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# 8TH NEAR EAST - SOUTH ASIA REGIONAL IRRIGATION PRACTICES SEMINAR

KABUL, AFGHANISTAN
1970

# FOREWORD

The Proceedings of the Eighth Near East South Asia Irrigation Practices Seminar are reported in this volume. The Seminar was jointly sponsored by the Royal Government of Afghanistan and the United States Agency for International Development. The Seminar was held in Kabul, Afghanistan, with field trips to irrigation development projects in the Helmand-Arghandab Valleys. The two-week Seminar opened in Kabul on September 19, 1970. The nations sending delegates to the Seminar included Afghanistan, India, Iran, Pakistan, Turkey, and the United Arab Republic. Observers attending the Seminar included representatives from the United States of America, the Food and Agriculture Organization of the United Nations, and the Ford Foundation.

The Near East South Asia Irrigation Practices Seminar Series had its beginning in Izmer, Turkey in 1956 and has been held bi-annually since that time in the following host countries: Tehran, Iran, 1958; Lahore, Pakistan, 1960; Ankara, Turkey, 1962; New Delhi, India, 1964; Amman, Jordan, 1966, and Lahore, Pakistan, 1968. All of these Seminars have been sponsored by the United States Agency for International Development.

The delegates to the Eighth Seminar, as in previous seminars, were selected by the respective governments from the personnel of organizations having the responsibility for the development and maintenance of irrigation projects and irrigated agriculture in their countries. In most cases, the delegates represented the high level, decision-making personnel concerned with the problems of improving agricultural production with sound water management.

At the Eighth Seminar the delegates dedicated themselves to the solution of the problems of Agricultural Water Management which were given high priority by the Executive Committee of the Seventh Seminar. In the Seventh Seminar, held in Lahore, Pakistan, many pressing problems of the developing countries were considered, and the Executive Committee of that Seminar recommended additional study and effort be given to certain specific problems. From those recommendations the major theme of the Eighth Seminar was developed.

The delegates to the Eighth Seminar worked diligently and tirelessly to develop sound recommendations for water development and on-farm water management to maximize agricultural production on the irrigated lands of the countries concerned. A free exchange of ideas and knowledge took place at the Seminar to the direct benefit of the delegates and the nations represented.

A. Alvin Bishop, Head
Department of Agriculture and Irrigation Engineering
Utah State University
Technical Advisor - USAID

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# Eighth Near East-South Asia Regional Irrigation Practices Seminar

**September 19-30, 1970**

**Kabul, Afghanistan**

Co-Sponsored by

**The Government of Afghanistan, Host**

and the

**United States Agency for International Development**

# Program

## EIGHTH NESA IRRIGATION PRACTICES SEMINAR

## September 19-30, 1970

**Saturday, September 19**

0800 *Registration of Delegates*

1000 *Inauguration*

*Recitation from the Holy Quran*

*Welcome Address* by H. E. Mr. Abdul Hakim, Minister of Agriculture and Irrigation

*Welcome Address* by Mr. Bartlett Harvey, Director, USAID, Afghanistan

*Response* by Mr. Jomma Mohammadi, President, Irrigation and Water Survey Dept.

*Orientation* by Dr. A. Alvin Bishop, Technical Advisor

1100 *Adjourn*

1400 *Executive Committee Meeting*

**Sunday, September 20**

Chairman: Mr. Jomma Mohammadi, Afghanistan

0830 *Country Progress Reports* by India, Pakistan and Iraq

1200 Recess

1400 *Country Progress Reports* by Turkey, UAR and Afghanistan

1600 Executive Committee Meeting

**Monday, September 21**

Chairman: Mr. M. A. Quraishi, India

0800 TECHNICAL SESSION: *Farm Management of Irrigation Practices*

On Farm Water Management, India's Approach, India

Financial Problems on the Farm Operations in Seyhan Project, Turkey

Irrigation and Drainage Practices Applied in Khuzestan, Iran

1200 Recess

1400 *Panel Meetings*

1900 Dinner sponsored by Mr. Abdul Hakim, Minister of Agriculture and Irrigation, Afghanistan

**Tuesday, September 22**

Chairman: Mr. M. M. H. Ghavamian

0800 TECHNICAL SESSION: *Farm Management of Irrigation Practices* (continued)

A Modified Concept of the Consumptive Use of Water in the Case of Rice, Pakistan

Irrigation Practices in East Pakistan, Pakistan

Irrigation and Drainage Practices in Haft Tappeh, Iran

1030 TECHNICAL SESSION: *Irrigation Institutions – Farm Relationships*

Irrigation Institutions and Water Management Aspects, Afghanistan

Water Changes in Relation to Benefits Derived from Irrigation and Water Changing Systems, Rules and Regulations, India

1100 TECHNICAL SESSION: *Farm Irrigation and Drainage Systems*

Water Management, Method of Application, Measurement and Control, Afghanistan

1200 Recess

1400 *Panel Meetings*

1600 *Executive Committee Meeting*

**Wednesday, September 23**

Chairman: Mr. Mohiuddin Khan, Pakistan

0830 TECHNICAL SESSION: *Farm Irrigation and Drainage Systems* (continued)

Karz Zakir Emergency Outlet Drains, Afghanistan

Planning and Designing for Optimum Farm Water Use, India

Principles and Procedures of Water Resources Investigation on the South Coast of Iran, Iran

Economical Use of Nile Water, UAR

1200 Recess

1400 *Panel Meetings*

**Thursday, September 24**

0830 TECHNICAL SESSION: *Farm Irrigation and Drainage Systems* (continued)

Irrigation and Drainage in Fayoum (a unique system), UAR

Reconstruction and Improvement of Irrigation Systems of Afghanistan, Afghanistan

TECHNICAL SESSION: *Irrigation Practices Research and Soil Salinity*

Contribution of $CaCo_3$ in Some Irrigation Water to Soil Deterioration, Afghanistan

1200 Departure for Field Trip to Kandahar and Helmand Valley

2000 Dinner sponsored by Governor of Kandahar

**Friday, September 25**

0800 Visit to Karz and Zakir and Visit to Diversion Dam of Zahir Shahi Canal

1200 Lunch sponsored by HAVA

1400 Visit to Khirqa-i-Mobaraka and tombs of Ahmad-Shah Baba and Mir Waise Neeka

1600 Visit to Boghra Diversion Dam and onward trip to Lashkar Gah

1900 Dinner sponsored by HAVA

**Saturday, September 26**

0800 Visit to Research Station and Livestock Farm

Visit to Grape-Drying Building

Visit to Marja Area and Darweshan Diversion Dam

1200 Picnic Lunch sponsored by Helmand-Arghandab Construction Unit

1300 Visit to Experimental Farm, Shamalan (Kharaba)

1400 Visit to Oil Mill and Cotton Gin (afternoon tea served by Helmand Oil Mill)

1900 Dinner sponsored by USAID/Lashkagar

**Sunday, September 27**

0800 Visit to historic Arch of Bost and return to Kabul

1200 Box Lunch on buses furnished by USAID/A

**Monday, September 28**

Chairman: Mr. A.M.F. Zitouni, UAR

0900 TECHNICAL SESSION: *Irrigation Practices Research and Soil Salinity*

Helmand Valley Shamalan Land Development Project Plans, Afghanistan

Systems Approach to Optimum Use of Irrigation Water, India

The Estimate of Water Consumption of the Agricultural Crops throughout Iran, Iran

1145 Water Quality in Relation to On-Farm Water Management in West Pakistan, Pakistan

1230 Recess

1400 *Final Panel Meetings*

1600 *Executive Committee Meeting*

**Tuesday, September 29**

Chairman: Mr. Jomma Mohammadi, Afghanistan

0830 TECHNICAL SESSION: *Education and Training*

Land Consolidation Activities and Regulations in Turkey, Turkey

Report of EDUCATION AND TRAINING Panel

Report of FARM MANAGEMENT OF IRRIGATION PRACTICES Panel

Report of IRRIGATION INSTITUTIONS – FARM RELATIONSHIPS Panel

1230 Recess

Chairman: Mr. A. T. Assifi, Afghanistan

1430 Report of IRRIGATION PRACTICES RESEARCH AND SALINITY Panel

Report of IRRIGATION AND DRAINAGE SYSTEMS Panel

1630 *Executive Committee Meeting*

1900 Dinner sponsored by USAID

**Wednesday, September 30**

0800 Executive Committee Meeting and Preparation of Final Report

Morning Free for Delegates

1400 *Closing Session*

Chairman: Mr. Jomma Mohammadi

Report of Executive Committee by Mr. Jomma Mohammadi, Afghanistan

General Resolution by Mr. M.M.H. Ghavamian, Iran

Seminar Report by Dr. A. Alvin Bishop, Coordinator

Delegate Appraisal by Mr. Mohiddien Khan, Pakistan

Observations of USAID by Dr. Joe M. Motheral

Closing Address by H. E. M. Ehsan Rafiq, Deputy Minister of Agriculture and Irrigation, Afghanistan

1900 Farewell dinner sponsored by Engineer Jomma Mohammadi, President of Irrigation and Water Survey

## *Recitation from the Holy Quran*

*In the name of Allah, the Beneficent, the Merciful.*

*He it is Who sends down water from the sky for you; it gives drink and by it (grow) the trees on which you feed.*

*He causes to grow for you thereby crops, and the olives, and the date palms, and the grapes and all the fruits. Surely there is a sign in this for people who reflect.*

*And He has made subservient for you the night and the day and the sun and the moon. And the stars are made subservient by His command. Surely there are signs in this for people who understand.*

*And what He has created for you in the earth is of varied hues. Surely there is a sign in this for people who take heed.*

*And He it is Who has made the sea subservient that you may eat fresh meat from it and bring forth from it ornaments which you wear. And you see the ships cleaving through it, so that you seek of His bounty and may give thanks.*

*And He has cast firm mountains in the earth lest it quake with you and rivers and roads that you may go aright.*

*And landmarks. And by the stars they find the right way.*

*Is He then Who creates, like him who creates not? Will you not then remember?*

*And if you would count Allah's favors, you would not be able to number them. Surely Allah is forgiving, merciful.*

*And Allah knows what you conceal and what you do openly.*

*And those whom they call on besides Allah created naught, while they are themselves created.*

*Dead (are they), not living. And they know not when they will be raised.*

*Your God is One God: so those who believe not in the hereafter, their hearts refuse to know and they are proud.*

*Undoubtedly Allah knows what they hide and what they manifest. Surely He loves not the proud.*

*Al-Quran XVI:10-23*

# DELEGATES

**Turkey**

(1) Seref Ozgul (Chief of Delegation)
Chief Consultant on Soil and Drainage
General Directorate of State Hydraulic Works

(2) Fikret Ercan
Agricultural Engineer
Farm Irrigation and Soil Conservation, Ministry of Village Affairs

(3) Warren Leatham
Water Resources Engineer
USAID, Turkey

**India**

(1) M. A. Quraishi (Chief of Delegation)
Additional Secretary
Ministry of Food and Agriculture

(2) N. P. Jahagirdar
Deputy of Agriculture
Bellary, Mysore State

(3) John T. Phelan
Chief Soil and Water Management
USAID, India

(4) J. P. Naegamvala
Member, Central Water and Power Commission
Ministry of Irrigation and Power

(5) L. Venkataratnam
Joint Director Agriculture Projects
Government of India

(6) Dr. B. A. Krantz
Professor of Water Science
Ford Foundation, India

(7) N. D. Rege
Joint Commissioner, Soil and Water Management
Government of India

**Iran**

(1) M.M.H. Ghavamian (Chief of Delegation)
Supreme Advisor to Minister
Ministry of Water and Power

(2) Asgar Manaavi
Managing Director
South-East Water Authority

(3) Shapoor Hajrasuliha
Head, Agricultural Research Department
Haft Tappeh Cane Sugar Project

(4) Abbas Ghaemossabahi
Engineer
Irrigation Department Planning Organization

(5) Houshang Sohaie
Head, Irrigation and Drainage Division
Ministry of Agriculture

(6) Farhad Esfandiari
Research, Scientific and Technical Cooperative
Ministry of Water and Power

**United Arab Republic**

(1) A.E.M. Rashwan
Sub-General Inspector
Egyptian Irrigation in Sudan

(2) A.M.E. Zitonn (Chief of Delegation)
General Inspector
Irrigation in Assuit

**Pakistan**

(1) Mohinddin Khan (Chief of Delegation)
Engineering Advisor
Government of Pakistan

(2) M. U. Arain
Chief Engineer
Sukkur Barrage, Government of Sind Province

(3) C. M. Hussain
Director Land Reclamation
Irrigation Department, Punjab

(4) L. Mastrofini
Water Resources Engineer
USAID, Pakistan

(5) G. Corey
Agricultural Engineer
USAID, Pakistan

(6) H. Rinnan
Irrigation Farm Advisor
USAID, East Pakistan

(7) A. M. Awan
Engineer
University of Lahore

(8) Paul R. Seaber
Hydrologist
USAID, Pakistan

(9) Igbal Ali
Reader
University of Lahore Lahore

(10) Ahmad Hassan Sheik
Vice Chancellor
Lahore University

(11) Earl S. Sumner
Irrigation Farming Advisor
USAID, Pakistan

(12) M. Aslam Rasheed
Lecturer
University of Engineering and Technology, Lahore

(13) S. Nazib Ahmad
Head
Civil Engineering Department
Engineering University, Lahore

(14) Riaz A. Khan
Head of Agronomy
West Pakistan Agricultural University

**Afghanistan**

(1) Jomma M. Mohammadi (Co-Chairman, Seminar)
President
Irrigation and Water Survey, MAI

