of 530,000 Ha. of total bottom land in the basin is irrigable according to preliminary soil classification studies.

As a result of preliminary investigation made during 1957-1958, 13 dams were chosen for construction. Their total storage capacity is 9,095 billion m³. Five of those dams and 4 river power plants will produce 2·6 billion Kwh. energy annually, and 2,67,000 Ha. of land will be irrigated ; 33,000 Ha. of land will be protected against flood damages.

Total estimated cost is 4,370 billion T.L., average estimated annual cost is 373 million T.L., annual estimated benefit is 631 million T.L., and benefit-cost ratio is 2·40 : 1.

The Ceyhan River Basin is divided into 14 individual projects. The Hacilar Village is located in the Kozan Plain which is in the Lower Ceyhan Project area. The Ceyhan Plain covers 205,000 Ha. and 1,27,000 Ha. land out of 1,60,000 Ha. irrigable land in this plain will be irrigated by Aslantas, Kesiksuyu, Savrun and Kozan Dams.

The capacity of right bank main canal is 76 m³/sec. at the beginning of the canal. The capacity of the left bank main canal is 103 m³/sec. including 15·0 m³/sec. water to irrigate 12,300 Ha. coastal plain in the adjacent Asi River Basin. The feasibility studies of Ceyhan Basin are being made by an American Engineering firm.

Bekirce and Alapinar Springs are located far down from the main canals, but they supply very little water as compared to the water to be carried by the canals. Since they provide development in a short period it is preferred to put them under service as a small project instead of waiting for the whole scheme.

COOPERATION BETWEEN FARMERS IN HACILAR VILLAGE AND THE GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS (DSI)

As mentioned previously, the villagers have sold their annual water rights for 270,000 T.L./year. Since they have some investment capability they want to develop their land resources by providing irrigation and drainage systems. First they engaged an engineering company to prepare a feasibility report and preliminary designs for the project. Then they applied to the General Directorate of State Hydraulic Works for cooperation in order to get their project realized by giving assurances satisfactory to State Hydraulic Works that they will do the following :

a. Provide without cost to DSI all lands, and rights-of-way necessary for the construction of the project.

b. Contribute 5 per cent of the actual cost of the project.

c. Maintain and operate the project after completion in accordance with regulations prescribed by the State Hydraulic Works and collect the necessary statistical data.

d. Pay 250,000 T.L. to DSI in three years.

The agreement between DSI and Hacilar Village is signed, and the project is ready for award to a contractor. The construction will begin this summer.

TECHNICAL DATA

Description. The land of Hacilar Village is surrounded by Delicay and Sumbas streams on the north. Sumbas stream on the east, Anavarza Hill and Castle on the south and

Ceyhan-Kozan Highway on the west. It covers 1534 Ha.

The plain is formed by the quaternary alluvial deposition of Delicay and Sumbas Streams. There is a fault line through the plain. A big earthquake accurred in 524 A.D. The plain used to be flooded by Sumbas and Delicay streams. It is now protected by levees.

Climate and Water Requirements. The Hacilar plain has a typical Mediterrenean climate with hot and humid summers and mild and rainy winters. The lowest recorded temperature is 4°C, the highest temperature is 36°C. Average annual rainfall is about 750 mm.

The water requirement has been determined by Blaney-Criddle method using data from Kozan and Ceyhan meteorological stations Average rainfall of driest five years has been considered. The field irrigation efficiency has been taken as 65 per cent.

The irrigation modulus has been found to be 0·867 lt./sn./da. for July. The water supply consists of the two Springs. There is no gaging station at these springs, but the discharges were measured several times. Bekirce spring has 930 lt./sec. permanent discharge and it belongs to the Hacilar Village. Alapinar spring has 270 lt./sec. discharge, but 70 lt./sec. belongs to Alapinar Village. Thus the Hacilar Village has a total of 1·130 m^3/sec. water for their project.

Quality of Irrigation Water. Bekirce and Alapinar springs are of excellent quality. According to the U.S. Salinity Laboratory Standards the water is C_2, S_1 class. This means that soluble salt content is medium and sodium hazard is low.

On the other hand, during land classification studies, the quality of the water-table and artesian water was examined also. The salt content of the water-table is moderately high but sodium hazard is low (C_3, S_1). Under the existing conditions, as long as the water-table stays below the root zone, it is not dangerous.

Artesian water is used as domestic water supply at the project area. According to the laboratory analysis this is of excellent quality for drinking.

Soil Resources. Soils of the project area have been developed under the influences of the Ceyhan River and side streams. The soils are strongly calcarious and there are alluvial deposits. The surface soils are gray-brown and very rich in organic matter. The subsoils are light gray-brown, yellow, and poor in organic matter.

Laboratory permeability of the project soils is very poor. On the other hand, with the exception of one profile, soluble salt and exchangeable sodium contents of the surface and subsoils are very low. Although the disturbed permeability of the subsoils was low, permeability tests made using auger hole method at the field have indicated satisfactory conditions (2 cm. per hour). A great part of the project area consists of Class Three soils. In 90 per cent of the area, surface and subsoils are heavy texture. A large portion of the area consists of smooth gently sloping land with 0·2 per cent slope.

Although the water-table is high in winter it goes down during summer after Delicay River dries. The physical and chemical conditions of soils are fairly good, but because of their heavy texture and because the lower part of the profile has impermeable strata they were classified as Class Three. On ten per cent of the total area, surface and subsoils are medium textured with underlying materials containing varying amounts of sand or gravel. The soils have the characteristics of Class 1 or Class 2, but having a very restricted impermeable layer, they are also classified as Class 3.

Proposed Structures. Bekirce spring will be connected to downstream channel of Alapinar spring by a 850-m. long canal, and then the water of both springs will be conveyed to the project area by a 3-Km. long conveyance canal and a inverted siphon passing the Delicay. The siphon has been constructed.

It is a cast-in-place reinforced pipe and has a 1·30 m. diameter. The siphon will be protected upstream and downstream by riprap.

The Irrigation System. After the siphon there is a 2,680 km. long main canal and 5 secondary canals (total length is 14·800 m.) A 1/5000-scale map of the project area, having 20 cm. contour intervals and showing the property lines, has been prepared. For the layout of the canals, property lines have been taken into consideration.

All the canals will be lined. There will be a turnout for each farm. The water level in the canals will be 20 cm. higher than land surface level. The thickness of the lining is 8 cm. for the conveyance and main canals, 6 cm. for the others. A freeboard is 20 cm. for the conveyance and main canals, 15 cm. for the secondaries, 12 cm. for tertiaries and 10 cm. for the others. The conveyance and the main canal will have 0·0001 slope in order to reduce the area which will be irrigated by pumping. A 35 Ha. area just below the main canal will be irrigated by pumping, another area of 1371 Ha. by gravity.

For discharges larger than 70 lt./sec., constant head orifice turnouts are used, for lower discharges, special farm turnouts have been selected. The minimum turnout capacity is 30 lt./sec.

The checks are designed for 3 cm. head loss, and because the water does not carry silt, the checks are equipped with check-boards instead of gates. The drop structures are combined with checks. Concrete pipe bridges are placed where drop structures are necessary, and are combined with them. All the canals have 1 to 1½ side slopes.

The Drainage System. The main drainage canal and laterals will be deep canals with 2·20 m. freeboard. Other drainage canals will be deep enough to obtain earth necessary for irrigation canal embankments and roads.

It is planned to construct two outlets with flap-gates at the north of Anavarza hill, and one at the south of Anavarza hill into Sumbas stream for waste water.

It may be useful eventually to have an intercepter canal along Delicay levee.

The permanent drainage discharge is 0·40 lt./sec./Ha. including 5 per cent seepage from lined canals, 8 per cent operation loses, 15 per cent surface flow, 10 per cent deep seepage, totalling 38 per cent of 0·8 lt./sec./Ha. irrigation modulus and 0·10 lt./sec./Ha. seepage from Delicay stream. Artesian seepage has not been observed.

Sources of Construction Materials

Embankments. Suitable materials for construction of levees and roads are available from required excavation of drainage canals.

Concrete aggregate. Adequate quality and quantity of concrete aggregate is available from the bed of Delicay stream. Average hauling distance for aggregate is 3 Km.

Riprap. Riprap material of satisfactory quality and quantity is available at Anavarza Hill. The average hauling distance is 3 Km.

Cement. Cement will be provided from the cement factory in Adana.

Cost Estimates. The unit prices of State Hydraulic Works based on 1962 price levels were used for cost estimating.

Description	Amount T.L.
Excavation	645,000
Construction	520,000
Linings	645,000
Structures	715,000
Haul	1,050,000
O and M Buildings	270,000
Communication System	40,000
Roads	415,000
Inverted Siphon	170,000
Subtotal	4,470,000
Contingencies 15%	670,000
Subtotal	5,140,000
Engineering, Design, Supervision and Administration	770,000
Rights of way	90,000
Total	6,000,000

Rights-of-way will be paid by the people of Hacilar Village canal which will pass through the land of other villages.

Agricultural Economy. Out of the 157 families in the Hacilar Village 127 own their land and the others are workers.

Ceyhan-Kozan asphalt road passes through the village, and the village is 40 Km. from Ceyhan, 7 Km. from Kozan. It is connected to Kadirli with a 22 Km. long asphalt road.

There are 268 lots in the Hacilar plain which cover 1,406 Ha. Out of this 255 lots which cover 1,351·7 Ha. belong to the Hacilar Village and 13 lots which cover 44·5 Ha. belong to the Gazikoy Village.

Table 1 shows the number of lots, the number of owners and average size of lots according to their sizes.

Not long ago farmers raised animals in the project area. As a result of introduction of market facilities they began to produce cotton and wheat. Under dry farming, the yield is 1,200 kg. per Ha. for wheat and 1,000 kg. per Ha. for cotton.

The present annual income is shown in Table 2.

In addition, they have 270,000 T.L. annual income from the sale of the water right. Total present annual income is 1,390,000 T.L.

According to soil and climatic conditions, and marketing facilities, the crop pattern was selected as follows for irrigated farming : plums 5 per cent, strawberries 4 per cent, tomatoes 5 per cent, cotton 28 per cent, wheat 18 per cent, pasture 30 per cent, rice 10 per cent, corn 18 per cent.

Net irrigable area is 1,336 Ha. The computation of annual income in irrigated farming is given by Table 3.

Assuming that the development period will be 5 years, the estimated annual income will be 4,720,000 × 0·90 = 4,250,000 T.L. Estimated annual benefit of project will be 4,250,000 to 1,390,000 = 2,860,000 T.L.

Economic Analysis. Based on an assumed project life of 50 years and an interest rate of 5 per cent, estimated average annual cost is as shown by Table 4.

A comparison of estimated annual benefits with estimated average annual costs indicates a benefit-cost ratio of 8 to 1.

Repayment. Annual average income of a farmer is calculated as 30,074 T.L. under the project. Annual average living expense is calculated as 10,400 T.L. at the present time. With a 25 per cent safety factor repayment capacity of a farmer, will be 147·56 T.L. per decar.

Assuming that the living standard of a farmer will increase 50 per cent, the repayment capacity will be 108·56 T.L. per decar, with an increase of 100 per cent, the repayment capacity will be 68·56 T.L. per decar.

Construction Programme. The feasibility report and preliminary designs of the project were prepared by **Isik Engineering Company** of Ankara. They were approved by State Hydraulic Works.

The project will be constructed by a contractor in three years. A control office will be established in Hacilar Village by the VI Regional Directorate of State Hydraulic Works.

For participation in the bidding, the contractors are requested to have 5 trucks, 1 excavator. (1·5 c·y), 1 loader (1 c·y) and 3 crushers.

As a requirement of the construction programme it was required that some part of project should be ready for irrigation each year. As customary, the contractor will receive payment on a monthly basis.

Operation and maintenance. The Eldermen's Commitee of the Hacilar Village will be responsible for the operation and maintenance of the project according to the conditions prescribed by the State Hydraulic Works. Maintenance will include, but not be limited to, maintaining the canals bridges,

TABLE 1. DISTRIBUTION OF LOT SIZES

Size Limits of Lots (Decar)	Lots			Owners			Average Size of Lots (Decar)
	Number	%	Area (Decar)	Number	%	Area (Decar)	
0—10	13	4·9	102·2	4	2·8	28·1	7·0
11—20	51	19·0	783·6	19	13·7	268·5	19·6
21—50	124	46·3	4,151·2	48	35·5	1,555·8	32·4
51—100	59	22·0	4,081·1	36	26·0	2,538·0	70·0
101—500	19	7·1	2,816·7	27	19·5	4,706·4	157·5
501 or larger	2	0·7	2,127·2	5	3·5	4,965·2	993·0
	268	100·0	14,062·0	139	100·0	1,4062·0	

TABLE 2. PRESENT ANNUAL INCOME

Crop	Area (Ha.)	Yield (Kg./Ha.)	Market Price (T.L./Kg.)	Gross Income (1,000 T.L.)	Production Cost (1,000 T.L.)	Net Income (1,000 T.L.)
Cotton	570	1,000	2·00	1,140	380	760
Wheat	725	1,200	08·0	696	346	360
Fallow	110	—	—	—	—	—
	1,405			1,836	726	1,120

TABLE 3. COMPUTATION OF INCOME UNDER IRRIGATION FARMING

Crop	Cultivated Area (Ha.)	Cultivated Area (%)	Yield (Kg. per Ha.)	Market Price (T.L./Kg.)	Gross Income (1,000 T.L.)	Production Cost (1,000 T.L.)	Net income (100 T.L.)
Plums	66·8	5	24,000	1·00	1,600	420	1,180
Strawberries	53·4	4	4,000	3·50	760	405	355
Tomatoes	66·8	5	40,000	3·50	1,335	445	890
Cotton	374·1	28	1,500	2·00	1,125	675	450
Wheat	240·5	18	2,000	0·80	385	160	225
Mixed Pasture	400·8	30	12,000	0·25	1,200	720	480
Rice	133·6	10	4,000	2·40	1,280	290	990
Corn	240·5	18	30,000	0·06	435	285	150
Total	1577·5	118			8,120	3,400	4,720

crossings, culverts turnouts, checks, and other water conveyance works in their original capacities. This will include removing obstructions in canals such as sediment and debris, vegetation, and other materials, prevention and prompt repair of damages caused by livestock, rodents, seasonal runoff or factors. All the structures will be maintained under good and effective conditions.

For operation, an area irrigation office will be established with an irrigation technician, a maintenance man, three ditch-riders, an accountant and warehouse watchman, a cashier and typist.

A pick-up truck will be sufficient for operation and maintenance activities. Cleaning of canals will be made by hand labour. Other necessary machines will be rented.

Modified demand system will be applied during operation of the project.

Suitable assessments will be made by the Eldermen's Committee (or Hacilar Village Irrigation District which will be established later), to provide funds for adequate maintenance and operation agreed upon. They will also contribute the amortization of project cost.

TABLE 4. ESTIMATE ANNUAL COST

	Description	Cost T.L.	Amortizasion, O and M Replacement Factor	Annual Cost T.L.
1.	Excavation	645,000	0·07016	45,000
2.	Construction	520,000	0·06016	31,000
3.	Lining	645,000	0·06016	39,000
4.	Structures	715,000	0·06016	43,000
5.	Haul	1,050,000	0·0548	58,000
6.	O and M Building	270,000	0·0650	18,000
7.	Communication System	40,000	0·07095	3,000
8.	Roads	415,000	0·7016	29,000
9.	Inverted siphon	170,000	0·06016	10,000
10.	Contingencies	670,000	0·0548	27,000
11.	Eng. Des. Sub. ad.	720,000	0·0548	42,000
12.	Rights-of-way	90,000	0·0548	5,000
				360,000

CHAPTER XII

RESEARCH

DETERMINATION OF POTENTIAL EVAPO-TRANSPIRATION BY USING THE THORNTHWAITE METHOD

by

Mufit Kulen and Orhan Akyurek*

THE THORNTHWAITE METHOD

The effects of various factors such as temperature, humidity, wind velocity, vapour pressure, and solar radiation on potential evapo-transpiration (P.E.T.) were studied by several researchers. Penman made the most complete approach in which P.E.T. is related to various factors including solar energy received. But this formula cannot be applied for any station desired because data required are not universally available.

On the other hand, Thornthwaite developed an empirical formula in which P.E.T. is expressed as a function of mean temperature.

The Thornthwaite formula is

P. E. T. = ct^a

P. E. T. = Potential evapo-transpiration, cm./month

t = Mean monthly temperature, degrees centigrade

c and a = Constants depending on the station.

The formula gives results for a month of 30 days where each day is assumed to receive sunlight during 12 hours. For obtaining actual P.E.T. values for any particular station and month, the results are multiplied by correction factors representing both the effect of latitude where the station is located and the effect of the variation in the duration of the days during that month from the 12 hour standard given.

APPLICATION OF THE METHOD

For finding monthly P.E.T. values a nomograph was prepared Fig. 1. The values for each year at a given station may be represented by a straight line in this nomograph. The straight lines for all stations meet at a point which is called the "Index Point". The slopes of these lines depend upon the values of "Annual Heat Index" for each station and year.

The annual heat index is the sum of the values of monthly heat indices given by

$$I = \left(\frac{t}{5}\right)^{1.514}$$

I = Monthly heat index,

I = Mean monthly temperature, degrees Centigrade.

This relationship may be represented by a graph or given in table form, as in Table 1.

The nomograph is used as follows for finding monthly P.E.T. value at a particular station :

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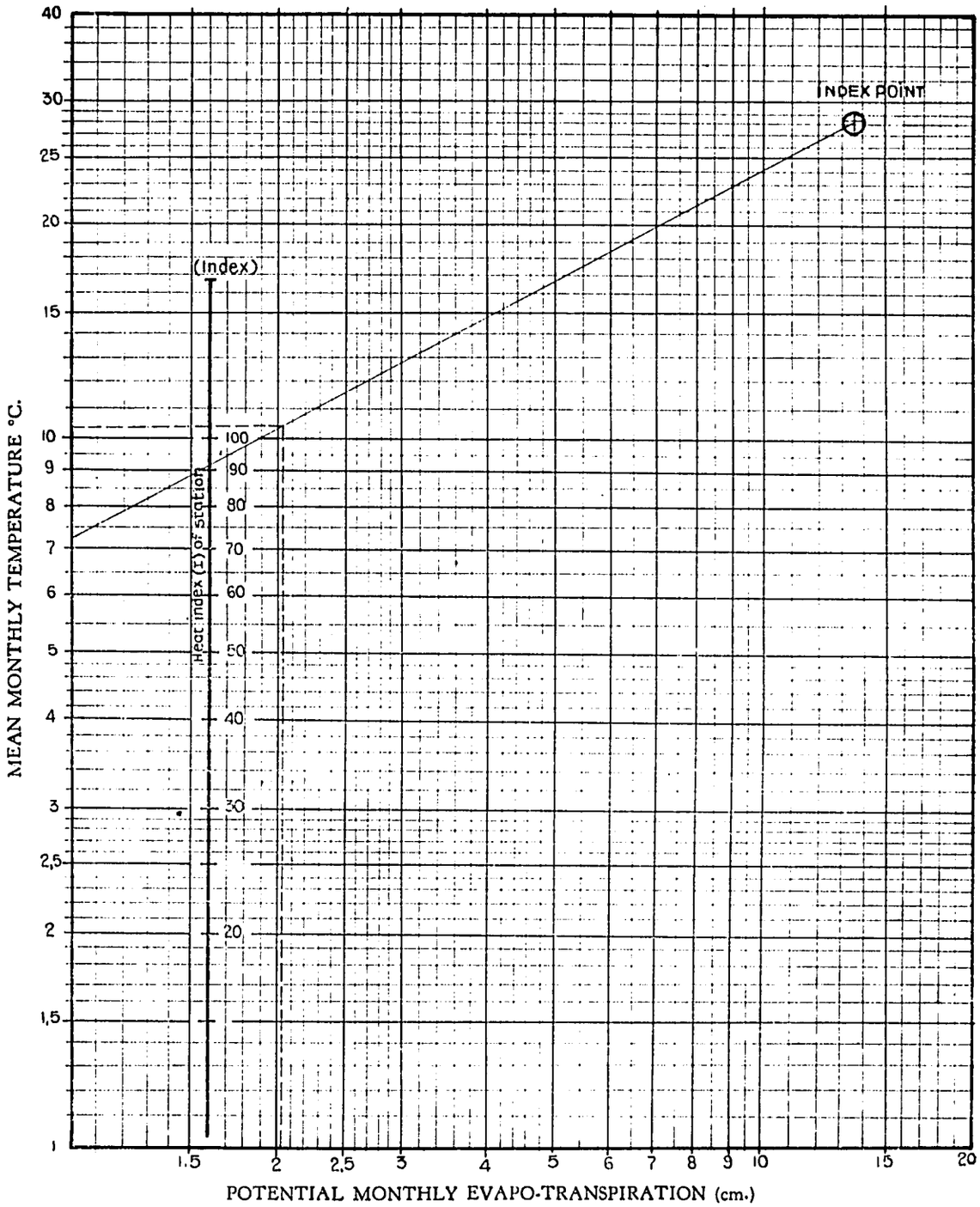
FIG. 1. NOMOGRAPH FOR COMPUTING MONTHLY EVAPO-TRANSPIRATION BY THORNTHWAITE METHOD



1. The monthly heat index values corresponding to monthly mean temperatures are taken from Table 1.
2. The value of annual heat index is found by adding monthly heat index values.
3. This value of annual heat index is marked on the heat index line in the nomograph.
4. A straight line is drawn passing through the index point and the point mentioned above. This straight line represents the relationship at the station for that particular year.
5. To find the P.E.T. for each month, a horizontal line is drawn from the point corresponding to the mean temperature for that month. Where this line crosses the sloping line previously established a vertical line is drawn to find the P.E.T. for that month.
6. The correction factor to be applied to the monthly P.E.T. values are given in Table 2. The factor corresponding to the latitude of the station and the month under consideration is taken from the table. The above value of P.E.T. is then multiplied by this factor to obtain the correct value.

Monthly P.E.T. for temperatures higher than 26·5°C. cannot be read from the nomograph. Such values are given in Table 3.

DISCUSSION

The Penman and Thornthwaite Methods were developed for conditions where the soil is sufficiently saturated for normal growth of plants. In semi-arid and arid regions the Blaney-Criddle Method, which is developed by statistical correlation, gives results which approach the actual conditions more closely. On the other hand, for humid and semi-humid regions the Penman Method is the most rational method because it is based on the principle of conservation of energy.

In the coastal plains of Turkey in the Mediterranean and the Aegean Regions, where semi-humid climate prevails, the Penman Method will give the best results. But there are not many stations where data required by this method are sufficiently available. A correlation between the Penman and Thornthwaite methods was established in the Lower Seyhan Project where there were sufficient data. The results for winter months were not in good agreement. But the results for the months from April through October were in good agreement. Fig. 2 gives the P.E.T. values

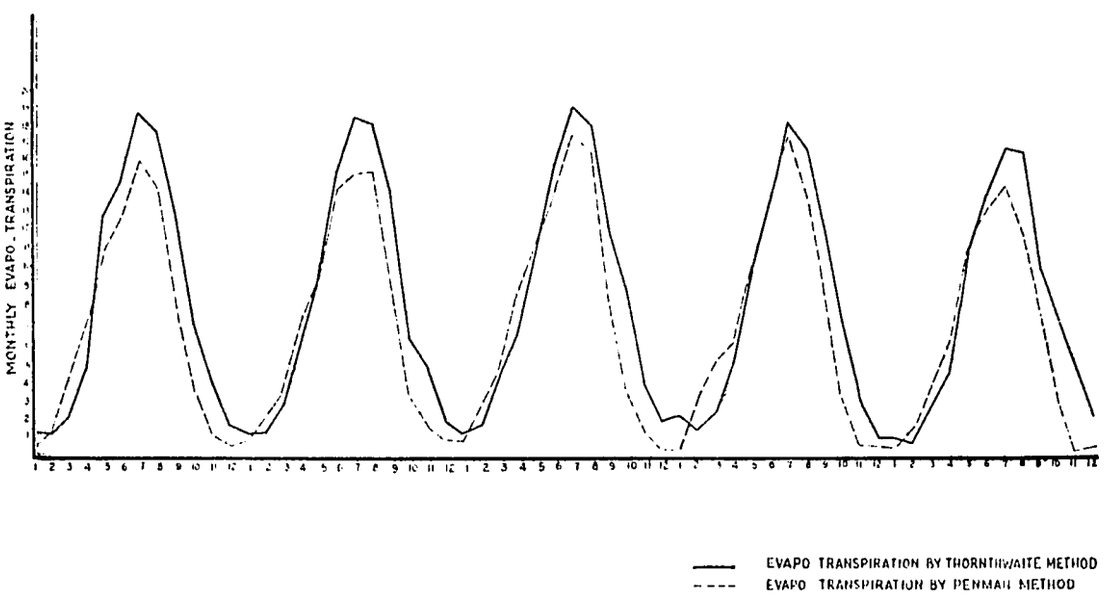


FIG. 2. POTENTIAL EVAPOTRANSPIRATION IN LOWER SEYHAN PROJECT FOR FIVE CONSECUTIVE YEARS

TABLE 1. HEAT INDEX VALUES CORRESPONDING TO MEAN MONTHLY TEMPERATURES

Mean Monthly Temp. °C.	Heat Index	Mean Monthly Temp. °C.	Heat Index	Mean Monthly Temp. °C.	Heat Index
0·0	0·00	13·5	4·50	27·0	12·85
0·5	0·03	14·0	4·75	27·5	13·21
1·0	0·09	14·5	5·01	28·0	13·58
1·5	0·16	15·0	5·28	28·5	13·94
2·0	0·25	15·5	5·55	29·0	14·32
2·5	0·35	16·0	5·82	29·5	14·69
3·0	0·46	16·5	6·10	30·0	15·07
3·5	0·58	17·0	6·38	30·5	15·45
4·0	0·71	17·5	6·66	31·0	15·84
4·5	0·85	18·0	6·95	31·5	16·23
5·0	1·00	18·5	7·25	32·0	17·01
5·5	1·16	19·0	7·55	32·5	17·01
6·0	1·32	19·5	7·85	33·0	17·41
6·5	1·49	20·0	8·16	33·5	17·81
7·0	1·66	20·5	8·47	34·0	18·22
7·5	1·85	21·0	8·78	34·5	18·62
8·0	2·04	21·5	9·10	35·0	19·03
8·5	2·23	22·0	9·42	35·5	19·45
9·0	2·44	22·5	9·75	36·0	19·86
9·5	2·64	23·0	10·08	36·5	20·28
10·0	2·86	23·5	10·41	37·0	20·70
10·5	3·08	24·0	10·75	37·5	21·13
11·0	3·30	24·5	11·09	38·0	21·56
11·5	3·53	25·0	11·44	38·5	21·99
12·0	3·76	25·5	11·78	39·0	22·42
12·5	4·00	26·0	12·13	39·5	22·86
13·0	4·25	26·5	12·49	40·0	23·30

in this project for the years 1945-49 found by the Penman and Thornthwaite Methods. The relationship between the two series of results is expressed by the following empirical formula :

$$\text{P. E. T. Penman} = 0{\cdot}84 \text{ P. E. T. Thornthwaite} + 0{\cdot}20$$

In order to obtain the best possible results for the Mediterranean and the Aegean Regions it is recommended to find the values given by the Thornthwaite method first. Then, by use of the above formula to convert these results into the values corresponding to what would have probably been obtained by the Penman method.

TABLE 2. CORRECTION FACTORS CORRESPONDING TO LATITUDE AND MONTHS

Latitude (Degrees)	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
10	1·00	0·91	1·03	1·03	1·08	1·06	1·08	1·07	1·02	1·02	0·98	0·99
20	0·95	0·90	1·03	1·05	1·13	1·11	1·14	1·11	1·02	1·00	0·93	0·94
30	0·90	0·87	1·03	1·08	1·18	1·17	1·20	1·14	1·03	0·98	0·89	0.88
36	0·87	0·85	1·03	1·10	1·21	1·22	1·24	1·16	1·03	0·97	0·86	0·84
37	0.86	0·84	1·03	1·10	1·22	1·23	1·25	1.17	1·03	0·97	0·85	0·83
38	0·85	0·84	1·03	1·10	1·23	1·24	1·25	1·17	1·04	0·96	0·84	0·83
39	0·85	0·84	1·03	1·11	1·23	1·24	1·26	1·18	1·04	0.96	0·84	0·82
40	0·84	0·83	1·03	1·11	1·24	1·25	1·27	1·18	1·04	0.96	0·83	0·81
41	0·83	0·83	1·03	1·11	1·25	1·26	1.27	1·19	1·04	0·96	0·82	0·80
42	0·82	0·83	1·03	1·12	1·26	1·27	1·28	1·19	1·04	0·95	0·82	0·79
45	0·80	0·81	1·02	1·13	1·28	1·29	1·31	1·21	1·04	0.94	0·79	0·75
50	0·74	0·78	1·02	1·15	1·33	1·36	1·37	1·25	1·06	0·92	0·76	0·70

TABLE 3. POTENTIAL EVAPO-TRANSPIRATION (P.E.T.) FOR MEAN MONTHLY TEMPERATURES ABOVE 26·5°C.
(Without Correction)

Temp. °C.	P.E.T. cm./month	Temp. °C.	P.E.T. cm./month	Temp. °C.	P.E.T. cm./month
26·5	13·5	30·5	16·5	34·5	18·2
27·0	14·0	31·0	16·8	35·0	18·3
27·5	14·4	31·5	17·1	35·5	18·4
28·0	14·8	32·0	17·3	36·0	18·5
28·5	15·2	32·5	17·5	36·5	18·5
29·0	15·5	33·0	17·7	37·0	18·5
29·5	15.9	33·5	17·9	37·5	18·5
30·0	16·2	34·0	18·1	38·0	18·5

ASSESSMENT OF IRRIGATION REQUIREMENTS OF CROPS ON CLIMATOLOGICAL BASIS

by

N. G. Dastane and Mahendra Singh*

INTRODUCTION

Only during the last three decades has climate been used to assess water needs of crops. Formerly these were obtained by studying transpiration ratios and later by noting the effects of different applications of water on yields. Beginning with work of Penman and Thornthwaite in 1948 several formulae using meteorological assessment have been proposed.

Irrigation needs can best be assessed by finding out consumptive use and estimating how much of this need is met by the natural rainfall and then adding unavoidable application losses. In practice, in surface irrigation systems in India, where the fields are rarely designed according to stream size, infiltration rate, slope and depth of water to be applied, irrigation efficiency can be taken as varying from 50 to 70 per cent only. Leaching requirements vary with the quality of irrigation water and salinity status of the soil. On normal soils and with canal water supply, leaching requirements are not important as salts get washed down annually by the natural rainfall.