(2) M. Akram
Irrigation Engineer
Irrigation and Water Survey Authority

(3) A. I. Issaq
Director General
Water Management, MAI

(4) M. Ebrahim Pearose
Director
Design, MAI

(5) R. Shinwari
Director General
Design, MAI

(6) Saleh M. Popalzia
General Director
Groundwater, MAI

(7) A. T. Assifi
Chief Engineer
HAVR

(8) M. A. Aman
Geologist
MAI

(9) Mir A. Shah
Irrigation Engineer
MAI

(10) A. H. Azizi
Office Engineer
Dam Design Section

(11) M. W. Audin
Director General Engineering Division
HAVR

(12) M. Siddiqi
Irrigation Engineer
MAI

(13) M. A. Ludin
Hydrologist
MAI

(14) Ghulam D. Sham
HAVR

(15) A. G. Shuja
Director General O & M
HAVR

(16) M. Hasheim Waheb
Irrigation Engineer
Irrigation and Water Survey Authority

(17) M. Formali
General Director Project Planning
HAVR

(18) M. N. Azimi
Irrigation Engineer
Small Dams Design, MAI

(19) George W. Clark
On-farm Irrigation Advisor
USAID

(20) A. S. Zia
Head, Agriculture and Rural Development
HAVR

(21) A. Ranimi
Soil Fertility Specialist
MAI

(22) Sanford Caudill
Irrigation Operations Advisor
HAVR

(23) A. Peyton
Agriculture
USAID

(24) W. L. McCaig
Acting Project Manager
USAID HAVR

(25) M. Jafer Kazemi
Engineer
MAI

(26) Adrian K. Long
Civil Engineering
USAID HAVR

(27) Paul Fitzhugh
Irrigation Operations and Maintenance
USAID HAVR

(28) Lawrence Eurhardt (Co-Chairman)
Chief Bureau of Reclamation, Kabul
USAID

(29) Edward Nichols
Design Engineer
USAID

(30) Lafe Shumway
Design Engineer
USAID

(31) G. S. Firoq
Engineer
HAVR

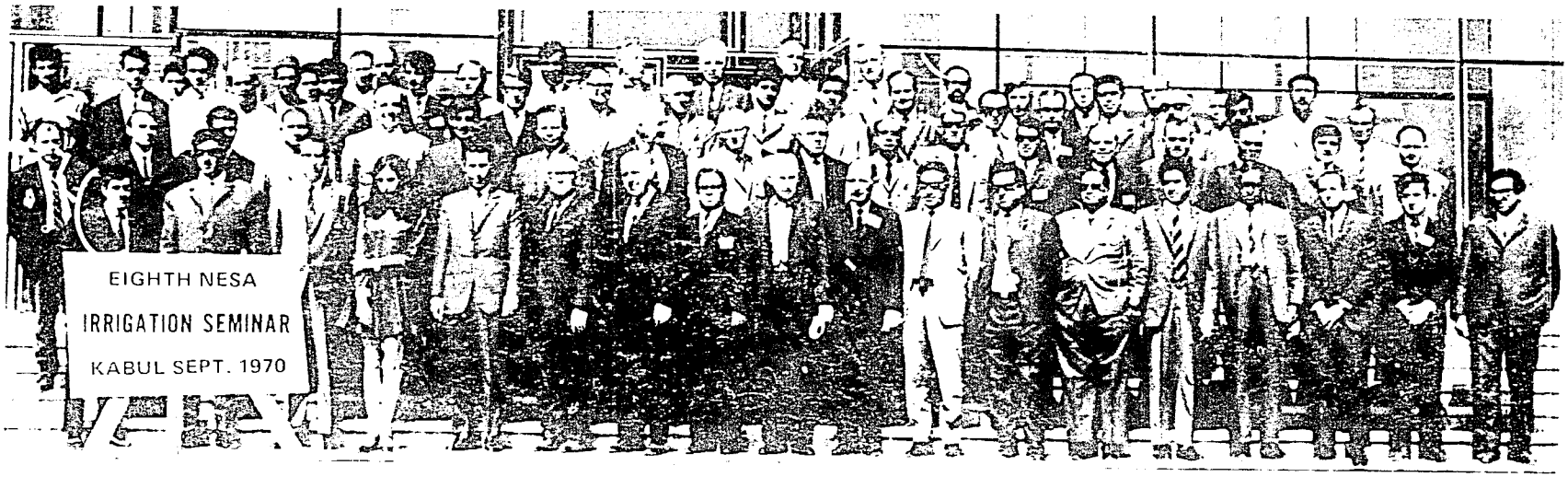
**Dept. of Agriculture, USA**

(1) Charles H. Treakle

**United Nations**

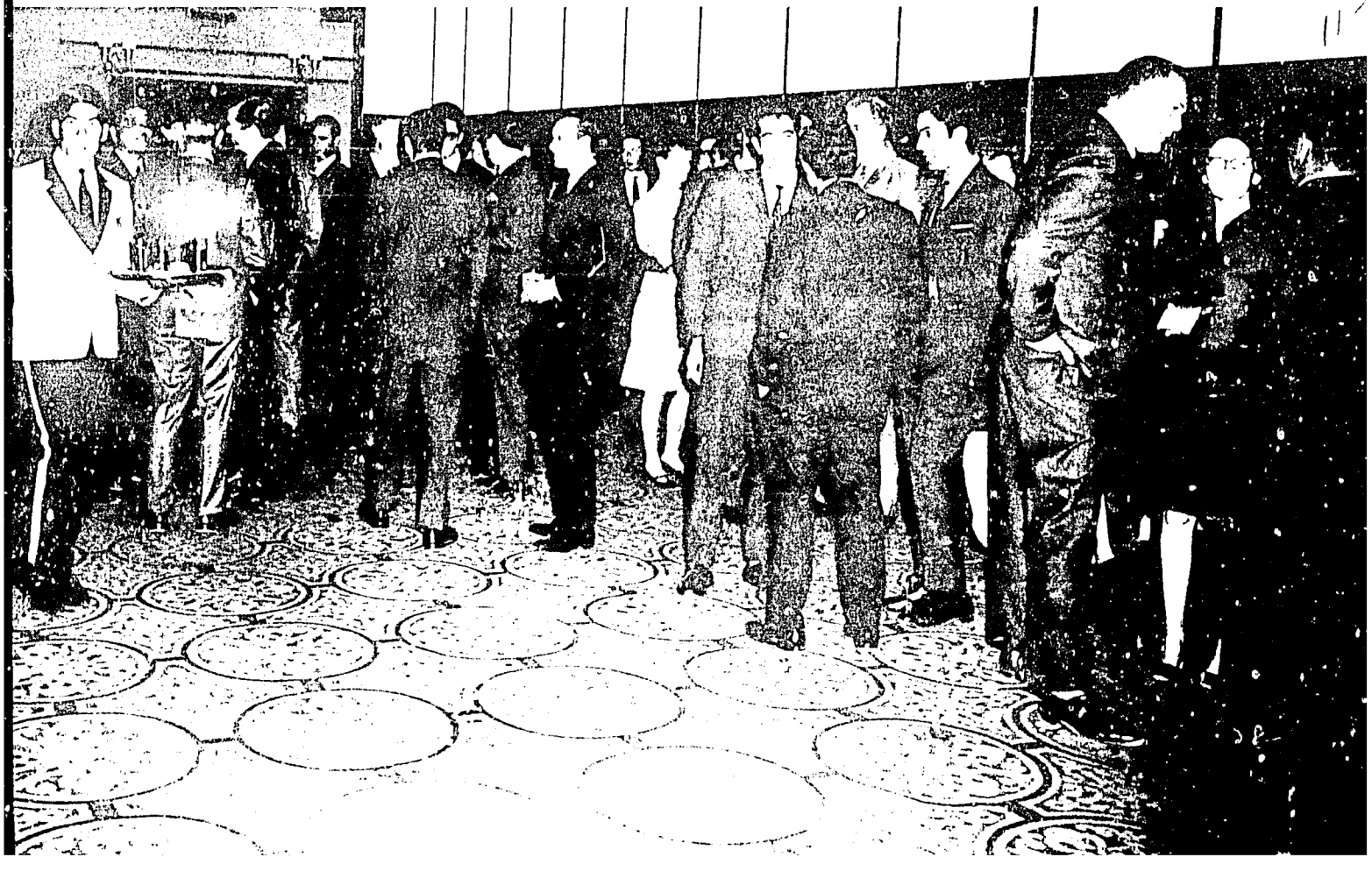
(1) Mr. B. Raham
Project Manager, UN/SF
UN

(2) T. ViveKananthan
FAO
UN




1. Azizullah Azizi
2. H. Ali Nedjem
3. G. H. Anwar Lodin
4. Paul Seaber
5. Miss Marie Siddiqi
6. Houshang Sohaie
7. A. Alvin Bishop
8. Warren J. Leatham
9. Dr. N. D. Rege
10. G. Nichols
11. J. P. Naegamvala
12. G. D. Sham
13. A. G. Shuja
14. N. P. Jaqirdar
15. A. S. Zia
16. L. Venkataratam
17. M. Aman
18. M. Jafer Kazemi
19. M. Formali
20. M. A. Quraishi
21. M. Akram
22. G. S. Firoq
23. Keith Long
24. Ebrahim Pearose
25. George Clark
26. John T. Phelan
27. Lafe K. Shumway
28. Abd El-Latif Mohamed Rashwan
29. M. U. Arain
30. A. M. E. Zitonn
31. M. Hashem Waheb
32. M. A. Quraishi
33. C. M. Hussain
34. M. A. Khan
35. A. H. Azizi
36. Redwanullah Shinwari
37. G. Nabi
38. A. Khabir
39. A. Taer
40. M. Polo
41. J. Afredi
42. Li Wazisi
43. Amin. Allah
44. M. Wali Audin
45. A. Hamad
46. A. Madjid
47. M. Nasim
48. A. Ghaemossabahi
49. F. Esfandiari
50. Mir Aqil Shah
51. E. Sumner
52. H. Rinnan
53. L. Mastrofini
54. B. A. Krantz
55. S. Hajrasuliha
56. P. Fitzhugh
57. N. M. Awan
58. Lawrence Ehrhardt
59. Fikret Ercan
60. A. F. Issaq
61. M. M. H. Ghavamian
62. B. Valery
63. Seref Ozgul
64. S. Pytigorski
65. J. Mohammadi
66. G. Corey
67. A. Manaavi
68. G. Saki
69. Iqbal Ali
70. G. Dastageer
71. A. R. Kohnaward

## Social Highlights of the Seminar



## Seminar Secretariat

A vote of thanks goes to these two efficient secretaries who helped keep things moving smoothly at the Seminar. They are Diane Rice and Mary Jean Sallee. They worked under the direction of Lawrence Ehrhardt.

# CHAPTER 1

# OPENING SESSION

## Chairman

## JOMMA MOHAMMADI

**President, Irrigation and Water Survey Department**

## Welcome Address

by

## H. E. ABDUL HAKIM

**Minister of Agriculture and Irrigation**

Excellencies, honorable delegates, distinguished guests, ladies and gentlemen:

Today I have the honor to open the Eighth Near East-South Asia Regional Irrigation Practices Seminar.

It is a great pleasure for me to have the privilege of welcoming each of you, on behalf of His Majesty the King, the government and the people of Afghanistan.

I wish you all an enjoyable time during your stay in our country.

Gentlemen, agriculture is the backbone of our economic existence. Agricultural products constitute the major portion of Afghanistan's exports and consequently are the source of foreign exchange. About 72 per cent of the national income is derived from agricultural products.

Yet, of a total surface area of around 160 million acres (64 million hectares) of

Afghanistan, not more than 12 million acres (4.8 million hectares), or 8 per cent, is cultivated in any given year.

More than one half of arable land lies fallow each year, because there is not sufficient water for the area served by an irrigation system. Total land area includes:

1) Desert and mountain area, 115 million acres (46 million hectares)
2) Arable, including irrigable and fallow, 33 million acres (13.2 million hectares)
3) Potentially arable, 3 million acres (1.2 million hectares)
4) Grazing land, 8.5 million acres (3.4 million hectares)
5) Forest land, .5 million acres ( .2 million hectares)

The foregoing statistics show that a large portion of potentially cultivable area has been left unused in the country due to an undeveloped irrigation system.

The Afghan government has been intensively engaged with nationwide planning and construction of irrigation development schemes in recent years, but still we have a long way to go to solve our irrigation problems.

Agriculture and irrigation development have great importance all over the world, especially in those countries where food supply and demand are not in balance. On the other hand, the world faces a population explosion which makes the problem of food shortage even more critical. In order to increase the inadequate amount of food per person, and to provide sufficient food for coming generations, we need improved methods of agriculture, which in turn rely to a great extent on sound irrigation systems and efficient use of them.

The development of agriculture and irrigation and solving of related problems comprise the major part of our economic development plan. I firmly believe that this kind of seminar helps us do better planning and directs us toward solving some of the problems with which we are confronted in the field of irrigation. Problems related to irrigation and drainage vary in different countries according to their natural and physical conditions. But discussing those problems gives us an insight toward solving them. Likewise we get an opportunity to hear about the accomplishment of other countries in the field of irrigation, and to consider the possibilities of adopting these methods in our country.

Man cannot experience everything directly, so he learns by the experience of others. Seminars of this nature enrich our experience to a great extent. Besides discussing the main problems, exchanging technical knowledge in water development and updating ourselves with the latest technological progress in irrigation, such as design and construction of sound irrigation systems, efficient water management and application, and other relevant subjects, are preparing the members to serve better their respective countries.

Finally I would like to express my deepest thanks and gratitude to the United States Agency for International Development for the assistance and cooperation in convening this seminar.

I will end with this quotation: "Irrigation in many countries is an old art – as old as civilization, but for the whole world it is a modern science – the science of survival."

# Welcome Address

by

**DR. BARTLETT HARVEY**

**Director, USAID, Afghanistan**

Mr. Chairman, excellencies, friends:

It is a great privilege to join His Excellency Minister Hakim in welcoming you here today. It is also a pleasure. On behalf of USAID/A I am frank to say we are glad you are here.

We are glad you are here because we like this beautiful country. We are fascinated by its problems and challenges, and we are delighted to have a chance to share our experiences with you.

We are glad for the chance to renew old friendships and build new associations.

We are glad because we need you.

There is a lot going on in agriculture here, a lot that is successful, some that is less so. Specialty products like karakul, melons and raisins are improving in quality and are in good export demand. The national wheat adaptive research program is impressive, and after harvest its results are gathered in time for campaign planning for the next planting, which is even more impressive. Fertilizer and the new varieties of high yielding wheat are increasing yields, but their spread is slow. Many thousand hectares of land have been brought under irrigation command, in both large and small systems, some of them very dramatic indeed.

But in this land where water is the dominant, scarce resource in agriculture, we need your help in developing systems of water management. Farmers here have a long tradition of effective water management within the limits of village organization, mud and sod technology, and flooded field agriculture. However, they need to learn, and we need to learn how to teach them, the management of large canals, of drainage, of furrow irrigation, and of multiple cropping.

Hopefully, you people will bring us new ideas, useful techniques, and most important, clues to modes of organization and management that will actually result in improved efficiency of water use by real dirt farmers on real dirt farms.

We look forward to these sessions with hope of great help from you in improving on-farm water management, i. e., in raising the limit on incomes imposed by Afghanistan's scarcest agricultural resource.

Good luck and God speed.

# Opening Address

## by

## Mr. JOMMA MOHAMMADI

Excellencies, honorable delegates, ladies and gentlemen:

As the head of the Afghan delegation to the Eighth NESA Irrigation Practices Seminar, I have the honor of welcoming each of the distinguished delegates representing the countries of the Near East, South Asia, and the concerned agencies.

I would also like to extend, on behalf of myself and the distinguished delegates, our sincere thanks to H. E. Mr. Abdul Hakim, Minister of Agriculture and Irrigation, for his deep interest in convening this seminar in Afghanistan and sparing some of his valuable time today for welcoming the delegates and inaugurating the Seminar.

It is indeed an honor and privilege for the government and people of Afghanistan to see that the Eighth NESA Irrigation Practices Seminar is being held in this historic place. Honorable delegates, it is our pleasure to be your hosts and at the same time we hope you will forgive short comings if any in the arrangements.

As it was rightly stated by H. E. the minister, of the total geographic area of the country, because of numerous natural problems, and shortage or lack of necessary facilities, only a small percentage is annually cultivated.

But on the other hand, we are fully aware of the urgent and ever growing demand for the increased agricultural products to satisfy the needs of our people.

Therefore, the government has given very high priority to this sector, namely to increase the agricultural production and to develop the irrigation facilities in every possible manner.

We have completed reconnaissance surveys of the country's land and water resources in most of the larger river basins.

Feasibility studies are undertaken for a number of selected areas. In fact, where studies were favorably completed, construction activities have been started and are going on in a number of basins, some of which you will be visiting shortly.

It is intended that the total agricultural production should be increased both by intensification on existing areas as well as by bringing new lands under irrigation. Major, medium and minor projects are and will be taken up in a balanced and complementary manner. Action is initiated to improve the yields on unit area by the use of better inputs, improved implements and modern techniques.

The results achieved in this direction in many parts of the country, for example from the wheat program, are highly satisfactory and encouraging.

However, in spite of what has been done so far in the field of developing land and water resources, much remains to be done yet. And here is an area where we sincerely welcome mutual understanding, cooperation and assistance. Under the present context, it is not only the funds and commodities that will help accelerate progress but of no less importance is the technical know how and exchange of experience and knowledge with different countries, especially those in the NESA region.

Situated as they are, the NESA countries are facing or would have faced problems similar to ours, and hence their experience would be valuable to us.

This seminar has brought together senior specialists dealing with similar problems in their respective countries and has given us all an opportunity to discuss and exchange views. We therefore attach great importance to this seminar and we are looking forward to the valuable guidance that the seminar will provide in the field of irrigation practices.

In conclusion, I would like to extend my sincere thanks to the United States Agency for International Development and the related staff, in particular Mr. Ehrhardt, for the valuable assistance in arranging this conference.

I would particularly like to mention Dr. Bishop's continued interest in the technical aspects of the seminar.

I would also like to express my sincere thanks to the Institute of Public Health, which made the premises available to us, and also to the Tourist Bureau, the Helmand Valley Authority and other organizations and individuals who have assisted us in convening this seminar. I wish here to express my appreciation and to thank my various colleagues who worked very hard to make this seminar a success.