Assessment of the effective rainfall is difficult. It varies with the initial soil moisture status, physical properties and slope of the soil, root zone of crop, management practices and intensity and distribution of rainfall itself. No formula or estimate has been found perfect in this respect. Instrument described by Ramdas (1960) seems satisfactory under disturbed soil conditions. The only satisfactory method is keeping a thorough and continuous record of soil moisture changes with the help of various soil moisture gauges. Rainfall over and above the soil moisture deficit can be considered as ineffective for all practical purposes.

The climatological approach to consumptive use gives a satisfactory account of crop water needs. According to the climatological concept, when the field is completely covered with vegetation and moisture supply is non-limiting, evapo-transpiration proceeds at the maximum level, 'Potential Evapo-transpiration' which depends on meteorological elements. The role of soil is completely passive under these circumstances. Inadequate cover as well as soil moisture, result in lower evapo-transpiration than the potential.

Comparative merits and limitations of determination of consumptive use of water by crops on soil depletion basis and climatological basis are shown in Table I.

Consumptive use studies were made at the Indian Agricultural Research Institute, New Delhi, during the last four years studying soil moisture depletion and recording meteorological data. Prashar and Singh (1963) compared estimates of evaporation obtained from meteorological data by the formulae Penman (1948) and Walker (1956), with moisture use by wheat, as evaluated from soil-moisture data. The ratio of consumptive use by Penman's formula, varied from 0·63 to 0·80 in 1958-59 and between 0·58 to 0·81 in

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1959-60. The values of consumptive use factors (Blaney and Criddle 1959) ranged between 0·67 to 0·81 and 0·61 to 0·84 in 1958-59 and 1959-60, respectively. The agreement by Walkers' formula was closer, the actual values being 2·05 and 2·29 and those obtained with Walkers' formula 1·70 and 1·87 in 1958-59 and 1959-60 respectively.

Bhattacharya and Srivastava (1962) obtained 8·50 inches actual use from their studies on wheat at Roorkee as compared to figures derived with the formulae of Lowry and Johnson (1942), Blaney and Criddle (1950), Penman (1948), Thornthwaite (1948), Hargreaves (1956) and Van Bavel (1957), which were 22·83, 8·31, 8·51, 11·21, 14·97 and 7·68 inches, respectively.

Ray (1963) studied consumptive use by sugarcane. Actual values varied from 0·47 to 0·64, 0·58 to 0·96 and 0·44 to 0·93 of those obtained from Penman. Thornthwaite and Ramdas' formulae respectively, depending upon the stage of the crop and the inter-crop.

TABLE 1. COMPARISON OF DETERMINATION OF CONSUMPTIVE USE OF WATER ON SOIL AND CLIMATOLOGICAL BASIS

Items	Soil Basis	Climatological Basis
Effective rainfall	Easy to account	Can be assessed only if there are no run-off losses
Dew and rainfall intercepted by vegetation	Not accounted for	Accounted for
Correction for available	Not necessary	Necessary
Correction for canopy percentage	Not necessary	Necessary
Knowledge of effective root zone	Absolutely essential and will affect estimations	Not essential for consumptive use estimation. Independent of crop species
Correction for maturity stage of a crop (yellowing)	Not necessary	Necessary
Shallow water table	Vitiates estimations, corrections necessary	Will not vitiate estimation
Soil water movement in capillary and vapour phase	Affects results	Will not affect results
Irrigation scheduling	Can be precisely based	Comparatively less precisely based for individual farms but satisfactory over large areas
Irrigation depth	Can be precisely determined	Comparatively less precise
Rapidity of measurement	Quick to time consuming depending on the method base. Time consuming and laborious for all practical purposes	Quick after initial work especially with the help of nomograms
Equipment	Simple to costly depending on the method used	Simple to costly depending on accuracy needed
Applicability	Individual farm fields	Useful over large areas

Farmers and canal engineers cannot be expected to use complicated formulas. Actually a high degree of precision is not needed for their purposes, thus a single device using a single correction factor would be desirable. Results obtained at I.A.R.I. are summarized in Table 2 which shows that values of consumptive use during the life of a crop vary from 0·50 to 0·75 of the evaporation from the standard U.S. Land Pan. The coefficient decreased with the time required to establish a canopy over the field and with the length of the time the crop remained yellow while approaching maturity. Inadequate canopy and maturity lower the ratio relatively more during the summer arid period compared to the humid and cool period or winter.

The open pan evaporimeter is a single, inexpensive and simple device. Conditions under which it is installed should be standardised as there are considerable variations in specification, of height above the ground level and the conditions in the vicinity, all of which affect the readings appreciably.

Table 2 also shows that magnitude of application losses is considerable, sometimes exceeding the values of correction factors for canopy, root depth, etc. It is, therefore, necessary to estimate actual and minimum application losses under different conditions of soil, crop, etc. for proper appraisal of irrigation requirements.

TABLE 2. CONSUMPTIVE USE OF WATER, OPEN PAN EVAPORATION AND IRRIGATION EFFICIENCY

S. No.	Worker	Year	Crop	Consumptive use (CU) mm.	Open Pan evaporation from U.S.A. evaporimeter (E) mm.	Factor CU/E	Period required for covering the field in weeks (canopy)	Duration for which crop remains yellow at maturity in weeks	Irrigation efficiency per cent
1.	Prashar	1958-59	Wheat	307	585	0·52	8	4	73
2.	Prashar	1959-60	Wheat	315	649	0·49	8	4	76
3.	Hukkeri	1960-61	Potato	319	420	0·76	5	3	46
4.	Ray	1961-62	Sugarcane	980	1,920	0·51	15	2	76
5.	Davenport	1961-62	Radish	150	200	0·75	3	0	81
6.	Davenport	1961-62	Turnip	165	285	0·54	4	0	76
7.	Davenport	1961-62	Beet	285	413	0·69	4	0	89
8.	Joshi	1963	Onion	486	748	0·65	12	2	75

CONSUMPTIVE USE AND WATER REQUIREMENTS OF COTTON AND RICE IN TURKEY

by

Nevzat Olzap, Nazim Durlu and Erdogan Omay*

INTRODUCTION

At the present time, several research institutions, namely, Tarsus, Eskisehir, and Menemen Irrigation Research Institutes, and Cumra Irrigation Research Station are dealing with consumptive use and water requirements.

Results obtained by the institutes at Tarsus and Menemen on the consumptive use and water requirements of cotton and rice are presented.

INFLUENCES OF VARIOUS QUANTITIES OF WATER AND NITROGEN ON COTTON VARIETIES.

Needs for study

Turkey's average annual lint production amounts to 180,200 tons from a total cultivated area of 650,000 hectares. Cotton is a key element in the Turkish economy, both for internal textile industry and for export as a main source of foreign exchange. Cotton cultivation is mainly concentrated in Southern Turkey. Since Turkey is located at the northern limit of cotton producing areas, varieties of short vegetation period are generally preferred and are usually irrigated during dry summer months.

Irrigation contributes greatly to increased yields which average about 450-600 kg. per hectare under dry farming conditions. Experiments were started in 1961 to determine the basic data necessary for the design of irrigation systems, to determine the proper irrigation time and frequency, the influence of nitrogen and water on the yields of Acala and Coker varieties, and subsequently, consumptive use and water requirements of the best varieties of cotton.

Methods

The experiment has been carried out for two years at the Tarsus Irrigation Research Institute in Southern Turkey, at 11·60 meters above sea level, under clay loam and silty clay soil conditions. A latin square was used for water quantities trial, with split plots for both varieties, and fertilization trials with four replications.

Treatments

A. Water Quantities

a_0 : Dry (check plot)

a_1 : Irrigated 3 times 75 mm. per irrigation

a_2 : Irrigated 4 times 75 mm. per irrigation

a_3 : Irrigated 5 times 75 mm. per irrigation.

B. Nitrogen Fertilization

b_0 : None

b_1 : N_4 (Four kg. of nitrogen per decare)

b_2 : N_8 (Eight kg. of nitrogen per decare)

b_3 : N_{12} (Twelve kg. of nitrogen per decare)

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A total amount of 5 kg. of P_2O_5 per decare was applied to all parcels.

C. Varieties

c_1 : Coker 100 A

c_2 : Acala 130-292

Agricultural Practices

Field preparation and seeding were completed according to local custom. A seed drill was used to sow the cotton in rows spaced one meter apart. The seeding dates were April 9, 1961 and April 17, 1962. At the time of seeding, 100 per cent of the phosphorus fertilizer and 50 per cent of the nitrogen fertilizer were applied along both sides of the rows at a distance of 8-10 cm. at 8-10 cm. depth. The remaining 50 per cent of nitrogen was applied before the first irrigation. At the time of first hoeing plants were thinned to a 25 cm. spacing. Pest control and cultural practices were carried out according to local custom.

Soil Moisture Control and Irrigation

Soil sampling to determine soil moisture was performed using three replications at 7-15 day intervals. Samples were taken at 30 cm. intervals in the soil profile down to a depth of 90 cm. Irrigations were started in the last week of May and following irrigations performed when the available soil moisture at the root zone decreased to 50 per cent. Water was measured by a water meter and an amount of 75 mm. was applied per irrigation.

The volume weight, field capacity, wilting point and available field capacity data based on 30 cm. samples taken from 90 cm. depth are shown in Table 1.

Sowing, irrigation and harvesting dates are shown in Table 2 ; water applied and yields, in Table 3.

Statistical analysis based on the yield samples collected three times during 1961 and 1962 follow :

1. Yield increased with the number of irrigations.
2. Four irrigations were significant at the level of 1 per cent in 1961, five irrigations were more significant in 1962. The fourth increased the number of flowers and bolls ; on the other hand, when fifth irrigation was not applied, bolls did not mature.
3. Yields for Coker variety were proportionately increased with the number of irrigations and quantity of nitrogen.

CONSUMPTIVE USE AND MONTHLY CONSUMPTIVE USE COEFFICIENTS

Blaney-Criddle formula was used with local meteorological records obtained during 1961 and 1962 at the Tarsus Irrigation Research Institute. Findings are presented in Table 4. Consumptive use stopped at the end of August, since there was no available moisture in soil to 90 cm. after that date.

CONSUMPTIVE USE BY COTTON IN THE MANISA PLAIN

This experiment was carried out for two years on cotton which is the principal crop of the Manisa Plain. A typical site was chosen near Veziroglu Village. Ground water during the vegetation period was below 150 cm. Soils are sandy silt loam.

Method of experiment

After the completion of village and seed bed preparation according to local custom Acala 1086 was drilled at the beginning of May and subsequently, thinned and hoed. During each of the two years three irrigations were applied as is usual local practice. Harvesting was completed by the first day of November, under three picking operations. The average yield of seeded cotton for the years 1962 and 1963 was 240 kg. per decare.

Soil sampling and moisture control

Data on volume, weight, field capacity, wilting point and available moisture capacity

TABLE 1. SOIL INFORMATION FOR TARSUS EXPERIMENTS

Years	Soil depth (cm.)	Volume weight (gr.)	Field capacity (mm.)	Wilting point (mm.)	Available Moisture capacity (mm.)
1961	0—30	1·45	108·0	69·8	38·2
	30—60	1·41	108·5	69·7	38·8
	60 – 90	1·39	105·3	68·4	36·9
1962	0—30	1·43	118·5	67·2	41·3
	30—60	1·40	118·7	69·9	48·8
	60 – 90	1·39	116·7	67·7	49·0

TABLE 2. DATES OF IRRIGATION AND HARVEST, TARSUS

Years	Dates of Sowing	Dates of irrigation					Dates of harvesting		
		1	2	3	4	5	1	2	3
1961	April 9, 1961	May 22, 1961	June 8, 1961	June 23, 1961	July 6, 1961	July 17, 1961	Aug. 27, 1961	Sep. 19, 1961	
1962	April 7, 1962	May 25, 1962	June 11, 1962	June 26, 1962	July 9, 1962	July 23, 1963	Sept. 3, 1963	Sept. 18, 1962	Oct. 3, 1962

TABLE 3. WATER APPLIED AND YIELDS AT TARSUS

Irrigation trials	Quantity of seasonal irrigation water (mm.)	Average yield/decare of seeded cotton (kg.)		
		1961	1962	Average
Not irrigated	...	82·7	113·4	98·1
3 times irrigated	225	187·6	183·9	185·8
4 times irrigated	300	235·3	220·1	227·7
5 times irrigated	375	255·5	225·5	240·5

based on each 30 cm. depth to 150 cm. taken before seeding, are shown in Table 5.

Soil moisture samples were taken (three replications) at 10-day intervals from seeding to harvest.

Irrigations

First irrigations were applied during the beginning of the flowering period. Water was measured using water meters mounted on tapped pipes to ensure homogeneous water discharge to the furrows.

The dates of seeding, irrigation and harvesting are shown in Table 6.

Consumptive use

The monthly and seasonal consumptive use during 1962 and 1963 are shown in Tables 7 and 8.

Use coefficient for Blaney-Criddle formula was computed using local meteorological records obtained during 1962 and 1963. Results are presented in Table 9.

Sowings were May 1, 1962 and May 2, 1963. The vegetation period was 184 days. The maximum daily consumptive use based on 16 days average of the period August 11-31, 1962 amounts to 10·3 mm., while it was 10·1 mm. for an average of 10 days covering the period August 5-15, 1963.

WATER REQUIREMENT FOR RICE

Rice acreage has been steadily increasing in Turkey, partly due to higher dividends obtained compared to other irrigated crops, partly due to the fact that ponding used for rice irrigation is also an excellent land reclamation measure and finally, due to the introduction of rice in crop rotation systems. This project was started in accordance with the recommendations made during the Second NESA Irrigation Practices Seminar held in Teheran in 1958 and is of great importance to Turkey as there is a shortage of irrigation in many rice growing areas. It was carried out during 1962 and 1963 at the Tarsus Irrigation Research Institute. Three replications were used under randomized block design using a lysimeter. Soil texture is silty clay. Parcels were 1·98 meters by 0·98 meter.

Treatments

(a) Irrigation applied at the rate of 1·1 lt./sec./Ha.

(b) Irrigation applied at the rate of 2·2 lt./sec./Ha.

(c) Keeping water level constant at the level of the upper part of lysimeter parcel (1·7 lt./sec./Ha. average).

(d) Keeping water level constant at the level of the upper part of lysimeter parcel and keeping valves of lysimeter open. (5·3 lt./sec./Ha. average).

(e) Application of a total of 100 mm. of water every other week (average rate 1·3 lt./sec./Ha.).

(f) Application of a total amount of 200 mm. of water every other 2 weeks (average rate 1·3 lt./sec./Ha.).

Water was applied until it reached the level of five or six centimeters on the parcels which were tilled properly after the harvesting of winter wheat. The seedlings were planted at the rate of 50 per parcel in June. Irrigation was applied in 1962 and 1963, respectively on 2nd and 15th July, 6th and 16th October at the determined rates. Planting, irrigation and harvest dates are shown in Table 10. Quantities of water applied by years, and the yields of rice obtained are shown in Table 11.

Statistical analysis showed :

1. No. significant difference in yields was observed between various treatments applied in 1962 and 1963.
2. Different rates of water application had no apparent effect on the thermic influence.
3. Although the weight per 1,000 grains decreased slightly when less water was applied, no difference was observed in the yields.

TABLE 4. COMPUTATION OF CONSUMPTIVE USE FACTORS FOR TARSUS

Months	t	p	f	u mm.	$k = \frac{u}{f}$
April	17·3*	8·85	113·54	47·0	0·41
May	21·4	9·81	175·72	89·9	0·51
June	24·7	9·83	190·91	153·52	0·80
July	27·1	0·99	204·98	167·9	0·82
August	27·8	9.40	195·88	64·5	0·33
			881·03	522·5	0·59

u = Monthly consumptive use (mm.); f = Monthly consumptive use factor; t = Monthly average temperature (°C.); k = Monthly consumptive use coefficient; p = Ratio of monthly daily hours to annual daily hours.
* Average sowing date: 8th April.

TABLE 5. SOIL MOISTURE INFORMATION FOR MANISA PLAIN

Soil Depth cm.	Volume Weight gr.	Field Capacity		Wilting Point		Available Moisture Capacity	
		%	mm.	%	mm.	%	mm.
0— 30	1·52	21·1	96·2	11.5	52·4	9·6	43·8
30— 60	1·54	22·0	101·6	11·9	55·0	10·1	46·6
60— 90	1·43	19·3	82·8	10·5	45·0	8·8	37·8
90—120	1·34	26·9	108·1	14·6	58.7	12·3	49·4
120—150	1·35	29·1	117·9	15·8	64·0	13·3	53·9

TABLE 6. DATES OF SEEDING, IRRIGATION AND HARVESTING, MANISA PLAIN

Years	Seeding Dates	Irrigation dates			Harvesting dates		
		1	2	3	1	2	3
1962	May 1	July 14	July 28	August	Sept. 13	Oct. 30	Nov. 17
1963	May 2	July 19	August 3	August	Oct. 14	Oct. 4	Nov. 19

TABLE 7. MONTHLY AND SEASONAL CONSUMPTIVE USE, MANISA, 1962

Months	Moisture in soil profile during the vegetation period mm.	Effective precipitation mm.	Water Quantity applied by irrigation mm.	Total	Moisture at the root zone (at the end of the month) mm.	Monthly consumptive use mm.	Daily average consumptive use mm.
May	490·0	4·6	...	494·6	453·9	40·7	1·32
June	453·9	3·9	...	457·8	404·7	53·1	1·77
July	404·7	25·4	237·3	667·4	433·1	234·3	7·56
August	433·1	...	141·6	574·7	280·8	293·9	9·48
September	280·8	11·5	...	292·3	203·0	89·3	2·98
October	203·0	45·6	...	248·2	230·0	18·2	0·59
		90·6	378·9			729·5	

TABLE 8. MONTHLY SEASONAL CONSUMPTIVE USE, MANISA, 1963

Months	Moisture in soil profile during the vegetation period mm.	Effective precipitation mm.	Water quantity applied by irrigation mm.	Total	Moisture at the root zone (at the end of the month) mm.	Monthly consumptive use mm.	Daily average consumptive use mm.
May	544·3	63·8	...	608·1	551·6	56·5	1·88
June	551·6	...	...	551·6	490·8	60·8	3·04
July	490·8	19·6	70·4	580·8	387·1	193·4	6·24
August	387·1	...	183·1	570·2	343·2	227·0	7·32
September	343·2	...	...	343·2	273·9	69·3	2·31
October	273·9	72·4	...	346·3	307·8	38·5	1·24
		155·8	253·5			645·5	

4. Reduction in water applications during the early vegetarian period has almost no effect on yields if adequate water is applied during the flowering and dough stages.

Water requirement for rice during flowering and dough is 2 lt./sec./Ha. Requirement during the balance of the vegetation period is 1 lt./sec./Ha.

TABLE 9. CONSUMPTIVE USE FACTORS, MANISA

Months	1962			1963			Two years average	
	u	f	$k=\frac{u}{f}$	u	f	$k=\frac{u}{f}$	u	k
May	40·7	178·59	0·23	56·5	167·26	0·34	48·6	0·29
June	53·1	196·88	0·27	60·8	197·33	0·31	57·0	0·29
July	234·3	207·69	1·13	193·4	213·24	0·9	213·9	1·02
August	293·9	201·23	1·46	227·0	202·10	1·12	260·4	1·29
September	89·3	158·15	0·56	69·3	161·60	0·43	79·3	0·50
October	18·2	127·95	0·14	38·5	127·95	0·30	28·3	0·22
Total	729·5	1070·69	0·68	645·5	1069·48	0·60	687·5	0·64

TABLE 10. PLANTING, IRRIGATION AND HARVEST DATES FOR RICE EXPERIMENT AT TARSUS

Years	Planting Dates	Beginning of irrigation	End of irrigation	Harvesting
1962	June 6, 1962	July 2, 1962	October 6, 1962	November 6, 1962
1963	June 19, 1963	July 15, 1963	October 16, 1963	October 20, 1963

TABLE 11. WATER APPLICATIONS FOR RICE EXPERIMENT AT TARSUS

Treatments	Average rate of water applied per hectare (m^3)			Average yield of rice kg./per hectare		
	1962	1963	Average	1962	1963	Average
a	8,910	8,730	8,820	6,180	6,550	6,370
b	17,810	17,460	17,640	7,730	7,420	7,580
c	15,960	12,450	14,210	8,240	7,160	7,700
d	47,190	38,910	43,050	8,760	7,210	7,970
e	10,210	11,130	10,670	7,210	6,850	7,030
f	9,280	11,130	10,210	7,210	6,800	7,010

WATER REQUIREMENTS OF CROPS ON SOIL MOISTURE BASIS

by

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Knowedge of the total and periodical water requirements of crops, consistent with good yields, and the effective rainfall, is of paramount importance for the efficient utilization of irrigation water. In India, work on water requirements of crops was initiated at Pusa, Bihar as early as 1907. This was about the time when Briggs and Shantz commenced their studies in the U.S.A. The earlier work consisted of determinations of transpiration ratios of different crops and factors affecting these ratios (Leather, 1910 ; Singh et al., 1935; Kulkarni and Inglis, 1938). These studies were conducted mostly in pots, using the gravimetric method. However, it was soon realised that the transpiration ratio could not be used to work out the actual water requirements of crops under field conditions.

This was followed by a period when field experiments were undertaken for finding out the optimum water requirements of crops. Different depths, delta and number of irrigations were applied at varying intervals and their effects on crop yields were observed (Thadani, 1937 ; Chaturvedi, 1945 ; Khan, 1945 ; Singh and Nijhawan, 1951 ; Datta and Bose, 1953 ; Phansalkar, 1956 and Tandon, 1956). The results of these experiments under-estimated the water needs during dry and hot periods and over-estimated the same during cool and wet periods. As weather and crop growth factors were not duly considered, the approach was found to be not very satisfactory. Rege et al., (1943) introduced the the concept of variable depths and intervals of irrigations in relation to crop growth and weather.

As a result of the advances made during the last three decades in the field of soil-water-plant relationships, it was realised that water requirements studies under field conditions should take into account factors such as the available moisture storage capacity of the root zone, the energy relationships between soil and water, the unequal availability of moisture in the available moisture range and the moisture movement under saturated and unsaturated soil conditions. This led to the organisation of the Section of Irrigation in the Agronomy Division at the Indian Agricultural Research Institute, in 1956. This paper deals with the work done by this section on the water requirements of crops based on soil moisture studies only.

In the various experiments, already conducted or in progress, the irrigation treatments were based on soil moisture regimes. One of the following criteria was used for scheduling irrigations in these experiments :

(a) Degree of soil dryness or wetness (percentage available moisture or moisture deficit) ;

(b) Degree of availability of water to plants (moisture tension basis) ; and

(c) Use of plant itself as an integrating tensiometer (indicator plant basis).

Irrigation water was measured with a Parshall flume, V-notch or a water meter at the field head-ditch. Calculations for the consumptive use of water were made using soil moisture data.

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Values of field capacity, wilting point and bulk density were taken for every 15 cm. soil layer down to 150 cm. depth. During the winter and hot weather, all the rainfall received was effective as it was always lower than the moisture deficit in the root zone. Precaution was always taken to prevent run-off losses by providing suitable levels around the plots. In the rainy season, consumptive use was estimated from the potential evapotranspiration corrected by a suitable factor, derived from the values obtained before and after the rainy season. Tensiometers or the resistance units were installed in the zone of maximum root activity which was studied at different stages of crop growth by either root excavation or indirectly by recording soil moisture changes at different depths. Overall moisture extraction patterns of different crops are shown in Table 1.

Table 1 clearly indicates that more than 80 per cent of the water need of the crops was met from the upper 60 cm. soil layer. Moisture depletion was, however, maximum from the top 30 cm. soil layer, indicating the zone of maximum root activity. Moisture extraction from the depth of 90 to 120 cm. was found to be negligible for all practical purposes.

The results obtained on water requirements of crops in various irrigation experiments are summarized in Table 2. This Table shows that in most of the cases crops responded favourably to the lowest tension tried. Higher degree of soil wetness than those used in the experiments may give higher crop yields but feasibility of such a practice is remote as it means in some cases irrigation on every third or the fourth day.

TABLE 1. MOISTURE EXTRACTION PATTERNS OF DIFFERENT CROPS UNDER OPTIMUM MOISTURE REGIME

Soil Depth	Per cent							
	Wheat (Chakraborty, 1962)	Sugarcane (Ray, 1963)	Potato (Ray, 1963)	Onion (Joshi, 1963)	Tabacco (Krishnamurthy, 1960)	Radish (Davenport, 1962)	Turnip (Davenport, 1962)	Beet (Davenport, 1962)
0— 15 cm.	32	39	44	92	22	48	49	45
15— 30 cm.	28	25	26	8	23	32	30	33
30— 45 cm.	22	17	16		42	10	17	18
45— 60 cm.		10	9			4	4	4
60— 75 cm.	18	6	4		9			
75— 90 cm.		3	1					
90—105 cm.					4			
105—120 cm.								

TABLE 2. WATER REQUIREMENT OF CROPS

Worker	Crop	Growth period	Soil dryness treatments tried	Optimum soil dryness before irrigation	Location of measurement for soil dryness (Depth below surface)	Location of measurement for soil dryness (Horizontal distance from plant base)	Consumptive use of water (mm.)	Water requirement (mm.)
Chakraborty (1962)	Wheat	Nov-April	0·5, 1·5 atm.	1·5 atm.	22·5 cm.	0	255	288
Ray (1963)	Sugarcane	Feb.-Feb.	0·7, 5·0, 10·0 atm.	0·7 atm.	22·5 cm.	11 cm.	980	...
Kukkeri (1961)	Potato	Oct.-Feb.	0·3 0·5 0·7 atm.	0·3 atm.	15-22·5 cm.	11 cm.	320	579
Joshi (1963)	Onion	Jan.-May	0·5, 0·65. 0·80 atm.	0·65 atm.	8 cm.	0	486	840
Krishnamurthy (1960)	Tobacco	Jan-June	0·3, 0·5, 0·8 atm.	0·3 atm.	15-22·5 cm.	8-11 cm.	495	630
Davenport (1962)	Radish	Oct-Jan.	0·2, 0.4, 0·6, atm.	0·2 atm.	15-22·5 cm.	4 cm.	152	230
—do—	Turnip	Oct.-Jan.		0·2 atm.	15-22·5 cm.	4 cm.	155	243
—do—	Beet	Oct.-Feb.		0·2 atm.	15-22.5 cm.	4 cm.	286	331

Similar trials are in progress on cotton, berseem, peas and paddy. This information can be applied to other areas with suitable modifications for the local soil and climatic conditions. For different soil types, moisture release curves have been prepared (Ray, *unpublished data*) for predicting soil moisture deficit at the higher limit of optimum moisture regimes for different crops. Such curves for three typical soils of India are shown in Fig. 1. Similarly, for different weather conditions relationships between potential evapotranspiration, calculated from weather factors and the consumptive use values for different crops are being worked.

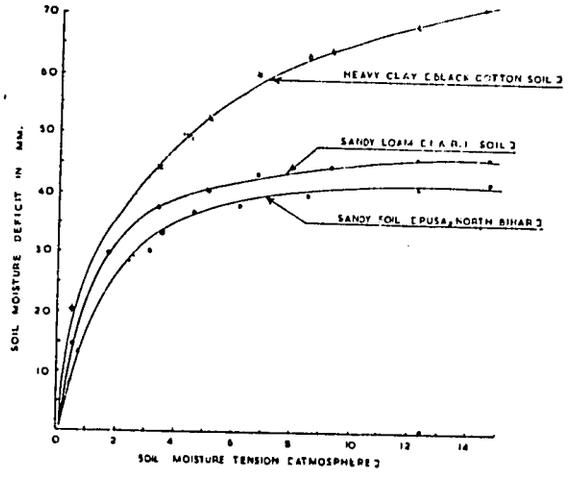

FIG. 1 MOISTURE RELEASE CURVES FOR DIFFERENT SOIL TYPES (FOR 0—30 Cm. SOIL LAYER)

REPORT ON WATER REQUIREMENTS IN U.A.R.

Compiled by

Dr. M. T. Eid*

INTRODUCTION

Due to shortage of water and high rate of population increase in U.A.R. immediate expansion of cultivated area associated with important projects of major water works development is urgent. This has led to increased attention to basic agronomic research for better and more efficient use of irrigation water. The Ministry of Agriculture established the irrigation water requirements research unit in 1948 and enlarged and reinforced it in 1959 to a research section. Eleven satellite stations were established at different localities where data upon irrigation water duties for different crops all over the country and for different seasons of the year were collected. Through field experiments, water duty was estimated by the use of weirs. In general, water was always supplied to field plots in different duties to ascertain crop and comparative results of the crop yield.

Under the first national five year plan started in 1960, more satellite stations were approved and they are under construction at the present time. The weir system by which water duties were measured, was altered to a simple and more practical device using water tanks to deliver irrigation water in known amounts. This new system will prevail at all satellite stations in the future.

This project has at least two main targets, the first is to estimate precisely the economic optimum of water for different field crops in the rotation and the second is to determine the interval of irrigation frequencies most suitable for such crops using different water charges.

Some of the objectives achieved are reported.

Measurements of Irrigation Water Duties

Distribution of Satellite Stations. Efforts were combined in 1948 between Ministry of Agriculture and Ministry of Public Works to carry out a project for measurements of irrigation water duties. Eleven satellite stations were established in different localities indicated in Table 1. The stations were distributed in a manner to cover all cultivated areas and to include testing of major field crops. In these stations, water was supplied in certain quantities according to the experimental plan and measured by weirs. It was the task of the civil engineer to operate this part of the work. The agronomist was in charge of the field experiments.

Under the first national five year plan, the project was improved with the alteration of the method of water duty measurements where water tanks were substituted for the weirs. Two cement tanks were built at each site in order to have continuous water flow. The distribution of water tanks was the same at the forementioned stations except that King Osman station was discontinued and a new station was established at Nobaria, Behra. Total number of field experiments under the new system was reduced to 21 experiments yearly.

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Note : Contributors were M.B. Kalil, Ex-director, Irrigation Requirement Research Station , A.A. Samaloty, Specialist in Irrigation Research ; and A.A. Gibaldi, Specialist in Irrigation Research.

Experimental Design. A uniform complete randomized blocks design was used at each site. Irrigation treatments included several variations including the amount of water used in general practice as a middle treatment The number of treatments was five for all crops with plot size of 1/80 feddan (52·5 sq. meters) for weir system experiments and 1/100 feddan (42 sq. meters) for tank system experiments.

Field capacity was determined for the soil of the experiment. Soil moisture per cent just before irrigation was determined. The difference between field capacity and soil moisture content just before irrigation was the amount of water that should be given at next irrigation. Soil moisture determination was made on soil samples taken by metal sampling tubes at every 10 cms. depth down to 60 cms.

Experimental field plots were treated alike in all agronomic managements : seed quantity, fertilizer treatments, insect control and method of harvest. Crop yield abtained from each plot was determined separately and reported. Results were subjected to statistical analysis to calculate reliability.