Finally, I would like to extend my sincere thanks and gratitude to each delegate for his participation. I wish you all a very pleasant stay in this country. I thank you, ladies and gentlemen, for your coming to participate in the inauguration of this seminar.

# Seminar Orientation

by

**DR. A. ALVIN BISHOP**

**Technical Advisor**

Excellencies, Director Harvey, delegates, ladies and gentlemen:

As your technical advisor, may I add a word of greeting to all delegates, participants, and observers to this seminar on irrigation practices. This seminar is the eighth in a series that had its beginning in Izmir, Turkey in 1956. The Near East-South Asia Irrigation Practices Seminar, over the years, has become a strong force to achieve better management of water on the farms in this part of the world. "On-Farm Water Management" is perhaps a more inclusive and a better descriptive term than "Irrigation Practices" because it automatically includes "Irrigation Practices" and "Drainage Practices." Of course, the NESA Irrigation Practices Seminars have dealt with all facets of water management for increased agricultural production, including water application, water removal, water requirements with frequency and amounts, physical systems, legal systems, social systems, financing, research and all related management factors.

Now we have inaugurated the eighth seminar. Delegates and participants will find that a vigorous program is in store for them. Technical papers have been prepared, panel meetings have been outlined, and physical arrangements are ready in order to provide an environment for a free exchange of knowledge. At a technical seminar such as this, there is no time available to indulge in discussions of political differences. Although the world is troubled and some may wish to discuss political issues, I believe that this seminar is not the place to mention items not directly concerned with the use and management of water on the farm. I hope that delegates will not attempt to misuse the seminar but continue the tradition already established in the NESA seminars and focus on the vital problems of increasing agricultural production with improved water management techniques.

According to the recommendations made by the executive committee at the seventh seminar at Lahore, Pakistan, two years ago, and I quote:

> Future seminars concerned with irrigation practices should continue to focus attention on the problems of achieving sound water management and efficient use of water on the farm. Participating countries should pool their efforts to realize this objective.

The eighth seminar has been designed around this central theme, and in order to generate a program for the seminar it was my pleasure to visit most of the countries in the region during February and March of this year. The enthusiasm I found for the seminars makes me believe that the one now beginning will be a great success. I know that the Afghan committee and the USAID/Afghanistan have been working long and hard on the arrangements in order to make the seminar successful and your stay in Afghanistan pleasant and productive.

It has been the practice in previous seminars to immediately establish an executive committee. This committee consists of the chairman or team leader of the delegates from each country, with the technical advisor as ex-officio member. This committee will have frequent meetings, the first one this afternoon at 2 p.m. The major responsibility of the executive committee will be to appoint the chairman for each session of the seminar and to determine the central theme for each panel discussion group. The seventh seminar at Lahore established six panels, as indicated in the proceedings of that seminar. A realignment and reemphasis of important problems is in order. All delegates should communicate their thoughts and ideas for panel discussions through their representative on the executive committee.

I know from my previous experience with the sixth and seventh seminars that the delegates will be busy and much will be expected of them to share knowledge and ideas and to develop new concepts for improving the water management of the Near East-South Asia region. I am sure that you will not be disappointed.

# CHAPTER II

# PANEL RECOMMENDATIONS

## Panel I

## Education and Training

### S. M. Popalzai - Afghanistan - Chairman

Water management on the farm and education could be the subjects of many volumes of writing. The purpose of this panel, however, was to study these subjects and report recommendations that could improve water management on the farms of NESA countries.

The panel first studied the recommendations of the seventh NESA seminar, found them just as valid and appropriate now, and recommends they remain in effect, supplemented by those of this seminar.

As agriculture is the basic and most important occupation in these countries, the panel recommends that continuing efforts be made to upgrade the status of farmers. Adult education and training should be designed to develop in the farmer a feeling of importance and the status of his occupation as a farmer.

Specific programs recommended:

(1) Water management on the farm should start with an allocation of water to the farm, based on crop requirements. This distribution practice will require the education of all levels of people involved. The farmer must understand irrigation crop requirements if he is to accept water under any condition different from his custom and tradition. To educate the farmer, all common methods and means of education should be used. Special emphasis is placed on the use of village demonstrations.

(2) Material relative to good irrigated agricultural practices should be provided as teaching instruments and tools for such subjects as reading, writing and arithmetic. The use of existing village schools is recommended for this purpose. Grade school students could associate such study with the principal work of their village, that of producing crops. This training is of long-term benefit, but parents also will benefit to a large extent. To place this recommendation into effective action would require cooperation from the educational leaders of the country. The benefits would be great and would supplement the existing educational process.

The knowledge of the irrigation specialist must be rewritten to the simplest possible level. Many farmers may be convinced only by visual means. This

is best shown by demonstrations, but in many cases pictures and drawings may be used. One subject, one or two-page pamphlets, with most subject matter illustrated, should be prepared for use by village teachers or extension workers.

Visits by farmers to demonstration farms or other farms where good irrigation practices can be seen are highly recommended. The exchange of ideas and successful practices among farmers should be encouraged and could be accomplished during these visits.

Demonstrations must be carefully planned to assure success in conditions where they are used. The first demonstration must be successful in order to develop the confidence of farmers in governmental employees and in the practices demonstrated.

Efforts should be made to bring all village leaders to recognize the need for improving the general welfare of the farmer by using better farming practices. All leaders in the country should be made aware of the efforts to improve the farmer's irrigation knowledge. National interest in this program is necessary.

Development of an organization to be called the NESA Irrigation and Agricultural Practices Association, or other appropriate title selected, is recommended for coordination of the advancement of improved irrigation practices in NESA countries.

To further the exchange of ideas and expand the use of successful irrigation practices, the panel also recommends that each participating country annually produce a suitable pamphlet or book. This publication should contain the report of progress and outline effective programs being conducted in that country. Enough copies should be made available for distribution to member countries.

A program of recognizing, by suitable award, those individuals who make outstanding contributions to the education of farmers should be established in each country.

Some NESA countries have already established educational institutions for training and education of lower level technicians and their supervisors in the specialty of water management. Thus, the foundation of such institutions is recommended to all participating countries. In this connection more cooperation between different countries in exchange of experts and trainees is recommended.

Providing training for farm cooperatives where they exist is recommended. The success of such cooperatives in some NESA countries should encourage all countries to study the formation of such cooperatives, and to provide the necessary help to these organizations.

The delegation leader should be assigned the responsibility for bringing these recommendations to the attention of leaders in their country and to present a copy of these proceedings, and ask for their help in carrying out the recommendations they recognize as most applicable to the country's needs. Attention should be drawn to the recommendations of the seminar.

Panel 1 Education aad Training Members, left to right: Mir Agil Shah, Afghanistan; Saleh M. Popalzai, Afghanistan; Dr. Iqbal Ali, Pakistan; Earl S. Sumner, Pakistan, USAID; Farhad Esfandiari, Iran; Asghar Manaavi, Iran; M. N. Azimi, Afghanistan; N. P. Jahagirdar, Indian; Sanford Caudill, Afghanistan, USAID

# Panel II

## Farm Management of Irrigation Practices

**M. A. Quraishi - India - Chairman**

The panel discussed at length various problems relating to farm management for irrigation practices since the last seminar met in September, 1968, especially in the new situation created in all NESA countries by the "Green Revolution" called the "White Revolution" in Iran.

It came to the notice of the panel that in some parts of some NESA countries, productivity of some crops had shown an increase which compares favorably with many advanced countries. The panel, however, realized that improved farm management and irrigation practices were adopted only by progressive farmers, while a majority of farmers still followed traditional practices.

In many NESA countries major irrigation projects having more than one million acres have been executed years ago. Still, the irrigation potential created by them is not being fully utilized. Some reasons are:

(1) Lack of proper land preparation.

(2) Lack of proper control of water distribution mainly due to absence of field channels.

(3) Lack of proper cropping patterns.

(4) Lack of credit, transportation, marketing, storage and processing arrangements.

In this context, the panel examined the actions taken by the NESA countries on the recommendations made by the sixth and seventh seminars. These recommendations were extremely useful and exhaustive. They are appended as a supplement to the recommendations of this panel, and are recommended again by this panel for adoption, subject to such modifications as may be necessary by the recommendations now made by this panel as given below:

(1) The panel feels that the necessary coordination between various government and public agencies concerned with farm management for irrigation practices is very often lacking. This coordination, especially between irrigation, power, agriculture, cooperative and credit agencies at all levels, is very important and should be realized.

(2) To ensure a long, useful life of existing and new storage reservoirs, special attention should be given to erosion control and sediment reduction measures in the catchment areas.

(3) Special incentives must be provided for the farmer to enable quick development of his farm. These incentives might take the form of government cost sharing on farm improvements, reduction of water charges for a limited period of time, the provision of credit at low rates, or any other means which will encourage rapid utilization of the irrigation facility.

(4) In areas where land ownership is in small units, special attention should be given to improved layout of minor water courses serving these small areas so as to reduce conveyance losses. The use of lined ditches and buried or portable pipe lines to serve these small farms should be encouraged.

(5) Top priority should be given to land preparation in the command area of all projects. The plan for the individual farm should include provision for adequate water distribution and control, the leveling of the fields, the disposal of excess surface and subsurface water, and the protection of the land against erosion, salinity and alkalinity.

(6) In the NESA region, rice is an extremely important crop and one that requires special field layout, land preparation and treatment. It is recommended that additional emphasis be given to evaluations and observations to determine the optimum field size and arrangement, water control, and drainage systems, etc., for different soil, water, climate and cultural traditions present in NESA areas.

(7) The use of sprinkler irrigation may be encouraged as one of the improved water management and application methods, depending on local climate, soil and economics and the limitation of available water.

(8) To expedite full utilization of irrigation projects, emphasis must be given to the cultivators' needs for improved seeds, fertilizers, machinery, and other inputs necessary to high production and the creation of credit, communication and marketing facilities so that all commercial inputs are readily available and surplus production can be marketed.

(9) Mechanization of farm practices needs to be encouraged. Practices especially important include seed bed preparation, land leveling, harvesting, and post harvest operations. Instructions in operation and maintenance of available implements must be provided to operators.

(10) The Green Revolution, in the wake of high yielding variety programs, multiple cropping or relay cropping, has resulted in local surpluses in many parts of NESA countries. Multiple cropping necessitates fast land preparation for the sowing of the next crop. Simultaneously, the produce must be harvested, stored, or marketed quickly. Without mechanical operations, all this is impossible.

As very few farmers can afford mechanical equipment themselves, it becomes necessary to organize custom service through governmental, commercial or private agencies. In some NESA countries Agro Industries Corporation has been set up by the government in the public sector. Such corporations, besides selling tractors and new improved agricultural implements, provide these implements on hire to farmers at a reasonable rate. Some private firms and progressive farmers have also entered this field of late.

(11) Farmers should be encouraged, especially in areas where new minor irrigation projects are proposed, to form irrigation associations or cooperatives, and give priority to these projects where such associations agree on cost-sharing on capital investment programs. These associations could function as intermediate agencies between the farmer and the government or credit institutions.

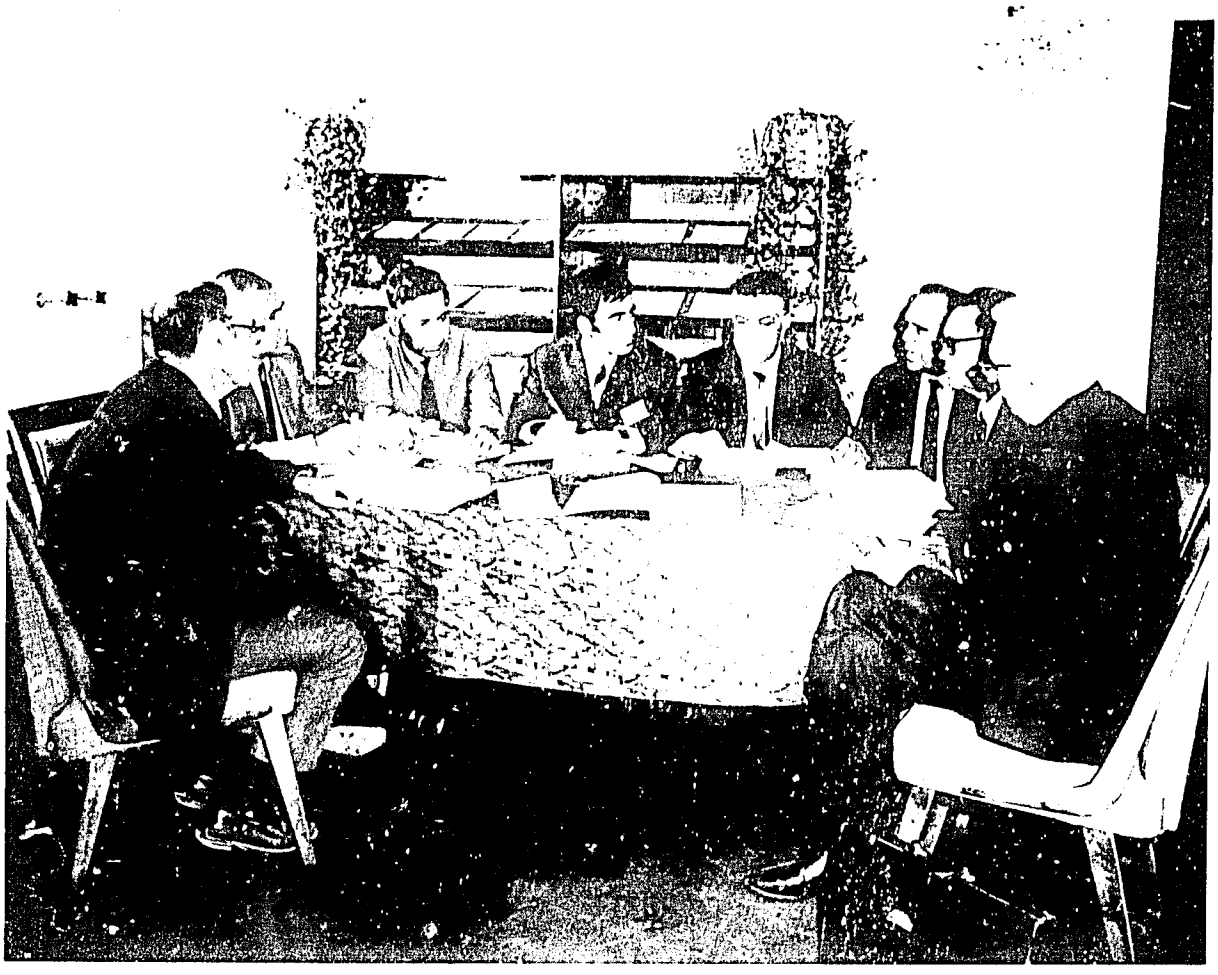
(12) Pilot projects and area development programs may be useful in perfecting workable organizations for meeting their needs, which can set the pattern for application to larger areas.

(13) Supervised credit programs should be adopted on a large scale and provided in all irrigation projects for quick agricultural development.

(14) Rules and regulations of credit agencies must be reviewed to facilitate easy and quick flow of credit to farmers.

(15) Steps should be taken to strengthen the extension service to guide farmers on the proper cropping patterns and crop rotation, the amount of water for each irrigation, control of disease and insect pests, and to follow improved cultural practices.

(16) Progressive farmers should be urged to maintain correct amounts of input and output, both quantitatively and financially. Simple forms which do not involve complicated and detailed entries could be designed for the purpose. These accounts would be useful in analyzing and evaluating farm economics.



Panel 2 Farm Management for Irrigation Practices Members, left to right: G. L. Corey, Pakistan, USAID; G. S. Firoq, Afghanistan; Ghulam Dostgir Sham, Afghanistan; A. Hamid Azizi, Afghanistan; A. Latif Moh, Rashwan, UAR; M. A. Quraishi, India; George W. Clark, Afghanistan, USAID; John T. Phelan, India, USAID

# Panel III

## Irrigation Institutions - Farm Relationships

### M. M. H. Ghavamian - Iran - Chairman

### OBJECTIVES

The objectives of this panel were:

(1) To discuss, examine and recommend the pattern of irrigation institutions that will, under normal conditions, conveniently handle water management to the optimum benefit of water users.

(2) To recommend institutional measures with respect to water rights, water use, water charges and water delivery.

(3) To assess the feasibility of forming irrigation or water management association and transferring the management and operation of irrigation, flood control and drainage to the organizations concerned.

### DISCUSSION OF PROBLEMS

Reviewing the problems raised in previous seminars, the following comments were made for consideration:

*(A) The need for laws and regulations regarding water rights, water use, land reforms and cropping patterns:*

(1) Some NESA countries either have incomplete or no laws and regulations regarding water rights, water use, land reforms and cropping patterns, with the result that the water users do not receive optimum benefits.

In recent years, some countries, such as Iran, India, and Pakistan, have enacted many of the laws and regulations recommended in the previous NESA reports. Some other countries, such as Turkey, have taken steps toward these goals. Other countries are still in the process of formulating suitable laws and regulations.

(2) In most countries, the beneficiaries do not fully cooperate for the success of the projects, due to lack of adequate information and knowledge.

(3) In some countries, utilization of water is hampered due to lack of proper law for land acquisition and provision of right-of-way for execution of projects and field channels.

(4) The lack of proper operational manuals for irrigation is still a hindrance to the proper use of water in most NESA countries.

(5) Some countries need land consolidation, land ownership reform, and cropping pattern laws and regulations in connection with irrigation development.

*(B) Water charges in relation to actual cost, rendered services and benefits derived by beneficiaries:*

(1) In most cases, water charges are fixed without due regard to the benefits derived by beneficiaries from regulated irrigation.

(2) Some countries do not have a price – cost computing division connected with irrigation projects The operation and maintenance costs of irrigation projects usually are not determined so as to assess the water charges correctly.

(3) In some countries water charges are assessed on the basis of the area commanded, whether irrigated or not.

(4) In some other countries water rates are fixed on a crop basis. Such countries have faced many difficulties due to beneficiaries not receiving demand notes in time.

(5) Collection of water charges is still a problem in some NESA countries.

### *(C) Irrigation Institutions:*

(1) Legislation in some NESA countries provides for farmers' organization to enjoy optimum utilization of water at field level. But most of them do not have such organizations for this purpose.

(2) In countries where farmers' organizations exist, they do not have proper detailed working procedures.

### *(D) Transfer of management, operation and maintenance of irrigation, drainage and flood control schemes to organizations of beneficiaries:*

(1) Some countries have made provisions in the laws and regulations to transfer management, operation and maintenance of irrigation, drainage and minor flood control schemes on the farms to the beneficiaries' organizations.

(2) Some countries face problems in making such a transfer, and some others are reluctant to do so until and unless the beneficiaries' organizations are sufficiently trained and capable of such operation and maintenance.

(3) Some countries have made provisions in the laws to operate and maintain the primary and secondary irrigation, drainage, and major flood control schemes by the public sector.

## RECOMMENDATIONS

The panel, having reviewed previous seminars' recommendations, having discussed the problems mentioned above, and realizing the importance of institutions and laws in water use and water management, recommends the following:

### *(A) Laws and Regulations:*

(1) Laws, rules and regulations governing the proper use of water by beneficiaries should be enacted with due regard to water policies and local conditions. Therefore, it is strongly recommended that sound laws, rules and regulations be framed and suitably enacted in all NESA countries.

(2) In countries where proper laws have not been enacted, laws for land ownership reform, land settlement, land consolidation and right-of-way should be enacted in connection with every irrigation project, to assure the efficient distribution of water.

(3) Every irrigation project should have a detailed cropping pattern carefully studied to give the greatest economic returns. It is assumed that these cropping patterns may change in line with the development of new production technology. These patterns can be enforced by whatever means the government sees fit.

(4) Where lacking, operation manuals for irrigation projects should be prepared by the appropriate authority to safeguard against the misuse of water and to assure proper delivery and optimum utilization.

### *(B) Water Charges:*

The panel feels that the recommendations made in the seventh NESA seminar should be considered as a fundamental basis and guideline for the assessment of water charges, and strongly recommends that, where necessary, laws and regulations should be set up for the collection of water charges.

### *(C) Irrigation Institutions and Farmers' Associations:*

The panel feels that the optimum utilization of water can never be achieved unless proper government irrigation institutions and farmers' associations are set up and well organized. With this aim in view, it is recommended that:

(1) In countries where no laws have been enacted, laws should be provided for the establishment of farmers' associations, farmers' organizations for optimum utilization of water at field level, and provision of facilities for these associations through allocation of long-term credits or other means.

(2) The farmers' associations should have rules, regulations and adequate working procedures.

(3) The government should provide training facilities for members of these associations and all help necessary for them to fulfill their responsibilities.

(4) Cooperation and close coordination among the different institutions responsible for the development of irrigation projects should be enforced by the governments.

(5) In countries where irrigation institutions and farmers' associations have not been developed, it is suggested that suitable types of farmers' associations be established on a pilot basis.

Economic and sociological research should be conducted on these pilot organizations to evaluate objectively the various types of organizational structures.

This information could then be used to help develop farmers' associations which would be best adapted to the culture of the specific country of area of the country. This type of information could be particularly useful in old irrigated areas where traditions are deeply rooted.

### *(D) Transfer of management, operation and maintenance of irrigation and drainage projects to organizations of beneficiaries:*

(1) Where not transferred, the operation, maintenance and management of irrigation distribution and drainage systems on the farm should be transferred to the beneficiaries through their self-organized associations. Such associations should be of a nature, size and pattern as will best fit the needs of the particular project or project entity.

Subject to supervision of governments, the operation and maintenance costs and collection responsibilities should also be transferred to the associations of beneficiaries.

(2) Where public interests are involved, the responsibility for operation and repair of such installations as dams, reservoirs, major canals, and drains, hydroelectric plants and other multipurpose structures should be assumed by the governments.

## CONCLUSIONS

(1) The panel feels that the attention of the various governments should be drawn to the recommendations of previous seminars, as to the emphasis to be placed by the NESA countries on the organizational, institutional and water management aspects of irrigation development, in order to achieve optimum utilization of water.

(2) Arrangements should be made to assess the progress and improvement being made in different NESA countries, whether through following seminar recommendations or irrespective of them, in order to evaluate and assist the governments through supplying required information to them.

This arrangement may be either through a joint agreement between NESA countries by the establishment of a specialized agency for this purpose or through an existing international organization.

(3) This panel recommends to the executive committee that these NESA seminars should be continued. Also, that in future seminars more emphasis should be given to the presentation of new research information pertinent to water management in agriculture.

Panel 5 Irrigation Institutions — Farm Relationships Members, left to right: Abdul Sattar Zia, Afghanistan; Ahmad Farid Yssaq, Afghanistan; [illegible] Nichols, Afghanistan, USAID; Abdul Ghaffar Shuja, Afghanistan; M. H. Ghavamian, Iran; Abbass Ghaemmosabahi, Iran; B. A. Krantz, India; N. M. Awan, Pakistan; Fikret Ercan, Turkey.

# Panel IV

## Irrigation Practices Research

### M. Formali - Afghanistan - Chairman

The importance of irrigated agriculture as a conspicuous means of supplying food for the growing world population is better understood today than it has ever been in the past.

Irrigated agriculture today produces amazingly large crop yields never attained in the past, but requires far better farm management and constant scrutiny of all the factors involved in raising a crop. This needs coordination between engineers, soil scientists, agronomists, plant pathologists, and the advocators of research findings.

## RECOMMENDATIONS

(1) Efficient farm management and constant awareness of the factors in crop production being the requirements for success in irrigated agriculture, the members of this panel recommend that factors pertinent to crop production be given due attention by NESA countries, and that a report on each item be given at the next seminar.

(2) Inasmuch as irrigation practices seminars are held every two years, it is considered very helpful and is strongly recommended that a permanent secretariat be established so that the findings and publications of the NESA countries pertinent to the recommendations of the panels can be forwarded to and distributed by that office.

Recommendations of the seventh seminar have been reviewed by the panel. These recommendations were used as a guideline and basis for further discussions.

With some modifications, the recommendations of the seventh seminar are reiterated as follows:

*(A) Irrigation Practices:*

(1) Methods for the determination of consumptive use and irrigation water requirements of different crops under varying soil and climatic conditions.

(2) Comparative studies of the economics of various irrigation methods on the farm such as slope irrigation, basin irrigation, etc., under specific conditions.

(3) Determination of irrigation water losses and economical methods for their control.

(4) Causes of sedimentation and erosion in farm ditches and suggested methods of control.

*(5) Determination of frequency and amount of irrigation for different crops under different soil and climatic conditions by employing various soil moisture measurements or measurement of plant tissues moisture (crop logging).

(6) Studies of the methods of soil moisture preservation in the field.

*(B) Land Drainage:*

*(1) Optimum water table under various soil and climatic conditions to eliminate the accumulation of excess salt in the root zone.

*(2) Optimum depth of water table for different crops under different soil and climatic conditions.

(3) Comparative study of the different types of drainage systems, i.e., open drain, tile drain, mole drain and vertical drainage by means of tubewells.

(4) Economical material for use in the tile drain, strainers and blind pipes of tubewell installations under different soil and water quality zones.

### *(C) Salinity Control and Reclamation:*

(1) Physico-chemical and mineralogical properties of soils and their interaction with the quality of water to be used for irrigation.

*(2) Leaching requirements of the soil with respect to chemical composition of soil and irrigation water.

*(3) Reclamation and other ameliorative methods, including the use of amendments and biological methods and simple leaching under specific conditions.

(4) Influence of exchangeable sodium on physical characteristics of soils.

(5) Organic matter, nitrogen, carbon-nitrogen ratio of soils as affected by crops and cropping systems during the processes of soil reclamation.

*(6) Soil moisture studies both in the field and in the laboratory to determine the movement of salts under saturated and unsaturated conditions.

### *(D) Water Quality:*

(1) Standards employed for the evaluation of quality of water suitable for irrigation, based on chemical properties of soils and water with specific reference to TDS, RSC, SAR, ESP and boron contents.

*(2) Improvement of water quality by mixing it with good water in proper proportions.

(3) Effect of irrigation water on the quality of drainage water and its suitability for irrigation.

(4) Influence of the use of fertilizers with irrigation water of various qualities.

### *(E) Soils:*

(1) Appraisal of the physico-chemical and mineralogical characteristics of soils in relation to different irrigation practices.

*(2) Suitable farming practices for the improvement of soil structure and soil and water conservation under different soil and climatic conditions.

*(3) Study of micro-nutrient status of the soil under different water table conditions.

*(4) Study of the formation of hardpans and finding measures for their prevention or correction.

### *(F) Crops:*

To get the optimum return from soil and water resources, special attention should be given to the study of, (a) salt tolerance of crops; (b) suitable crop rotations and cropping patterns; (c) high-yielding varieties; (d) sowing time, seed rate, preparation of seed-bed; (e) application of deficient plant nutrients.

### *(G) Fertilizers:*

(1) Determination of response to the macro-nutrients (N, P and K) and micro-nutrients (copper, zinc, iron, boron) when applied alone or in combination. Suitable suggestions for fertilizer requirements, mode and time of application, method of irrigation and time of irrigation for the optimum yield under irrigated conditions.

(2) Recommendations on the basis of yield data and soil tests as an aid in developing suitable measures for fertilizer use.

### *(H) Weed Control:*

The problem of weeds in canals, drainage channels and cropped fields is a serious one. Herbicides for the control of weeds at these places will differ in nature. This aspect should be given greater attention, as the weed problem is assuming serious proportions, the more so when the water used is silt-free. Special attention should therefore be directed to finding suitable types of herbicides for different problem areas.

### *(I) Pest Control:*

Pests sometimes result in the complete failure of crops despite favorable conditions for optimum growth. Research on effective pest control measures therefore needs to be pursued vigorously.

*NOTE: The items with the asterisk on should be reported by the participating countries during the next seminar.

Panel 4 Irrigation Practices Research Members, left to right: Seref Ozgul, Turkey; Muhammad Hussain, Pakistan; Mehrabuddin Foroughi, Afghanistan; Paul R. Seaber, Pakistan, USAID; Mohammad Aman, Afghanistan; Harold Rinman, Pakistan, USAID; Shapoor Hajrasuliha, Iran; Paul Grzybowski, Afghanistan, USAID

# Panel V

# Irrigation and Drainage Systems

## R. Shinwar - Afghanistan - Chairman

The panel has reviewed the report of the seventh NESA Panel V on Irrigation and Drainage Systems and generally concurs in the material presented, with some suggested additions or modifications. The presentation of the seventh NESA panel provides an excellent inventory of procedures and requirements needed to develop primarily a new irrigation project. The suggestions the panel of the eighth NESA made are covered in the following paragraphs:

(1) **Investigation and planning.** The available water supply should be programmed for optimum integrated use of both the surface and sub-surface water supplies as well as their re-use within acceptable limits and under varying methods of modification of the quality standards, to make them useable for productive purposes.

(2) **Construction.** Maximum possible use should be made of locally available materials for permanent type construction, if they meet accepted modern construction principles and specifications.

(3) **Operation and maintenance.** Beneficiaries of the project should be required to participate in and assume a greater share of the operation and maintenace responsibilities, through village complexes, cooperatives and associations, or on an individual basis where necessary through contribution of monies, labor or materials, and have a voice in operational procedures.

In most countries of the NESA area, in fact in many parts of the world, a major portion of the irrigated land is privately owned and is serviced from what may be called out-of-project systems. The operators of these systems and the farmers should have the full range of technical services available to them from all levels of government to inform them concerning the benefits derived through the implementation of modern irrigation and agricultural technologies. This would enable and assist them in achieving the necessary improvements in facilities and practices to realize the agricultural potential of the various areas and of the nation as a whole. This could be attained through self-help procedures or small-project concepts of operations in connection with the numerous privately owned and operated irrigation systems. The Irrigation Institutions-Farm Relationship, and the Education and Training Panels of this seminar have no doubt covered many aspects of this.

Main stem irrigation distribution facilities must be designed so as to supply the farmer with the proper amount of water at the proper time and for an adequate length of time so that optimum production can be attained, provided efficient and effective irrigation procedures, in balance with cultural and tillage practices, are utilized. The farm unit, together with the cropping pattern, soil and climate conditions, form the basis for determining the water supply required to operate the farm successfully. On this premise, increased attention should be directed to the conditions that are prevalent on the farms of the area concerned.

As stated previously, a major portion of the agricultural areas in many nations is under private ownership and in many countries the irrigation system is privately owned. The attainment of potential production levels will depend upon the successful operation of these privately owned farms by the farmers themselves. In many instances the supply and conveyance systems in existence are either improperly located, designed, or constructed, resulting in inefficient systems wasteful of water and difficult to operate and maintain. It is recommended that where these conditions are found, rehabilitation and betterment works be conducted. This would encompass such works as: (1) diversion and intake facilities; (2) cross drainage; (3) conveyance and distribution systems, etc.

The panel wishes to underscore the necessity for governments to enact the enabling legislation which would permit carrying out these recommendations.