Weir System Experimental Results. Results of forty-four field experiments for seven field crops at nine satellite stations (localities) are summarized. The country was divided into four sub-regional zones, North Delta, South Delta, Middle Egypt, and South Egypt. At every sub-regional zone, different crops were tested at more than one locality. The weir system experiments were started in 1952 and continued up till now with a large accumulation of results, however presentation is made only for experiments having statistically significant results. Table 2 shows the most economical irrigation water requirements in cubic meters per feddan at different localities and Table 3 summarizes these results according to sub-regional zones.

Cotton. Irrigation water requirements for cotton showed considerable differences among different sub-regional zones in Egypt. Least water requirements were for North Delta where long stable varities are grown. A range between 2,160 and 2,592 cubic meters per feddan with an average of 2,332 was most economic.

Higher water requirements were noted for cotton varieties grown in South Delta. A range between 2,490 and 3,308 cubic meters per feddan with an average of 2,758 was found best for that sub-region.

For Middle Egypt, where medium stable varieties of cotton are grown, irrigation water requirements for that crop ranged between 2,796 and 3,609 cubic meters per feddan with an average of 3,209.

Such different water requirements may be attributed to at least two factors, the first is the difference in average seasonal atmospheric temperature and the second is the inherited variations among different varieties.

The over-all average water requirements for cotton in Egypt were found to be 2,766 cubic meters per feddan.

Rice. Paddy cultivation in U.A.R. is confined mostly to the north and south delta where soil, climatic, and water conditions permit. Rice area every year is assigned in advance according to available water expected for the season. Maximum rice area attained was about 800,000 feddans. Rice varieties prevailing in U.A.R. are of the Japonica type, usually transplanted in late May or early June and ripened in October.

Irrigation water requirements for rice showed no much variation between the two main subregional zones North and South Delta. A very narrow range between 7,807 and 8,170 cubic meters per feddan with an average of 7,988 was found in long experimental periods (Table 3).

Corn. Two crops of corn are usually grown in Egypt. Early summer corn planted in May is the main crop while late summer corn planted in July makes a subsidiary crop. Water supply for early summer corn is

TABLE 1. DISTRIBUTION OF SATELLITE STATIONS

Regional zone	Site	Governo-rate	No. of Weirs	No. of yearly expts.
North Delta	Serwi	Damietta	2	2
North Delta	King Osman	Behera	2	2
North Delta	Saka	Kafr El Sheik	3	3
South Delta	Itiai El Barood	Behera	3	3
South Delta	Gimiza	Garbia	3	3
South Delta	Behtim	Kalubia	3	3
Middle Egypt	Sids	Beni Suef	3	3
Middle Egypt	Malawy	Minia	2	2
South Egypt	Shandawil	Souhag	3	3
South Egypt	Mattana	Kena	4	4
South Egypt	Kom-Embo	Aswan	3	3
		Total	31	31

TABLE 2. IRRIGATION WATER REQUIREMENTS FOR COTTON

Sub-regional zones	Localities	Irrig. W. Reqs. in m^3/Feddan	
		Annual Result	Average
North Delta	Saka	2,245	2332
	Saka	2,592	
	Serwi	2,160	
South Delta	Gimiza	2,581	2758
	Gimiza	2,650	
	Itiai El Barood	2,490	
	Behtim	3,308	
Middle Egypt	Sids	3,609	3209
	Sids	3,251	
	Malawy	2,766	
South Egypt			
Over-all average			2766

* Results on cotton represent experiments carried out in the period from 1953 up to 1962.

usually critical, especially at the first growth period when river discharge is at minimum.

Experiments on corn indicate medium need with little fluctuation between sub-regional zones. A range between 1,770 and 1,832 cubic meters per feddan with an over-all average of 1,811 is the most economical. Table 4 shows results of eight experiments in three sub-regional zones for the period between 1953 and 1962.

Wheat. Wheat is one of the low water requirement crops in Egypt. As a winter crop, the number of irrigations for wheat never exceeds four.

Results in the four sub-regional zones indicated wide variations not only among zones but also between localities and years. Table 5 shows that requirement for wheat varies from 1,016 to 1,398 cubic meters per feddan with an over-all average of 1,270.

Clover. Clover is the main winter green fodder in U.A.R. It lasts over six months with three green cuts and seed yield. As such, perpetual vegetative growth has high water requirements especially in southern regions where moderate air temperature prevails during the winter. Highest levels were attained in the Southern region with an average of 3,720 cubic meters per feddan while it was 2,258 at the very north and 2,571 the middle section.

Barley. Results of four experiments on barley are summarized in Table 7 which shows three sub-regional zones. In general, barley has a low water requirement averaging 1,195 cubic meters per feddan.

Barley is known in Egypt as the field crop most resistant to drought. On coastal planes of sandy soils without irrigation and low precipitation barley used to grow and to produce under severe conditions of soil salinity and shortage of water.

Beans. Horse beans in Egypt is considered as one of the main winter crops for human and animal use. It is adapted in the south region of the country to very low water requirements. Such crop is called "bali" where water supplied to the soil before planting in considerable quantity is sufficient for the growing season. Cooking qualities of bali beans are much superior to the "miskawi" crop which is given three to four irrigations during the season.

Results in Middle Egypt indicated the lowest irrigation requirements of any field crop. A range of 928 to 1,032, with an average of 980 cubic meters per feddan, was the most economical optimum (Table 8).

Tank System Experimental Results. In this system water is controlled and measured volumetrically using cement tanks of known capacities. Tank system experiments started only in 1962 and thus few results are available (Table 10).

Most economical irrigation water requirements for cotton was found to be on the average about 3,253 cubic meters per feddan, for corn around 1,948 and for horse beans about 1,400 m^3 per feddan. Though few individual experiments have been conducted for only one season they are of considerable reliability due to the accuracy of water measurements.

Results obtained under the two systems closely agree except for horse beans where the latter system yields higher water requirements.

Irrigation frequencies for field crops

One of the main targets was the determination of optimum time for irrigation or the best time interval between two irrigations in order to sustain high economical production.

Due to strict water control, intervals between two successive irrigations can be adjusted to any desirable time. In practice, the usual period for summer crops is generally eighteen days based upon preliminary results. Ministry of Agriculture has done research work on time of irrigation using field experiments on cotton, corn and horse beans in

TABLE 3. IRRIGATION WATER REQUIREMENTS FOR RICE

Sub-regional zone	Localities	Irrig. W. Reqs. in M^3/Fed.	
		Annual Result	Average
North Delta	Saka	7,374	7,807
	Serwi	8,240	
South Delta	Gimiza	8,170	8,170
Over-all average			7,988

TABLE 4. IRRIGATION WATER REQUIREMENTS FOR CORN

Sub-regional zones	Localities	Irrig. W. Reqs. in M^3/Fed.	
		Annual Result	Average
North Delta	Saka	1,830	1,830
South Delta	Gimiza	1,559	1,832
	Gimiza	1,894	
	Behtim	1,608	
	Itiai El Barood	2,267	
Middle Egypt	Sids	2,413	1,770
	Sids	1,754	
	Giza	1,240	
Over-all average			1,811

TABLE 5. IRRIGATION WATER REQUIREMENTS FOR WHEAT

Sub-regional zone	Localities	Irrig. W. Reqs. M^3/Fed.	
		Annual Result	Average
North Delta	Saka	877	1,016
	Saka	1,156	
South Delta	Gimiza	255	1,398
	Gimiza	1,260	
	Behtim	1,980	
Middle Egypt	Sids	935	1,319
	Sids	1,112	
	Malawy	1,330	
	Giza	1,900	
South Egypt	Mattana	1,344	1,344
Over-all average			1,270

TABLE 6. IRRIGATION WATER REQUIREMENTS FOR CLOVER (SEED CROP)

Sub-regional zone	Localities	Irrig. W. Reqs. in M^3/Fed.	
		Annual Result	Average
North Delta	Saka Serwi	2,015 2,500	2,258
South Delta	Gimiza Behtim Itiai Barood	2,869 2,508 2,473	2,617
Middle Egypt	Sids Sids	2,254 2,818	2,536
South Egypt	Mattana	3,720	3,720
Over-all average			2,783

TABLE 7. IRRIGATION WATER REQUIREMENTS FOR BARLEY

Sub-regional zone	Localities	Irrig. W. Reqs. in M^3/Fed.	
		Annual Result	Average
North Delta	King Osman	1,493	1,493
South Delta	Gimiza Gimiza	906 1,340	1,123
Middle Egypt	Sids	905	905
Over-all average			1,195

TABLE 8. IRRIGATION WATER REQUIREMENTS FOR HORSE-BEANS

Sub-regional zone	Localities	Irrig. W. Reqs. in M^3/Fed.	
		Annual Result	Average
Middle Egypt	Sids Malawy	1,032 928	980
Over-all average			980

different localities since 1954. Using the tank system for water measurements at some satellite stations, it was possible to arrive at sound results on these mentioned field crops.

Cotton. Cotton experiments were conducted at the four subregional zones and for different seasons. Results of seven experiments at three localities and subregional zones are summarized and presented in Table 11.

A uniform experimental design in randomized complete blocks with six replicates and four time intervals for irrigation was used. Irrigation intervals tested were 12, 15, 18 and 21 days. Plot size was chosen to be 1/12 feddan with 1/40 feddan harvested for yield estimates. Total water duties for each treatment were almost the same.

From Table 10, time intervals of fifteen days was statistically significant for cotton. Increasing time intervals to eighteen days resulted in reducing cotton yield by about 23.45 per cent on the average in Middle

TABLE 9. SUMMARY RESULTS OF IRRIGATION WATER REQUIREMENTS BY SOME FIELD CROPS IN U.A.R.

Crops	Sub-regional Zone				Average
	N. Delta	S. Delta	M. Egypt	S. Egypt	
Cotton	2,332	2,758	3,209	—	2,766
Rice	7,807	8,170	—	—	7,988
Corn	1,830	1,832	1,770	—	1,811
Wheat	1,016	1,398	1,319	1,344	1,270
Clover	2,258	2,617	2,536	3,720	2,783
Barley	1,462	1,123	905	—	1,195
Horse beans	—	—	980	—	980

TABLE 10. IRRIGATION WATER REQUIREMENTS FOR COTTON, CORN, WHEAT AND HORSE BEANS

Crop	Sub-regional zones	Localities	Irrig. W. Reqs. in M^3/Fed.	
			Annual Result	Average
Cotton	Middle Egypt	Sids	3,253	3,253
Corn	South Delta	Gimiza	1,240	1,948
	Middle Egypt	Sids	2,656	
Horse beans	Middle Egypt	Sids	1400	1,400

Egypt, about 18·53 per cent in South Delta and about 16·54 per cent in North Delta.

Corn. Corn is considered one of the most water sensitive plants grown in U.A.R. Excess water, even at one irrigation, always resulted in corn yield reduction.

Experimental design for testing time intervals of irrigation for corn was complicated where irrigation water requirements for that crop were also tested. In Table 12, results of typical experiments conducted at Sids satellite station are shown. Three irrigation periods 12, 15 and 18 days between every two successive irrigations were tried. Four water duties were tested at each period ranging from 1,774 up to 2,656 cubic meters per feddan. All agronomic treatments were the same including time of planting, thinning, fertilizer quality and quantity as well as time of fertilizer application.

Irrigation time intervals were significant in their effect upon corn yield. Most economic period was found to be twelve days.

Concerning corn water requirements under the three time intervals tested, it was found that 2,656 cubic meters are more suitable for the twelve days period, 2,109 cubic meters for the fifteen-day period and 1,774 cubic meters for the eighteen day period.

Horse beans. The same type of experimental design as used for corn was used for horse-beans. In this case, four time intervals of 20, 30, 40 and 50 days with three different water duties each were tried.

Table 13 results at Sids satellite station in 1962-1963 indicated that the best time interval was 30 days.

TABLE 11. EFFECT OF IRRIGATION FREQUENCIES UPON COTTON

Sub-regional zones	Localities	Year	Irrigation frequencies in days				L.S.D.
			12	15	18	21	
North Delta	Saka	1953	6·31	6·45	5·54	5·04	0·64
	Saka	1954	6·03	6·24	4·76	4·40	0·48
	Saka	1955	8·30	8·21	7·24	6·83	0·41
Average Yield Kentar/Fed			6·88	6·97	5·85	5·42	
Av. Water duty M^3/Fed			232				
South Delta	Gimiza	1954	4·63	5·21	4·04	3·49	0·46
	Gimiza	1955	8·30	9·10	7·89	7·12	0·56
	Gimiza	1956	5·38	5·86	4·80	3·92	0·96
Average Yield Kentar/Fed			6·10	6·72	5·57	4·84	—
Av. Water duty M^3/Fed			2667				
Middle Egypt	Sids	1956	8·70	8·57	6·56	6·67	1·16
Av. Water duty M^3/Fed			3419				

* Kentar = 157 kilograms of cotton lint and seeds.

TABLE 12. EFFECT OF IRRIGATION FREQUENCIES UPON CORN

Irrig. Freq. in days	Water duty M³/Fed.	Corn Yield in Ard./Fed.	Average
12	1,961	21·04	21·73
	2,167	21·78	
	2,404	21·43	
	2,656	22·69	
15	1,908	17·00	19·45
	2,109	20·14	
	2,341	19·96	
	2,643	20·68	
18	1,774	20·75	19·21
	1,974	17·93	
	2,177	18·32	
	2,377	19·86	

* Ardab corn seeds = 140 kilograms.

TABLE 13. EFFECT OF IRRIGATION FREQUENCIES UPON HORSE-BEAN YIELD

Irrig. Freq. in days	Water duty M³/Fed.	Horse-bean yield Ard/Fed.	Average
20	1,333	8·91	10·45
	1,494	10·63	
	1,245	11·81	
30	1,243	9·52	10·38
	1,287	10·64	
	1,313	10·99	
40	1,370	7·21	9·08
	1,352	9·06	
	1,391	10·97	
50	928	10·25	9·53
	1,014	8·66	
	1,018	9·68	

* Ardab horse-bean seeds = 140 kilograms.

Most economical water duty was 1,313 cubic meters per feddan at frequency of 30 days. General practice at the present time is 50 days irrigation frequency with 928 cubic meters as water duty per feddan.

Future prospects

The programme to the present has followed a single course where only one or two types of field experiments could be conducted every year. Attention is now being drawn

to experimental designs and research work in the field of water requirements in relation to vital factors affecting plant growth and development.

At present, the research programme is being modified to cover other targets and to enable scientific considerations concerning the following points in relation to irrigation.

1. Differential consumptive water use by the crop during its various stages of growth.
2. Relationship between crop rotation and water consumptive use by different crops in the rotation.
3. Soil structure, texture and chemical properties including salinity and alkalinity in relation to water use.
4. Water quality.
5. Drainage.
6. Sub-regional climate.
7. Organic and inorganic fertilizers.
8. Weed control—water use interaction.

A coordinated research programme between workers in soils, plant physiology, plant nutrition, meteorology, weed control and irrigation requirements is under consideration to fulfil specific targets of the national second five-year plan which will start in 1965.

RESEARCH FINDINGS AND APPLICATION OF WATER REQUIREMENTS OF CROPS AND DUTIES THEREOF IN INDIA

by

S. N. Gupta and A. P. Bhattacharya*

SYNOPSIS

The paper gives a general idea of the characteristic features of India with respect to soil and climate, as their wide variations have an important bearing on the water requirements of crops.

Early concepts on duty of water advocated by R.B. Buckley and Bligh in the nineteenth century are discussed.

Past studies consist of experiments on water requirements of wheat initiated in the Punjab in the beginning of the present century. These brought out the advantages of making smaller compartments and delivering water directly to these with the help of water courses. Experiments on wheat in Banaras and Bombay gave the total depth of water required and also the number of waterings. For rice, water requirements were studied at Madras (Siruguppa, Coimbatore) and West Bengal. They related both to the total depth of water and the effect of submergence on the yield of rice. For sugarcane, duties and water requirements were worked out for Maharashtra and Madras. Water requirements of other crops, including cotton, maize, ragi, sorghum, groundnut, bananas, lemons, jawar studied in the past have also been described.

Among recent experimental studies, the work up to 1961-62 on the basis of investigations on the depth of watering and interval between irrigation treatments and later on the soil-moisture deficit aspect is described for wheat in U.P. Work on wheat is also detailed for Delhi and Gujarat. For rice, the studies in U.P. up to 1962 with the old approach and from 1963 with submergence (both continued and with drainage) and irrigation at field capacity are discussed. Work on rice is also described for Cuttack, Bihar, West Bengal, Gujarat, Mysore, Bangalore, Hyderabad. Among other crops studies are discussed for sugarcane, gram, potato, cotton, linseed, tobacco.

An idea is given regarding the scope for future. The need for standardizing techniques on an all-India basis is impressed. The importance of having better liaison between research and extension workers is stressed.

GENERAL

India is primarily an agricultural country, its total geographical area being 806·3 million acres. In 1960-61, the net area sown was 328·0 million acres. While the total cropped area was 376·2 millon acres. Out of the total area under cultivation, nearly 18·3 per cent is irrigated. A comparative idea of the role of agriculture and irrigation for India with respect to other important agricultural countries can be formed from a perusal of Table 1. It may be seen that the percentage of cropped area to total area is highest for India.

There are two well-defined crops seasons in India (i) kharif, from April to September,

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TABLE 1. CROPPED AND IRRIGATED AREA AND AGRICULTURAL POPULATION FOR VARIOUS AGRICULTURAL COUNTRIES

Name of Country	Total area	Arable land and land under tree crops	Irrigated arable land and land under tree crops (1955)	Population (1959) (in thousands)	Agricultural population (1945-59) (in thousands)	Per cent ratio of cropped area to total area	Per cent ratio of irrigated area to cropped area	Per cent of agricultural population to total population (1945-59)
	(in	1,000	hectares)					
U.S.S.R.	2,240,300	221,366	11,128	210,500	97,100 (1930-44)	9·88	5·03	50
Europe	493,000	154,000	2,554	421,300	...	31·24	1·66	33
U.S.A.	782,798	188,309	11,959	177,700	22,158	24·06	6·35	13
North and Central America	2,426,000	258,000	15,177	260,100	...	10·63	5·88	24
South America	1,776,000	73,000	4,582	136,200	...	4·11	6·28	59
India	328,888	159,662	21,959	402,600	249,122	48·55	13·75	70
China	876,101	109,334	24,679	476,000 (1937)	395,500	11·20	22·56	85
Asia	1,739,000	325,000	73,280	946,000	...	18·69	22·55	64
Africa	3,025,000	236,000	6,033	249,200	...	7·80	25·56	66
Oceania	854,000	28,000	704	13,400	963 (Australia)	3·28	25·14	31
World (Total)	13,529,000	1,405,000	138,137	2,936,700	...	10·39	9·83	56

Note : (1) Source : F.A.O. Production Year Book 1960, pages 3 to 17
(2) One hectare is equivalent to 2·471 acres.
(3) Figures for Europe exclude U.S.S.R.
(4) Figures for Asia exclude China Mainland.

(ii) rabi, from October to March. Sometimes, intermediate crops are sown between these seasons which are known as zaid crops in U.P. and Punjab. The major kharif crops are rice, jawar, bajra, maize, cotton, sugarcane, sesamum and groundnut, while the major rabi crops are wheat, barley, gram lineseed, rape and mustard. The seasons and duration of principal crops are given in Table 2.

Table 3 shows the area under irrigation from various sources. It may be seen that government canals form the most impotrant source of irrigation in India.

The two outstanding features of agricultural production in India are the wide variety of crops and the preponderance of food crops over non-food crops. Table 4 gives the area under various crops and it may be seen that the area under food crops was 299 million acres in 1958-59 against 73 million acres for non-food crops.

Fig. 1 gives a soil map of India indicating the principal classifications of soils, namely alluvial soils, red soils, laterite soils, black soils and clayey soils[2]. Alluvial soils cover large portions of Assam, Bengal, Orissa, Bihar, U.P. and Punjab. Red soils are found in Madras, Andhra Pradesh, Bihar and Orissa. Laterite soils occur on the summits of hills in Orissa, Madhya Pradesh, Travancore, Deccan and Central India. Black soils are available in Bombay, Madhya Pradesh, Andhra, Mysore, Central India and Madras. Clayey soils are found in Punjab and U.P.

India can be divided broadly into four regions in accordance with the extent of normal annual rainfall, viz. (i) over 2,000 mm., (ii) between 1,200 and 1,600 mm., (iii) between 900 and 1,100 mm., (iv) below 800 mm[3].

Rainfall in India is marked by its unequal distribution throughout the seasons, its uneven distribution over the surface of the country and its liability to frequent failure.

Because of the variation in the intensity and pattern of rainfall and also of soil type in various regions of India, timely artificial application of water for the proper crops growth is an important factors. Further, because of the limited available supplies, it is of importance to utilise every cusec of water for the maximum crop yield and, therefore, the subject of water requirements of crops has received attention of agriculture and irrigation departments in various States for over a century.

EARLY CONCEPTS.

In the nineteenth century, the duties for various crops in different States were studied by R. B. Buckley[5]. According to him, if D is taken as the duty of water, i.e. the number of acres of crop matured by 1 cubic-foot per second flowing continuously for a defined time.

Tables 5 and 6 give figures for the duties for the years 1885-86 to 1889-90 for the kharif and rabi seasons for various irrigation systems in India. These give an idea how duties vary both from year to year and canal to canal. Whereas the kharif duties varied from 60 to 150 acres, the rabi duties ranged between 30 and 170 acres in 1889-90.

The above duties were worked out for discharge at the head of the irrigation system. Duties were also worked out by Buckley on the discharge utilised. Tables 7 and 8 give kharif duties for the Upper and Lower Ganges Canals for the years 1885-86 to 1889-90 calculated on the basis of the discharge utilised. A study of these Tables shown wide variation in duties in the two canals and in different parts of the same canal system.

Efficiency of water management in a running canal system has an important bearing on the duty. It was assessed by Buckley that the duty for wheat on the Jamna Canal in Bombay in 1889-90 was as low as 32·4. Experiments conducted on this canal by gauging the discharge actually run on to the fields in two cases indicated the depths of watering for wheat to be 25 and 17 inches respectively.

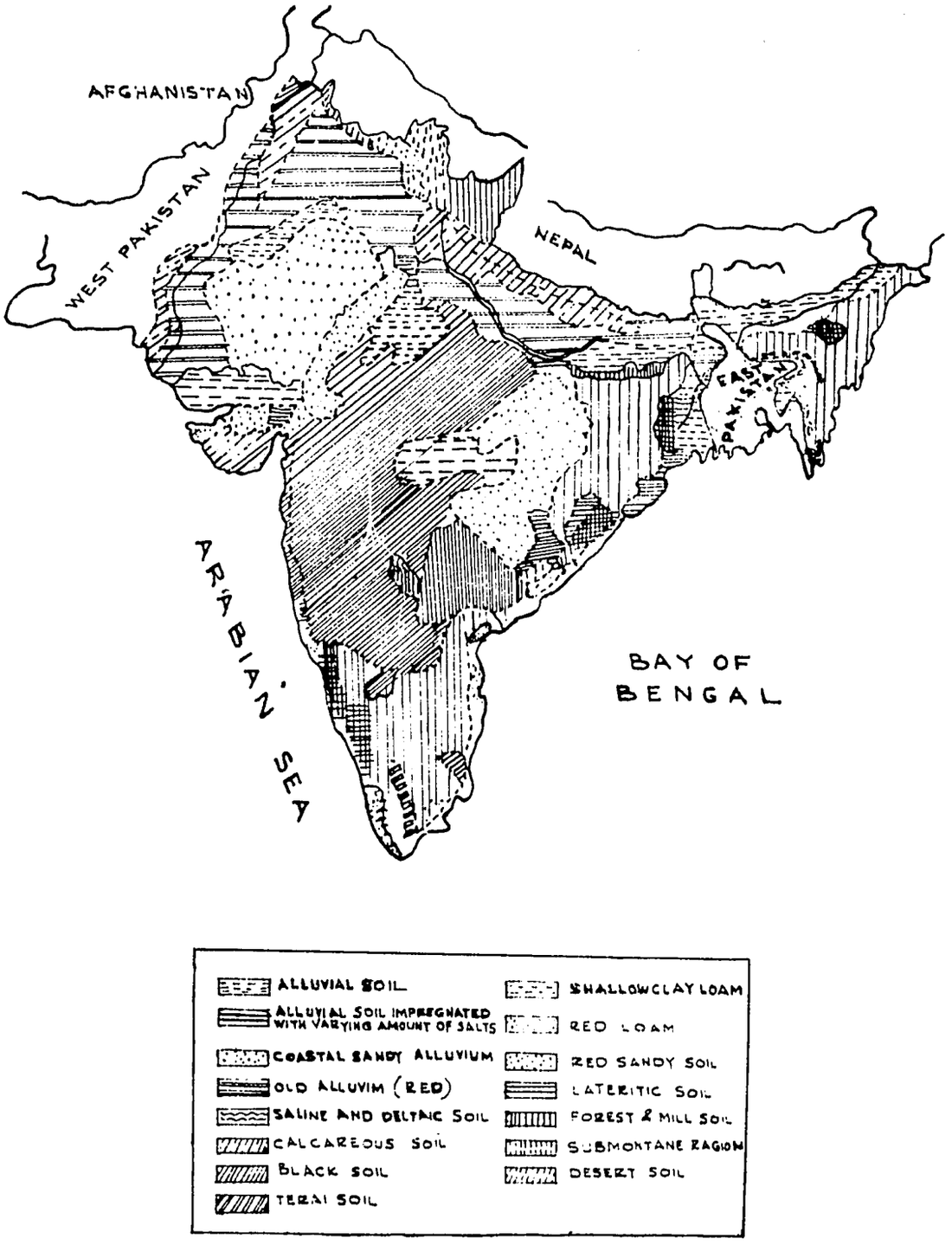
AFGHANISTAN
WEST PAKISTAN
NEPAL
EAST PAKISTAN
ARABIAN SEA
BAY OF BENGAL
ALLUVIAL SOIL
ALLUVIAL SOIL IMPREGNATED WITH VARYING AMOUNT OF SALTS
COASTAL SANDY ALLUVIUM
OLD ALLUVIM (RED)
SALINE AND DELTAIC SOIL
CALCAREOUS SOIL
BLACK SOIL
TERAI SOIL
SHALLOW CLAY LOAM
RED LOAM
RED SANDY SOIL
LATERITIC SOIL
FOREST & MILL SOIL
SUBMONTANE RAGION
DESERT SOIL

FIG. 1.

Likewise, for the Nira Canal in Bombay, for a depth of 3·57 inches at the head, the actual depth delivered in the field was found to be only of the order of 2 to 2·5 inches. It was thus concluded that large quantities of water were lost in conveyance. Further, the study of duty of water in periods of pressure is very important, especially as in Bengal and Madras where only one crop is under irrigation in one season, being all rice during kharif.

For the then Bombay Presidency (now Maharashtra and Gujarat), mention has been made by Buckley that experimental studies gave the total depth of watering needed for wheat to be 20 inches consisting of three to four waterings of 2·5 inches on the field plus rainfall.

For Egypt, the duties were quoted by R.B. Buckley as equivalent to 41 for rice and 83

TABLE 2. CROP SEASONS AND DURATION, INDIA

Crop	Season		Duration
Rice	Winter		5½—6 months
	Autumn		4—4½ months
	Summer		2—3 months
Wheat	Rabi		5—5½ months
Jowar	Kharif		4½—5 months
	Rabi		4½—5 months
	Zaid Kharif		2½ months
Bajra	Kharif		4½ months
Maize	Kharif		4—4½ months
Ragi	Kharif		3½ months
Barley	Rabi		5—5½ months
Gram	Rabi		6 months
Sugarcane	Perennial		10—12 months
Sesamum	Kharif		3½—4 months
	Rabi		5 months
Groundnut	Kharif	Early	4—4½ months
		Late	4½—5 months
Rape and mustard	Rabi		4—5 months
Linseed	Zaid Rabi		4 months
Castor	Rabi		5—5½ months
	Kharif	Early	6 months
		Others	8 months
Cotton	Kharif	Early	6—7 months
		Others	7—8 months
Tobacco	Kharif		7 months
Jute	Kharif		6—7 months

Source : India 1961, The Publications Division, Government of India, page 245.

TABLE 3. AREA UNDER IRRIGATION IN INDIA FROM VARIOUS SOURCES (1960-61)

Source		Area in million acres
Canals	Govt.	22·4
	Private	3·0
Wells		17·4
Tanks		11·5
Other sources		5·9
Total		60·2

Source : Directorate of Economics and Statistics, Department of Agriculture, Ministry of Food and Agriculture, Government of India.

TABLE 4. AREA UNDER VARIOUS CROPS IN INDIA (1958-59)

Crops	State in which grown	Area in thousand acres.
Food Crops		
Rice	Assam, Bengal, Bihar, Madras, Andhra, Orissa, M.P. and U.P.	81,000
Jowar	Andhra, Mysore, Gujarat, Maharashtra, Madras, and Madhya Pradesh	44,438
Bajra	Bombay, Punjab, Madras, U.P., Rajasthan, Andhra, M.P. and Gujarat	28,185
Maize	Punjab, U.P. and Bihar	10,534
Ragi	Mysore and Madras	6,313
Wheat	U.P., Punjab, M.P., Maharashtra and Gujarat	31,164
Barley	U.P., Bihar and East Punjab	8,190
Other cereals and small millets		13,143
Total cereals and millets		222,967
Gram	Punjab, U.P., Bihar and Madhya Pradesh	24,828
Tur or Arhar		6,145
Other pulses		29,225
Total pulses		60,198
Total foodgrains		283,165

(Contd.)

Table 4 (*Contd.*)

Crops	State in which grown	Area in thousand acres.
Sugar	U.P., Punjab and Bihar	4,922
Condiments and spices		3,244
Fruits and vegetables		6,221
Other food crops		1,901
Total food crops		299,453
Non-food crops		
Groundnut	Maharashtra and Madras	15,451
Castor	Andhra and Madras	1,212
Sesamum	Andhra, Madhya Pradesh and Madras	4,666
Rape and Mustard	Pubjab, U.P. and Bihar	3,059
Linseed	Madhya Pradesh, Bihar and Andhra	3,365
Coconut	Madras and Kerala	1,713
Other oilseeds		2,838
Total oilseeds		32,304
Cotton	Maharashtra, Gujarat, M.P., Andhra and Madras	19,683
Jute	Assam, Bihar and West Bengal	1,748
Other fibres		1,631
Indigo		17
Opium		76
Coffee	Madras, Mysore and Kerala	295
Tea	Assam and West Bengal	784
Tobacco		967
Fodder crops		13,401
Other non-food crops		2,402
Total non-food crops		73,308
Total food and non-food crops		372,762

Source :—Directorate of Economics & Statistics, Department of Agriculture, Ministry of Food & Agriculture, Government of India.