Panel 5 Irrigation & Drainage Systems Members, left to right: A. A. Mahmoud Elsayad Zitonn, UAR; M. U Arain, Pakistan; Warren J. Leatham, Turkey, USAID; Adrian K. Logg, Afghanistan, USAID; Leo Mastrofini, Pakistan, USAID; J. P. Naegamvala, India; Redwanullah Shinwari, Afghanistan; Mohammed Wali Audin, Afghanistan; Amir Houshang Sohaie, Iran

# Membership of the Panels

**Panel I — Education and Training**

Saleh M. Popalzai, Afghanistan (Chairman)
Mir Agil Shah, Afghanistan
Dr. Iqbal Ali, Pakistan
Earl S. Sumner, Pakistan, USAID
Farhad Estandiari, Iran
Asghar Mangavi, Iran
M. N. Azmi, Afghanistan
N. P. Jahagirdar, India
Sanford Caudill, Afghanistan, USAID

**Panel II — Farm Management of Irrigation Practices**

M. A. Qurashi, India (Chairman)
G. L. Corey, Pakistan, USAID
G. S. Firoq, Afghanistan
Ghulam Dostigir Sham, Afghanistan
A. Hamid Azizi, Afghanistan
A. Latif Moh. Rashwan, UAR
George W. Clark, Afghanistan, USAID
John T. Phelan, India, USAID

**Panel III — Irrigation Institutions — Farm Relationships**

M. H. Ghavamian, Iran (Chairman)
Abdul Sattar Zia, Afghanistan
Ahmad Farid Issaq, Afghanistan
G. E. Nichols, Afghanistan, USAID
Abdul Ghaffar Shuja, Afghanistan
Abbass Ghaemossabahi, Iran
B. A. Krantz, India
N. M. Awan, Pakistan
Fikret Ercan, Turkey

**Panel IV — Irrigation Practices Research**

Mehrabuddin Formali, Afghanistan (Chairman)
Seref Ozgul, Turkey
Muhammad Hussain, Pakistan
Paul R. Seaber, Pakistan, USAID
Mohammad Aman, Afghanistan
Harold Rinnan, Pakistan, USAID
Shapoor Hajrasuliha, Iran
Paul Fitzhugh, Afghanistan, USAID

**Panel V — Irrigation and Drainage Systems**

Redwanullah Shinwari, Afghanistan (Chairman)
A. A. Mahmoud Elsayad Zitonn, UAR
M. U. Arain, Pakistan
Warren J. Leatham, Turkey, USAID
Adrian K. Long, Afghanistan, USAID
Leo Mastrofini, Pakistan, USAID
J. P. Naegamwala, India
Mohammed Wali Audin, Afghanistan
Amir Houshang Sohaie, Iran

# CHAPTER III

# CLOSING SESSION

## Recommendations of Executive Committee

### I. PERMANENT ORGANIZATION

Noting that the NESA Seminars on Irrigation Practices have been held once every two years since 1956,

Considering the increased usefulness of the seminar's recommendations in helping some of the NESA countries in solving the irrigation and drainage problems of the NESA region,

Realizing the necessity of the establishment of a permanent organization in the region to perpetuate the seminar series so that the countries concerned may continue to meet every two years to exchange ideas, discuss problems and propose solutions to such problems, and

Having regard to the recommendations made by the different working panels;

Therefore, the Executive Committee of the eighth Irrigation Practices Seminar recommends that the establishment of a permanent organization be considered by the governments of the NESA countries, with a secretariat to undertake the arrangement of the seminars and other relevant activities.

It is suggested that the country representation be in the form of a committee, with membership from various organizations having to do with "On-Farm Water Management," and that the international secretariat be appointed from the committee of the country which will host the following seminar.

As one of the governments of the NESA region intends to make an invitation to hold the ninth Irrigation Practices Seminar in its country, therefore, the Irrigation Practices Seminar Committee of that country is requested to appoint an executive secretary and an appropriate secretariat to serve for the next two years.

Upon the agreement in principle of the NESA countries, the secretariat will proceed with drafting the necessary constitution and such bylaws as may be required for due consideration and approval during the next seminar, in 1972.

Since USAID has co-sponsored all previous seminars and has indicated a willingness to continue this cooperation, the Executive Committee recommends that USAID continue its support to future seminars.

### II. FOCUS OF THE NEXT SEMINAR

The Executive Committee recommends that future seminars continue to be concerned with the many problems related to "On-Farm Water Management."

The Executive Committee has given careful study to the panel recommendations and suggests that the NESA countries adopt these recommendations. Furthermore, the Executive Committee recommends that the topics for technical papers for the next seminar be drawn from the following topics suggested by the panels:

#### (A) Education and Training

(1) Effective program to familiarize farmers with improved methods of water application

(2) Successful methods used in inducing farmers to believe in and change to improved methods of water application

(3) The success of village schools in agricultural areas in presenting irrigation programs

(4) Other training programs resulting in

improved water management on the farm

**(B) Farm Management for Irrigation Practices**

(1) Results of pilot project on improved management practices

(2) Custom services to assist in achieving better management

(3) Impact of credit agencies

(4) The use of improved varieties of rice and wheat to introduce modern irrigation practices

(5) Other successful programs resulting in better "On-Farm Water Management"

**(C) Irrigation Institutions — Farm Relationships**

(1) Recent experience in drafting or implementing water management laws

(2) Results of programs for the rehabilitation of irrigation and drainage systems at the farm level

(3) Other institutional developments

**(D) Irrigation Practices Research and Salinity**

(1) The determination of consumptive use and irrigation water requirements for different crops and physical conditions

(2) The use of low quality water for irrigation and reclamation

(3) The economic aspects of reclamation and improvement of agricultural lands

(4) The optimum depth of water table for good growth and yield of crops and salinity control

(5) Materials for the drains, strainers, blind pipes and tubewells for different soil and water quality conditions

**(E) Irrigation and Drainage Systems**

(1) The design of a system to achieve farm efficiency and maximum production

(2) The design of a system to deliver adequate quantity at the desirable frequency, considering farm size, soils, cropping pattern, etc

(3) The selection of a proper drainage system

## III. GENERAL RECOMMENDATIONS

**(A) The establishment of a permanent secretariat**

**(B) The duration of the seminar be two weeks as heretofore, with**

(1) Four days of discussion

(2) Three or four-day field trip

(3) One free day for delegates

(4) Five or six days for panels and discussion (more time for panels)

**(C) Not more than 30 technical papers be accepted for presentation**

(1) Presentation time 10 to 15 minutes.

(2) Discussion time 20 to 30 minutes

(3) Maximum time for presentation and discussion 45 minutes

**(D) Papers must be received by the secretariat two months before the next seminar and circulated one month before the next seminar.**

**(E) All delegates should be housed in one hotel if possible.**

**(F) Country reports and technical papers should reflect the activities between 1970 and 1972.**

Executive Committee Members, left to right. Mohiyddin Khan, Engineering Advisor, Government of Pakistan; Seref Ozgul, Chief Consultant on Soil and Drainage, General Directorate of State Hydraulic Works, Turkey; M. M. H. Ghavamian, Supreme Advisor to Minister, Ministry of Water and Power, Iran; Joma M. Mohammadi, Chairman, Executive Committee, President, Irrigation and Water Survey, Ministry of Agriculture and Irrigation, Afghanistan; Dr. A. Alvin Bishop, Seminar Technical Advisor, Head, Department of Agricultural and Irrigation Engineering, Utah State University, USA; M. A. Quraishi, Additional Secretary, Ministry of Food and Agriculture, India; A. M. E. Zitonn (Absent when picture was taken) General Inspector, Irrigation in Assuit, UAR

# DELEGATES' APPRAISAL

by

**MOHIUDDIN KHAN**

**Pakistan**

Excellencies, Mr. Mohammadi, Dr. Bishop, distinguished delegates, ladies and gentlemen:

It is a great pleasure for me to present the delegates' appraisal of the Eighth NESA Regional Irrigation Practices Seminar in this historic city of Kabul. It is essential to increase agricultural production in the NESA countries to meet the ever increasing demands of the population. Most of the NESA countries have a physical potential for increasing their crop yields. Irrigation and drainage are two of the important factors contributing to the increase of agricultural production. It is significant to note that at present the area irrigated throughout the world is only about 15 per cent of the total cultivated land. This shows the need for increased effort.

Afghanistan offers a good example of a country where irrigation could revolutionize the economy. The arid climate, limited water resources and vast cultivable areas offer a challenge for adopting the most scientific irrigation practices for optimum development. Irrigation has been practiced from time immemorial in this country and the greatest need is the modernization and extension of these systems. For a hilly country with limited water resources, the present irrigated area of 2.9 million hectares is by no means a small achievement.

Of the 15 member countries of the NESA region only six have taken part in this seminar: Afghanistan, Iran, India, Pakistan, Turkey and UAR. Although the number of countries represented at this seminar is small, yet 20 technical papers and six country reports were presented. Some of the technical papers were of a high standard, based on original study and research. The five panel reports have also made a useful contribution to the irrigation practices in the region. The topics selected for the next seminar are useful.

The field trip, though it involved unavoidable travel over a long distance from Kabul, was very well planned and excellently organized. The delegates started their visits with Karz and Zakir drainage system out-falling into Tarnak river near Kandahar. The recovery of the productivity of this fertile land by open drainage is a demonstration of the efficiency of the system. The next works visited were the Arghandab diversion dam, Zahir Shahi canal from the same river and Thogra diversion dam on Helmand river. On the third day, the research station near Lashkargah, Marja area, Derve Shan diversion dam and Shamlan canal were visited. The irrigation and drainage systems in the area have created complicated problems which have been effectively tackled. We are thankful to Mr. Assifi, Mr. Shuja and others for their untiring efforts to make all information available and the visit comfortable.

Visits to the historic monuments in the Helmand Valley gave us an insight into the proud history of Afghanistan.

We are grateful for the dedicated work of the chairman of the Seminar Managing Committee, Mr. Mohammadi, and various Afghan agencies and delegates who made the seminar a success. Dr. Bishop has played a vital role in the seminar; his guidance during the meetings, panel discussions and the Executive Committee meetings was valuable. USAID did much for the success of the seminar. The delegates have contributed a lot to the success of the seminar by reports, suggestions and discussions. I hope the future seminars will also enrich our knowledge. Thank you!

# RESOLUTION

## Prepared and presented by


## M. M. H. GHAVAMIAN

## Iran


Excellencies, distinguished delegates, ladies and gentlemen,

It is a great pleasure and delight for me to have the opportunity to express our feeling regarding the arrangements of the Eighth Irrigation Practices Seminar held in the historic town of Kabul.

Allow me to extend our unanimous vote of thanks and gratitude on behalf of all delegates to this seminar to our host, the Royal Government of Afghanistan, whose hospitality, assistances, efforts and cooperations have enabled the seminar to be a successful one.

The arrangements made for the interesting and informative long trip to Helmand Valley, the sincere and enthusiastic reception of the delegates by different authorities and officials, have impressed us deeply and their efforts are most appreciated.

Dr. Bishop, the Senior Advisor to the Seminar, whose efforts, valuable advices and sincere cooperation for the success of the Seminar are well known to all of us, should also be thanked.

We have also to express our thanks to the Royal Government of Afghanistan and the USAID program for co-sponsoring the seminar, as well as other governments which have participated in the seminar.

The sincere and friendly hospitality and assistances of our colleagues from Afghanistan, for which we are deeply grateful, have rendered the stay of the delegates a memorable, enjoyable and pleasant one in Kabul.

Therefore, on behalf of the Executive Committee, it is a great pleasure to request that the seminar adopt a resolution extending our thanks and gratitude to our host, the Royal Government of Afghanistan, to the governments of other participating countries, to our Senior Advisor, Dr. Bishop, and to the USAID program for all they have done to make this seminar a successful one.

***

The resolution was adopted unanimously by applause.

# SEMINAR REPORT

by

**DR. A. ALVIN BISHOP**

**Technical Advisor**

Mr. Chairman, excellencies, delegates, and fellow workers:

It is my pleasure to make a seminar report.

The initial planning for this seminar actually began two years ago at Lahore, Pakistan, when the Executive Committee of the seventh seminar outlined the scope and objectives for a future seminar. In February and March of this year I had the pleasure of visiting most of the 15 NESA countries to discuss the detailed plans for the seminar. For me this was a pleasant experience. To meet with many of the delegates at that time, to renew friendships and discuss the importance of water to agriculture, was very rewarding. I was especially pleased with my visit to Afghanistan for here we began the detailed planning necessary to discharge all of the duties of the host country. I believe I can say without contradiction that many here in Afghanistan were afraid that an international seminar might be too big a job for a small country. However, we did go ahead with plans and I am extremely pleased with the way Afghanistan has provided so much more than the essential requirements for a successful irrigation seminar. I believe all of the arrangements have worked out very well

Regarding the seminar itself: I believe we have had a productive meeting. We have listened to more than 20 technical papers and have participated in discussions. The panels have been hard working and have developed many fine recommendations for serious consideration by the nations of this region. The seminar has provided for a free exchange of knowledge at an international level. This exchange of knowledge has taken place, not only during the formal meetings, but discussions have continued into the halls during the refreshment breaks, on the buses during the field trip, and even on the banks of the canals and the farmers' fields of the Helmand Valley.

I believe that our intense interest and high concern for sound "On-Farm Water Management" is fully justified. Water is the most manageable of the basic resources. We have to accept the climatic factors essentially as they are given. Likewise, the soil cannot be moved about or greatly changed with regard to its basic characteristics. However, water can be moved from place to place, it can be manipulated with regard to quantity and time so as to maximize its utility for agricultural production

I believe that cultivated agriculture is one of the most important discoveries of mankind: the ability to manipulate the environment by tilling the soil and planting seeds so as to produce the requirements of food and other necessities of life. Another highly important discovery of man has to do with irrigation: the ability to control the soil moisture so as to produce crops in arid areas which would otherwise be desert, and obtain maximum yield in sub-humid areas.

As in previous seminars, the delegates came to this seminar well prepared and very knowledgeable about the irrigation problems and practices of their respective countries. They were able to discuss important issues with vigor and authority. I compliment all delegations for their high interest and individual efforts to make the seminar a success.

I want to compliment and, at the same time thank, the Government of Afghanistan and all officials, delegates and others in this fine country for inviting us here for this seminar.

I also wish to thank my colleagues in USAID, especially Mr. Hubbard, Mrs. Rice and Mrs. Sallee, for their untiring efforts in supporting all aspects of the seminar.

Now, as we approach the time to officially

close the eighth NESA Irrigation Practices Seminar, I think we will all increase our efforts to achieve better "On-Farm Water Management" in the NESA region. I believe that objectives of this seminar have been fully realized. Thank you.

# Closing Address

by

**H. E. DR. MOHAMMAD HESAN RAFIQ**

**Deputy Minister of Agriculture, Afghanistan**

Mr. Chairman, distinguished delegates, ladies and gentlemen.

It is a great pleasure and honor to us that the Eighth NESA Irrigation Practices Seminar has been held in Afghanistan and that delegates from friendly countries, namely India, Iran, Pakistan, Turkey and UAR have participated in this seminar. I had to be away at Islamabad to take part in the Tenth Regional Conference of the FAO for Middle and Near East and hence could not participate in the sessions of this very useful seminar. I have been following with interest the proceedings of the plenary sessions as well as those of the working groups, which are of interest not only to Afghanistan but also for all the countries of the NESA region. Here I would like to mention that in the tenth FAO conference which I attended in Islamabad, the question of irrigation facilities and better use of land and water resources was discussed. While you were busy with your deliberations here, the FAO conference in Islamabad, comprised of 17 countries from Middle and Near East, along with many associate members and observers, also devoted its attention to irrigation and better use of land and water. Apart from other decisions, the FAO conference recommended that the FAO and UNDP should assist the member countries in their programs for regional applied research.

Mr. Chairman, I was informed that even though there was not enough time, 20 technical papers were read and discussed and some very important recommendations of interest to the member countries were made.

I hope that your trip to the Helmand Valley Project, which is our most important irrigation and agricultural project, was of interest to you. I am sure the recommendations of this Eighth NESA Irrigation Practices Seminar will throw more light on the problems of the region and help to solve them.

In the end, I wish to thank this distinguished gathering and delegates from all countries who have taken part in this seminar. Your valuable suggestions have no doubt raised the status of the seminar. At the same time, I would like to thank the USAID for having assisted this seminar.

I hope your stay in this country has been comfortable and that you will be carrying back with you pleasant memories of this ancient and historic country.

Finally, I would like to thank you again, every one of you, who have participated in this seminar and made it a success. With these few words, I declare this seminar to be closed.