TABLE 5. DUTY AT HEAD OF SYSTEM IN KHARIF SEASON FOR VARIOUS IRRIGATION SYSTEMS IN INDIA

Canal	Number of acres of crop matured by 1 cubic foot per second				
	1885-86	1886-87	1887-88	1888-89	1889-90
Bengal :					
Sone	80	95	74	65	68
N.W. Provinces :					
Upper Ganges	78	80	66	73	83
Eastern Jumna	90	92	94	104	94
Punjab :					
Western Jumna	86	66	90	73	78
Bari Doab	59	69	61	62	58
Madras :					
Kistna	...	145	101	166	114
Penner	...	130	193	168	147
Bombay :					
Mutha	98	52	49	53	114

Source : Irrigation Works in India and Egypt by R.B. Buckley, page 223.

TABLE 6. DUTY AT HEAD OF SYSTEM IN RABI SEASON FOR VARIOUS IRRIGATION SYSTEMS IN INDIA

Canal	Number of acres of crop matured by 1 cubic foot per second				
	1885-86	1886-87	1887-88	1888-89	1889-90
Bengal :					
Sone	99	78	68	78	52
N.W. Provinces :					
Upper Ganges	171	131	155	168	143
Eastern Jumna	129	130	108	124	153
Punjab :					
Western Jumna	96	134	48	107	123
Bari Doab	153	128	125	141	169
Bombay :					
Nira	60	69	...	106	95
Jamda	...	24	19	47	33
Krishna	22	32	31	25	36
Ekruk Tank	28	20	24	41	56

Source : Irrigation Works in India and Egypt by R.B. Buckley, page 224.

TABLE 7. DUTIES UTILIZED ON THE UPPER GANGES CANAL IN THE KHARIF SEASON

	1885-86 (acres)	1886-87 (acres)	1887-88 (acres)	1888-1889 (acres)	1889-90 (acres)
Duty of the canal on its discharge at head	78	80	66	73	83
Duty of the canal on its discharge "utilised"	86	100	69	76	90
Duty of the distributaries on their discharge at head	88	102	72	76	95
Base of the above duties	115 days	137 days	103 days	111 days	134 days
Volume of water in cubic feet used (at the distributary head) per acre	113,260	115,690	122,400	125,450	121,970

Source : Irrigation Works in India and Egypt by R.B. Buckley, page 228.

TABLE 8. DUTIES UTILIZED ON THE LOWER GANGES CANAL IN THE KHARIF SEASON.

	1885-86 (acres)	1886-87 (acres)	1887-88 (acres)	1888-89 (acres)	1889-90 (acres)
Duty of the canal on its discharge at head	43	33	41	53	58
Duty of the canal on its discharge "utilised"	69	64	60	72	74
Duty of the distributaries on their discharge at head	95	88	102	104	94
Base of the above duties	115 days	137 days	103 days	111 days	134 days
Volume of water in cubic feet used (at the distributary head) per acre	104,540	135,040	87,120	91,480	121,970

Source : Irrigation Works in India and Egypt by R.B. Buckley, page 229.

for the *sefi* or hot weather crops, irrigated from April to July, consisting of cotton, vegetables, summer maize and sugarcane.

The subject of duties was also studied by Bligh in the last century[6]. He gave figures for duty for kharif irrigation varying from 50 to 100 acres and for rabi from 50 to 250 acres for Northern India, the loss of water between the head of a canal and the fields varying from 10 to 20 per cent. Bligh gave total water requirements of rice as 5 ft. or 60 inches, which is in conformity with the recent experimentally determined figures for U.P. He stressed the importance of irrigation by rotation in minimising losses by evaporation and percolation, as was also recommended by R. B. Buckley. Bligh's figures for water requirements of rice for Madras were 5 ft. for monsoon rice crop and 4 ft. for cold weather rice crop. For Madras 1 cusec irrigate 66⅔ acres of rice and double that amount of dry crops. For new tank projects in Madras, the duties were taken as 50 for rice and 100 for dry crops, including evaporation and absorption losses.

REVIEW OF PAST WORK

Before 1900, the water requirements of various crops were being assessed by irrigation engineers on field observations and very little experimental work was conducted. In subsequent years, studies on water requirements were taken up for three principal crops, viz. (i) wheat, (ii) rice, (iii) sugarcane

Wheat. Earlist work was begun on wheat in the Punjab where studies were initiated by R.G. Kennedy from 1904-05 to 1906-07[7, 8, 9]. These indicated that there was considerable waste of irrigation water on the part of the zamindar, particularly in the first irrigation mainly due to the fact that large compartments (*kiaris*) were made and water was run from one compartment to another. The waste of water could be prevented to a considerable extent by making the '*kiaris*' smaller and supplying water directly to each compartment from a water-course. Total depth of watering was assessed to be 7·90 inches and 10·18 inches for three and four waterings on an average. Actual water use by the Zamindar indicated over-irrigation to the extent of 30 per cent.

The role of proper land levelling in economical use of water for irrigation was clearly brought out. Five to six inches of watering were required for a ploughed field with clods unbroken but two to three inches sufficed for a simllar field whose clods were broken and ground levelled.

Studies on the average utilisation of canal water by the Zamindar were initiated by F. W. Woods in the Punjab in 1918. The field data was subsequently analysed by B. H. Wilsdon and M. L. Mehta of the Punjab Irrigation Research Institute in 1929[10]. For wheat, four waterings (including '*rauni*' or pre-sowing irrigation) were regarded as admissible. Actual water use in the fields indicated an average waste of 25 per cent of water applied for irrigation. The greatest waste was found to occur in the months of June to September. It was also observed that the surplus water was leading to waterlogging. A number of measures were suggested for the prevention of waterlogging including economy of water in the field by making proper '*kiaris*'.

Experiments conducted at the Banaras Hindu University, Banaras in 1936 indicated the total water requirements of wheat to be 7·35 inches[11].

Sir Claude Inglis gave a figure of 180 for the duty for rabi for the Deccan in 1917

Rice. Water requirements of rice were taken as 40 inches for the Punjab in 1929 by B. H. Wilsdon and M. L. Mehta[12].

In Madras, experiments were conducted at the Paddy Breeding Station, Coimbatore during the years 1932 to 1934 for determining the quantity of water required for different stages of growth for Vallaisimba (white rice—a special variety) ripening in 160 days with a duty of 84·8 acre inches of water[13]. Seasonal water requirements of this variety of

rice were indicated for various stages of plant growth as (i) from preparation of plots to planting—25·63 acre inches, (ii) from planting to flowering—48·27 acre inches, (iii) from flowering to last irrigation—10·89 acre inches, total being 84·79 acre inches (including irrigation and rainfall).

Experiments were conducted for a period of five years from 1938-39 onwards at Coimbatore by the Madras Department of Agriculture[13]. Best yield was obtained with continued submergence with 2 inches depth of water for which the yield was the same as that recorded with applications of 2 inches depth at intervals of 3 days and 4 inches at 6 days. Duties of rice for experiments conducted at a number of stations in Madras from 1938 onwards worked out to 81 for the first crop (June-December), 54 for the second crop (February-May) at Maruteru, 37 at Pattukottai, 51 for single-crop rice at Central Farm Coimbatore, for single crop at Siruguppa. The duty for rice was found to be 60 on an average.

In West Bengal, experiments with the pot culture technique were conducted on watering needs of rice in the Department of Agriculture, Calcutta University by P. K. Sen in 1937[14]. Best results were obtained with a treatment which was dry germination, saturated during pre-tillering, submerged during pre-tillering and pre-flowering, saturated again during flowering and dry finally during post-flowering. *Boro* i.e. spring rice (November-April) gave maximum tillering and yield, *ans* i.e. summer rice (April-July) minimum and *aman* i.e. winter rice (June-December) intermediate yield and tillering.

Sugarcane. Sir Claude Inglis gave a figure of 60 for the duty of sugarcane for canals in the Deccan in 1917[12].

Water requirements of sugarcane were taken to be 40 inches with 12 waterings by Wilsdon and Mehta for the Punjab in 1929.

The duty for sugarcane was worked out to be 90 on the basis of experiments conducted by the Madras Department of Agriculture from 1938 onwards.

Pot culture studies were conducted in Bombay on water requirements of sugarcane in 1938-39 for two types of soils, viz. Murum Black Soil near Malegaon Colony and Chopan Black Soil near Pahunyachiwadi[15]. Water requirements of sugarcane were indicated as 101·4 and 92·7 inches for the two types of soils. Over-irrigation was detectable to the extent of 32 to 34 per cent.

Other Crops. Among other crops, water requirements were given by Wilsdon and Mehta for the Punjab in 1929 as (i) cotton —20 inches with 6 waterings, (ii) maize—18 inches with 5 waterings.

For Madras, calculated duties of water were given from 1938 onwards as (i) cotton —265 (August-March) at Siruguppa and 190 (6 months duration) at Coimbatore, (ii) ragi —126 (July-October) at Siruguppa and 130 (May-September) at Coimbatore, (iii) sorghum —163 (June-September) at Siruguppa and 120 (March-June) for Coimbatore, (iv) groundnut —156 (July-October) at Siruguppa (v) Banaras —136 at Maruteru.

Soil surveys of Mahi Project indicated water requirements for Maharashtra as (i) 125 inches for bananas, (ii) 62 inches for lemons.

Experiments were conducted in Sind (now in Pakistan) from 1940 to 1945 on water requirements of cotton and jowar[16]. Findings were similar to those for the Punjab regarding the economical water use in plots irrigated directly as compared to those irrigated from adjacent plots. Water requirements were found to vary directly with plot size, being minimum for 1/2 acre plots for cotton and 1/4 acre for jawar.

The practice regarding duties and water requirements of crops in Uttar Pradesh is as below[17].

The average depth per watering at the outlet head is taken as (i) rabi—5·25 inches, (ii) sugarcane—6·50 inches, (iii) rice—7·5 inches.

Areas which can be irrigated per cusec week corresponding to the above depths are (i) rabi —32 acres, (ii) sugarcane—26 acres (iii) rice —22 acres. The period for one watering is generally fixed as (i) rabi—8 weeks, 6 weeks, 4 weeks according as the rainfall is below 40 inches, between 40 and 45 inches, above 45 inches, (ii) sugarcane—4 to 6 weeks according as the rainfall is below or above 40 inches. The maximum period of one watering of rice is taken as 2·5 weeks throughout Uttar Pradesh.

RECENT EXPERIMENTAL STUDIES.

Wheat. In Uttar Pradesh, planned experiments were initiated by the U.P. Irrigation Research Institute in 1942-43 with the randomized block system layout, experimentation being confined to the determination of the best combination of the depth of irrigation and interval between irrigation treatments for arriving at the maximum yield[18]. There were a number of experimental stations in different climatic and soil zones of Uttar Pradesh, viz. Bara Banki, Bulandshar, Atarra, Bahadrabad, Dhanauri, where experiments were conducted from 1942-43 to 1949-50. From 1956-57, the Experimental work was confined to Dhanauri alone. For the years 1960-61 and 1961-62, levels of nitrogen were also studied with respect to levels of irrigation. The approach has been changed from 1962-63 by the adoption of the soil-moisture deficit aspect inclusive of irrigation efficiencies. Empirical formulae for the determination of water requirements from climatological data and also evapotranspiration measurements are being taken up.

Generally, the optimum depth of irrigation was indicated to be 3 inches for Eastern and Western U.P., although water depths for Dhanauri were slightly lower, being 2·5 inches, while the corresponding depth for Southern U.P. was found to be 4 inches, two waterings being given in these experiments apart from pre-sowing irrigation plus rainfall. The interval between irrigation treatments was found to vary from 4 to 6 weeks. The optimum level of nitrogen was found to be 40 lbs. per acre, 20 lbs. by artificial manure and 20 lbs. as green manure and compost manure. In the course of these experiments, yields as high as 26 maunds per acre or 24·07 in 100 kg. per hectare were obtained.

Another set of experiments on water requirements of wheat along with dosage of nitrogen was taken up by the Crop Physiology Section of the Department of Agriculture, Uttar Pradesh, at seven experimental stations during the years 1950-51 to 1953-54[19]. The soil types were mostly loam except for Bharari (Jhansi), for which it was parwa. The depth of irrigation applied was 3 inches, wheat grown in the drier parts of the State generally required three waterings, whereas for wetter places like Gorakhpur, two waterings were sufficient.

Experiments were started by the Crop Physiology Section of the Department of Agriculture, U.P. in 1961-62 on the effect of frequencies of irrigation and doses of nitrogen on wheat yeilds[20]. Three irrigation treatments of 3 inches applied at tillering, pre-heading and milk stages of growth and 50 lbs. of nitrogen gave best results. The beneficial role of nitrogen in economising water use was also brought out.

Water requirements of wheat were found to be 36 cm. with three irrigation treatments at the Indian Agricultural Research Institute, New Delhi[21].

In Gujarat, optimum water requirements were found to be 18 acre inches with 5 to 6 waterings for tubewell areas. For the Mahi Canal commanded area, optimum water requirements were indicated to be 21 inches.

Rice. Experiments were initiated in Uttar Pradesh by the U.P. Irrigation Research Institute on water requirements of rice in 1945. The work was carried out at Nagina, Atarra, Tisuhi and Bahadrabad from 1945 to 1949. In 1961, they were started at Dhanauri. The layout was the usual randomized block system, the object being the determination of the best combination of depth of watering

and interval between irrigation treatments plus rainfall. In 1961 and 1962 studies, the level of nitrogen was also studied along with the irrigation treatments. From 1963, soil-moisture regime concept was introduced along with a study of the effect of continued submergence with depths of 2, 4,6, 8 inches and submergence with drainages

The total watering needs of rice were indicated to be 7 ft. for Atarra and Tisuhi. For Dhanauri, this figure has been found to be of the order of 5 ft. Submergence of 4 inches with three drainages at pre-tillering, pre-flowering and pre-dough stages seems to give best results. The optimum level of nitrogen has been indicated to be 60 lbs. per acre. Yields as high as 38 maunds per acre or 35·18 in 100 kg. per hectare were recorded in the experiments conducted so far.

Experiments conducted at the Indian Agricultural Research Institute, New Delhi, in 1960 indicated that irrigation at field capacity seemed to be the best for maximum yield and compared favourably with 6 and 12 cm. depth of submergence[23]. Lower levels of soil moisture reduced the yield. Submergence seemed to be beneficial in killing weeds which, otherwise, lowered the yield significantly.

Experiments conducted at the Central Rice Research Institute, Cuttack, for the years 1953-54, 1958-59, 1959-60 gave indications that water requirements of rice decreased with manurial applications, a combination of ammonium sulphate, farmyard manure and superphosphate gave the best yield[24].

In Bihar, the effect of light irrigations in spells of drought was studied on the yield of late *aman* (winter) paddy variety, 498-2A at the Irrigation Research Station, Bikranganj for five years from 1958-59 to 1962-63[25]. Total water requirements of 38 inches were met by 30 inches of rainfall and 8 inches of irrigation. The maximum yield was 37·5 maunds per acre or 34·71 in 100 kg. per hectare.

In West Bengal, experiments have been initiated at the Department of Agriculture, Calcutta University[10]. Physiological studies with the pot culture technique indicated osmotic pressures and transpiration rates for *aus, boro, aman* varieties to be in a descending order. In the Kalyani studies in West Bengal, best results were obtained by an application of 16·5 inches in 9 doses, giving the highest yield of 40 maunds per acre or 37·64 in 100 kg. per hectare[26].

In Gujarat, three varieties of paddy were experimented upon[22, 27]. Eight waterings gave the best results. For manuring, it was found that the yield went on increasing up to 80 lbs. N per acre, although an economic dose was 40 lbs. N per acre.

In Mysore, studies at the Mysore Engineering Research Station showed that the application of water for only five days in a week gave better yield than continued submergence[28]. Variations were also noticed in water requirements of different varieties of rice.

A study of 100 fields in 10 villages in Bangalore District indicated the number of waterings required for transplanted paddy to be 23[29]. Total water requirements were found to be 59·93 inches or 5 ft., out of which rainfall contributed 13·93 inches, the rest (46·00 inches) being met with by artificial application.

Work on water requirements of rice was initiated at the Hyderabad Engineering Research Laboratories in 1948[30]. The duty on *abi* (crops grown from 15th June to 15th November) and *tabi* (those grown from 15th January to 15th May) rice crops was given as 174 and 71 as a result of observation in cultivators' fields. Water requirements were calculated from daily evaporation losses to be 39·42 and 43·89 inches for the *abi* and *tabi* seasons. Adopting water requirements of rice to be 42·53 inches and a base of 123 days, the duty was calculated as 67·38 acres per cusec at the field.

Other crops. For sugarcane, field studies were carried on the effect of heavy irrigation in deep soils in Jinti area, Distributary No. 18, Nira Right Bank Canal in Maharashtra in 1948-49. Total water requirements of sugarcane were indicated to be 90 inches, 45 inches being consumed in evaporation and 45 inches in transpiration. Over-irrigation was assessed to be of the order of 20 per cent. A slow but definite rise in the water-table was evident as a result of over-irrigation for which lower depths were recommended[31].

For Delhi, total water requirements of sugarcane were found to be 163 cm. with 14 waterings[21].

Gram. In Gujarat, three waterings applied after 35, 50 and 65 days from sowing increased the yield of gram after paddy particularly in combination with 30 lbs. of P_2O_5 per acre[22-27].

Potato. Experiments at the Central Potato Research Institute, Simla have shown that 8 to 9 days irrigation interval was optimum for potatoes in north India[32]. The results of an experiment conducted on the basis of soil-moisture regime concept on lateritic soils at Kharagpur have shown that 17·5 inches of irrigation water or 17·80 inches total water were required for obtaining the best yield[33].

Cotton. In general, irrigation requirements of the crop in Gujarat varied between 6 and 10 inches[22-27]. The low irrigation requirements may be ascribed to high rainfall during monsoon season and good moisture storage capacity of the soil. If rainfall is included, the water requirements would be comparable to that in Delhi, which is stated to be 980 mm. by Dastane and Mohinder Singh[21].

Work done at the Research Station in Siruguppa (formerly in Madras) in 1942-43 showed that irrigation alone increased the cotton yield by 37 per cent[34]. When combined with application of fertilisers, the yield was raised by 114 per cent over control.

For linseed, work done at the Institute of Agriculture, Anand (Gujarat) during the years 1959-60 and 1960-61 showed the best irrigation treatment to be an interval of 15 days and 30 lbs. of nitrogen plus 30 lbs. of P_2O_5 per acre[35].

For tobacco, experiments conducted at the Central Tobacco Research Institute, Rajahmundry gave best results with one irrigation of 1 to 1·5 inches around 40 days after planting[36].

SCOPE FOR FUTURE

The review of work done on water requirements of crops in India, shows that studies have been undertaken with diverse approaches and techniques. In view of the extreme importance of the subject to the country, it is imperative that maximum utilisation should be made of available water supplies with a view to augment crop production. For this an intimate knowledge of water requirements of principal crops for various regions of India is essential. Water requirements have to be studied not only with respect to crop and region but also in respect of type of soil and climatic conditions. While the need for a systematic study of the subject is paramount it is important that the techniques should also be standardized on an all-India basis.

While research on the subject is important and should form the basis of long-term programme, plans will have to be framed for the dissemination of the knowledge gained by research to the cultivator whose practices regarding management of water have to be improved thereby. Wherever tentative data is available as a result of preliminary experimental findings, such information should be immediately communicated to the cultivator. Where no such data is available, fairly reliable estimates may be framed by the climatological approach. Improvements can be effected later in techniques and cultural practices regarding management of water on the basis of further research. A closer liaison needs to be established between the research and extension workers on the subject.

Table 9 gives duties of various crops in different regions of India. Table 10 gives countrywise yields of various crops. It appears that there is ample scope to revise duties and improve yields in India if experimental techniques are implemented in the field and the management of water and land is suitably improved.

TABLE 9. SHOWING STATEWISE DUTIES IN ACRES PER CUSEC FOR DIFFERENT CROPS IN INDIA.

Name of crop	U.P	Punjab	West Bengal	Madras	Andhra	Orissa	Maharashtra	Gujarat
Rice	55	50	90	60	60	125	70	70
Wheat	...	200	120—180	...	...	200	100—250	100 for 1st watering 280 for subsequent waterings.
Sugarcane	104	...	180	...	...	...	...	...
Cotton	...	100	...	180	...	200	210	210
Jowar	...	...	...	.	...	...	210	210
Rabi	128	200	70	180	.	200	120 to 250	120 to 250
Kharif	...	80	65	...	...	...	100	100

Sources : (i) Irrigation (Practice and Design), Vols. I and II by K.B. Khushalani, pages 97 to 99.
(ii) Irrigation Engineering by V. B. Priyani, pages 25 and 26.
(iii) A Text Book of Irrigation by Shahane and M.K.R. Iyengar, pages 77 to 79.

TABLE 10. YIELDS OF CROPS BY VARIOUS COUNTRIES IN 100 KG. PER HECTARE.

Name of Country	Wheat	Rice	Cotton	Potatoes	Tobacco	Linseed
India	7·9	13·6	0·9	71	7·4	2·7
China	10·9	34·7	3·7	...	11·8	...
Asia	8·9	16·5	1·4	91	8·0	2·8
Denmark	41·3	...	...	172	..	10·0
West Germany	33·8	...	...	216	27·1	7·1
Italy	18·1	52·4	3·2	102	15·6	8·4
Europe	19·3	44·0	3·1	145	11·2	4·7
U.S.S.R.	11·0	22·1	7·3	91	12·4	2·1
U.S.A.	14·3	37·5	5·2	196	17·5	4·6
North & Central America	13·6	27·4	5·2	175	15·5	4·9
South America	11·6	17·9	2·0	63	9·3	7·2
Africa	7·1	15·2	2·4	85	7·5	5·3
Australia	11·1	59·5	1·1	120	12·0	4·9
New Zealand	35·4	...	...	...	22·1	12·0
Oceania	11·6	42·6	...	125	14·0	5·6
World (Total)	12·2	22·0	3·2	111	10·5	4·1

Note : (1) Source : F.A.O. Production Yearbook 1960, pages 35 to 139.
(2) 100 kg. per hectare is equivalent to 1·08 maunds per acre.

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MANUFACTURE OF SIMPLE TENSIOMETERS AND GYPSUM BLOCKS AND THEIR USE FOR IRRIGATION PURPOSES

by

Sefik Yesilkoy*

INTRODUCTION

In the past, Turkey has imported the tensiometers and gypsum blocks used to determine moisture tension in soils in laboratory and field research conducted by the several soil, fertilizer and irrigation research institutes and stations maintained by TOPRAKSU.

Those now being used at the Soil and Fertilizer Institute located in Ankara have all been constructed in the laboratory at the institute. The cost of manufacturing the devices in the laboratory is one tenth the price of importing them.

TENSIOMETERS

The construction of a simple tensiometers

The body of the tensiometer is made of yellow brass metal tubing. This is cut in any desired length depending on the depth at which the porous cup is to be placed. Both ends of the tube are filed smooth. A hole is made about 10 cm. below the upper end with an electric drill. A 4 cm. length copper tube slightly smaller than the hole is inserted in this hole and soldered. A glass tube 6 cm. long used as the air trap is cemented at the upper end of the body with litharge cement. This cementing agent is made using a mixture of 100 ml., 1+3 glycerine + water solution and 260 gm. of litharge. The same cement is also used to fasten the porous ceramic cup to the other end of the brass body. The body of the tensiometer is then painted. It is very important that care is taken not to contaminate the porous cup with paint. As this will cause low conductance which slows down the response of the tensiometer.

A soft rubber stopper is used to close the glass airtrap. A thin vaccum plastic tubing is used as connection material between glass manometer and the copper tube. Capillary glass tubing is preferred for the manometer, because only small amounts of mercury will be needed. This is important if costs are to be kept at a minimum.

The ceramic porous cup is the most important part of a tensiometer. The following materials in the ratios shown were used to make the paste for the porous cups.

35 per cent illite clay mineral, from Ordu, Ulubey-Akoluk village.

40 per cent clay, from Bilecik, Sogut Inhisar country.

20 per cent quartz, from Istanbul, Qatalca-Kabakca village.

5 per cent $CaCO_3$.

The illite is wet sieved through a 200 mesh sieve and the clay remaining on the sieve is discarded. The same procedure is used to prepare the plastic clay. Quartz and $CaCO_3$ are ground until they pass a 200 mesh sieve. Materials are then mixed in the above described ratio and a paste made with water. A little of sodium silicate is added as a dispersing agent. The paste is transferred to a closed porcelain mixture and throughly mixed. After mixing, the paste is poured into a porous mould made of gypsum.

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After the desired cup thickness of aproximately 4 mm. is obtained in the mould, it is air dried and baked in an oven at 1,000 to 1,050°C. The strength of the ceramic cup increases and its porosity decreases as the temperature of the oven increases, and vice versa.

An important characteristic of the porous cup is its air-entry value, which determines its usefulness and the working range of the tensiometer. This value should be above 57 cm. of mercury, which is about 0.85 atmospheres in Ankara. In order to determine the air-entry value it is filled with distilled water and connected to a mercury glass manometer. The porous cup is exposed to the atmosphere and the water into the cup removed by evaporation. This causes the mercury column rise to its maximum height, which for a good useable cup, should be only few centimeters below the barometric reading.

Porous cup, which have air-entry values above 57 cm., are selected and used in making tensiometers.

Use of the tensiometer

In practice a holder is necessary to support the mercury-pot and glass manometer. A small soil sampler is used for installing the unit to the active root zone, and the lowest part of the hole is carefully bored to secure a snug fit between cup and soil. Boiled water is used for filling the tensiometer. It is important to note that the mercury column tends to act like a thermometer, and pressures indicated may merely show changes in the volume of water in the tensiometer caused by changes in the temperature. This undesireable effect may be reduced by painting the tensiometers white and placing the holder where direct sun-light will not reach the mercury-glass manometer.

These simple tensiometers have been used in field and green-house experiments. The purpose of the experiments was to determine the time for irrigation. The moisture retention curve for soil used in these experiments was determined as indicated by Fig. 2.

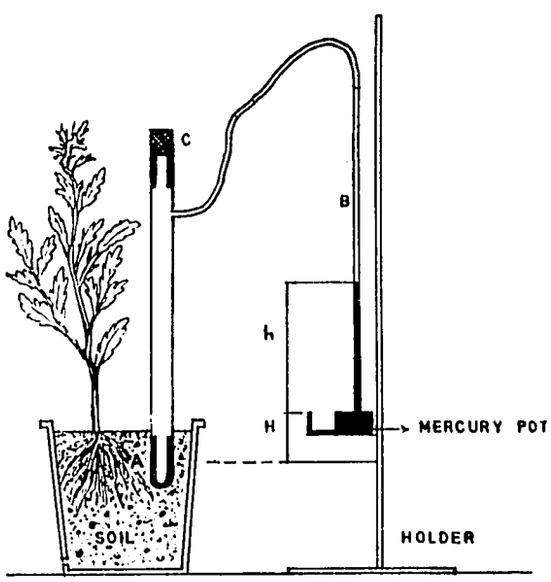

FIG. 1. SCHEMATIC OF A SIMPLE TENSIOMETER

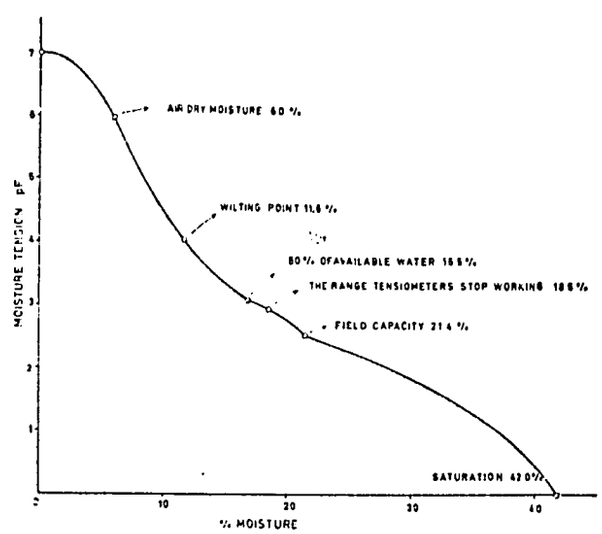

FIG. 2. MOISTURE RETENTION CURVE

The moisture content of the soil at various tensions was found and plotted on a graph paper. The moisture content of air dry soil sieved through a 2 mm. sieve was accepted as the moisture content of the soil at pF = 7·0 ; the moisture contents at pF 4·19, 2·54, 0 were found respectively using pressure membranes at 15 at. moisture, equivalent centrifuge and saturation per cent.

The graph shows that the available water is as 9·8 per cent. Tensiometers can work up to 0·85 of atmospheric pressure, which corresponds in this case, with pF = 2·94 and 18·5 per cent moisture.

When the tensiometers are used to measure the tension of soil moisture the distance from the highest level of mercury to the middle of the porous cup (H) Fig. 1, should be subtracted from the height of the mercury column in the glass manometer (h) times 13·6. The later distance is to be taken from the surface of the mercury in the mercury pot to the highest level of the mercury in the column.

GYPSUM BLOCKS

Construction of gypsum resistance units

Research has indicated that screen type electrodes are superior to other designs, hence this type was selected. Wire cloth, 30 mesh, is cut ½ inch by 1½ inches for electrodes. Wire leads are cut any desired length from lamp cord having plastic insulation. Wires are stripped for 1·8 inch and one end soldered to the electrodes. The other end is stripped for ½ inch, dipped in a soft solder flux, and into a pot of molten solder. This keeps the leads from fraying and facilitates attaching to the resistance bridge.

A split mold was made of aluminium which permits casting 10 units at a time. It can be easily taken a part for removal of the units. Electrodes soldered to the lamp cords are put into the mold with the aid of a pincers. The electrodes are spaced 3/16 inch apart using spacers, with the large flat surface parallel to the largest surface of the block.

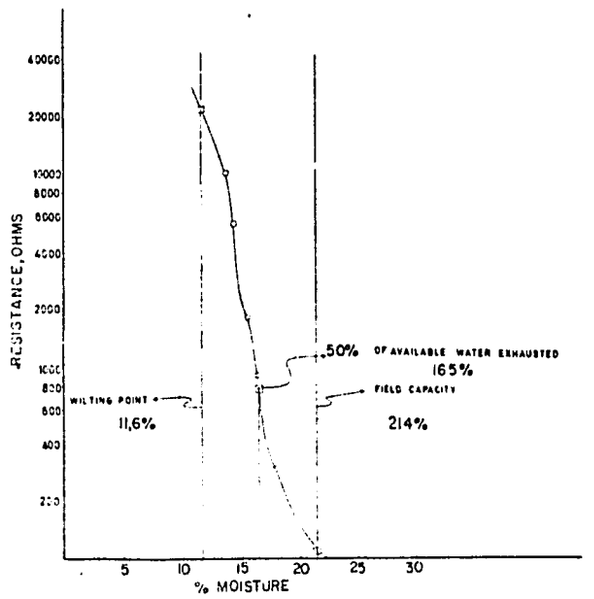

FIG. 3. CALIBRATION CURVE FOR GYPSUM BLOCK

They are held in place by clamping the lead wires firmly in the holes of the mold which have been drilled for that purpose. The blocks are cast from a mixture of 130 parts of casting plaster with 100 parts of water. The material is mixed for one minute in a soil dispersion mixer then poured into the molds. The spacer is removed 30 seconds after the plaster is poured and the blocks surfaces are smoothed and allowed to harden for half a day before they are removed from the cells. After removal, they are cured by drying for two weeks. They are then immersed in distilled water and the resistance read after one hour.

Calibration

The units must be calibrated to read either moisture tension or moisture content. When they are calibrated in terms of tension they provide an indication of moisture available to a crop. As available moisture is related to the force or tenacity with which water is held in the soil, the moisture content need not to be determined. Thus a single calibration curve for resistance units theoretically should apply to all soils, regardless of texture, if

blocks can be uniformly constructed. Since the calibration for tension-resistance relationship needs special use of pressure membrane and pressure plates, moisture content-resistance calibration curve was used. All soils have a different moisture retention relation ; hence, it is not possible to find a porous block that gives a single moiture content-resistance relation for all soils. For this calibration a special box was made from galvanized material with separate cover. Both the cover and the body were perforated in order to get moisture loss from the box during calibration.

First, six gypsum blocks were placed in the box and their leads brought through the small holes in the walls. Then the soil, which had been sieved through 2 mm. sieve was put in box. A very firm contact must be made between the soil and the units. The soil was wetted to saturation and left for drying. Daily readings in ohms were taken with a Bouyoucos moisture meter potentiometer. When a reading was obtained soil sample was removed from immediately around the block and the moisture content determined. Six different readings and their moisture contents were used to draw a moisture resistance curve. The characteristic points in the moisture retention curve were determined as described for tensiometers.

Resistance-moisture relationships derived from such calibration should always be checked in the field. Under field conditions, units respond rapidly to changes in the moisture content and are more apt to reflect the true calibration curve of the soil.

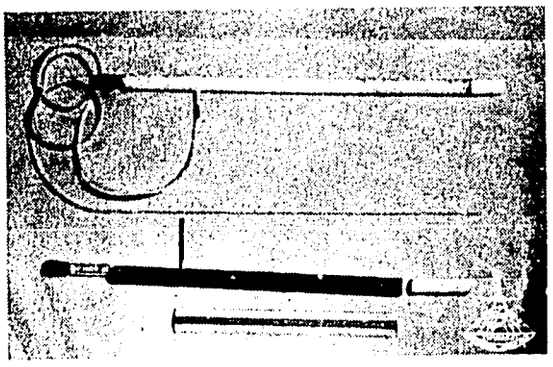

FIG. 4. Tensiometers before and after completion of construction.

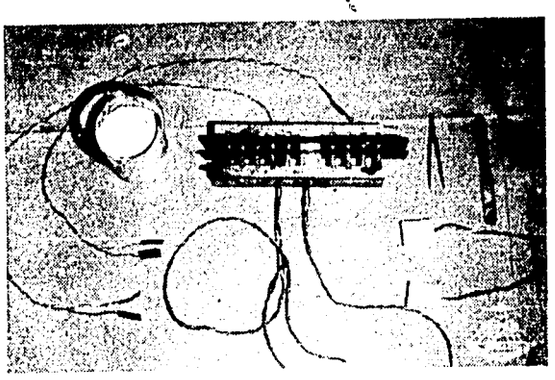

FIG. 5. The mold, electrodes, and other equipment used during casting of gypsum blocks. Two blocks already finished on the right.

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WEED CONTROL PROBLEMS OF IRRIGATION SYSTEMS IN TURKEY

by

Ismail Baykal*

INTRODUCTION

A weed may be defined as a plant which grows where it is not wanted. It may be a weed in one place and a desirable plant elsewhere. For example mustard may be cultivated in special fields, but it is considered a weed when it grows in a corn field.

In Turkey some farmers use cattails (Typha Latifolia) to build burn roofs. However, the same plant is considered harmful when it grows in a drainage canal. Canal weeds increase silting and seepage and harbour harmful insects, such as mosquitoes, and rodents. Also their seeds are carried by water to cultivated fields and infest them with new weeds.

The problem of weed control in irrigation systems is very important in the Near East and South Asia countries because some regions in these countries have tropical or subtropical climates.

THE MOST IMPORTANT CANAL WEEDS IN TURKEY

Because the climatic conditions are different in various parts of the country the problems of weed control are different. The following are the most common weeds in Turkey. Although it is not complete, large list is given at the end of this paper.

Typha Latifolia (Cattail)
Phragmites Communis (Common Reed)
Sparganium Romosum (Burr Reed)
Cyperus Articularus (Jointed Sedge)
Carex Spp. (Sedges)
Ceratophyllum Demersum L. (Hornwort)
Myriophyllum (Parrot's Feather)
Ranunculus Spp. (Buttercup Spp.)
Callitriche Spp. (Water Starworts)
Heteranthera (Mud Plantain)
Potamogeton Spp. (Pond Weed)

Each kind of weed shows a different reaction to chemicals. For example, in the case of Potamogeton Perfoliatus positive results are obtained in 24 hours by the application of 400 p.p.m. of Aromatic Solvent Naphta for 45 minutes. On the other hand, Potamogeton Pectinatus requires 800 p.p.m. of the above chemical for a positive result.

EQUIPMENT FOR APPLYING HERBICIDES

Various kinds of herbicides may be applied by sprayers, dusters or fumigant injectors for general weed control purposes. In irrigation systems, sprayers are used for dispersing liquid chemicals (oil, emulsions, or solutions) in water which is flowing in the ditches or canals. For applying liquid herbicides a high-power sprayer with a long boom is most suitable. There are equally spaced nozzles on the boom from which liquid chemicals are sprayed under pressure uniformly over the area. For proper application the pressure should be between 150 to 300 lbs./sq. inch.

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PHENOLOGIC HABITS OF WEEDS

The reaction of a weed to the application of chemicals varies according to the stage of growth of the plant. For example, positive reaction is obtained by the application of 150 grams of active 2·4-D Acid per decare for the control of a young water cress, but it would require 250 grams of the same chemical for a mature plant of this kind, and the corresponding cost would be about twice the cost of the control of the young plants.

INFESTATION DENSITIES

The size of the infestation area and the density of weeds determines the cost of the eradication. In order to keep the cost low it is preferable to carry out spotted application. It is necessary to wash thoroughly those weeds which are more resistant to chemicals. Chemicals such as Amino-Triazole, Dalapon, Reglon, Gramoxon, and Endothal are effective, but as these chemicals are expensive, they should be applied at the spots with the highest dosages.

SOURCES OF INFESTATION

The sources of infestation and the kinds of weeds must be determined. In a new irrigation system perhaps only three or four kinds of dangerous weeds may be found, but other species may invade later. It is necessary to know what kinds of weeds may spread from the source down the irrigation system so preparations may be made beforehand.

WEED CONTROL IN THE UNITED STATES

Since 1958, the research work being carried in the United States has been followed. Research and practice in the United States indicated that Amino-Triazole, 2·4-D Acetic Acid, Hydrothal, Endothal, and Dalapon are effective for weeds which are resistant to most other herbicides.

For example, it is considered that the application of 50 per cent active Amino-Triazole at 2 kg./decare in early spring and 1·5 kg./decare in a second application will be sufficient during an irrigation season. The second application is performed when the new growth reaches 10 to 20 inches. Dalapon (which is composed of 85 per cent active 2·2, Dichloropropionic Acid) will serve the same purpose when applied in the amounts of 3 kg./decare in the first and 2 kg./decare in the second application. Those are total herbicides and should be used far from cropped area.

It is important to use proper methods when applying herbicides during the irrigation season. The herbicide must kill the weeds and the chemical must decompose in a short time so that the concerned canal may be used safely for irrigation. Good results were obtained in the United States against chemical resistant weeds by using quick action herbicides such as Benoclor 3 C*.

WEED CONTROL IN TURKEY

Turkey has 3,700 km. of irrigation main canals, 1,000 km. of drainage canals, and 835 km. of levees, in addition to much greater lengths as secondary and tertiary canals which must be operated and maintained properly. Weed Control is also an important activity for the improvement of drained and reclaimed lands.

Weed control activities are carried out in the following three phases :

(a) **Investigation** : Investigations are conducted in the problem areas to establish the kinds of weeds causing trouble and their degree of infestation.

(b) **Research** : By using samples obtained during the investigations research work is carried out to determine the phenologic habits of the weeds concerned, to select the most suitable method for controlling them, and the most effective herbicide.

*Benoclor : Chemically it resembles somewhat the structure of aromatic solvent naphtha.

Some representative results of tests are given at the end of this paper.

(c) **Application** : This phase consists of the implementation of the findings of the above two phases.

APPLICATION

(a) **Total Herbicides** : Because total herbicides are very effective it is necessary to apply them at locations which are far from the vicinity of sensitive cultural crops, and preferably at drainage systems. When it is inevitable to use such herbicides, then they should be applied at least three months before the growing season of sensitive crops. Although total herbicides may be used safely during the irrigation season on drainage systems which are not connected to any irrigation system below and do not have appreciable seepage, for crops which are very sensitive, such as cotton, the herbicides should be applied in early spring or after harvest season.

At the present the two important total herbicides used in Turkey Amino-Triazol and 2-2, Dichloropropionic Acid. Among other places, they were used in the Meric-Evros Flood Control Project against cattails, tules and sedges in the amounts of 3 kg./decare and good results were obtained. In some heavily infested areas in this project a second application was used when regrowth was observed and thus provided weed control for the whole year.

Total herbicides were also used in the irrigation systems of the Izmir Region which were heavily infested with cattails and common reeds with densities of 200 roots per square meter and heights over 3 meters. In this case, also 2-2, Dichloropropionic Acid was used with a concentration of 3 kg./decare. In one area it was applied with water as inert ingredient and in another area with Xylol-Toluol as activator.

In the case of water mixture the effect of the herbicide was observed within three days after application. In the second case, application in the morning produced results by the evening of the same day in the form of rapid yellowing and withering. Both applications were successful. However, in a highly infested area regrowth was observed 30 days after the application. After the first application it was necessary to burn the plants and make a second application with a concentration of half of the first one.

Another type of total herbicide was applied in the Manisa Region. This consisted of the following mixture* :

Gesatop (Simazine 50 WP)	1·25 Kg.
Gesaprim (Atrazine 50 WP)	1·25 Kg.
Gramevin (Dalapon)	1·25 Kg.
Dicoppur—Flussig	1·20 Kg.
Total of Chemicals	4·95 Kg.

An amount of up to 4·95 Kg./decare was applied. After a strong application the effect lasted for 8 to 9 months.

(b) **Selective Herbicides** : The side slopes of levels are protected by grass cover in many instances because this provides a faster and less expensive protection than riprap or masonry lining which would only be used where water velocity exceeds two meters per second. When grass cover is used there is usually the problem of eliminating the broad leaved and deep rooted plants which also grow along with the grass. Selective Herbicides eliminate most kinds of these without damaging the grass.

*Gesatop : 2-chloro-4,6-Bis (ethylamino) -s-triazine Co. Gelgy.

Gesaprim : 2-chloro-6-ethylamino-4- isopropylamino 1,3,5-triazine

Gramevin : 2,2-Dichloro propionic acid Co. Shell Co. Dowach.

Dicopur flussig : 2,4-Dichloro phenoxy aceto acid triethanol amin.

This is performed by the application of a mixture of 2,4—D as an active ingredient. A concentration of 150 to 200 grams per decare is used. The best example of this type of weed control is its application on 170 kilometers of the levees in the Meric-Evros Flood Control Project.

(c) **Aquatic and Semi-Aquatic Herbicides :** In the application of herbicides in irrigated areas the application usually must be confined to non-irrigation season or the effects should diminish after application so that the culture crops will not be damaged. Although there are many kinds of powerful herbicides, it became necessary to develop new types which, while having fast action, would also decompose very soon after application. For this purpose the Turkish-staff developed a herbicide consisting of a mixture of Xylol and Toluol with an emulsifier.

This mixture gave good results with a concentration between 300 and 400 p.p.m.

The following formula may be used to determine the amount of herbicide required for selected application conditions with water discharge in the irrigation ditch where the herbicide is to be applied :

$$I = \frac{60\ PQT}{d \times 10^6}$$

I=The amount of liquid herbicide (in liters) to be applied during the time (t) ;

P=Selected concentration for the herbicide in parts per million by volume in the following water of the ditch ;

Q=Water discharge in the irrigation ditch (liters/sec.) ;

t=Selected duration of application of the herbicide (minutes) ;

d=Density of the liquid herbicide (Grams cm^3).

To serve as an example herbicide for use against Moses (Chara), and Pond Weeds (Potamogeton Pectinatus, Potamogeton Natans) was computed :

Herbicide : Aromatic solvent naphtha plus 10 per cent duromus oil, density 0·84 gm/cm^2.

Concentration desired : 400 p.p.m. in 30 minutes

Q=500 liters/sec.

Solution :

$$I = \frac{400 \times 500 \times 60 \times 30}{0{\cdot}84 \times 10^6} = 428{\cdot}5 \text{ liters.}$$

In the above example the proper application of the herbicide was selected as 400 p.p.m. If a solution of tar oil and benzol is to be used the proper concentration would be between 200 and 250 p.p.m. which would be more economical where these chemicals are available.

However, this was not the case and this herbicide was used in the Adana and Tarsus Areas where weed densities were between 800 and 1,000 roots per square meter and the lengths of weeds were as much as 8 meters.

The herbicide was applied at two stations. After the first application the concentration decreased to 200 p.p.m. 1,500 meters downstream. This was selected as the site of the second application and 200 p.p.m. was applied in order to increase the concentration to 400 p.p.m. again.

Conclusion :

Experience in weed control shows that the average cost is between 100 to 120 T.L./decare and with selected herbicides or aquatic and semi-aquatic herbicides it is between 10 to 15 T.L./decare.

These are much lower than the cost of mechanical weed control. In a badly infested canal, weed control with draglines costs 1,480 T.L./decare, whereas it costs 120 T.L./decare using total herbicides.

Mechanical weed control of aquatic weeds is not effective because the weeds soon grow again and cutting of the weeds causes transportation of the weeds downstream where they re-establish themselves and spread the infestation.

In protecting the grass cover on flood control levees, manual labour costs are 30 to 40 T.L./decare, whereas the cost of applying selective herbicides is 10 to 15 T.L./decare, as mentioned above.

Chemical weed control is also advantageous because it can be accomplished in a very short time. A dragline may clean a canal at the rate of 100 to 150 meters per day. But a power sprayer can apply herbicides on 10 to 15 kilometers per day. Also the first cost of the spray is much less than that of the dragline.

Today weed control forms one of the most important items in the operation and maintenance of irrigation systems. The General Directorate of State Hydraulic Works has engaged in large-scale weed control since 1958. "Canal Weed Control Laboratories" are being built by the General Directorate and will be much useful in the development of weed control practice in Turkey.

APPENDIX "A"

RESULTS OF LABORATORY RESEARCH

Test Group No. 1

Plant : Potamogeton Natans

Herbicide : Aromatic Solvent Naphtha Soluble Oil.

Date of Application : December 9, 1960

Procedure : The herbicide was applied with the following concentrations on plants in two sets of test-tubes. The contact time was one hour and the temperature, 20°C. At the end of one hour the plants were washed, and the contents of test-tubes replaced with clean water.

(A) Date of Observation : December 9, 1960
(Three hours after application)

Test No.	Herbicide p.p.m.	Observations
1	0	Plant was normal
2	400	Yellowish
3	600	Pale Green
4	800	Plant almost dead
5	1,000	Pale yellow and decaying
6	1,600 b	Pale yellow and decaying

(B) Date of Observation : December 17, 1960.

Test No.	Herbicide p.p.m.	Observations
1	0	Plant was normal
2	400	Decaying
3	600	Decaying
4	800	Decaying
5	1,000	Decaying
6	1,600	Decaying

Test Group No. 2

Plant : Potamogeton Natans

Herbicide : Copper Sulphate Aromatic Solvent Naphtha Soluble Oil.

Date of Application : January 2, 1961

Procedure : The herbicide was applied with the following concentrations in two sets of test-tubes. The contact time was 30 minutes, and the temperature 30°C. At the end of 30 minutes the plants were washed and contents of test-tubes replaced with clean water. One day after the application the plants were exposed to sunlight for two hours and returned to the laboratory.

(A) Date of Observation : January 7, 1961

Test No.	A.S. Naphtha p.p.m	$CuSO_4$ p.p.m.	Observations
1	0	0	Plant was normal
2	100	0	Leaves light and dark brown
3	100	10	Leaves light and dark brown
4	100	50	Leaves dark brown
5	200	0	Leaves and body brown
6	200	50	Leaves and body brown

(B) Date of Observation : January 18, 1961

Test No.	A.S. Naphtha p.p.m.	$CuSO_4$ p.p.m.	Observations
1	0	0	Plant was normal
2	100	0	Upper part decayed lower part alive
3	100	10	Blackish brown, leaves wrinkled
4	100	50	Blackish and decaying
5	200	0	Blackish and decaying
6	200	50	Blackish and decaying

Test Group No. 3

Plant : Myriophyllum

Herbicide : 1/5 Crude Naphtha (Tar Oil) + Benzol 4/5

Date of Application : March 6, 1961.

Procedure : The herbicide was applied with the following concentrations on plants in two sets of test-tubes. The contact time was one hour and the temperature, 20°C. At the end of one hour the plants were washed and the contents of the test-tubes were replaced with clean water.

(A) Date of Observation : March 8, 1961

Test No.	Herbicide p.p.m.	Observations
1	0	Plant was normal
2	50	Plant was normal
3	100	Plant was normal
4	150	Plant was normal
5	200	Pale yellow
6	250	Pale yellow

(B) Date of Observation : March 10, 1961

Test No.	Herbicide p.p.m.	Observations
1	0	Plant was normal
2	50	Pale yellowish
3	100	Pale yellowish
4	150	Pale yellowish
5	200	Blackish and yellow, decaying
6	250	Blackish and yellow, decaying

(C) Date of Observation : March 13, 1961

Test No.	Herbicide p.p.m.	Observations
1	0	Plant was normal
2	50	Starting to decay
3	100	Starting to decay
4	150	Blackish yellow
5	200	Blackish, completely withered
6	250	Blackish, completely withered

Discussion of the Results

The results of Test Group No. 1 indicate that the effective concentration of Aromatic Solvent Naphtha starts at 400 p.p.m.

In Test Group No. 2, activation of the effectiveness of Aromatic Solvent Naphtha was attempted by adding Copper Sulphate. A solution of 200 p.p.m. A.S. Naphtha and 10 p.p.m. Copper Sulphate, gave equivalent results and was more economical.

In Test Group No. 3, use of the residue tar oil from the Ankara Works was attempted and, as may be observed from the tables, beginning with a concentration of 50 p.p.m. this herbicide had sufficient effectiveness. Use of this herbicide in countries which have oil industry is strongly recommended.

APPENDIX "B"

LIST OF SOME WEEDS IN TURKEY

Latin name	Common name
Anagallis spp.	
Apium nodiflorum	Celery
Adiantum capillus veneris	Common Maindenhair
Anagallis arvensia	
Angelica Heterucarpa	
Alisma plantago aquatica	Water Plantain
Nelumbo penta petala	
Chara Nitella gracilis	
Chara Tolipella prolifera	
Geratophyllum demersum	
Geratophyllum submersum	
Chenopodium rubrum	
Cardamine hirsuta	
Cardamine amara	
Cyperus longus	Galingale
Conjugatae spirogyra	
Chenepodium urbicum	Lamb's quarters
Carex Paniculata	Sedges genus
Carex lengus	
Cyperus olivaris	
Cladium mariscus	Clados
Hippuris vulgaris	Mare tail = horstail
Helosciadium nodiflorum	Umbellifera
Hydrocotyle umbellata	Water penny-wort

Latin name	Common name
Iris pseudacorus	Yellow flag
Juncus striatus	Arrow Grass Fam.
Juncus alpinus	
Juncus lamprocarpus	
Jussiaea grandiflora	
Juncus acutus	
Lippia repens	
Lemna minor	Duck Weed
Lemna gibba	Duck weed
Limnanthemum nymphoides	
Myriophyllum exalbescens by Fernald	Water Milfoil
Myriophyllum exalbescens spicatum.	
Mentha silvestris	
Milium Sp.	
Nuphar luteum	
Najas major	
Nasturtium officinale	
Potamogeton filiformis	Broad leaved pondweeds genus
Potamogeton Alpinus	
Potamogeton Nodosus	
Potamogeton Berchtoldii	
Potamogeton Perfoliatus	
Potamogeton Vaginatus	
Potamogeton Caulinia minor	

Latin name	Common name
Potamogeton foliasus	
Potamogeton illinoensis	
Potamogeton densus	
Potamogeton amplifolius	
Potamogeton vulgaris	
Potamogeton crispus	
Potamogeton pectinatus	Angel's hair (Horsetail moss)
Potamogeton Natans	
Polygonum lapathifolium L.	Pale smart weed
Polygonum persicaria	
Phragmytes communis	
Ranunculus aquatilis	Vorn buttercup genus
Ranunculus montanus	

Latin name	Common name
Rumex conglomeratus	Curled dock genus
Stachys hirta	Hedge Nettele
Stachys alpine	
Sagittaria rigida	
Crispus holoshoenus	Wood grass genus
Scirpus maritumus	Wool grass genus
Salvinia natans	Water fern
Typha latifolia	Cattails
Typha angustifolia	Cattails
Sparganium ramosum	
Vallisneria spiralis	Eel grass
Zanichellia palutris L.	

METHOD FOR SCHEDULING AND DETERMINING DEPTH OF IRRIGATION EMPLOYING CONSUMPTIVE USE

by

Dr. S. E. Roy*

The scheduling and depth of application of irrigation water on many diversion irrigation systems in India as also in other developing countries of the Near East and South East Asian Region is oriented more from the stand-point of availability of water in the rivers and the canal systems during certain periods rather than from the actual requirements of the crops concerned. This is not conducive to obtaining maximum production benefit from the irrigated agriculture. To achieve this latter objective, it is highly essential that irrigation systems should be designed and constructed to cater for the actual irrigation needs of the crops, after taking into account various climatic and soil factors which influence these needs. On the other hand, it is also equally necessary that the cropping and the allied agricultural practices should be carefully planned after taking into account the probable pattern of supplies in the irrigation systems. In both these approaches, it is necessary to have a precise appraisal of the optimum irrigation requirements of crop. This paper describes how consumptive use and other relevant factors can be used to work out the optimum depth and scheduling of irrigation for obtaining maximum results.

Natural Water Supply and Precipitation

The purpose of irrigation is to supplement deficiencies in natural water supply in order to grow crops. By far the most common form of natural water supply available to crops is precipitation. Accordingly it is important to understand that following characteristics of natural precipitation :

1. the form of precipitation,
2. the intensity of rain storms,
3. the distribution, in the crop season and throughout the year,
4. the amount, and
5. the frequency of precipitation showers.

If the precipitation occurs in the form of rain frequently and at low intensities then run-off is low and most of the moisture can be stored in the soil available for plants.

Not all rainfall is effective for meeting plant needs since it often falls in showers of uneven intensity, scattered at random through a rainy season or two in the year. Other factors remaining constant, at higher intensities, a rainstorm tends to run-off the surface to a greater extent causing erosion. This factor, together with interception which occurs to a greater extent when showers are of a lower intensity, chiefly controls the amount of effective rainfall. The effective rainfall has to be taken into consideration for designing a proper irrigation system, and for adjusting the time and depth application of supplementary irrigation water. The proportion of rainfall taken in by the soil is also dependent on the infiltration and percolation rate, the slope characteristics and the crop cover, besides the intensity of rainstorms.

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Because of the time and space variability and uncertainty of rainfall, it can best be approached using probability. A short period of drought may adversely affect crop yields, while a severe drought may completely destroy a crop. In order of importance, the following probabilistic characteristics of rainfall should be determined by statistical analysis of existing data :

i. Frequency, duration and intensity of droughts (sub-normal rainfall spells) expected within normal cropping seasons.

ii. Minimum amounts of precipitation expected over the growing period and the year, in successive weeks, with frequencies.

iii. Intensity distribution of rainstorms.

Generally, the more humid the region, the greater the disparity in seasonal distribution of precipitation and intensities at which the storms occur and the greater the frequency and duration of droughts. Thus probabilistic factors become more important in humid regions needing supplementary irrigation than in arid ones. Precipitation has its greatest impact on scheduling and depth of application as far as irrigation design and operation are incurred.

As an example, the storm intensity of rain showers in Kharagpur, West Bengal is given in Table 1 which also shows the estimated intake for each group of storm intensities for a paddy cover on 2 per cent slope. Almost 30 per cent of the total annual rainfall is lost by surface run-off and interception under the conditions specified. Besides these losses, if the rainfall occurred in large amount over prolonged rainy periods, there may have been considerable deep percolation losses.

The year to year variation can be discerned from Table 2 which gives the annual amount of rainfall for Kharagpur for the year 1957 to 1963. The standard deviation about the mean of 54·02″ is 5·94″, and the co-efficient of variability 11·06 per cent.

The rainfall distribution by months, averaged over the last seven years is presented in Fig. 1 and Table 3. This Table and Fig. 1 also presents the minimum rainfall expected in each month, once in 5 years, and once in 10 years.

Principles for Determining Time of Irrigation and Depth of Application.

Crop growth is dependent on a bio-physical system which consists of the dynamic conditions of the crop, the soil and the atmospheric environment. It is important to take cognition of the inter-relationships involved of these three factors. Ideally, irrigation should be designed to supplement natural soil moisture to maintain an optimum moisture regime for crop growth and yields.

Significance of Soil Moisture — Plant Growth Relationships.

The concept of optimum moisture regime is inextricably tied up with plant physiological processes. A plant requires water to maintain turgidity of its cells and their growth. The water which maintains turgidity, does so through a delicate system of physiologically controlled valves — Ideally, the roots must take in water at a rate only slightly greater than the rate at which stomatal openings transpire water through leaves. The diffusion pressure deficit (DPD) of plant tissues, therefore, becomes an important measure of the need for water by a plant. The same pressure concept may by extended to the soil moisture surrounding the crop root system. Plant roots can utilise water only if the pF at which the moisture in the soil is held is less than 4·2 or 4·3. Below this the plant is unable to maintain the turgidity required by the cells for their proper physiological functions, and the crop permanently wilts and dies. However, before this extreme state is reached, the moisture content in the soil may be at sufficiently high tension as to effect the plant tissues adversely, and thereby detrimentally affect crop growth. Moisture in the soil that is above field capacity is not retained against gravity due to the laxity of surface tension

TABLE 1. RAINFALL STORMS GROUPED ON THE BASIS OF INTENSITY OF RAINFALL, AND ESTIMATED INTAKE OF EFFECTIVE RAINFALL ON 3 PER SLOPE WITH PADDY COVER, AT KHARAGPUR, W. BENGAL.

Intensity (Inches/hour)	No. of storms per year	Amount contributed in groups (inches)	Estimated Effective rainfall (inches)
0·5 — 0·5	50	11·4	9·1
1·0 — 1·0	12	4·7	3·6
2·0 — 2·0	17	15·5	11·3
3·0 — 3·0	5	9·2	6·2
4·0 — 4·0	8	11·4	6·8
— 5·0	1	1·9	1·6
Total	93	54·1	38·0

TABLE 2. ANNUAL AMOUNT OF RAINFALL FOR KHARAGPUR, WEST BENGAL SHOWING VARIATION FOR THE YEARS 1957-1963.

Years	Annual total rainfall in mms.	Annual total rainfall in inches
1957	1,134·3	44·66
1958	1,348·6	53·09
1959	1,601·4	64·05
1960	1,297·4	51·08
1961	1,491·6	58·72
1962	1,385·0	54·53
1963	1,348·0	50·64
Average of 7 years	1,372·3	54·02

forces. The available moisture content is the difference between the field capacity and the permanent wilting point.

In the lower ranges of available moisture content the extra energy expanded by the plant to take in water is such as to inhibit maximum crop growth by a reduction in turgor pressure within plant cells. Plants roots also require a considerable amount of oxygen for respiration, which if reduced in supply due to an excessive amount of water in the root zone, will result in an inhibited rate of crop growth. Fig. 2 gives the relationship between the moisture content of the soil and the rate of crop growth. For most crops the optimum growth occurs at about 80 per cent of the available moisture content. However, if the moisture regime is maintained above 50 per cent yields are significantly less.

Effect of Insolation on Transpiration

Although it is generally agreed that a reduction in soil moisture has some effect in reducing the rate of transpiration, this is controlled by the insolation. High intensity of sunlight acts to collapse the guard cells of plants and thus close the stomatal openings. The rate of transpiration is closely related to the vapour pressure deficit in the air when the stomata are almost fully open, as in dull cloudy conditions, low intensities of sunlight, and at night. However, under the influence of bright sunlight, the transpiration rate is reduced far below that which may be determined by normal physical evaporation rate calculations based on vapour pressure differentials. The tendency is for vegetation to reduce the diurnal, seasonal and annual amplitude of variation on water use to make it a more steady rate. The moderated consumptive use rate is affected simultaneously by many complex soil moisture, meteorological, and plant physiological factors, thus serving as an index that directly incorporates the chief factors affecting the water requirement of crops.

Consumptive Use as it Affects Irrigation

In working out an integrated system design, it is essential to give due weight to all the complex factors that affect the system. This would have become a stupendous problem if it was impossible to find a suitable index that would be representative of the effects of the several complex variables involved. Consumptive use, which is essentially the evapotranspiration rate, the rate at which wtaer is lost from the soil controlled by the effect of soil factors, crop physiological factors and the meteorological factors, is such an index.

The Effective Root Zone

Quantitative soil storage capacities and use of water by crops can best be understood in the light of the effective root zone concept. After a crop germinates, its root system continues to develop both horizontally and vertically, depending on the characteristics of rooting of the particular species, the soil moisture conditions surrounding the roots and the mechanical impedance offered by the soil. Tap-rooted crops extend more vertically whereas fibrous rooted crops such as the cereals and other grass family crops and tubers such as potatoes and groundnuts, rapidly extend their roots more in the horizontal direction, and are thus shallow rooted. However, the moisture contents of the different layers of the soil exercise an effect on the depth of rooting to a greater extent than the physical impedance of the soil as manifest by the bulk density. The root system of normally deep rooted crops may be severely inhibited by close proximity of the water-table, so that the roots may tend to extend predominantly in the upper layers where the oxygen regime is more favourable for root respiration. If on the other hand, the soil has greater moisture content in its deeper layers, at less than field capacity, root extension downward is induced which not only increases the effective root zone pasturage and depth, but also by doing so, makes the crop more able to withstand drought.

Rate of Removal of Soil Moisture from Various Depths.