# Summary of Observations on the Irrigation Seminar by USAID

by

**DR. JOE M. MOTHERAL**

**USAID Afghanistan**

Excellencies,

It is an honor to be invited to appear before this group of experts in the closing hours of the NESA Irrigation Practice Seminar, the eighth in a fruitful series.

In tackling a most difficult problem area, you have acquitted yourselves very well indeed. As a resident in this country, I am especially pleased by the level and quality of participation by Afghan delegates and supporting staff.

My assignment is to sum up the highlight findings of the seminar. This is a formidable task at best, and it is complicated by the fact that circumstances have prevented my attendance at any but the opening session.

Fortunately, many delegates have made their views available both in writing and conversationally. A thread of concensus runs through their observations, and it is on these that I shall draw for the remarks that follow.

First, it is clear that, as problems, the elements of planning, design and construction of irrigation works are rapidly assuming second place to the economic and social rigidities prevalent in this region. Certain cultural values — centuries in the making and of substantial utility in their day — are now emerging as positive barriers to the rationalizing of water where it counts, namely, on the land.

This Seminar has succeeded in pinpointing the causes of mismanagement of water resources. It has largely failed in identifying techniques for their resolution. There has been a tendency to skirt the issue by resorting to a safehaven of emphasis on still more engineering inputs without full regard for human implications.

You will understand, I trust, that this criticism derives from my background as a social scientist. Similarly, you will comprehend that it derives from an attitude of sincerity and, most of all, that it is true.

How to attack the outmoded practices that characterize water distribution on the land? I wish that there were pat, workable means for accomplishing this miracle of modified human behavior. There are not.

It strikes me, however, that a start can be made by far greater resort to a multi-team approach among the relevant disciplines. Those of you in the engineering profession should have free call on economists, sociologists, cultural anthropologists, public administration types, historians and any other specialized personnel who strive for access to people and their ways of thinking.

On this point, my recommendation for the next irrigation practices seminar is that you encourage infiltration into your ranks by those of diverse disciplinary persuasions — and that you exploit their ideas to the fullest practicable extent. You will find them to be provocative, probably annoying and extremely useful.

Revision of institutional structures as a corrective measure so far overshadows other considerations at this seminar as to leave the rest in a secondary though significant role. However, in the provision of suitable water service down to the farmer level, operation and maintenance of irrigation systems have been stressed.

I note, too, that rehabilitation and remodeling of existing systems have received considerable, and appropriate, attention. This approach, plus development of new minor irrigation works, represents the

main thrust of USAID assistance in Afghanistan, as well as in nearby countries in this region. Frequently, there is justification for large, costly multi-purpose projects, but, dollar for dollar, the more modest projects generally offer the highest returns.

The visit by seminar delegates to the Helmand-Arghandab Valley region made an obvious impression upon those who participated. Numerous comments, both critical and complimentary, have emerged from this trip, as is to be expected from a group of trained observers seeing, in most cases for the first time, the results of a costly investment in a comprehensive development program.

Again, many of the remarks by delegates concerning HAVR centered upon landholding patterns, social practices, traditional attitudes toward water use, and the whole matrix of governing customs. To be sure, notice was taken of the strengths and weaknesses of the physical works in the valley, but it was the constraints imposed by the people upon themselves that became the main focus of interest. It follows that no amount of professional and budgetary outlays will override the institutions that guide the performance of the beneficiaries of an irrigation program.

The values that ensue from daily personal contacts among scientists of like interests, as epitomized by this seminar, have been noted by a number of the delegates. In this connection, two hopes have been expressed. One is that data and analytical materials will be exchanged in the future on a person-to-person basis. The other is that the NESA Irrigation Practices Seminar will become a permanent feature of the professional and practical endeavors going forward in this important part of the world.

In closing, I would be remiss in failing to commend the Ministry of Agriculture and Irrigation of the Royal Government of Afghanistan for its tireless efforts to make the seminar the success that it has been. The Afghan officials involved have had only a limited experience in directing regional or international conferences, but this inexperience was barely perceptible in the smooth operation that has occurred. Mr. Juma Mohammad, President of the Department of Water Survey and Irrigation, is entitled to special credit in this regard.

On the American side, Dr. Bishop and Mr. Ehrhardt have worked ceaselessly to make you welcome, comfortable and fit for productive deliberations.

In behalf of the United States AID Mission to Afghanistan, I thank all of the contributors to this seminar for a job well done.

# CHAPTER IV

## Country Progress Reports

## AFGHANISTAN

Irrigated agriculture is the mainstay of the Afghan economy. More than 85 percent of the population obtain their living from agriculture. The major part of Afghanistan is mountainous and unsuited for crop cultivation. The potential cultivable areas are estimated to be 14 million hectares — only 22 percent of the total area of Afghanistan, and of this, 5.3 million hectares are presently under irrigation. Due to a lack of adequate irrigation facilities, however, the land area cultivated in any one year, excluding dry lands, is estimated to be 2.9 million hectares.

Afghanistan's surface water resources are quite limited. The most important rivers rise in the Hindu Kush range. Most are snowfed, which results in wide seasonal fluctuations of river flow. Open intakes and weirs of stone, brush and wood are used to divert river waters into the main canals. These are often destroyed by floods as flood water enters the canals, overflows the banks and sometimes destroys the crops on cultivated land. The water supply in canals is irregular over the year and the land commanded by the canals has an uneven supply. Those near the end receive insufficient water.

Further expanding irrigated areas by building reservoirs and sinking wells holds much promise for the future. However, present irrigation water is not being used with great efficiency, and improvement of irrigation systems and increasing yields on presently cultivated areas in many parts of the country will probably prove less expensive for obtaining an increase in agricultural production than building additional large dams.

The most important crop is wheat, totaling two to three million hectares, of which about one-half is under dry land cultivation. Cotton and sugar beets are grown on some 72,000 hectares. Fruit production is widespread and important for export. Rice, corn and oil seeds are other important crops.

The government of Afghanistan, realizing the need for full utilization of natural resources of the country, has conducted its efforts toward land development and irrigation works in the past years.

The major accomplishments over the past two years are summarized here:

Use of better variety of seeds, especially wheat, use of chemical fertilizer, and favorable climatic conditions caused an overall increase in farm production during the year 1968-69.

Analysis of 1968 and 1969 by hydrology records indicates that generally the runoff during

those years was below average.

Surface water investigation, which requires long term studies, is continuing at existing gauging stations.

At present, 175 gauging stations are equipped with automatic recorders, cable ways and measuring facilities in various parts of the country.

Water measurement is made regularly at the existing gauging stations; data collected from the field are computed, arranged in appropriate forms and analyzed in order to serve their purposes.

## SOIL SURVEYS

The last two years' activities are summarized below:

(1) Soil investigation and photographic interpretation of Tarnak Valley is being carried out.

(2) Work on soil classification of the above area has continued.

(3) Soil fertility investigation in the following ten provinces is being carried out: Kalat, Logar, Maidan, Nangarhar, Laghman, Kunar, Kapisa, Parwan, Kunduz and Ghazni.

(4) More than 1,100 soil samples from various projects have been analyzed at the Soil Laboratory for determination of their chemical and physical characteristics.

(5) Detailed soil, aerial and topographic surveys for 19,740 hectares of land in the Kunduz and Khanabad basin have been completed.

(6) Damsite surveys for small dams and design for irrigation schemes have been completed in the past four years for the following provinces:

### In Ghazni Province

(a) Geological and hydro-technical survey of Khojagan damsite on the Ghazni river.

(b) Geological and hydro-technical survey of Parak damsite on Ghazni river tributary.

(c) Preliminary hydro-technical survey of Ghazni damsite on the Ghazni river.

(d) Preliminary hydro-technical survey of the Siogil damsite on Ghazni river tributary.

### In Phariab Province

(a) Preliminary survey of Khistpul damsite on the Shirintago river.

(b) Preliminary survey of the Qarashiekhi damsite on the Shirin Tagao river.

(c) Preliminary survey of Sahil Kishlak damsite on the Almar river.

(d) Preliminary survey of the Burgankalan damsite on the Oasir river.

### In Jauzgah Province

Preliminary survey of the Saripul damsite on the Saripul river.

### In Kunduz Province

Detailed geological, hydro-technical and design work on an area of 2,000 hectares for irrigation development in the south of the Kunduz-Aliabad area.

### In Kunar Province

Hydro-technical work and design for Asmar pumping station and Pirumi pumping station.

## DETAILED SURVEY FOR KUNDUZ AND KHANABAD PROJECT

In the past, general and preliminary surveys of existing resources of water and soil in the Kunduz-Khanabad valley have been completed, with a view toward the expansion and improvement of agriculture in that area. The total area of 199,500 hectares has been divided into six regions.

With the approval of the International Development Bank, the government has given priority to Region No. 6. This region covers an area of 19,740 hectares, of which 5,000 hectares will be new land

brought under command.

In years past, aerial photography and the making of detailed topographical maps, geophysical and drilling investigations in the area of the proposed irrigation network, investigations concerning socio-economic conditions, design and plan operations have been completed.

In the future, construction work will be started and will consist of the following activities:

(1) Establishment of the Abgardan head water dam near the Chagha Pul on the Khanabad river.

(2) Establishment of a new network and improvement of existing irrigation systems over the total area of 19,700 hectares, of which 5,000 hectares will be new land.

## GROUNDWATER INVESTIGATION

To expand the cultivated area and increase crop yields, agricultural lands not presently cultivated due to a shortage of irrigation water will be irrigated by underground water.

Investigation and research of underground water have been initiated and completed in the following regions totaling 2,000 square kilometers:

(1) Katawaz and Maqor

(2) Between Kabul and Charikar

(3) Between Kabul and Sarobi

In the past few years hydro-geological investigation, geophysical studies and the drilling of test wells were initiated in these various regions.

In summary, the main activities of the past two years are as follows:

(1) Water table contour maps of 1:50,000 scale with five-meter contour interval for Kabul-Charikar, and 1:100,000 maps of Nahar-Abistada and Upper Tarnak basin have been prepared.

(2) Inventory, surface drainage, geological, water quality, groundwater discharge and groundwater maps of 1:50,000 scale have been prepared.

(3) Index maps of Katawaz and Charikar to scale of 1:50,000 and 1:5000 have been prepared.

(4) A total of 526 electrical soundings have been made.

(5) Ten wells have been electrically logged.

(6) Twenty-nine small diameter boreholes to a total depth of 1,966 meters and 25 large diameter boreholes to a total depth of 1,238 meters have been tested. Draw-down and recovery tests have also been made in the boreholes in the Katawaz and Charikar areas.

Followup activities in various regions will be continued on a larger scale.

## IRRIGATION AND LAND DEVELOPMENT PROJECTS

### Helmand-Arghandab Valley Progress Since 1968

#### *(A) Progress in investigation and feasibility studies:*

(1) Investigations involving detailed land classification, permeability determinations, groundwater elevation operations, water distribution analysis and system analysis, crop census, land use, etc., of 143,000 acres of land in the Central Arghandab area have been completed and the initial draft of the feasibility report has been prepared.

(2) Investigations of the 50,000 acres of land in Darweshan was started in March, 1969.

(3) Investigations of the 7,700 acres of land in the Babjee area have been completed and a feasibility report has been prepared.

#### *(B) Progress in irrigation and land development projects:*

(1) Topography of the 64,000 acres of land in the Shamalan area has been mapped. Alignment surveys and designs of the west Shamalan canal for an area of 17,000 acres in the Shamalan project has been started.

(2) Excavation of 120 kilometers of farm

drains in a 4,500-acre area of Marja in Blocks 6F, 7F, 1A, 8a, 8b, 8c, 9a, and 9b, has been 75 percent completed.

(3) Excavation of collector drains in the 3,000 acres of land in the Nad-e-Ali pilot project was started in early 1970. To date about 70 percent of the drains have been completed.

(4) The 30-kilometer-outlet drain system for the 24,000-acre Karz-Zakir area in the Central Arghandab project near Kandahar has been completed.

(5) Land development in the 1,000-acre Block 2E2 in the Darweshan area has been completed. This includes land leveling, farm drains excavation, sub-lateral construction, main turnouts and farm turnouts construction.

(6) Land development on the Bolan Research farm and the Bolan Livestock farm has been completed. This involves land leveling, head ditch construction, and farm turnouts.

(7) Design of the headgates in the Seraj canal intake and second main storm drainage crossing has been completed and construction has been started.

## Nangarhar Valley Project

The following amount of important work has been carried out during the past two years:

(1) The government-owned mechanized agricultural farm No. 3 (Ghazabad) after completion in May, 1969 officially has been put into operation.

(2) Land development of the 2,115 hectares of government-owned mechanized agricultural farm No. 1 (Khaddu) has been completed.

(3) With minor exceptions, construction of the farmstead of the Khaddu farm has been completed. Following are the main structures on the farm: 41 apartment houses, a maintenance unit for servicing agricultural machinery, an oil storage, a garage for motor cars, a cattle farm for 500 head of cattle, etc.

(4) Work has been done on agricultural development, planting of a citrus and olive tree plantations, introduction of seed houses on the farms capable of producing seed and seedlings for sub-tropical crops and trees.

(5) Further work on land and agricultural development of the area outside the farms has been continued.

(6) A total of 89.5 kilometers of different types of drains and 98.7 kilometers of approach ways and field roads have been built.

(7) The irrigation system, the main canal, the power station and other structures have been in operation without any trouble and in conformity with operational standards.

## Parwan Irrigation Project

The upper part of the Kabul valley consists of the area between the Panjsheer and Shakar Darah rivers. Only about 38,400 hectares of land are now irrigated on a permanent basis. Therefore, with the existence of vast cultivable areas, the potential for irrigation for these lands appears to be great.

The first phase of development of this project will cover an area of 25,000 hectares of land of which 16,000 hectares will be served by a gravity system and 9,000 hectares by pumping. The main part of this project will consist of the construction of a nine-meter high and 34-meter long diversion dam on the Panjsher river near Gulbahar, digging a 24-kilometer main canal of $29m^3$/sec. capacity. Construction of 180-meter long siphon under the Salang and 680-meter long siphon under the Ghorband river and digging of a 19-kilometer long, $10m^3$/sec. capacity generating 2,000 kilowatts power east branch and 24-kilometer long $9m^3$/sec. capacity south branch.

The construction of the project was initiated in mid-1968. Progress to date is summarized as follows:

(1) Ninety percent of the excavation work of the intake and temporary diversion canal has been completed.

(2) Eighteen kilometers of the main canal have been dug and five kilometers of the canal have been lined. Furthermore, 12 structures on the main canal are completed.

(3) The Salang syphon is completed.

(4) Ninety-five percent of the work on the Ghorband siphon is completed.

(5) Excavation on the power plant canal is completed.

## Sardah Project

Construction of a dam 29 meters high having a 220 million cubic meters capacity, outlet, spillway of $35m^3$/sec. at a distance of 200 meters from the intake on the Jilga river, was completed. The principal work to be done on the project will consist of digging 70 kilometers of canals on the right and left banks of the river, 500 kilometers of secondary canals, 200 kilometers of drainage networks, and 5,600 of land leveling.

Current work on installment of irrigation networks and on land development is progressing satisfactorily.

The right branch canal of 7.2 $m^3$/sec capacity has been dug for about 13 kilometers, and work on the siphon crossing the Jilga river is completed. The left branch of $7.8m^3$/sec capacity has been dug for more than 10 kilometers. One hundred and ninety-eight large and small structures have been built in an area of 1,500 hectares. Land has been leveled.

The Jilge valley in the Sardah region contains 27,500 hectares of agricultural land, of which 26,400 hectares can be irrigated from the reservoir; 1,000 hectares will be irrigated from the water flow of the Jilga river, and the remainder of the area from underground canals (karazes).

With the establishment of canals and irrigation networks, about 14,000 hectares will be irrigated annually from the reservoir. The other 6,400 hectares, due to the limited capacity of the reservoir, would not be cultivated every year, but used in rotation.