Another factor which enters into consideration of proper irrigation scheduling and

depth, is the fact that the roots of the same plant growing in a moist soil will extract more water than if it grows in a drier soil. Also, the tendency is for the crop to extract amounts of moisture in a pattern similar to that of its root extension (Fig. 3). The tendency for properly irrigated crops is to assume the shape of extraction pattern of the moist soil curve. The topmost quarter of the root zone supplies approximately 40 per cent of the total moisture, whereas the successively deeper quarter horizons supply 30, 20 and 10 per cent respectively. The topmost layers get wetted to the greatest extent most frequently, and the depth of irrigation is generally insufficient* to reach beyond the effective root zone. Thus, shallow rootedness is induced by greater frequency of application with less depth of irrigation per application, and vice versa. Hence, it is generally more efficient to apply greater quantities of irrigation subject to the limitation of the water holding capacity of the soil.

The Water Reservoir Capacity

The water holding capacity of soil is chiefly a function of its texture and structure. Table 4 gives approximate values for average structural conditions and may be used as a guide for determining the interval and depth of irrigation.

The structure also affects the water holding capacity and the maximum available moisture content. The more developed the structure, the greater is the water holding capacity, and the greater is the proportion of this water holding capacity in the form of available moisture content. Well structured soils have lower bulk densities and greater amounts of available moisture per foot, than poorly developed soils.

The depth of the effective root zone depends on factors already described and also on the climate and length of growing season. However, for regularly irrigated and normal soil conditions, the effective root zone for any particular crop tends to be nearly constant. Since most crops are grown in their particular soil textural preferences, over a fairly constant growing period, the effective root zone for an irrigated crop can more or less be accurately defined. Table 5 gives the approximate effective root zone depths of some principal crops.

The amount of available water that is retained within the effective root zone depth is the water reservoir from which the crop extracts water to sustain itself.

Rainfall entering the soil will first go to make up the deficit in the available water reservoir, until the effective root zone has reached its maximum water holding capacity throughout its depth. Any further water taken in by the soil appears as deep percolation loss. As the plants deplete the available moisture, it should be replenished at a level not materially below 50 per cent available moisture in order to sustain optimum crop growth. If no natural rainfall occurs, irrigation should make up the deficit up to the maximum storage capacity of the entire root zone, but not beyond*.

Scheduling and Depth of Application of Irrigation.

A crop requires moisture to germinate. Its need for water keeps growing from emergence, through its vegetative growth and flowering stages. The water needed starts to decline at the wet fruit stage and continues to do so through its dry fruit stage upto harvest. The moisture requirement is essentially the consumptive use, which is represented by the curve in Fig. 4.

The ratio of consumptive use to evaporation, which is the co-efficient K, in Blaney and Criddle's formula, varies considerably with the stage of growth, as shown by the smooth curve in Fig. 4. Since evaporation

* Generally Scientific Irrigation Practice contemplates application of sufficient water to fill the root zone and provide adequate leaching to maintain a favourable salt balance. Soil conservation against salinity should be an important objective of irrigation practice also.
—Editor

* Somewhat more than this is required for leaching to maintain salt balance—Editor.

TABLE 3. AVERAGE RAINFALL DISTRIBUTION BY MONTHS FOR KHARAGPUR, WEST BENGAL, AND MINIMUM RAINFALL EXPECTED ONCE IN 5 YEARS AND ONCE IN 10 YEARS.

Month	Minimum expected rainfall once in		Average monthly rainfall	
	5 yrs.	10 yrs.	in mm.	in inches
January	0	0	13·3	0·52
February	0	0	35·0	1·37
March	0·1	0	13·9	0·54
April	0·3	0	44·5	1·75
May	1·0	0·6	95·8	3·77
June	3·1	1·2	197·1	7·76
July	10·2	8·7	306·4	12·06
August	7·2	4·7	230·0	9·05
September	8·7	5·5	309·7	12·19
October	1·2	1·0	126·3	4·97
November	0	0	0·01	0·0001
December	0	0	0	—

TABLE 4. WATER HOLDING CAPACITY AND MAXIMUM AVAILABLE MOISTURE CONTENT OF VARIOUS TEXTURAL CLASSES OF SOIL.

Soil texture	Inches per foot of depth	
	Water-holding capacity	Available water
Sandy	1·3	1·2
Loamy sand	1·5	1·4
Sandy loam	1·8	1·6
Fine sandy loam	2·2	1·8
Clay loam	2·7	2·1
Clay	3·4	2·6

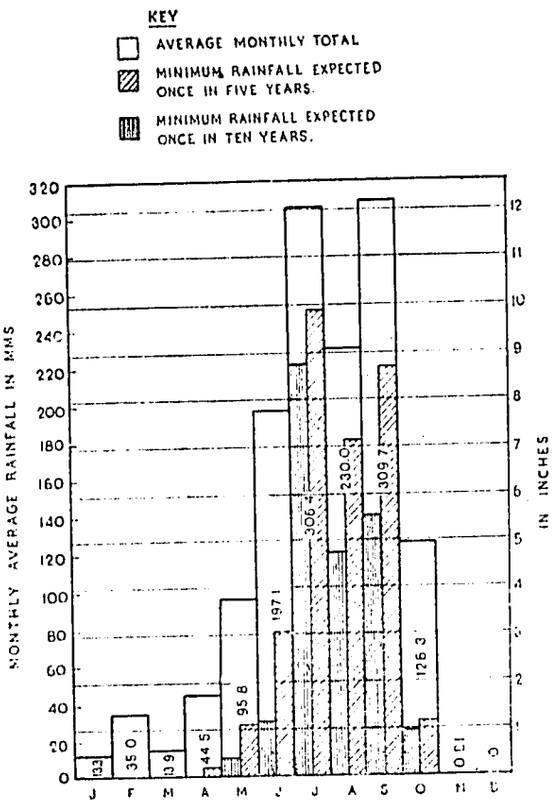

FIG. 1. RAINFALL DISTRIBUTION BY MONTHS (7 YEAR AVERAGE) FOR KHARAGPUR, WEST BENGAL SHOWING EXPECTED MINIMA ONCE IN 5 YEARS AND ONCE IN 10 YEARS.

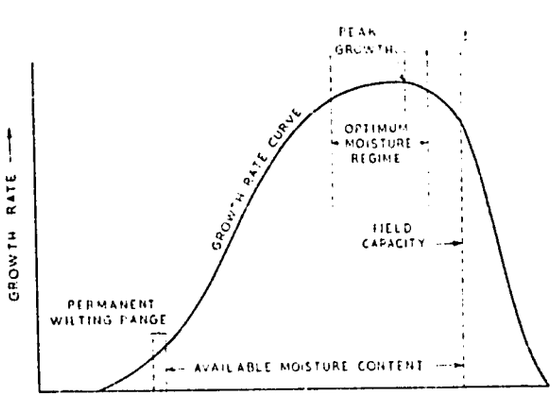

FIG. 2. SHOWING SOIL MOISTURE PLANT GROWTH RELATIONSHIPS.

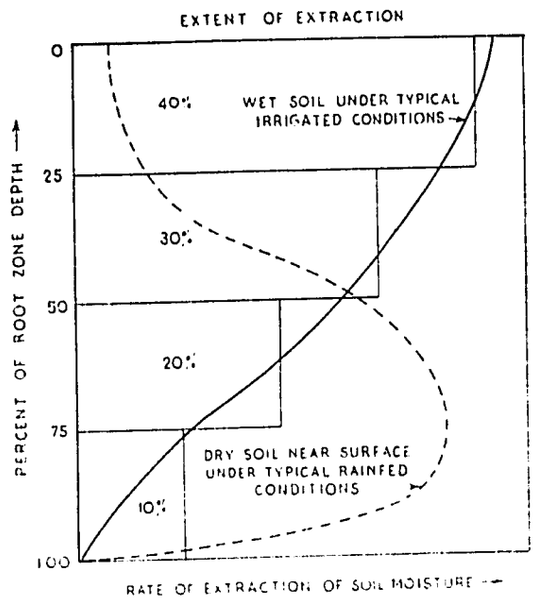

FIG. 3. EXTRACTION PATTERN WITH DEPTH AND VARIATION IN SOIL MOISTURE CONTENT BY HORIZONS FOR TYPICAL IRRIGATED AND RAINFED CONDITIONS.

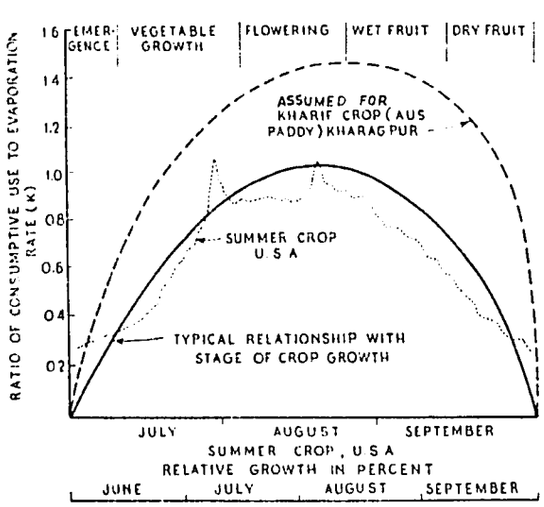

FIG. 4. TYPICAL EXPECTED VARIATION OF RATIO OF CONSUMPTIVE USE TO EVAPORATION RATES DURING THE RELATIVE STAGES OF CROP GROWTH IN THE SUMMER CROPPING SEASON, U.S.A., AND THE KHARIF SEASON, FOR UPLAND PADDY IN KHARAGPUR.

integrates several weather factors, this dimensionless ratio related to the stage of crop growth should be most significant. This curve has been shown to be remarkably constant in a certain region of the U.S.A., the ratio approaching unity near the peak at the beginning of the flowering stage, if instead of using the time scale for the abscissa, a scale of the relative stage of maturity of growth is used.

This curve has great importance in the scheduling of depth of application of irrigation and gives due regard to both the physiological needs of the plant and the potential evaporation rate of the atmosphere. Examples to employ this conceptual are given subsequently.

Examples to Determine Time and Depth of Application of Irrigation.

Perhaps, the best means of explaining the application of consumptive use to design of an irrigation system is by concrete examples. It is required to work out the scheduling and depth application of irrigation and the irrigation system required for a farm near Kharagpur that is to grow 15 acres of upland paddy in the kharif season, and 15 acres of potato in the rabi season.

Determination of Amount and Spacing of Natural Water Supply.

The rainfall distribution by weeks is preferable for precise scheduling of irrigation. However, since no direct consumptive use measurement has been undertaken here or elsewhere in India, only the rainfall distribution data by months as given in Table 3, comparable to the consumptive use figures calculated from meteorological data by months, are used. The effective rainfall expected in any month during the kharif season crop is given in Table 6, which is calculated by multiplying the amount of rainfall expected each month by the actually determined factor of 0·8 for paddy on 2 per cent slope. The deficiencies to be met each month of a normal season as well as during a deficit season expected once in five years are given in Table 6 also. Since virtually no rainfall occurs during the growing season of potato, irrigation must replenish the total consumptive use in each month.

Column 5 of Table 6 is obtained by calculating consumptive use by the Blaney and Criddle method for the months of June, July, August and September. Column 6, which is obtained by deducting this from the net effective rainfall Column 3. In a normal year, a deficiency of 3·43″ occurs in the month of August. The minimum expected effective rainfall taken in by the soil once in five years is presented in column 4, and the corresponding deficit, in column 7. Although irrigation of 3·43″ is required normally every year in the month of August only, if maximum yields are to be assumed, considerably greater deficits need to be made up if assurance is desired against droughts having a probability of occurring once in five years. The design for an irrigation system which is required to make up a deficit that is normally only a small fraction of the total consumptive use in the growing season is best based on the estimated deficiencies expected once in five, or preferably, once in ten years. The scheduling and amount of application per irrigation would be such as to make up the moisture content of the soil to field capacity, if the available moisture content falls below, perhaps, 75 per cent, so as to ensure optimum yields of *aus* paddy. The deficiency must be met whenever required. Hence, flexibility in time of application should be the chief characteristic desired of such an irrigation system.

Determination of Consumptive Use.

It is beyond the scope of this paper to deal with the various methods of determining consumptive use. Usual direct methods are both expensive and slow to yield usable results. Of the indirect methods that may be used in developing countries where meteorological stations have less elaborate equipment and are few in number, some of the simpler consumptive use formulae such as

those of Thornthwaite, Blaney & Criddle and Lowry & Johnson are useful.

The average monthly temperatures utilised for the determination of consumptive use rates by the Thornthwaite method, and the standard deviation of the monthly pairs for 1962 and 1963, for Kharagpur is given in Table 7.

The latitude correction for Kharagpur, West Bengal, used for consumptive use determination by this method and by the Blaney & Criddle formula is given in Table 8.

The heat index in the Thornthwaite Method given in column 5, Table 7 is derived from the formula :

$$i = (t/s)^{1.514}$$

where (t) is the average monthly temperature in °F.

The annual heat index for Kharagpur is 152·14. The proportions of the annual consumptive use for each month is given in column 6 of Table 7. It is not possible to determine the actual consumptive use figures without obtaining the index point for Kharagpur, which cannot be ascertained as yet due to paucity of data. Indications are, however, evident that the consumptive use values obtained by this method are lower than those obtained by the Lowry & Johnson method calculated below :—

For the Lowry & Johnson method the maximum monthly temperatures are used to derive the effective day degrees which is subsequently used for calculating consumptive use by the relationship

$$U = 0.8 + 0.156\ F$$

where U = cosumptive use in acre-feet per acre.

F = effective heat in thousand of day-degrees.

The total day-degrees for the year is 21,148·2. If the general crop seasons for Kharagpur are divided as follows :

Kharif	—	June to September
Rabi	—	October to February
Zaid	—	March to May, values of day degrees are presented in column 6 of Table 9.

The day-degrees must be determined for the actual cropping season, and the proportion of each month's day-degrees to the seasonal total should be determined in order to obtain the monthly consumptive use. This is done in Table 10 for the *aus* paddy and the potato growing season. The Lowry & Johnson method is suitable for estimating water requirements in a river basin or in a large watershed of a river valley, and may be suited for other arid regions, similar to the western portion of the U.S.A. to yield the consumptive use within a reported accuracy of ± 20 per cent. The values presented here are merely to serve as a check against the more reliable values obtained through other formulae.

The Blaney & Criddle method also utilises the monthly temperature (t), which when multiplied by the per cent day time hours (P), yields the monthly consumptive use factor (f), as given in the equation below

$$f = \frac{t \times p}{100}.$$

The monthly consumptive use factor when multiplied by a coefficient (k), obtained from observed data, yield (u), the monthly consumptive use in inches,

$$u = kf.$$

Since sufficient work has not yet been done in Kharagpur so far, to assign reliable values for (k), the generalised form of the consumptive use curve as given in Fig. 4, obtained from a great deal of data for conditions prevailing in the U.S.A., has been used to derive the values of (k) employed in the determination of the monthly consumptive use for the potato crop and the *aus* paddy crop in Kharagpur. Preliminary data leads to the conclusion that the ratio of consumptive use to evaporation rate for a *kharif* crop

TABLE 5. EFFECTIVE ROOT ZONE DEPTH OF SELECTED CROPS.

Crop	Depth of rooting (in ft.)
Alfalfa	8 — 10
Cotton	6
Maize	4
Wheat	4
Groundnut	4
Upland paddy	4
Lowland paddy	2

TABLE 6. DEFICIT RAINFALL TO BE MET BY IRRIGATION FOR *AUS* PADDY IN KHARAGPUR, DURING NORMAL SEASON AND DURING MINIMUM MONTHLY RAINFALL EXPECTED ONCE IN THE 5 YEARS.

Month	Normal rainfall expected (in inches)	Effective rainfall taken in by soil (in inches)	Minimum expected rainfall once in 5 years (in inches)	Consumptive use (Blaney and Criddle's Method (in inches)	Deficit to be met by irrigation (in inches)	
					Normal Years	Once in 5 years
June	7·76	6·22	2·48	5·48	0·74	3·0
July	12·06	9·65	8·14	9·58	0·07	1·44
August	9·05	7·24	5·76	10·67	3·43	4·89
September	12·19	9·75	6·96	7·94	1·81	0·98
Total	41·06			33·67		

in North India, as is given by the appropriate hypothetical curve in Fig. 4, which is in effect the coefficient *k* in Blaney & Criddle's formula is considerably higher than that of a summer crop in the U.S.A.* The shape of the curve has been fitted to that for all crops, which is shown by the smooth curve for a summer crop in the U.S.A. in Fig. 4.

Values of monthly evaporation in inches per month at Kharagpur are shown in Fig. 5. Values of consumptive use computed by Blaney & Criddle formula are given in Table 11.

Available Storage Capacity of effective root zone.

For calculation of effective root zone

*It is difficult to understand on physical grounds how the consumptive use could materially exceed the evaporation potential, especially by as much as 40 per cent. That is, the value of the ratio should not exceed unity. The Blaney & Criddle '*k*' is not fundamentally the ratio of consumptive use to free evaporation. It is not non-dimensional, but has the dimensions inches (day degrees) (per cent daytime hours). In inch units, it may approach unity for free evaporation—Editor.

TABLE 7. AVERAGE MONTHLY TEMPERATURE AND "HEAT INDICES" UTILISED FOR DETERMINATION OF USE RATES BY THE THORNTHWAITE METHOD FOR KHARAGPUR, WEST BENGAL, FOR THE YEARS 1962-63.

Month	Average 1962°C.	Monthly 1963	Temperature average 1962-63	Heat Index	Monthly percentage Annual Consumptive use
January	18·16	18·05	18·45	7·40	4·86
February	23·15	24·75	23·91	10·67	7·01
March	27·45	27·8	27·6	12·70	8·34
April	30.77	30·27	30·6	15·05	9·89
May	31·40	30·6	31·00	15·10	9·91
June	29·95	30·1	30.00	15·03	9·87
July	29·45	29·65	29·5	15·00	9.84
August	28·9	29·67	29·3	14·94	9·82
September	29·67	31·37	30·5	15.05	9·59
October	25·87	26·7	26·3	12·00	7·89
November	22·97	28·47	25·7	11·20	7·36
December	20·35	20·16	20.3	8·00	5·25
Mean	26·59	27.34	26·9	152.14	Q = 1·865°C. C.V. = 6·97 %

TABLE 8. LATITUDE CORRECTION FOR KHARAGPUR, WEST BENGAL (22·5°N) USED FOR CONSUMPTIVE USE DETERMINATION BY BLANEY AND CRIDDLE'S AND THORNTHWAITE'S METHOD.

Month	Correction for Blaney & Criddle's Method (% Daylight hours)	Correction for Thornthwaite's Method (30 days or 12 hours each) Mean possible duration of sunlight.
January	7·63	0·94
February	7·19	0·898
March	8·40	1·03
April	8·56	1·06
May	9·24	1·14
June	9·11	1·125
July	9·35	1·15
August	9·02	1·12
September	8·31	1·02
October	8·13	1·00
November	7·49	0·92
December	7·54	0·93

TABLE 9. MAXIMUM MONTHLY TEMPERATURE, MONTHLY AND SEASONAL EFFECTIVE DAY-DEGREES USED IN CALCULATION OF CONSUMPTIVE USE RATES BY THE LOWRY AND JOHNSON METHOD, FOR KHARAGPUR, WEST BENGAL FOR THE YEAR 1962-63.

Month	Max. Tem. 1962	Monthly in °C 1963	1962-1963 Average in °F	Effective Day Degrees (°F)	Seasonal Effective Day Degrees for main growing seasons
January	25·95	25·8	78·62	1,446·6	Rabi season (continued)
February	32·45	30·55	88·70	1,582·0	
March	35·00	34·7	94·64	1,880·0	5,975·8 Zaid Season
April	37·65	37·7	99·86	2,035·8	
May	36·25	37·85	98·78	2,060·0	
June	34·55	34·2	93·92	1,857·6	7,427·6 Kharif Season
July	32·55	33·65	91·58	1,844·0	
August	33·55	32·4	91·40	1,841·0	
September	37·50	32·25	94·82	1,884·6	
October	29·55	29·25	84·92	1,639·0	7,785·8 Rabi Season
November	33·00	26·6	85·64	1,609·20	
December	26·85	27·2	80·60	1,509·0	
				Total Annual	21,148·2

TABLE 10. DERIVATION OF CONSUMPTIVE USE BY THE LOWRY AND JOHNSON METHOD FOR *AUS* PADDY AND POTATO GROWING SEASONS IN KHARAGPUR, WEST BENGAL.

Month	Effective Day Degrees (thousands) °F.		Consumptive use		Crop
	Monthly	Seasonal	Monthly	Seasonal	
June	1·8576	7·4272	5·87	23·50	Kharif season *aus* paddy
July	1·8840		5·83		
August	1·8410		5·83		
September	1·8846		5·97		
November	1·6092	4·5648	6·32	18·14	rabi season potato
December	1·5090		6·00		
January	1·4466		5·82		

depth, it may be assumed that root extension takes place at a rate of 1′ to 1½′ per month of active growth. If the soil is a fine sandy loam and is assumed to be unrestricted for both crops, 1½′ per month would be a better estimate, particularly in the warm climate of Kharagpur. The available storage capacity within the effective root zone for *aus* paddy and potato is calculated using 1·8″ per foot of available water stored for a fine sandy loam, as obtained from Table 4. Available water storage capacity in the effective root zone would be as given in Table 12*.

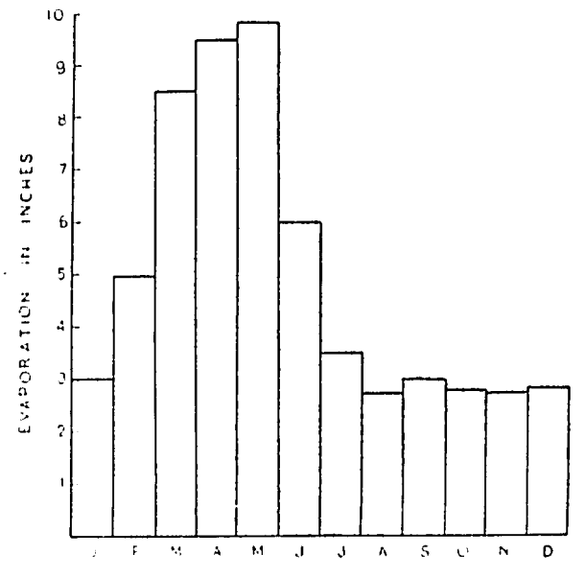

FIG. 5. EVAPORATION RATES BY MONTHS, IN INCHES FOR KHARAGPUR.

The ratio of root depth to consumptive use is remarkably constant under normal conditions of unrestricted root extension. Hence, it would be wasteful and wrong to apply equally heavy applications of irrigation at the initial stages when both root extension is limited, and the consumptive use rate is low, as at later stages of growth. Initially, also k, the consumptive use-evaporation rate ratio is low as given in Fig. 4. For maximum crop growth both the potato and the paddy crop soil should have the moisture depleted at the rate of the consumptive use to an extent of 75 per cent of the available moisture content. This ideal may, however, be unfeasible or uneconomical to attain. Hence, Table 12 gives the maximum amount of moisture to be depleted from the soil to reach both 75 per cent of available moisture content, (AMC) and to a more feasible 50 per cent AMC.

Determination of frequency of Irrigation

The maximum safe interval of application of irrigation be ascertained by dividing the amount of moisture that can safely be depleted for each month of growth by the consumptive use per day, if there is no rainfall. This assumption requires that the entire root depth should be brought upto the field capacity at each irrigation, from the level of depletion required. Table 13 gives the ideal irrigation intervals based on these computations.

The requirements for paddy crop would mostly be met by the effective rainfall. In a normal year, the average deficiency expected over the season is only 0·81″. In the first two months, the rainfall taken in by the soil barely exceeds the consumptive use, and there can be little or no carry over into August which has an expected deficiency of 3·43″. Hence, in normal years, a total irrigation of 3·43″ needs to be given during August. This irrigation should be applied if no rain falls in about 11 days. Since it is in the rainy season, it would be advisable to make up this deficit in at least two applications of 2·3″ depth each, or in three applications of 1·2″ depth each, in order to maintain the available moisture content above 50 per cent and considering an overall irrigation efficiency of 75 per cent. The amount must be adjusted by deducting the effective intake amount from any small showers that may occur during the deficiency period.

* It is believed the limitations imposed on root growth are unrealistic for healthy crops ; further more water would move from below by capillary force as the upper zone dries out. Practice in the U.S. is to utilize the storage capacity of the entire root zone, to depths of at least 4 feet, throughout the entire growing season, for normal soils. Extensive measurements of soil moisture during growing seasons confirms the validity of this approach—Editor.

TABLE 11. CALCULATION OF MONTHLY AND SEASONAL CONSUMPTIVE USE BY THE BLANEY AND CRIDDLE METHOD FOR *AUS* PADDY AND POTATO.

Month	Mean monthly tem. in °F (t)	Per cent daytime hours (p)	Consumptive use factor (f)	Monthly consumptive use coeff (k)	Monthly consumptive use in inches (u)	Seasonal consumptive use in inches (u)
June	86·00	9·11	7·83	0·7	5·48	for
July	85·10	9·35	7·98	1·2	9·58	*aus*
August	84·74	9·02	7·62	1·4	10·67	paddy
September	86·90	8·31	7·22	1·1	7·94	33·67
November	78·26	7·49	5·85	0·35	2·05	for
December	68·54	7·54	5·18	0·85	4·40	potato
January	65·12	7·63	4·98	0·90	4·48	10·93

TABLE 12. MAXIMUM AVAILABLE WATER STORAGE CAPACITY FOR FINE SANDY LOAM SOIL FOR *AUS* PADDY AND POTATO.

Month of growing season	Average Depth of rooting (in feet)	Maximum available water storage capacity (in inches)	50% AMC	Maximum permissible depletion 75 % AMC
1st Month	1½	2·7	1·4	0·7
2nd Month	3	5·4	2·7	1·4
3rd Month	4	7·2	3·6	1·8
4th Month (paddy only)	4½	9·1	4·5	2·3

TABLE 13. DETERMINATION OF IDEAL IRRIGATION INTERVALS FOR *AUS* PADDY AND POTATO, IN KHARAGPUR, WEST BENGAL.

Crop	Month	Consumptive use Rate/day	Maximum amount of depletion permissible to maintain above (in inches)		Irrigation interval (days)	
			50 % AMC	75 % AMC	50 % AMC	75 % AMC
Paddy	June	0·186	1·4	0·7	7·25	3·65
	July	0·309	2·7	1·4	8·75	4·40
	August	0·343	3·6	1·8	10·50	5·25
	September	0·232	4·5	2·3	19·60	9·80
Potato	November	0·067	1·4	0·7	20·9	10·5
	December	0·142	2·7	1·4	19·00	9·5
	January	0·144	3·6	1·8	25·00	12·5

For years of less than normal rain, supplementary irrigation is obviously necessary in Kharagpur. Irrigation should be applied at an average frequency interval of 10 days, although it would suit the soil conditions and plant needs better if a shorter interval of application at less depths, was scheduled for the earlier stages of growth. This taxes the capacity of the irrigation system, and may not be practicable, nor economical. Rainfall should be treated just as if it was irrigation occurring at random. The deficiency should be supplemented to the extent of the difference determined by deducting the effective rainfall from the consumptive use over the period since the last rainfall or irrigation application. This frequency could be fixed as 10 days to maintain a moisture regime above 50 per cent of available moisture content, or as 6 days, for constantly maintaining the available moisture content above 75 per cent.

For the potato crop for which no rainfall is expected, an average interval of 22 days throughout the season could be scheduled from the data in Table 13, in order to keep the moisture content above a 50 per cent level; whereas an 11-day interval frequency would be convenient to be maintained above 75 per cent. The schedule of irrigation for the lower of these is given in Table 14 for the 22-day frequency, and the 11-day frequency, is given in Table 14.

Determination of depth for application

Once the frequency has been decided on, the cumulative consumptive use for the number of days since the last irrigation is all that is required to determine the depth per application. The frequency has already been determined in such a manner as not to permit the cumulative use to exceed the soil moisture deficiency in the effective root zone. Ideally, the depth of application should increase in successive fixed intervals as both the depth of the effective root zone and the consumptive use rate increases upto at least the wet fruit stage. This may be observed in Tables 14 and 15, which also give the actual amount to be applied for irrigation, assuming 75 per cent overall application efficiency for the 22-day interval schedule (Table 14), and 60 per cent efficiency for the 11-day interval schedule. Fig. 6 indicates the soil moisture deficiency in the effective root zone as the increasing consumptive use extracts water from the soil. The figure is thus a diagramatic representation of Table 14.

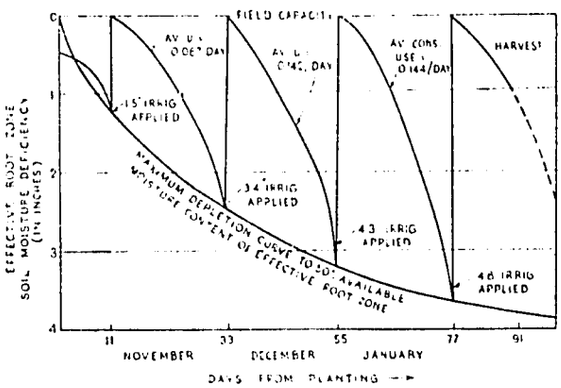

FIG. 6. SHOWS IRRIGATION SCHEDULE AND DEPTH PER APPLICATION FOR POTATO CROP IN KHARAGPUR, W. BENGAL, FOR 22 DAY INTERVALS TO MAINTAIN MOISTURE REGIME ABOVE 50 PER CENT AVAILABLE MOISTURE CONTENT.

The first irrigation is scheduled on the eleventh day after planting. It can safely be assumed that the moisture content so soon after the monsoon, would be quite near the field capacity and would be sufficient to take care of the emergency stage. The delta required to make up the moisture deficiency between applications totals 10·9″ which is the seasonal consumptive use for potato as determined earlier by the Blaney & Criddle formula. It is seen that 14·0″ of water at the source of supply is adequate to mature the crop, assuming a 75 per cent irrigation efficiency. In order to maintain 75 per cent available moisture content, seven irrigations spaced 11 days apart are necessary with the depths of application as indicated in Table 15. Although the consumptive use as determined by the indirect method employing only meteorological data remains the same, in actual fact it is greater when a higher moisture

TABLE 14. DEPTH OF APPLICATION FOR IRRIGATION FOR A 22-DAY INTERVAL IRRIGATION SCHEDULE FOR POTATOES IN KHARAGPUR.

Serial order of irrigation application	Schedule date (days after planting)	Soil moisture deficiency between applications—to keep above 50% AMC (in inches)	Depth per Irrigation at 75 % efficiency (inches)
Planting date to first irrigation	—	0·5 (from carry over)	—
First	11	1·1	1·5
Second	33	2·5	3·4
Third	55	3.2	4.3
Fourth	77	3·6	4·8
Total :		10·9	14·0

TABLE 15. DEPTH OF APPLICATION PER IRRIGATION FOR A 11-DAY INTERVAL IRRIGATION SCHEDULE FOR POTATOES IN KHARAGPUR.

Serial order of irrigation application	Schedule date (days after planting)	Soil moisture deficiency between applications—to keep above 75% AMC (in inches)	Depth per irrigation at 60 % efficiency (inches)
Planting date to first irrigation	—	0·40 (from carry over)	—
First	9	0·53	0·8
Second	20	0.75	1·2
Third	31	1·00	1·7
Fourth	42	1·75	2·9
Fifth	53	2·00	3·3
Sixth	64	2·25	3·7
Seventh	75	2·25	3·7
Total :		10·93	17·3

regime is maintained. Also, the irrigation efficiency reduces when it is applied with greater frequency at less amounts.* Hence, a 60 per cent over all efficiency is used here, for calculating the water required at the head, which is 17·3″ per acre.

When adequate consumptive use, evaporation and certain other meteorological data, become available it would be possible to make nomographs to work out the scheduling and depth per application for every crop and agro-climatic-soil region. This would simplify the calculations and make it possible for the agriculturists to base the scheduling of irrigation on consumptive use.

Capacity of Irrigation Systems

Knowing the amount to be applied, the minimum time between applications and the area one can design the capacity using simple volume-flow relations. For the example the maximum demand on the system will be based on the 11-day rotation with an application of 4″. For the 15-acre farm, since 1 cusec equals 1 acre-inch per hour.

$$Q = ad/t = (15)(4)/(12)(11) = 5/11 \text{ cusec}$$

It is assumed that labour will be available only 12 hour per day†.

In some cases the minimum safe period over which the planting may be spread may take precedence over the critical irrigation period.

ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of R.B. Singh, Y.P. Rao, Ph. D. Research Scholars, and T.K. Sarkar, Research Scholar, at the Indian Institute of Technology, Kharagpur, in obtaining much of the data used in this paper.

* I would expect the reverse effect—Editor.

† It is not clear what happens to the stream during the other 12 hours each day—Editor.

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THE EFFECT OF FERTILIZERS ON WHEAT PRODUCTION UNDER IRRIGATED AND DRY FARMING CONDITIONS IN TURKEY

by

Necdet Yertsever*

INTRODUCTION

Prolonged cultivation and intensive crop production has depleted Turkish soils of much of their native fertility. Fertilizer use is a relatively new development in Turkey, and plant nutrients have not been replaced as fast as they have been removed. Therefore, the proper use of fertilizers is receiving considerable attention and study.

At present there are no well established rotations or agricultural practices in general use, and crop residues are not being returned to the soil. As a result the soils are very low in organic matter, and the renewal of plant nutrients has depended on the mineral weathering of the soils. Soils have received essentially no maintenance agricultural practices, and have generally been so heavily depleted of available nutrients, that today they produce only 4 to 5 times the quantity of grain used for seed. Under these conditions, increased production depends on improved agricultural management systems, including adequate use of commercial fertilizers.

A second factor responsible for the growing interest in, and the increased usage of, fertilizers in Turkey is the increasing conversion from dryland to irrigated farming. The development of irrigation system has accentuated infertility of the native soils and the need for increased fertilizer usage. Maximum benefits from irrigation depend on sound and adequate fertilizer practices.

In Turkey, under both dryland and irrigated agriculture, wheat is one of the principal crops grown. Therefore, it is receiving special attention. To establish a sound fertilizer programme it is necessary to have a valid base for estimating the kind and amount of fertilizer needed for optimum production. This paper reports some of the preliminary data that have been obtained for the fertilization of wheat.

SOIL AND CLIMATIC CHARACTERISTICS OF THE EXPERIMENTAL AREAS

The Central Anatolia region of Turkey is the principal wheat production area of the country. Therefore, most of the experiments were carried out in this region. The area is a dissected plateau that includes mountains, foothill slopes, lake basins, and a few narrow alluvial plains. In the Konya area elevation is about 900 meters, while in some of the other experimental areas the elevation may vary from 700 to 1,500 meters. The high elevations, together with mountain ranges that surround the area, seriously restricts the natural rainfall. Crop production, therefore, is primarily limited by inadequate moisture. Wheat and barley, because of their adaptability to semi-arid conditions, are the principal crops grown in this area.

The annual rainfall of about 400 mm. is not distributed ideally for crop production. The highest amounts occur during the winter

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and early spring months. Very little rainfalls during the summer. Therefore, winter crops grow fairly well but spring sown crops require irrigation for successful growth. Under Turkish conditions, dryland farming usually involves fallow every other year.

The Principal soil groups in the Central Anatolia region are the red and reddish brown soils. These are generally fine in texture, medium to shallow in depth, and calcareous in nature. They are moderately infertile, especially with respect to nitrogen and phosphorus, and due to the hot dry climate are suitable only for the production of small grains. Yields fluctuate widely from year to year depending on the annual rainfall. Under irrigation, cereal grain production is especially high, and all crops grow very well when the soils are fertilized properly.

EXPERIMENTAL PROCEDURES

Experiments were conducted at several locations over a period of several years to determine the response of wheat to nitrogen, phosphorus, and potassium alone and in combinations.

1. **Locations :** In Central Anatolia, under dryland conditions experimental sites were located at Bala, Polatli, Altinova, Gözlü, Konuklar, Cicekdag, and Malya State Farms. Under irrigation, experiments were located at the Cumra Irrigation Experiment Station and the Eskisehir Irrigation Research Institute.

2. **Experimental Methods.** The experimental plot design is a 4 × 4 × 2 factorial for nitrogen, phosphorus, and potassium, respectively ; with 4 rates of phosphorus, and 2 rates of potassium. The treatments were arranged in a randomized block design, and each treatment was replicated 3 times. The dryland plots were 3 × 10 meters, or 30 square meters, with a harvested area of 2 × 8 meters, or 16 square meters. Each location consisted of 96 plots. The irrigated plots were 2·25 × 12·0 meters, or 28 square meters with a harvested area of 2 × 10 meters, or 20 square meters.

3. **Fertilizer Rates and Method of Application :** The fertilizer rates under dryland conditions were as follows : Nitrogen at 0, 2, 3, and 4 kg. N per decare ; phosphorus at 0, 4, 6, and 8 kg. P_2O_5 per decare, and potassium at 0 and 3 kg. K_2O per decare.

   Under irrigation the rates at Cumra were for nitrogen 0, 3, 6, and 9 kg. N per decare, for phosphorus 0, 4, 6, and 8 kg. P_2O_5 per decare, and for potassium 0 and 4 kg. K_2O per decare. At Eskisehir the rates were 0, 3, 6 and 9, 0, 4, 8, and 12, and 0 and 4 kg. per decare, respectively, for N, P_2O_5 and K_2O. The nitrogen carrier was 21 per cent ammonium sulfate, the phosphorus carrier was 16 per cent powdered superphosphate, and the potassium carrier was 48 to 52 per cent potassium sulphate.

   The nitrogen and potassium fertilizers were spread broadcast by hand, before seeding, while the phosphorus was applied in bands with a drill at seeding time.

4. **Seeding.** In the drying experiments soft red wheat, 111/33 was fall sown with the actual date of seeding varying slightly depending on climatic conditions. Under irrigation the Q, 93/44 variety of wheat was used.

5. **Irrigation.** The plots were flood irrigated twice during the growing season, and in each case the soil was moistened to field capacity. The first irrigation was generally done when the wheat was in its early growth stage, and the second, when the heads were just emerging.

6. **Rotation :** The experiments under dryland conditions were conducted

both in a wheat-fallow rotation and in a continuous wheat rotation. Under irrigation the rotation was sugar beets-wheat-beans-wheat. The yields reported are those for wheat following beans.

7. **Cultural practices.** Standard cultural practices for wheat were followed at all locations. However, no herbicides or insecticides were used.
8. **Harvesting.** The outside borders were first removed, then the remaining plot was cut by hand and threshed in a special plot thrasher.
9. **Soil Samples.** Soil samples were collected from the plot area before fertilization and seeding. Composite samples were taken at a depth of 0 to 20, and 20 to 40 cm. The samples were then analysed in the Soil and Fertilizer Research Institute Laboratory. The following analyses were performed: soil texture, saturation percentage, pH, electric conductivity, total salt, lime, available phosphorus and potassium, organic carbon, and the carbon-nitrogen ratio. Tables 11 and 12 present the results of these analyses for two different representative locations. According to these analyses the soils differs from all loams to clay loams in texture, with a pH of about 7·5 indicating a high lime content. Available phosphorus was low, averaging 1 to 3 kg. P_2O_5 per decare by the Olsen method. All the soils were high in potassium. Total salts were very low or only a trace.

EXPERIMENTAL RESULTS

Each year the grain yields from each location were analysed statistically to determine whether any significant responses to the various added fertilizers had been obtained. These results showed that in the Central Anatolia region, where a wheat-fallow rotation was practised, only the phosphorus treatments gave statistically significant wheat yield responses under dryland conditions. No response was obtained for either nitrogen or potassium (*see* Table 1). Under irrigated conditions both nitrogen and phosphorus fertilizers gave statistically significant increases in wheat yields, especially when used in combination. No statistically significant yield increases (*see* Table 2) were found for potassium fertilization.

DETERMINATION OF PRACTICAL FERTILIZER REQUIREMENTS.

The highest wheat yield, as indicated earlier was obtained with phosphorus alone under dryland conditions, and with phosphorus, and nitrogen under irrigation. However, simply determining a response is not enough. The most economical rates of application according to the soil needs must be determined. The objective of fertilizer use by farmers is an economical response through maximum yields. Therefore the relationship between increasing fertilizer usage and increasing yields must be known.

Determination of the amount of fertilizer required for a given condition depends, in most instances, on two conditions. First, the response of the crop to the fertilizer as determined experimentally under known fertility conditions; and second, the relationship between the cost of the fertilizer and the price of the crop. Therefore, the evaluation of the fertilizer responses presented here will be derived directly from the field experiments.

To evaluate the relationship between fertilizer usage and crop response there are four general expressions in common use, (1) the Mitscherlich equation, (2) the Cobb-Douglas formula, (3) the quadratic formula, and (4) the square root formula. The quadratic formula was found to be the most suitable for the data obtained, and gave a standard polynomial parabolic curve when expressed as the following mathematical function:

$$Y = a + b\,x - c\,x^2$$

where Y = Total yield
x = Amount of fertilizer used
a = Yield without fertilizer
b and c = Constants showing the response to fertilizers with increasing yields.

TABLE 1. ANALYSIS OF VARIANCE FOR WHEAT YIELDS AND FERTILIZER APPLICATIONS AT THE BALA STATE FARM UNDER DRYLAND CONDITIONS.

Source of variation	d.f.	SS.	MS.
Total	95	186·69	—
Replications	2	9·17	4·59
Treatments	(31)	(115·49)	3·72*
N	3	0·44	0·15
P	3	106·58	35·50*
K	1	0·38	0·38
N P	9	2·41	0·27
N K	3	2·95	0·98
P K	3	0·35	0·12
N P K	9	2·38	0·26
Error	62	62·03	1·00

* Significant at the 1 per cent probability level.

TABLE 2. ANALYSIS OF VARIANCE FOR WHEAT YIELDS AND FERTILIZER APPLICATIONS UNDER IRRIGATION AT THE CUMRA IRRIGATION EXPERIMENT STATION.

Source of variation	d.f.	SS.	MS.
Total	95	233·71	—
Replications	2	13·01	6.50
Treatments	(31)	(187·54)	6·05*
N	3	142·94	47·65*
P	3	11·77	3·92*
K	1	0·09	0·09
N P	9	9·30	1·03
N K	3	6·14	2·05
P K	3	2·16	0·72
N P K	9	15·14	1.67
Error	62	58·30	0·78

* Significant at the 1 per cent probability level.

As is well known, yield increments decrease with successively increasing increments of fertilizer.

Dryland Conditions

In order to use the quadratic expression in a practical way the values of a, b and c must be determined from the experimental data. Using the results obtained under dryland conditions in Central Anatolia, and using the method of least squares, the following values were obtained :

$$a = 116{\cdot}38$$
$$b = 12{\cdot}53457$$
$$c = -0{\cdot}90633$$

The quadratic formula, then, becomes

$$Y = 116{\cdot}38 + 12{\cdot}53457\,x - 0{\cdot}90633\,x^2$$

On the bases of this formula the data in Table 4 have been calculated, showing the total yield, the yield increase (y) for each successive unit increments of fertilizer used, and the absolute change (or the first derivative dy/dx) in yield increase with changes in fertilizer increments. The relationship between the actual experimental yield obtained and those calculated by the quadratic formula used in Table 4, is shown graphically in Fig. 1. The standard error has also been calculated and is shown under the curve on the graph. For the dryland experiments conducted in Central Anatolia the standard error was found to be $\pm$ 2·95 kg./dec. The correlation index for the quadratic formula was found to be 0·99.

The optimum rate of phosphorus application for wheat under dry land conditions for maximum production was found to be 7 kg. P_2O_5 per decare when the fertilizer is applied in bands at seeding time. This rate is not the best economic rate which is the rate of the point where the last increment of fertilizer applied will just produce a profit. Calculations for this value are shown in Table 5.

In calculating the data in Table 5, all of the production costs have been taken into consideration. Two types of production costs are

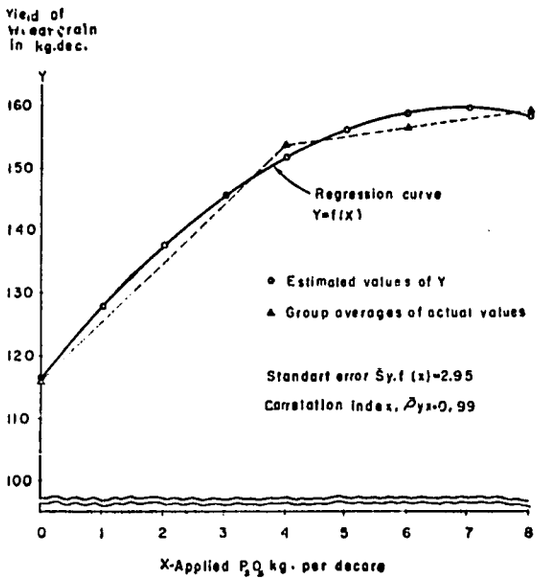

FIG. 1. RELATION OF YIELD OF WHEAT OF FERTILIZER APPLIED, UNDER DRY FARMIG CONDITION IN CENTRAL ANATOLIA.

involved, namely the fixed and the variable costs. The fixed costs included such items as plowing, seedbed preparation, harvesting, etc. Under Turkish village conditions there is no extra cash outlay for the family labour used to spread the extra fertilizer or harvest the increased yields. The variable costs, therefore, were considered only as those representing the cost of the different amounts of fertilizer.

Table 5 shows that, under the conditions of Central Anatolia, the first 1 kg. P_2O_5 per decare which costs 2·75 T.L. gave a yield increase of 11·63 kg./dec. of wheat and a net return of 8·49 T.L. per decare. Each successive 1 kg./dec. of P_2O_5 fertilizer used gave a smaller yield increase and net return. The fifth increment, which gave a 4·37 kg./dec. yield increase valued at 3·19 T.L., was the last successive 1 kg. P_2O_5/dec. increment of fertilizer in which the values of the increased wheat yield exceeded the cost of the fertilizer. When 6 kg. P_2O_5/dec. were used, the sixth increment gave a yield increase valued at 1·88 T.L. or 0·87 T.L. less than the cost of the

TABLE. 3. WHEAT YIELD RESPONSES* TO PHOSPHORUS FERTILIZER TREATMENTS UNDER DRYLAND CONDITIONS AT EIGHT DIFFERENT LOCATIONS, AND FOR SEVERAL YEARS IN CENTRAL ANATOLIA.

Place of Experiment	Years	Applied P_2O_5 kg. per decare			
		0	4	6	8
		Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.
Bala	1956/57	155·8	185·8	193·0	187·9
Bala	1958/59	194·8	210·8	216·7	224·4
Bala	1959/60	199·3	199·6	208·5	198·4
Bala	1960/61	152·5	249·6	223·1	247·7
Average		160·6	211·5	210·3	214·6
Polatli	1957/58	201·0	215·3	248·7	216·8
Polatli	1958/59	54·2	81·6	99·3	125·1
Polatli	1959/60	93·0	160·3	182·3	208·2
Polatli	1960/61	122·0	168·7	148·8	145·8
Average		117·5	156·6	169·8	174·0
Konuklar	1958/59	59·4	90·0	84·4	102·2
Konuklar	1959/60	71·0	80·0	99·0	110·0
Konuklar	1960/61	111·1	132·9	149·8	134·9
Average		80·5	100·9	111·1	115·7
Malya	1958/59	160·7	196·8	196·4	202·5
Malya	1959/60	107·7	124·5	152·0	120·5
Malya	1960/61	84·7	93·5	129·1	119·6
Average		117·7	138·2	159·2	147·5
Kocas	1959/60	132·8	189·0	168·0	185·3
Kocas	1960/61	90·7	119·1	124·4	145·6
Average		111·7	154·4	156·2	165·4
Alirnova	1960/61	118·1	149·8	165·7	149·8
Cicekdag	1960/61	57·9	93·7	70·6	74·6
Gözlü		165·1	224·5	210·7	274·0
General Average		116·1	153·7	156·7	159·5

* Since no yield responses were obtained for either nitrogen or potassium, only the phosphorus response data are reported.

TABLE 4. THE CALCULATED TOTAL YIELDS AND YIELDS CHANGES WITH SUCCESSIVE INCREMENTS OF FERTILIZER. DRYLAND EXPERIMENTS IN CENTRAL ANATOLIA.

Rate of applied P_2O_5 kg./dec.	Under dryland conditions in Central Anatolia ($Y = 116.38 + 12.53457x - 0.906633x^2$)		
	Total yield Y kg./dec.	Average yield change $\triangle y$ per increment of fertilizer kg./dec.	Absolute yield change dy/dx, per increment of fertilizer kg./dec.
0	116.38	—	—
1	128.01	11.63	10.72
2	137.82	9.81	8.91
3	145.83	8.01	7.10
4	152.00	6.19	5.28
5	156.39	4.37	3.47
6	158.96	2.57	1.66
7	159.71	0.75	—0.15
8	158.65	—1.06	—1.97

TABLE 5. CALCULATION* OF THE ECONOMIC OPTIMUM FERTILIZER RATE.

Rate of applied P_2O_5 kg./dec.	Increment of fertilizer kg./dec.	Cost of each successive increment of P_2O_5 fertilizer T.L /kg./dec.	Average yield change $\triangle y$ per increment of fertilizer kg./dec.	Value of the wheat yield increase T.L./dec.
0	0	—	—	—
1	1	2.75	11.63	8.49
2	1	2.75	9.81	7.16
3	1	2.75	8.01	5.85
4	1	2.75	6.19	4.52
5	1	2.75	4.37	3.19
6	1	2.75	2.57	1.88
7	1	2.75	0.75	0.55
8	1	2.75	—1.06	—0.77

* The prices used for the calculation were those prevailing in 1963, which were 0.44 T.L. per kg. of 16 per cent powdered superphosphate, and 0.73 T.L. per kg. for soft wheat.

fertilizer increment. Thus the economic optimum rate was found to be 5·0 kg. P_2O_5 per decare.

Irrigated Condition.

Wheat under irrigation responded to both nitrogen and phosphorus fertilization, as shown in Table 2. The experimental data showing the wheat yield increases for the various rates of nitrogen and phosphorus are presented in Table 6. From these data, both the absolute maximum rates and the economic optimum rates have been calculated independently for each element and are shown in Tables 7, 8, 9 and 10, and Figs. 2 and 3.

The data show that, under irrigation in Central Anatolia, the amount of fertilizer required for the maximum possible yield was 10 kg. P_2O_5/dec. for phosphorus and 15 kg. N/dec. for nitrogen. However, the amounts required for the attainment of the economic maximum wheat yields were found to be 7·0 kg. P_2O_5/dec. for phosphorus and 12·2 kg. N/dec. for nitrogen.

CONCLUSIONS

On the basis of current prices of fertilizer and wheat, the most beneficial kind and quantity of fertilizer for use in the Central Anatolia region are as follows :

1. Under dryland conditions and in a rotation of cereals and fallow, the quantity of phosphorus fertilizer required, when banded and applied at seeding time, to produce the maximum possible wheat yield was 7 kg. P_2O_5 per decare. To produce the optimum economic wheat yield, 5·0 kg. P_2O_5 per decare were required.

2. Under irrigation conditions in a rotation of sugar beets-wheat-beans-wheat and with nitrogen applied broadcast before seeding, the quantity of phosphorus required when applied in bands at seeding time, to produce the maximum possible wheat yield was 10 kg. P_2O_5 per decare. Under these

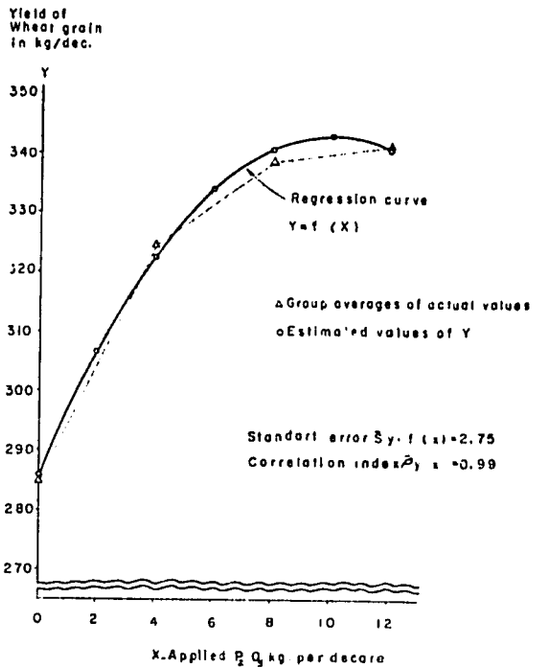

FIG. 2. RELATION OF YIELD OF WHEAT OF FERTILIZER APPLIED UNDER IRRIGATED CONDITION IN CENTRAL ANATOLIA.

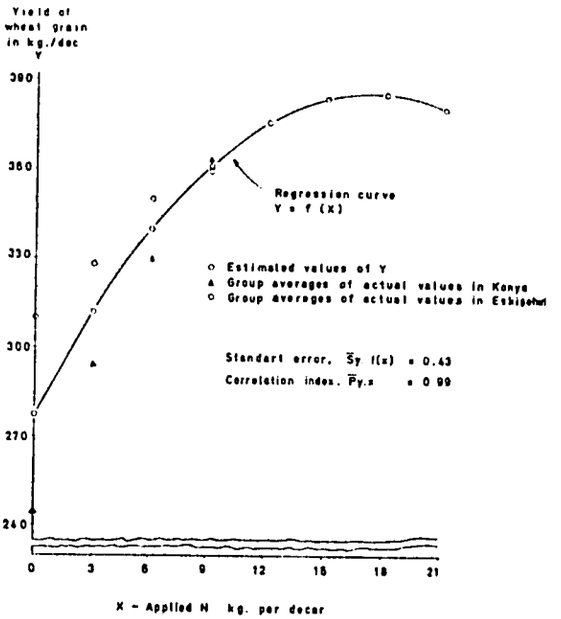

FIG. 3. RELATION OF YIELD OF WHEAT TO FERTILIZER APPLIED UNDER IRRIGATED CONDITION IN CENTRAL ANATOLIA.

TABLE 6. RESULTS OF FERTILIZER EXPERIMENT ON WHEAT UNDER IRRIGATION AT TWO DIFFERENT LOCATIONS IN CENTRAL ANATOLIA.

Location of Experiment	Years	Applied P_2O_5 kg. per decare					Applied N kg. per decare			
		0	4	6	8	12	0	3	6	9
		Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.	Yield kg./dec.
Cumra*	1958/59	255·6	292·7	298·0	292·6	—	228·1	278·5	306·9	325·3
	1959/60	392·0	406·0	418·0	440·3	—	328·0	396·0	437·0	490·0
	1962/63	204·3	231·1	231·5	229·3	—	178·1	208·4	246·4	263·4
Average		284·0	309·9	315·8	320·6	—	244·7	294·3	330·1	361.6
	1958/59	395·0	434·5	—	439·0	481·5	410·5	437·5	438·5	463·5
	1959/60	269·0	336·0	—	371·0	380·0	328·0	334·0	362·0	360·0
	1960/61	181·3	219·3	—	238·7	241·3	206·4	216·0	229·6	232·7
	1961/62	299.4	352·9	—	364·2	363·8	295·6	328·1	372·3	384·3
Average		286·3	335·7	—	353·2	341·6	310·1	328·9	350·6	360·4

* Because of wind erosion damage the yields at Cumra for the years 1960/61 and 1961/62 have been omitted.

TABLE 7. CALCULATED TOTAL YIELDS AND YIELD CHANGES WITH SUCCESSIVE INCREMENT OF PHOSPHORUS BASED ON IRRIGATED EXPERIMENTAL RESULTS IN CENTRAL ANATOLIA.

	Under irrigated conditions in Central Anatolia $Y = 285{\cdot}81 + 11{\cdot}55375x - 0{\cdot}5797x^2$		
Rate of applied P_2O_5 kg./dec.	Total yield Y kg./dec.	Average yield change Δy per increment of fertilizer kg./dec.	Absolute yield change dy/dx, per increment of fertilizer kg./dec.
0	285·81	—	—
2	306·60	20·79	9·24
4	322·75	16·15	6·92
6	334·26	11·51	4·60
8	341·14	6·88	2·28
10	343·38	2·24	0·04
12	340·98	—2·40	—2·36

TABLE 8. CALCULATED TOTAL YIELDS AND YIELD CHANGES WITH SUCCESSIVE INCREMENT OF NITROGEN FERTILIZER BASED ON IRRIGATED EXPERIMENTAL RESULTS IN CENTRAL ANATOLIA.

	Under irrigated conditions in Central Anatolia $Y = 277{\cdot}36 + 12{\cdot}61822x - 0.36647x^2$		
Rate of applied N kg./dec.	Total yield Y kg./dec.	Average yield change Δy per increment of fertilizer kg./dec.	Absolute yield change dy/dx. per increment of fertilizer kg./dec.
0	277·36	—	—
3	311·92	34·56	10·42
6	339·88	27·96	8·22
9	361·24	21·36	6·02
12	376·01	14·77	3·82
15	384·17	8·16	1·62
18	385·75	1·58	—0·57
21	380·73	—5·02	—2·77

TABLE 9. CALCULATION* OF THE ECONOMIC OPTIMUM PHOSPHATE FERTILIZER RATES.

Rate of P_2O_5 kg./dec.	Increment of fertilizer × kg./dec.	Cost of each successive increment of P_2O_5 T.L./dec.	Average yield change Δy per increment of fertilizer kg./dec.	Value of the yield increase T.L./dec.
0	—	—	—	—
1	1	2·75	10·97	8·23
2	1	2·75	9·82	7·36
3	1	2·75	8·65	6·49
4	1	2·75	7·60	5·62
5	1	2·75	6·34	4·75
6	1	2·75	5·17	3·88
7	1	2·75	4·01	3·01
8	1	2·75	2·87	2·15

TABLE 10. CALCULATION* OF THE ECONOMIC OTIMUM NITROGEN FERTILIZER RATES.

Rate of N kg./dec.	Increment of fertilizer × kg./dec.	Cost of each successive increment of N kg./dec.	Average yield change Δy per increment of fertilizer	Value of the yield increase kg./dec.
0	—	—	—	—
2	2	6·10	23·77	17·83
4	2	6·10	20·84	15·63
6	2	6·10	17·91	13·43
8	2	6·10	14·97	11·23
10	2	6·10	12·02	9·01
12	2	6·10	9·11	6·83
14	2	6·10	6·18	4·64

* The prices used for the calculation of these data were those prevailing in 1963, which were 0·44 T.L. per kg. of 16 per cent powdered superphosphate, and 0·64 T.L. per kg. of ammonium sulphate, and 0·75 T.L./kg. for hard wheat.

same conditions the amount of nitrogen required to produce the maximum possible wheat yield was 15 kg. N per decare. However, the amounts of fertilizer required to produce the economic optimum wheat yields were 7·0 kg. P_2O_5/dec. of phosphorus and 12·2 kg. N/dec. of nitrogen.

In comparing the two systems, dryland and irrigation, it will be seen that only 5·0 kg. P_2O_5/dec. were required to produce the economic optimum wheat yield under dryland conditions while 7·0 kg. P_2O_5/dec. were required under irrigation. These results emphasize the importance of fertilizer under irrigation, and the need to understand the management systems when making practical fertilizer recommendations to a farmer.

For many farmers the amount of money they have available for the purchase of fertilizer is limited. The analysis of the data presented here permit the calculation of the fertilizer amounts that will give the highest cash return for the money available to purchase fertilizers. Generally this amount will be less than the amount of fertilizer required to produce the economic optimum wheat yields. For example, under the dryland conditions in these experiments a farmer with adequate money might apply phosphorus fertilizer at a rate of 5 kg. P_2O_5/dec. at a total cost of 13·75 T.L. and receive a net return of 29·21 T.L. Such a farmer will have earned a profit of 29·21 T.L. per decare, but received only about 2·00 T.L. for each Lira spent on fertilizer. A farmer with limited money might apply only 1 kg. P_2O_5/dec. at a cost of 2·75 T.L. and earn a net profit of 8·49 T.L. Thus the second farmer, while earning over 3·00 T.L. for each Lira spent for fertilizer is receiving less than one-third of the net return possible from each decare of land.

Farmers in the Central Anatolia area usually lack either the capital or the credit to buy sufficient fertilizer to allow them to apply the rates required to obtain economic optimum yields. They will, therefore, usually use fertilizers in amounts somewhat less than required for maximum returns per decare. In practice the amounts of fertilizer required to produce the economic optimum yield will vary with fluctuations in rainfall, especially in the dry seasons. Although the rates of fertilizer being used by the farmers are less than that required to produce the economic optimum yields, the farmers are receiving, even in dry years, a profitable return on the money they spend on fertilizer. This has been a distinct advantage in the promotion of fertilizer use in the Central Anatolia region. At the present time the Soil and Fertilizer Research Institute is recommending phosphorus fertilization at a rate 4 kg. P_2O_5/dec. under dryland conditions. Under irrigation, phosphorus is recommended at a rate of 6 kg. P_2O_5/dec. and nitrogen at a rate of 10 kg. N/dec. While these amounts are somewhat lower than justified, they represent practical rates for fertilizer use under the farming conditions in Turkey.

FERTILIZERS IN RELATION TO EFFICIENT USE OF IRRIGATION WATER

by

Mukhtar Singh and R. T. Gandhi*

SYNOPSIS

The results of studies having a bearing on fertiliser-irrigation relationship are reviewed with reference to (i) fertilizer effect on the absolute and the relative transpiration/evapotranspirations (ii) comparative responses to fertilizers under irrigation and non-irrigated conditions, and (iii) fertilizer and irrigation interaction in field experiments including varying levels of the two factors.

The data presented have been generally drawn from work in India, but reference has also been made to related studies elsewhere. The main conclusions indicated by the review are as follows :—

(1) Transpiration ratio is reduced or water use efficiency is raised by fertilizers which increase dry matter production. The absolute water transpired also increases markedly under pot culture conditions but to a very small extent under actual field conditions. Fertilizers, therefore make for more efficient use of water than suggested by the pot culture studies.