## Kalagai Irrigation Project

This project, designed to serve a gross area of 2,500 hectares, consists of a diversion weir across the Kunduz river, a head regulator, distribution structure, and a new canal 16 kilometers long, to irrigate about 1,000 hectares of land presently under rain-fed cultivation. As reported at the last seminar, the diversion weir, head regulator, distribution structure and about three kilometers of new canal have been completed. Except for a few structures, the new ca is now nearing completion.

The alignment of the new canal had to be amended to do away with tunneling in loose material. The canal runs along the fairly steep slopes of hillsides for about 5,000 meters and necessitated the provision of aqueducts. A further constraint for construction works was the existence of the Kabul-Kunduz highway, just below and parallel to the canal alignment in this difficult section.

## Sharawan Intake and Canal

As scheduled, the project was due for completion in 1969. But unprecedented floods in August, 1969, overtopped the incomplete earth diversion dyke and washed most of it off. Reconstruction works could not be commenced in time to restore the intake. A temporary intake was provided for the 1969-70 cultivation season. It is proposed to commence work on restoration of the intake at the end of this irrigation season (October, 1970).

## Small Irrigation Projects

The Ministry of Agriculture and Irrigation of the Royal Government of Afghanistan has assumed the responsiblity for assisting land owners and farmers in improving the existing irrigation systems throughout the country. In discharging this responsibility, improvements on a number of small irrigation projects are being planned and designed by the Design Office of the Water Survey and Irrigation Department. Construction works are usually done by the Construction Department of the Ministry, and/or in some instances by the people themselves, under the engineering supervision of the Design Office. The status of those projects has been published in the Progress Reports of the past seminars.

Following is a presentation of the current works and accomplishments in the improvements on irrigation systems in this country since the last NESA Irrigation Practices Seminar in 1968.

| Project | Scope of Work | Status |
|---|---|---|
| Khosistan, Kapisa Province | 24 km. canal rehabilitation; 12.8 km. canal extension including three tunnels and nine laterals | Completed |
| Karim, Laghman Province | Rehabilitation of 10 km. canal and extension of seven km. Also construction of new headworks | Design completed |
| Faizabad, Badakhshan Province | Constructing 760 meter-covered masonary intake, 4.6 km. lined canal and bench flume wash crossings; two road crossings; 16 km. earth canal; a river crossing | Construction 30 percent completed |
| Kama Canal Kunar Province | New intake, rehabilitate the existing canal, and extend the canal into a new area | Reconnaissance report completed |
| Taliquan, Sharawan Takhar Province | Masonry overflow weir | Design completed |
| Khawaja Canal, Takhar Province | Flood damage prevention | Design 50 percent completed |
| Khanabad | Two new siphons | Design completed |
| Naqu Canal, Kunduz | Canal overflow spillway | Design completed |
| Nahre Shahi, Balkh Province | Gated intake and spillway | Design underway |
| Surkhakan Laghman Province | Rehabilitate the existing canal for six kms. Extend it for six kms. | Design underway |

# INDIA

The cultivable area in India is estimated to be about 480 million acres, of which more than 390 million acres (gross) are cultivated at present. Only about 20 per cent of the cultivated area presently receives irrigation water and there are very definite limits of additional areas which can be brought under irrigation. Water for irrigation is, therefore, a valuable resource which has to be used in an efficient manner in agricultural production.

The basic concept of concentration, effective use and better management of the resources, including water, is getting national acceptance in our country and has emerged as the present strategy for agricultural development in India. India has concentrated its intensive agricultural development program with use of high-yielding varieties of crops and high rates of inputs in areas which have either an assured irrigation water supply or adequate rainfall.

A policy for irrigation water management, giving great emphasis to optimum production per unit volume of water through adequate and timely application of irrigation water with optimum use of inputs, has been accepted to replace the traditional practice of spreading available irrigation water to as many acres as possible, as has frequently been done, with the hope of achieving far more extensive social benefits.

Recent experiments and demonstrations in India have shown that the productivity of a given quantity of water can be increased by about 200 per cent in certain situations if the fields are properly leveled, the irrigability characteristics of the soil are known, and the best possible cropping pattern and correct methods and schedules of water application are followed. Accordingly, the new strategy for reaching self-sufficiency in food production through applications of the new technology and high yielding varieties of crops with the use of high inputs places great emphasis on utilizing the available water for the maximum benefit possible.

In India, irrigation is a state responsibility. In most of the states there is a separate irrigation department to handle major and medium as well as minor irrigation schemes. Small schemes irrigating below 100 or 200 acres are dealt with by the State Revenue or Agriculture Department. While the responsibility for creation of the irrigation potential with major and medium projects and delivery of water up to the farm for use in irrigation farming has been with the Irrigation Departments, the actual division and distribution of water at the field level and its use have been left to the farmers concerned.

Though in normal course the State Department of Agriculture is expected to give necessary guidance in equitable distribution and efficient use of irrigation water, in practice it has not been possible to carry out this function. As such the farmer uses water as much as he gets irrespective of crop needs. This is reflected in the low efficiency of irrigation obtained as well as development of waterlogging conditions and development of salinity and alkalinity problems in a number of irrigation projects, such as in Punjab, Uttar Pradesh, and Maharashtra.

The water utilization from a large number of projects has not been up to the mark as prerequisites

such as identification of suitability of soils, land development, cropping pattern, etc., have not been paid adequate attention. There are no organizations developed for distribution of water at the field level. In most of the irrigation projects, irrigation water beyond the outlets is conveyed either through crude field channels or water flows from one field to the next lower down within the command of the outlets.

Farmers have not been getting adequate assistance, either technical or financial, in construction of distribution systems, nor for land shaping and levelling. On account of the above drawbacks, in spite of substantial progress having been made in creation of the irrigation potential, its impact in increasing production has not been appreciable.

The Agricultural Production Board took notice of the growing disparity between the creation and utilization of the irrigation potential and decided to create a water management unit in the Department of Agriculture to examine the problems of command areas from the point of view of intensification of agricultural production and optimum utilization of the water available. The Ministry of Food and Agriculture therefore created a water management unit in 1966-67, now called the Water Management Division. This is manned by specialists in soils, agronomy and engineering. This division has also the expertise available from USAID in the above subjects as in agricultural economics.

It was soon realized by the government that full agricultural benefit from the irrigation resources created can be derived only when integrated operation programs envisaging simultaneous activities in agriculture and allied fields are planned and undertaken on an area basis in the commanded areas of the projects. As a result of this, a new developmental program called "Area Development for Irrigation Projects" has been adopted in some of the major projects.

## REGIONAL WATER MANAGEMENT PILOT PROJECTS

With introduction of the "Area Development Program" and creation of the Water Management Division in the Department of Agriculture, the problems of commanded areas of irrigation projects started receiving special attention. It was soon realized that the proper utilization of irrigation water involves the study of a multitude of factors, including soil and climatic conditions, water requirements of different crops, irrigation practices, drainage facilities, etc. To study problems of water management in depth and to develop guidelines for treatment measures as well as to develop a plan of action, it was decided to have a few pilot projects in the principal soil and water resource areas.

Three such regional water management pilot projects (detailed below) have been established under Central Sector, with technical collaboration with USAID. Three more such projects are being set up this year. The primary objective of these projects is to study the soil and water problems in the area and to develop and demonstrate standards and techniques for optimum utilization of the soil and water resources available. These projects will also develop technical guides for application of improved practices, and will provide data and experience on the need for alternative methods and techniques, as well as cost and reward of carrying out the treatment measures. Training for field technicians as well as specialists in different disciplines will also be imparted for undertaking water management practices in larger areas.

### Pilot Project — Bellary (Mysore State)

The project at Bellary in Mysore State has been established to develop and demonstrate improved water management practices in the Tungabhadra project commanded area.

A work plan to serve as a guide to the staff and consultants for the operations proposed was prepared first after a survey and collection of data. Studies have been undertaken to evaluate methods of irrigation suited to the soil, crop, topography and irrigation water supply, as well as to determine exactly the irrigation needs of different crops so as to obtain data for regulating the delivery of water supply through the distribution system.

### Pilot Project — Patiala (Punjab State)

The second regional pilot project is located at Patiala in the Punjab State to represent the lighter textured soils with high water tables. This project started functioning in January, 1969. The objective

of this project is to develop the most suitable scientific methods of water management so as to derive maximum benefits from the irrigation resources created in this region. In addition to the studies mentioned in the above project, studies to determine the criteria and designs for field drainage have been included in this project.

### Pilot Project — Azamgarh (Uttar Pradesh State)

The third project is located at Dohrighat (Azamgarh) in Uttar Pradesh. The objective of this project is to develop methods and practices for optimum utilization of the land and water resources for increasing agricultural production in the region from the existing low levels. This project started functioning in July, 1969. Investigations and data collection have been completed. Evaluation of different irrigation practices and other studies have been included.

## ECONOMIC ANALYSIS OF IMPROVED IRRIGATION FARMING

The extent to which the water management practices being developed in the pilot projects will be adopted by the farmers depends ultimately on what effect it has on the net income to the farmers. A study has, therefore, been undertaken in the pilot projects to measure this effect before recommending changes in irrigation farming methods. To make these measurements, it is essential to establish a benchmark of the present income under existing irrigation farming practices. Thus a survey has been undertaken in the pilot projects by interviewing the cultivators to ascertain the present cultural practices, cropping pattern and resulting crop yield. From the information collected is derived the present net income to the cultivators.

Crop production cost information is developed to itemize power (both bullock and electric), implements and labor costs. For power and implements these costs are sub-divided to show ownership and operating or fixed and variable cost associated with bullock farming. When alternative irrigation methods are tried in the pilot project area, effect of these on the cultivators' net income will be measured. Those practices which show the most favorable response will be recommended.

## WATER USE AND MANAGEMENT THROUGH INTENSIVE AGRICULTURAL DEVELOPMENT PROGRAM

A scheme to assist cultivators to solve their water use problems was launched under the intensive agricultural district program from 1965 onward. Water use demonstrations on individual farmers' holdings were organized. The main items of work emphasized in these demonstrations are:

(1) Improved irrigation distribution

(2) Construction of field channels with simple structures

(3) Adoption of improved methods of irrigation

(4) Land shaping and leveling; and remodeling field layout

(5) Field drainage practices

Rotation irrigation was introduced successfully after getting the field channels and control structures constructed in the district of Sambalpur in Orissa State. The farmers have appreciated the benefits of this measure. Areas in the tailends of the commands of the turnouts which were not getting irrigation water are now getting an adequate amount of water by this measure. Similarly, demonstrations on remodeling farm layout with the construction of field channels as well as drainage channels, land leveling, etc., were undertaken in Thanjavur district in Tamil Nadu State. Farmers have appreciated the new layout with large size plots (about one acre in size). They can irrigate each field independently and have complete control over water and the means for effective drainage of the fields. They are happy in the modifications by which they have the additional benefit of a half per cent gain of land in the cultivation area. More of them are interested in having such development programs on their farms. A large area program has, therefore, been chalked out in this region. The work is undertaken by a government agency and the cost recovered from the farmers in installments. Similar works have been undertaken in other intensive agricultural districts.

The experience from these demonstrations show that farmers, once convinced of the utility of

the programs come forward to make such improvements on their lands and show a willingness to invest for such development. There is an acute demand for equipment for land shaping and leveling as well as for technical assistance for planning and construction of irrigation distribution systems. These demonstrations have revealed the importance of integrating water management practices into the package of practices and services required for increasing agricultural production to high levels on a sustained basis. They have also shown that for enhancing production from low levels to high levels using high yielding varieties and high inputs, improvements in the efficiency and effectiveness with which water is managed by cultivators are vitally important.

## INTRODUCTION OF IMPROVED IRRIGATION METHODS

Improved surface methods of irrigation-border strip, graded furrow, contour furrow, etc., have been successfully demonstrated in a number of places and are being adopted by the farmers. Sprinkler irrigation has been demonstrated successfully for irrigating wheat on the sand dunes-affected areas in Punjab. A number of farmers have started installing sprinkler irrigation in areas of sandy soils where water conveyance by open channels is difficult and where water is scarce.

Studies have been conducted and recommendations given for introduction of sprinkler irrigation for the stabilization of sand dunes to prevent siltation of the canals in the Rajasthan State. In states like Punjab, Haryana and Gujarat farmers have started making underground pipelines for conveyance of irrigation water. Similarly, lining of irrigation channels to reduce the seepage losses is getting acceptance from farmers, and improved materials like prefabricated concrete sections, prefabricated cement asbestos channel sections, synthetic films, etc., are being used by farmers.

However, much more work has to be done to arrive at efficient water management practices for different situations. Hence, regional pilot projects on soil and water management have been conducted as indicated elsewhere.

## EVALUATION OF IMPROVED PRACTICES

A review of the different types of pipelines being used in the country has been conducted and suggestions made, giving the scope for using the different types of pipes for water conveyance underground. A study of the economics of sprinkler irrigation was conducted and sprinkler irrigation was compared with surface methods of irrigation. It was found that the sprinkler irrigation can be preferred where water is scarce and expensive and land leveling cost for surface methods are substantial and their maintenance costly in hilly areas like Mandi district in Himachal Pradesh.

Similarly, studies are being conducted in the agricultural universities to determine the suitability of different methods under the various existing conditions.

## AREA DEVELOPMENT PROGRAM

Integrated and multi-purpose agricultural development programs have been taken up in some of the newly developed irrigation project areas. In these projects besides irrigation water management, there is provision for marketing complexes and rural roads. A beginning has been made in the commanded areas of three projects: Kosi (Bihar State), Nagarjunasagar (Andhra Pradesh) and Tungabhadra (Mysore State). Provisions are made for inputs and other services necessary for an integrated development program. It is proposed to extend this program to a few other project areas in the fourth Five-Year Plan.

## PUBLICATION OF TECHNICAL BULLETINS

There is a dearth of literature on the subject of water management. The water management division at the center prepares technical bulletins, memoranda, etc. The following bulletins are already prepared:

(1) Technical Series I — Cylinder infiltrometer method for determination of intake characteristics of soils.

(2) Technical Series II — A guide for estimating irrigation water requirements.

(3) Technical Series III — Handbook on Irrigation Water Management — Sec. I — Soil survey and land classification.

(4) Technical Series 3-H Handbook on irrigation water management Sec. II - Soil–water-plant relationships.

## RESEARCH IN WATER MANAGEMENT

Research in water management has been a neglected technology in India. But it has now been given top priority under the agricultural research program. Lack of research information and the results from successful experience in scientific irrigation farming limit widespread undertaking of extension programs to aid cultivators in their water use problems. With the launching of an intensive agricultural development program, the problems of providing facilities for an assured supply of water and its controlled application became more acute.

Realizing the importance and the urgency with which studies on water management have to be carried out, the Indian Council of Agricultural Research has chalked out a well coordinated research program by strengthening a few of the existing agricultural research stations as well as setting up new centers. At these locations a highly accelerated water use and soil management research program has been launched, geared to provide information on irrigation water use for the important crops of the country under each major soil, climatic and cropping pattern complex.

Besides these research centers, each state government has established demonstration farms in different districts. A multi-disciplinary approach has been adopted in tackling the water management problems on a regional basis. Each station is manned by a team of scientists of different disciplines.

A water technology center is also being established this year at the Indian Agricultural Research Institute in New Delhi, which will deal with national problems as well as impart training at various levels in the field of water management.

# IRAN

**Geography.** Iran is located between the latitudes 25° to 40° north and longtitudes 44° to 64° east. It is bounded on the north by the the Union of Soviet Socialist Republics, on the east by USSR, Afghanistan and Pakistan, on the south by the Persian Gulf and Sea of Oman, and on the west by Iraq and Turkey.

**Area.** The total area of Iran is 1,650,000 square kilometers (628,000 square miles), of which 31 million hectares are arable, 19 million hectares are in forests, 10 million hectares are in pastures, and the rest is built-up area or waste land. The total area under cultivation is 19 million hectares, of which 7,100,000 hectares are presently cultivated each year.

**Population.** According to the census of 1966 the population of Iran has reached 25.8 million and is increasing rapidly. In recent years the average annual increase of population in Iran has been about 2.9 percent.