(2) The responses to fertilizers are generally of a higher order under irrigated conditions than under non-irrigated conditions.

(3) The response to frequent irrigation is generally enhanced by increase in the levels of fertilizer application. Evidence of positive interaction between the two factors in different crops, viz. wheat, cotton, potatoes, root crops and tobacco, is recorded. Thus additional water necessitated by frequent irrigations is best utilised with higher levels of fertilizers, more particularly the nitrogenous ones.

Irrigation water is an expensive commodity and must be used efficiently. Efficient use has two broad aspects, viz., (1) reduction of unproductive water losses such as deep percolation, run off, and seepage, and (2) the economic use of water according to crop's requirements consistent with the most profitable returns. The first aspect necessitates consideration of measures such as land preparation, levelling, proper field layout, provision of irrigation structures, etc. The second aspect requires the consideration of optimal levels of associated factors of crop production. It is to be normally expected that soil and crop management factors which ensure the balanced development of plants and high crop yields will also make for efficient water use. As fertilizer use is one of the most important management factors influencing plant grow and yield, its consideration assumes special significance in relation to the use of irrigation water.

Considerable data are available from work done in India and abroad to throw light on the fertilizer—irrigation relationship. The results of studies having a bearing on the subject are reviewed here. The available information with particular reference to Indian

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work is classified and discussed under three headings :

(1) Fertilizer effect on the absolute and the relative transpiration/evapo transpiration.

(2) Comparative response to fertilizers under irrigated and non-irrigated conditions.

(3) Fertilizer and irrigation inter-action (in field experiments including varying levels of the two factors).

Fertilizer Effect on the Absolute and the Relative Transpiration / Evapo-transpiration.

Pot-culture studies by Leather (1910-11) at Pusa, Bihar, with 14 crops showed that fertilizers which increased growth expressed in terms of dry matter production also raised the transpirational water loss. To illustrate, his data for wheat and *juar* are presented in Table 1.

With 10 crops, the increase in dry matter with N+P fertilizer was relatively greater than in transpiration, inasmuch as the transpiration ratio or the unit water requirement was reduced in manured series, signifying economy in water use through fertilizer treatment. In four crops, however, the transpiration ratio was not influenced by manuring (Table 2).

Although Leather's work (*loc. cit.*) indicated decrease in transpiration ratio with manuring of rice, experiments by Ganguly (1950) in Assam did not reveal such effect, inspite of well pronounced effect on dry matter and on water transpired. Chaudhry and Mahapatra (1963) also recorded no fertilizers transpiration ratio of rice in experiments extending over three years.

It can be generalised from pot-experiments in India that with the exception of a few crops, fertilizer application reduces transpiration ratio. This is in accord with the conclusion emanating from the literature review by Briggs and Shantz (1913).

While the evidence of water economy with fertilizer use is convincing recent work on water consumption in relation to fertilizer application do not support the result emanating from pot-culture studies of Leather and others that fertilizers increase the absolute transpiration markedly. In fact, Penman (1948) showed that under conditions of adequate moisture supply and complete plant cover transpiration is not a function of the yield. The radiant energy received per unit area is the dominant factor influencing transpiration. Schofield (1952) and Weaver and Pearson (1950) found little increase in evapo-transpiration by the addition of a nitrogenous fertilizer even though the growth of grasses was trebled and doubled respectively. The apparent discrepancy between results from Leather's data and recent studies on water consumption in relation to fertilizers may be ascribed to over-exposure of plants and border effects in pots, resulting in inflation of transpiration.

Carlson *et al.* (1959) studied the effect of nitrogen, plant density and irrigation on evapo-transpiration and yield of corn for two years at Upham, North Dakota. Application of 120 lb. N/acre induced only a small increase in evapo-transpiration as against a large increase in dry matter and grain yield, especially under irrigated conditions. Treatment with nitrogen improved markedly water use efficiency defined as the ratio of dry matter produced to evapo-transpiration (Haise and Viets 1957) under irrigated conditions.

Comparative Responses to Fertilizers under Irrigated and Non-irrigated Conditions :

Yates *et al.* (1963) summarised the responses to sulphate of ammonia on wheat under irrigated and non-irrigated conditions as recorded at experimental farms in India. The relevant data are reproduced in Table 3.

It was concluded that response of irrigated wheat was 70 per cent greater than that of the non-irrigated crop. These authors also mentioned that similar results were obtained on cultivators' fields.

TABLE 1. INFLUENCE OF FERTILIZER APPLICATION ON DRY MATTER AND TRANSPIRATION (LEATHER 1910-11)

	Wheat (1906-07)				Juar (Sorghum) (1908)		
	O	N	NP	NPK	O	N	NP
Dry matter seed (g.)	3·93	3·23	19·6	13·9	2·25	1·60	7·25
Total (g.)	16·88	15·30	62·2	46·5	13·70	16·50	73·4
Water transpired (kg.)	15·63	15·4	33·7	26·6	5·03	6·66	32·1

TABLE 2. INFLUENCE OF FERTILIZER USE ON THE TRANSPIRATION RATIO OF CROPS (LEATHER 1910-11)

	Transpiration Ratio	
Crops	No manure	Manured
Maize	450	330
Sarson	740	620
Barley	680	480
Oats	870	550
Peas	830	530
Gram	1,400	1,000
Wheat	850	550
Guar	1,100	600
Rice	1,000	800
Rahar	1,100	600
Murwa	250	250
Kodo	300	300
Linseed	1,000	1,000
Juar	400	400

Evidence in support of low response to fertilizer under non-irrigated conditions is also found in the results of experiments under Fertilizer Use Project (Anon, 1959), as shown in Table 4.

Thus on medium black soil at Obedullaganj, the response of wheat to nitrogen was of smaller magnitude under non-irrigated conditions but increased with one or two irrigations. In other words, irrigation not only increased yield but also enhanced the response to nitrogen. Phosphate was apparently not limiting in the soil at Obedullaganj and response to this was not marked either under irrigated or non-irrigated conditions.

Differential response of wheat to N and P under irrigated and non-irrigated conditions is also illustrated by results of model agronomic experiments at Power Kheda, Madhya Pradesh (Anon, 1961, 1962, 1963). The summarised results are presented in Table 5.

An irrigation experiment on cotton conducted at Siruguppa during 1942-43, referred to by Raheja *et al* (1961) also indicated more pronounced response to manuring under irrigated conditions.

While bulk of the evidence goes to show higher response to fertilizers with irrigation, there are instances where fertilizer application gave almost similar increases in yield both with and without irrigation (Mehrotra and Garg, 1963).

Higher responses to fertilizers under irrigated conditions than under non-irrigated conditions, implies efficient use of fertilizers with irrigation. As a natural corollary to this efficient use of irrigation water with fertilizers follows.

Fertilizer and Irrigation Interaction.

In this section reference will be made to results of experiments where treatments comprised varying levels of fertilizer and of irrigation (in terms of frequency or depth of irrigation), but non-irrigated plots were not included. The point of interest in this connection is whether the two factors interacted or not, i.e. the response to one was modified by the level of the other or they acted independently. Pertinent to this inquiry are only such experiments which showed substantial responses (main effects) to both the factors individually.

Wheat.

The results of an irrigation-cum-fertilizer experiment on wheat conducted at Lyallpur, Punjab (Anon, 1945, 1946) during 1944-45 and 1945-46 under an I.C.A.R. scheme on water requirements of crops in the Punjab are given in Table 6.

The response to irrigation frequency improved with the increase in the level of nitrogen application in both years, although the optimum number of irrigations varied in the two years. Similar interaction trend was obtained in recent experiments in U. P. (Mehrotra and Singh, 1963).

Evidence in support of the inter-dependence of fertilizers and irrigation frequency in wheat is also furnished by the results of experiments conducted in Gujarat in recent years as reported by Gopani (1963). At Kholwad, Jamnagar, Halwad, Kukda, and Pilwai centres, a positive interaction was indicated. From the results for other centres the absence of interaction trend could be attributed to little or no response to one of the other factor.

In the scheme of model agronomic experiments (Anon, 1961, 1962 and 1963), on heavy black soil at Power Kheda, Madhya Pradesh, the response to frequent irrigations was relatively small in magnitude in the absence of fertilizers. Increasing levels of nitrogenous and phosphatic fertilizers were reflected in enhanced response to frequent irrigations. The data are summarised in Table 7.

In the experiments under the fertilizer use project (Anon, 1959) it was concluded

TABLE 3. IRRIGATION AND THE RESPONSE OF WHEAT TO NITROGEN.

Soil type	No. of experiments		Response to 20 lbs. N per acre (md. per acre)	
	Irrigated	Unirrigated	Irrigated	Unirrigated
Black soil tract	120	23	2·5	0·2
Gangetic alluvium	34	14	3·3	2·8
Indus alluvium	44	22	3·0	2·0
Overall (unweighted means)	198	59	2.9	1·7

TABLE 4. RESPONSE OF WHEAT TO VARYING LEVELS OF N AND P WITH AND WITHOUT IRRIGATION AT OBEDULLAGANJ, MADHYA PRADESH (FERTILIZER USE PROJECT, 1959).

	Yield in mds. per acre (three years averages)					
	Yield without N	Response to		Yield without N	Response to	
		20 lb. N	40 lb. N		20 lbs. P_2O_5	40 lb. P_2O_5
No irrigation	9·7	+ 2·5	+ 3·1	11·5	− 1·0	+ 1·2
One irrigation	12·5	+ 2·0	+ 4·1	13·3	+ 1·8	+ 2·0
Two irrigations	12·2	+ 4·6	+5·3	15·6	− 1·7	+ 1·5

TABLE 5. RESPONSE OF WHEAT TO NITROGEN AND PHOSPHATE AT POWER KHEDA UNDER-IRRIGATED AND NON-IRRIGATED CONDITIONS.

	Response in md./acre					
	Response to 20 lb. N/acre.			Response to 20 lb. P_2O_5/acre		
	1956-57	1957-58	1958-59	1956-57	1957-58	1958-59
Non-irrigated	+ 1·8	+ 0·6	+ 2·2	0·0	+ 0·9	+ 2·2
Irrigated	+ 3·1	+ 1·3	+ 4·3	+ 3·6	+ 3·2	+ 2·6

TABLE 6. INTER-ACTION BETWEEN IRRIGATION AND NITROGEN ON WHEAT AT LYALLPUR (PUNJAB) (ANON, 1945, 1946).

No. of irrigation of 3″ each.	Yield of wheat grain (md./acre) 1944-45			1945-46		
	O	25 lb. N per acre	50 lb. N per acre	O	25 lb. N per acre	50 lb. N per acre
One irrigation	—	—	—	19·1	17·9	17·2
Two irrigations	23·3	26·3	25·0	20·3	22·1	22·8
Three irrigations	25·9	29·5	31·0	21.8	23·6	22·6
Four irrigations.	26·1	30·3	31.8	—	—	—

TABLE 7. INTER-ACTION BETWEEN IRRIGATION FREQUENCY AND FERTILIZERS AT POWER KHEDA, MADHYA PRADESH.

No. of irrigations of 3″ average depth each.	Yield in md/acre (Average of three years 1956-57 to 1958-59)					
	No N	30 lb. N per acre	60 lb. N per acre	No P	30 lb. P_2O_5 per acre	60 lb. P_2O_5 per acre
Two	13·8	18·5	20·8	13·0	19·8	20·3
Three	14·1	21·3	23·8	14·5	21·8	23·0
Four	15·5	21·4	25·3	14·6	22·7	24·8

TABLE 8. INTER-RELATION OF IRRIGATION AND FERTILIZER ON YIELD OF WHEAT UNDER INTENSIVE CROPPING (PRASHAR, 1961).

No. & delta of irrigations	Grain yield md./acre.					
	No N	30 lb. N per acre	60 lb. per acre	O	P	PK
Two (6·3 in.)	17·2	25·0	27·7	21·7	74·5	24·7
Three (9·0 in.)	21·7	25·6	31·2	24·7	26·2	27·6
Four (12·0 in.)	20·3	24·9	29·1	22·1	25·1	27·0

P=40 lb. P_2O_5/acre. K=40 lb. K_2O/acre.

that generally the responses to both nitrogenous and phosphatic fertilizers were higher when applied along with higher levels of irrigation.

Although there is considerable evidence to demonstrate the association between irrigation frequent and fertilizer use in wheat, there are cases where the responses to the two factors were additive and the interaction was not well marked (Prashar, 1961).

Cotton

In the Sudan, Gregory *et al* (1932) were probably the first to demonstrate irrigation depth — nitrogenous fertilizer interaction which was confirmed by Crowther (1934). In the Punjab, heavy irrigations enhanced the response to nitrogen on light sandy soil in a field where cotton was grown after fallow but not when it followed *toria* (Dastur and Singh, 1942, 1944). In an experiment under the Indian Council of Agricultural Research Scheme on water requirements of crops at Lyallpur (Anon, 1945, 1946), irrigation frequency and nitrogen reinforced each other (Table 9).

The association between the two factors was also brought out in some of the experiments at Dhadesugar, Mysore, where moisture deficiency is generally severe. On the other hand, in the experiment at the Indian Agricultural Research Institute, New Delhi, the interaction was generally non-significant as the cotton crop was exposed to conditions of high water-table and excess water during the the period of fruiting and flowering.

Potatoes.

That the two factors, irrigation frequency and nitrogen, are inseparables, was brought out consistently in the experiments at the Central Potato Research Station, Patna, conducted by the senior author (unpublished) during 1950-51 to 1956-1957. In these experiments, the varying levels of nitrogen included the 'zero' level. The interaction was also noted in the experiments at the Indian Agricultural Research Institute, New Delhi, even though the lowest level of nitrogen was 50 lbs. N per acre (Table 10).

The need for frequent irrigations at low tension was best indicated at the highest levels of nitrogen and potassium. There was no interaction between water regime and phosphate application in this experiment.

Pushkarnath *et al* (1960) and Pushkarnath and Swaminathan (1963) also concluded from the summarised data of irrigation experiments conducted for three years at three centres that at shorter intervals of irrigation, the responses to nitrogen were significantly higher. There was, however, no clear-out interaction between potassium and irrigation frequency.

Root crop

Davenport (1962) studied the inter-relation of the two factors in an experiment with four water regimes at two levels of nitrogen (with and without 60 lbs. N per acre) on three root crops (raddish, turnip and best-root) at the Indian Agricultural Research Institute, New Delhi. Yield increased with the improvement in the moisture status of the soil consistently in the crop treated with nitrogenous fertilizer, but the increase was not well pronounced in the absence of nitrogen.

Tobacco

In an experiment on tobacco (Nicotiana rustica) at the Indian Agricultural Research Institute, New Delhi, Awatramani (1958) found that water regimes resulted in smaller variations in yield at lower levels of nitrogen. The best response to the moist regime treatment was obtained with 120 and 160 lb. N/acre, as shown in Table 11.

In the above-mentioned experiment spacing was wide ($2 \times 1\frac{1}{2}$ ft.). The experiment was repeated for two further years but with close spacing of plant ($1\frac{1}{2}$ ft. $\times$ 9 in.), with the result that responses to irrigation and nitrogen were additive. This might be ascribable to closer spacing. Moreover, the

TABLE 9. INTER-ACTION BETWEEN IRRIGATION AND NITROGEN AT LYALLPUR (AVERAGE OF 2 YEARS 1944-45 TO 1945-46).

No. depth of irrigation	Yield of seed cotton in md./acre			
	No nitrogen	40 lb. N	80 lb. N	120 lb. N
3×3″= 9 in.	10·8	12·4	14·3	14·9
5×3″=15 in.	11·6	14·2	16·4	18·1
7×3″=21 in.	12·0	15·4	18·1	18·4

TABLE 10. INTER-ACTION BETWEEN WATER REGIMES AND FERTILIZERS (NITROGEN AND POTASH) AT DELHI.

Moisture tension before irrigation Aver. Delta (in)	Yield of potatoes in md./acre (1958-59 to 1960-61)					
	50 lb. N	100 lb. N	150 lb. N	No K	75 lb. K_2O	100 lb. K_2O
0·2 to 0·3 Atm. (16·8)	284	307	322	272	313	329
0·5 Atm. (13·5)	257	289	259	240	273	293
Above 0·7 Atm. (12·7)	247	262	261	233	270	267

TABLE 11. INTER-ACTION BETWEEN WATER REGIMES AND NITROGEN IN TOBACCO CROP AT NEW DELHI (DATA OF AWATRAMANI, 1958).

Delta	Water remain Tension before irrigation	Yield of cured weight in md./acre.				
		No N	40 lb. N	80 lb. N	120 lb. N	160 lb. N
18·5 in.	Wet (0·2-0·3 Atm.)	12·2	14·4	19·3	22·9	23·1
17·0 in.	Moist (0·3-0·5 Atm.)	14·4	19·8	22·8	25·4	28·5
15·8 in.	Semi-moist (0·5-0·7 Atm.)	13·3	18·5	20·1	24·4	24·8
13·3 in.	Dry (above 0·7)	12·2	16·8	21·2	20·8	19·4

opportunity of desuckering (following topping) in tobacco is reduced in frequently irrigated crop. As the combination of frequent irrigation and nitrogen induces rapid growth of suckers, any delay in their removal would adversely effect the cured weight under such a treatment combination, and would therefore militate against the significance of the interaction.

Sugarcane

The results of experiments on inter-relation between irrigation and nitrogenous fertilizers in India on sugarcane have been summarised in recent reviews (Raheja *et al.* 1961 ; Varma, 1962). Interactions were noted in the experiments at Padegaon, Maharashtra, and at Pusa and Patna in Bihar. The interaction was non-significant in experiments in the Punjab. Mention may also be made here of the irrigation experiment on this crop at the Indian Agricultural Research Institute, New Delhi where three levels of nitrogen (50, 100 and 150 lbs. N/acre) were included. The exclusion of the 'zero' levels of nitrogen was presumably responsible for the non-significance of the interaction.

General Discussion

The relationship between fertilizer application and irrigation in crops is essentially a corollary to the nutrient-moisture relationship in plants. Irrigation can influence response to fertilizers in two ways, (*i*) by increased availability or intake of nutrients contained in fertilizers, and (*ii*) by improved utilisation of the absorbed nutrients. The availability of nutrients may not, however, be seriously affected unless the available moisture is reduced to very low levels (Richards and Wadleigh, 1952). Under non-irrigated conditions, the moisture status of the soil may limit the absorption of nutrients to some extent but more particularly their expression in growth. Therefore, the application of fertilizers may not lead to well marked favourable response. The low responses to fertilizers under non-irrigated conditions as cited in this paper are evidence in this direction. Moreover, the low yields over a succession of years under unirrigated conditions deplete the soil of the plant nutrients at a slower rate than under irrigated conditions. It is to be expected that because of bigger crops with moisture control through irrigation, the inherent fertility of the soil is depleted at a faster rate inasmuch as, before long the nutrients begin to limit production. Improved moisture supply without fertilizers in a nutrient-deficient soil will merely increase evapo-transpiration, as growth and consequently the yield is limited by the nutrient supply (the principle of limiting factors). The application of fertilizers to supplement the improved moisture supply would, therefore, lead to the coordinated development of the plants resulting in higher yield, and increased efficiency of water utilisation. It can be concluded from the review presented in the preceding pages that there is considerable economy in water use with fertilizer application.

If the two factors, fertilizers and irrigation, act independently, application of economic doses of the former will be justified over a wide range of the levels of the latter. In such cases, the given amounts of water application will be used more efficiently with fertilizers than without them. The irrigation practice will of course depend on the water supplies available. If the two factors show positive interaction, higher levels of irrigation and fertilizers should best be combined to achieve the most efficient utilisation of the additional water. From the data regarding interaction of the factors, referred to in this paper, it would appear that the crop receiving fertilizers needs to be irrigated more frequently than the one which is not manured. Since frequent irrigations increase the evapo-transpiration, it follows that fertilizer application increases consumptive use. Although theoretical considerations as well as empirical data suggest that under conditions of complete crop cover and ample moisture supply, evapo-transpiration is independent of the size of a crop (Penman, 1948 and Schofield,

1952), such conditions will only obtain during a part of the life cycle of the crop. In the early stages of crop growth, vegetative growth stimulated by fertilizer application would tend to increase transpiration but depress evaporation. The application of fertilizers supplying nitrogen may also prolong the growing period in most, if not in all crops. It is, therefore, logical to expect that generally, fertilizer application would tend to increase evapotranspiration. This is also supported by the data recorded by Carlson *et al.* (1959). The magnitude of increase in evapo-transpiration would, however, be generally small as compared with the large response to fertilizer in growth and yield. The large increase in the absolute transpiration under pot culture experiments (Leather, 1910-11, and Ganguly, 1959) appears to have resulted from the over-exposure of the plants grown in pots as mentioned earlier. The role of fertilizers in the efficient use of water would, therefore, be much greater than that suggested by the pot culture studies.

In most of the irrigation experiments conducted in the past, fixed water depths were supplied irrespective of the irrigation interval, instead of shallower applications to the soil moisture deficit before irrigation, in the treatments scheduled to receive frequent irrigations. Where the interaction between the two factors was significant, the irrigation requirements of a fertilized crop computed from such experiments would indicate exaggerated values as compared with those based on soil moisture deficit.

The absence of fertilizer irrigation interaction, in some cases, on the yield of the plant part of commercial interest, calls for some explanation. As extension growth depends upon moisture supply and meristematic activity depends on nutrients such as Nitrogen (Growther, 1934), favourable interaction in growth or dry matter production is generally to be expected. The effect on the final yield of the plant part of commercial interest would, however, depend on the correlation of growth to the yield. In crops where a vegetative plant part represents the yield, e.g., in potatoes, tobacco, sugarcane, leafy or root vegetables, the occurrence of a positive interaction is a distinct possibility. In cases where vegetative growth is stimulated at the expense of the development of the reproductive plant parts, or where secondary effects such as lodging or production of ineffective tillers in cereals, suckering in tobacco, shading due to rank growth in cotton, come into play, the interaction in yield of reproductive parts may some times be masked. Moreover, as irrigation increases the removal of soil nutrients, even from the unfertilised soil, the interaction between fertilizer and irrigation may be obscured within a certain range of soil fertility.

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CHAPTER XIII

FIELD TRIPS

AGRA AND VICINITY

Field trip to Agra was made on Saturday, March 7 via bus. The first stop was to inspect the new GURGAON Canal near Ballabhgarh where lining was being installed. This canal has a capacity of 1·960 cusecs and serves 600,000 acres. Lining consists of two layers of brick tile separated by 1 : 3 portland cement mortar. The first layer is placed in 1 : 5 mortar and tile spacing is 1/4" to 3/8". Laying is by hand.

The trip also provided for short periods of sightseeing both at the tomb of Emperor Akbar near Sikandra and the Taj Mahal near Agra. Lunch, which was provided by the host Government of India, was enjoyed by all delegates at the Clark-Shiraz Hotel.

In the afternoon, a visit was made to the Shri Govind Prasad Agarwal Farm near Achnera village. This farm is one of the most progressive of the area and is a demonstration of how modern methods of mechanical farming plus latest information on seeds, fertilizer and irrigation, if used properly, can increase production tremendously.

The farm is surface irrigated from the Gapau Tributary with a portion of the field ditches lined with brick masonary. A 600 foot portion has been lined experimentally with mud mixed with bitumen.

The flat bed or check basin system of irrigation is being used for small grains, corn peas and fruit with a furrow system being used for potatoes and sugarcane.

A highlight of this visit was the observation of the border strip method of irrigation on wheat. The borders were 30′ by 230′ and were being irrigated by two wooden flumes from the field ditch. It was apparent that with improved seed, modern methods of cultivation, and the improved method of irrigation, this field of wheat would yield a high return. The farm, in general, presents an exceptional opportunity as a demonstrational unit to surrounding farmers and it was the concensus of all delegates that the visit was worthwhile. After refreshments the delegates returned to New Delhi.

ROORKEE AND VICINITY

At 6·45 a.m. March 12, the delegation loaded on 3 buses departed New Delhi for Roorkee, some 108 miles north and east of Delhi in Uttar Pradesh State. Overnight lodging was established at Roorkee so each day's tour started from and ended there.

Roorkee is located on the banks of the Ganga canal, about 20 miles below the canal head works at Hardwar. India's oldest college of Engineering, formerly known as the Thomson Civil Engineering College is now part of the Engineering University in Roorkee. Also, the Irrigation Research Institute and the Central Building Research Institute are located here.

Breakfast for the delegation was arranged for at the Wheler Club, located in the cantonment area near Meerut. This is about 42 miles out of New Delhi. This cantonment is one of the largest in India and its history goes back to the early 1830's.

After lunch at the Hotel Polaris, Roorkee, the delegation toured on to Hardwar to inspect the Ganga Canal Headworks. On the way brief stops were made at the Dhanauri Experimental Farm and the Bahadarabad Hydraulic Research Station.

The Experimental Farm is an eight-acre area for agriculture, operated by the Irrigation Research Institute of Roorkee, to conduct a series of experiments on wheat and rice in the State of Uttar Pradesh. This is part of the scheme for research on minor irrigation and water use financed by the Government of India through the Ministry of Food and Agriculture as part of the Third Five Year Plan.

Experiments were planned upon three approaches to study water requirements :

a. Soil moisture deficit ; employing for wheat, depletion levels of 20 per cent, 40 per cent and 50 per cent. When soil moisture depletion reached any of these levels, irrigation was applied.

b. Climatological approach, that made use of empirical formulae as Blaney-Criddle, Thornthwaite Lowry-Johnson, Hargreaves and Van Bavel.

c. Evapo-transpiration measurement during crop growth was being studied in chambers 8′×8′×8′. These concrete-walled tanks were used and soil moisture measurements were being made in the root zones. Water input and outflow studies were also being made. A tubewell provides the water source for the farm.

The Bahadarabad Field Research Station comprises 70 acres on the left bank of the Ganga Canal. The station was started in 1947 and is an outdoor hydraulic laboratory for model studies. A number of barrages, spillways, headworks, and other structures and models have been studied here. The water source from Ganga Canal was high enough so that pumping and re-circulation of water is not necessary. A hydro-electric power station of 20,400 kw. capacity utilizes the drop in the canal at this point to provide power for the surrounding area including the hydraulic laboratories.

The Headworks of the Ganga Canal, located near Hardwar are so constructed to withstand a maximum flood of 660,000 cusec flow. The river is the one of the most sacred in India and Hardwar is the centre of Hindu pilgrimages to this outflow glacier melt from the lofty Himalayas. The width of the river at the headworks is 2216·5 ft. Wooden drop gates that fold flat to the river bed allow by-pass of monsoon floods. Normal minimum cold weather discharge is between 5,000 and 6,000 cusec. The head discharge of the Ganga Canal was 6,750 cusec. In 1946 this was increased to 8,400 cusec and in 1957 the capacity was again increased to 10,500 casec. Ganga Main Canal is 810 miles long and 2,266 miles of distributaries deliver the water.

In December 1839, Col. P.T. Cautley of Bengal Artillery was sent to Hardwar to study the quickest means of building an irrigation canal from the Ganges River. The crop failures and following famine, misery such as was unknown in civilized Europe, which took many lives and sacrifice of a million sterling for food, changed irrigation from speculation to a question of when it could be ready.

A river gauging station was set up. The low flow (December and January) was measured at 8,000 cusec, and the safe dependable supply was estimated at 7,000 cusec. The canal capacity was set at 6,750 cusec. By 1854 the major construction was completed and water started, but some work continued until 1878-80. It was declared after the famines of 1878-80, that the Ganga Canal had more than paid for itself in the protection from famine and its mitigating aspects over an area much larger than the canal command area.

On march 13, the delegation travelled by bus to Dehra Dun and on to Dak Pathan. Near this small colony is the site of a barrage

on the River Yamuna for diverting water into a lined channel for power generation. The site is 75 miles from Roorkee and some of the route climbed by ziz-zag manner over the Shivalok mountain range and passed through some of India's better forest area.

The Yamuna Scheme includes a concrete barrage across the Yamuna River at Dak Pathan, about 2 miles downstream from the junction of the rivers Tons and Yamuna. The structure will be 1764 feet long with a left bank canal with a bed width of 36 ft. and capacity of 7,000 cusec. This canal drops 65 feet where a 33·75 kw. capacity power house will be installed and near outfall of the Ahsan River a second drop of 100 feet will provide potential for a power house of 51·00 mw. capacity. There is no irrigation scheme included in the present plan. Stage II and stage III of Hydel Scheme was not visited as times did not permit the extra travel.

A walk through tour of the construction work in progress on Dak Pathan Barrage was very interesting to the delegation. The large amount of hand labour and its organization attracted many questions. For a construction job of this size there were very few heavy machines being employed and many members of the delegation commented upon this observation. The use of steel and forming work was held to the minimum by employing masonary work and cut stone as well as rough stone for building.

During the stop to inspect the canal lining operations, a lot of interest was developed. Flat burned brick was laid on sand bedding. Concrete tiles 12″×12″×2″ thick are used on the inside and standwiched mortar ½″ to 5/8″ was used between the brick and tiles. The bed was built up of 4″ thick concrete *in situ*. Joints were sealed with tar. The concrete tiles were manufactured in 5 factories located at convenient sites along the canal so as to reduce the haulage distance. All tile was cured in special tanks for 21 days before drying and haulage to placement site. Canal construction joints were at 33 feet intervals.

Cost of brick-tile lining on side work was Rs. 150 per sq. ft. and for the bed was Rs. 65 per sq. ft.

A brief stop was made at Kalsia, near the Canal to rest house to inspect one of the oldest canals of India. It is thought that the first construction took place between 1628 and 1659. The canal was abandoned several times and restored a number of times. In 1822, remodelling started and by 1830, it was in operation again. Water is diverted from the Yamuna River. It had a capacity of 2,000 cusec but remodelling during 1954-61 increased the capacity to 4,000 cusec. The canal length with branches is 129 miles. There are 848 miles of distributaries.

The delegation arrived back in Roorkee for supper and the night stop.

Upon departure from Roorkee for return to New Delhi, on Saturday March 14, a brief stop was made at the Irrigation Research Institute. This stop proved to be much too short as many delegates were extremely interested in some of the studies and research in progress.

A stop was made at State Tubewell No. 1, some 33 miles out of Roorkee. The State of Utter Pradesh has 7,000 state owned and operated tubewells each with a capacity of about 1½ cusec. The Indo-Gangetic alluvium has proven a good source of water for tubewell development. Well No 1, was constructed in 1937 to a depth of 305 feet. The strainer was set at 107 feet and discharge obtained by electric-powered pump was 34,500 gal. per hour. The culturable command area is 711 acres and one mile of lined channel was part of the construction. About 1 rupee for 16,000 gallons of water is the normal charge to the farmer. During the 26 years of operation the well has operated 122,544 hours and is still working satisfactorily.

Lunch was again arranged at the Wheler Club in Meerut. The delegation arrived in New Delhi on schedule. Everyone was somewhat dusty and tired but happy with the trip and complimentary toward the efforts and arrangements made for them to see some of India's irrigation efforts.

ERRATA

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