**Climate — Temperature.** The climate varies from hot and dry, with a maximum temperature of 34°c to 50°c (93°F to 122°F) during the summer months, to sub-zero temperatures in the winter period for most of the country, except along the Persian Gulf.

**Rainfall.** The major part of the country is arid or semi-arid, where the rainfall is restricted to winter months. There are other parts, such as northern flanks of the Alborz mountains, where there is sufficient rainfall for agriculture. On the plateau the average annual rainfall of over 200 millimeters in the north decreases to less than 120 millimeters in the south and southeast. The climate and rainfall conditions make irrigation essential for raising crops in the greater part of the country. Table 1 shows the distribution of rainfall in Iran:

**Table 1.**

| Annual rainfall (Millimeters) | Recipient area (Millions of hectares) | Ratio of recipient area to total area of the country (Per cent) |
|---|---|---|
| Less than 100 | 22 | 13 |
| 100 to 250 | 100.5 | 61 |
| 250 to 500 | 28 | 17 |
| 500 to 1000 | 13 | 8 |
| Over 1000 | 1.5 | 1 |
| Total | 165 | 100 |

**Soil Study.** A systematic map of the soil cover of Iran was prepared by the Soils Institute of Iran in 1964 on a 1:2,500,000 scale.

## PROGRESS SINCE SEVENTH SEMINAR

### Agriculture

Under present and future economic conditions of Iran, agriculture is of special significance. The social and economic benefits resulting from the land reform program, including land distribution among the farmers, which was completed during the third development plan, have played an important role in agricultural development of the country.

Major objectives of the agricultural policy in

Iran's fourth Five-Year National Development Plan (1968-1972) are as follows:

(1) Achieving a minimum average annual growth of five per cent in the gross product of the agricultural sector in order to meet the constantly increasing nutritional demands of the population as well as the supply of raw materials for domestic industries and export.

(2) Increasing the productivity of labor and land by dissemination of modern techniques in production and operation.

(3) Raising the employment level in rural areas by diversifying occupations, developing cottage industries and providing new employment opportunities for those entering the rural labor market during the plan period.

(4) Conserving, developing and improving natural resources such as water, soil, pastures, forests, fish and wild game, as well as effectively and reasonably exploiting these resources.

(5) Transforming the structure of rural society on the basis of cooperative and self-help activities.

In view of the above, the total livestock and other agricultural products which were 2,183,187 and 11,437,160 tons respectively in 1965 will be increased to 2,675,883 and 19,130,260 tons respectively in 1972.

To achieve the above objectives the projects to be implemented during the Fourth Plan have been prepared on the following basis:

(1) Utilization of land resources in a suitable and balanced manner

(2) Better utilization of water resources

(3) Mechanization of agriculture

(4) Expansion of the use of animal and chemical fertilizers

(5) Plant protection

(6) Supply and distribution of sapling and seeds

(7) Land reform

(8) Extension of modern agricultural research

(9) Improvements in the rural economy and the marketing of agricultural products

(10) Agricultural credits

(11) Animal husbandry

(12) Maintenance and correct utilization of pastures

(13) Conservation and utilization of forests

The land utilization at the beginning and end of the Fourth Plan is given in Table 2.

### Water

Shortage of water is one of the most important factors limiting the expansion of agriculture in Iran.

The general and long-term objective of water resources development plan is based on control and regulation of all water resources that can be economically utilized in agriculture, industry and urban development, in the light of modern technical progress. The estimated increase in the area of arable land for cultivation, and lands which will receive improved irrigation in the course of the Fourth Plan, is given in Table 3.

## IMPORTANT WATER PROJECTS IN THE FOURTH PLAN

The development plan for water resources has been drawn up with due regard to water basins and regional development policies.

Total investments provided for water resources development in the Fourth Plan amounts to about USA $708 million. The projects, in terms of the nature of work involved, may be summarized as follows:

(1) Completion of irrigation networks of dams already constructed. This group of projects consists of the completion of irrigation networks in areas where reservoir dams have been constructed and their proper and complete exploitation necessitates the completion of such irrigation networks. The required

**Table 2 – Land utilization at the beginning and end of the fourth plan (thousands of hectares)**

| Type of Land Utilization | 1967 (end of Third Plan) Area | 1967 Percentage of total land area of country | 1972 (end of Fourth Plan) Area | 1972 Percentage of total land area of country |
|---|---|---|---|---|
| 1. Total land under cultivation including: | 19,000 | 11.5 | 19,000 | 11.5 |
| (a) Area under annual and permanent cultivation | 7,100 | -- | 7,650 | -- |
| Area under irrigated cultivation | (3,150) | -- | (3,450) | -- |
| Area prepared for cultivation beneath dams | -- | -- | (100) | -- |
| Area under dry farming | (3,950) | -- | (4,100) | -- |
| (b) Area temporarily fallow | 11,900 | -- | 11,350 | -- |
| 2. Permanent pastures and meadows (1) | 10,000 | 6.1 | 10,000 | 6.1 |
| 3. Forests and copses (2) | 19,000 | 11.5 | 19,000 | 11.5 |
| 4. Uncultivated land capable of reclamation and development (3) | 31,000 | 18.8 | 31,000 | 18.8 |
| 5. Uncultivatable land (mountains, deserts, lakes, swamps, cities, roads etc) | 86,000 | 52.1 | 86,000 | 52.1 |
| Total | 165,000 | 100 | 165,000 | 100 |

(1) Only includes relatively good pasture-land.
(2) Part of these forests and copses is also permanent pastures.
(3) Part of these areas is presently in use as second and third class pastures.

investments for completion of the above irrigation networks amounts to about USA $101 million. To complete the projects started in the Third Plan an investment of about USA $251 million is required. In addition, to extend and improve the irrigation networks an amount of about USA $71 million should be invested.

(2) Implementation of eight projects which have been started since 1968 and which will go into operation during Fourth and Fifth Development Plans. The capital investments in the new projects for the development of surface water resources amounts to about USA $143 million.

(3) To provide engineering services for present projects under execution or projects to be considered and implemented in the future, a total expenditure of USA $40 million is foreseen in the Fourth plan.

(4) Another USA $62 million is also provided in the plan to cover the required expenditure for Tehran Water supply, water nationalization, research laboratory, etc.

The dams and irrigation networks to be constructed in the Fourth Development Plan, and the area of the studies relating to surface water and groundwater resources in the Fourth Plan, are shown in Figures 1 and 2 respectively.

## PRINCIPLES, POLICIES AND EXECUTIVE MEASURES

According to the tenth principle of the Revolution of H.I.M. the Shahanshah Aryamehr and the people of Iran, the water resources have been nationalized, and with regard to the extended importance, studies and experiences in this respect, a

**Table 3 -- Estimated increase in area of arable land ready for cultivation, and land which will receive improved irrigation in the coarse of the fourth plan**

| Title of Project | Increased area of arable land (in thousands of hectares) | Improved Irrigation (in thousands of hectares) | Total (in thousands of hectares) |
|---|---|---|---|
| 1. Irrigation network of Empress Farah dam (Sefid Rud) | 96 | 20 | 116 |
| 2. Irrigation network of Mohammad Reza Shah Pahlavi Dam (Dez) | 30 | 65 | 95 |
| 3. Irrigation network of Dariush the Great dam (Dorudzan) | 54 | 16 | 70 |
| 4. Irrigation network of Aras dam | 39 | 18 | 57 |
| 5. Irrigation network of Shah Abbas the Great dam (Zayandeh Rud) | 25 | 70 | 95 |
| 6. Irrigation network of Cyrus the Great dam (Zarineh Rud) | 25 | 11 | 36 |
| 7. Irrigation network of Jiroft dam | 6 | 16 | 22 |
| 8. Irrigation network of Shahpur I dam (Mahabad) | 10 | 6 | 16 |
| 9. Irrigation network of Woshmgir dam (Saagar Savar) | 10 | 10 | 20 |
| 10. Development of Ghazvin plain | -- | 44 | 44 |
| 11. Karun irrigation network | 24 | 6 | 30 |
| 12. Marun irrigation network | 6 | 56 | 62 |
| 13. Garmsar irrigation network | -- | 20 | 20 |
| 14. Irrigation network of Farahnaz dam (Varamin) | -- | 30 | 30 |
| 15. Exploitation of groundwater resources | 60 | 60 | 120 |
| 16. Other irrigation networks | 15 | 52 | 67 |
| Totals | 400 | 500 | 900 |

special summary of views, guidelines and outline of the policy is being presented under "A Few Remarks on Iranian Water Policy" in Appendix A to this report.

Furthermore an information digest on water resources and related development projects in Iran is presented in Appendix B in order to give an outline of the magnitude of activities in the field of water resources in Iran.

## APPENDIX A: A FEW REMARKS ON IRANIAN WATER POLICY

Iranian water policy has been drawn up with regard to water resources and climatological conditions, from a natural resources point of view, and, financial resources and possibilities of the country, from a national wealth point of view. By this comment it is meant that the water policy is drawn up in accordance with the actual conditions of the environment where it should be implemented; and one may be assured that such policy will serve the requirements of the country and through which the conditions necessary for proper and best use of water for national needs will be provided.

The best use of water is m[illegible]ted in terms of proper conservation, protection, free and reasonable supply and use of water resources. In this connection the policy does not only safeguard the interest of the communities but provides for the maximum and best kinds of use of water resources, and at the same time facilitates, as a basic means, the implementation of development plans of the country.

Having these views in mind, it is felt that the water, being a national resource and wealth belonging

to the nation or community living in the area, should not be used as a means of making profit whether by public or by private sector. In other words, the water resources should be used to the benefit and in the service of the people.

In order to give the outline and guidelines of fundamental principles of water resources management and utilization in Iran the following paragraph is taken from the "White Revolution" by His Imperial Majesty The Shahanshah Aryameh in 1965, which explains the fundamental basis of the "Tenth Revolution Principle":

> Any person has the right to utilize water to the extent of his actual and reasonable needs for domestic, agricultural or industrial usage. But this right may not become the property of anyone and no one is permitted to waste whether deliberately or by mistake, any portion of this national wealth or may convert it to a non-usable form, or use it as a means of commercial and profit making activities by speculation.
>
> Governments should be charged with preparation of projects for control of river and flood waters, as well as exploration of underground water reservoirs, and determination and designation of economical, technical and social priorities of such projects within the framework of a general economical plan for the country, and naplementation of these projects in accordance with the development plans, which should be drawn up and prepared with due regard to all financial possibilities and human factors which can be provided in the country. This will enable the people to enjoy this gift of God in the most profitable manner, with a minimum investment, at the lower costs, and with the shortest possible delay of time.

Having the above mentioned explanations in mind, one may formulate the basic and fundamental principles of water policy as follows:

(1) Right and freedom of usage

(2) Limitation of use to actual and reasonable requirements (allocation of water)

(3) Nationalization of rights (abolition of right of ownership in water)

(4) Prevention of wastage and pollution

(5) Prevention of speculation and profit making

(6) Comprehensive management in every form

(7) Control of resources by proper exploitation through implementation of development plans

(8) Consideration of economic feasibility (maximum use with least investment) at lowest costs and in the shortest time.

To implement the water policy, the law for water and its nationalization have been drawn up with due regard to government control and management on the basis of the above mentioned principles, with a resource oriented approach.

By this law water resources have been nationalized in the interest of the people, and greater influence has been given to the public authorities on development and use of water. Such changes impose greater responsibility on public authorities, and information may be exchanged on the result of experience and difficulties, in order to help other countries in solving their relevant problems.

The following general recommendations can be made:

(1) Preparation of a comprehensive water resources planning program is most important. Such planning should be focused on:

(a) Assessment of water availabilities

(b) Projected water demands

(c) Development of a long-term strategy (master plan)

(2) Strengthening of manpower, both quantitatively and qualitatively, is vital. This may be achieved by:

(a) Establishment of a training and educational body for lower and higher water specialists

(b) Utilization of management consultation

(3) Efforts are to be made to conserve and increase the efficiency of water use. This may be achieved by:

(a) Improvement of irrigation networks in the farms (waste prevention)

(b) Improvement of farming activities such as water application, land leveling, farming methods, etc.

(c) Development of ground water resources, with due control against over exploitation

(d) Establishment of agro-industry companies or farm cooperatives

(e) Initiation of an applied research program with an aim to render applied water engineering services, and more specifically to study the aspects of water use and its efficiency

(4) Large scale and intensive agriculture should be encouraged.

The traditional agriculture which constitutes a sizable portion of the agriculture, as usual, is as inefficient as everywhere. Efforts in modernization, rehabilitation of old systems, elimination of water waste, etc., are of help; but the governments should somehow subsidize them, and with regard to our experience, the planning should have as its focus the development of large scale agro-industry or agribusiness.

To assure the most profitable utilization of water resources, it is essential that surface, ground and atmospheric water resources are exploited. With regard to interdependencies of natural resources, the compatibility of projects to be executed is controlled in order to eliminate the conflicts arising from different uses. In this connection it is most desirable, as expressed, that a comprehensive framework program be prepared, taking into account the necessity for integrated, multi-purpose development projects and conjunctive use of water.

Obviously, such programs include the evaluation of different resources, determination of potential needs and poles of production and activites to be undertaken in an area, recommendation of priorities, etc. Such master plans enable public and private sectors to direct their activities within an approved framework. It is to be noted that savings in the investments by adopting of such procedure may be more appreciable than expected.

Water, having great impact on demography, living standards and amenities, is one of three basic elements of the environment, and it is to be emphasized that water development programs should be elaborated in a way which maintains and improves the quality of the environment.

Regarding organizational issues, a central office is set up to direct and apply the country's water policy.

All functions regarding implementation of the development projects and application of water policies are conveyed to executing bodies in different regions. Regional authorities are established by a special constitution and with full power on an independent and autonomous basis.

Thus the central office is responsible for leading, coordinating and patching together the activities, and at the same time enforcing rights of sovereignty. The general studies, preparation of statistics, collection of information and, in general, the infrastructural and basic activities are prepared and carried out by or under direct supervision of the central organization, with the help of executive regional bodies. In this way the formation of rules, regulations, standards, codes, instruction manuals, bylaws, etc. is done in the central headquarters with due regard for the experiences, difficulties and opinion of the executing regional bodies.

The regional executing bodies are responsible for supervision of all activities regarding the implementation of development plans and application of water policies in every respect. The regional bodies are granted adequate administrative, technical and financial independence, and at the same time they are bound by unified rules of procedure, regulations, codes and standards in order to safeguard the harmony of the activites within the whole of the

country. So the implementation activities are completely decentralized, while the programming, development planning and policy-making activities are centralized to the benefit of a common goal.

With regard to the equal right of people in using water and the principle of nonprofit exploitation of water, the water allocation rates are strictly enforced by public authorities. Controlling the water allocation within the master plan, the water is to be put at the disposal of users at an equal and unique price based on actual costs. By this, more expensive exploitation in some areas is subsidized from revenue of the areas where the costs are lower.

It is desirable that water development costs and benefits be compared and the projects be approved for execution only when an acceptable revenue-to-cost ratio is expected from its implementation. This allows authorities to decide upon the execution of a project from among several alternatives. However, fiscal evaluation of social reform and goals in some areas is not possible, and in these cases such economic consideration may not be applied.

In pricing water services (for domestic, industrial or agricultural purposes) no discriminative measure should be applied in favor of other activities in order to allow and preserve the right and freedom of free and equal use of natural gifts and resources by the people, unless provision of such measure is required for the enforcement of a specific policy.

With regard to the international aspects of water policy, the unification of standards, rules, regulations, procedures, policies, laws, etc., are desirable and recommended due to their outstanding expected universal results. With regard to the existing difficulties arising from a variety of such rules and procedures in the world, it is hoped that a common cooperative effort can be established among different countries in order to unify water policies in the world, to establish technical and economic cooperation in water management and development, to coordinate water activities on a universal basis, to cooperate socially and economically on an international or regional basis.

Exploitation of common resources existing between different countries, such as international rivers, interconnected groundwater reservoirs, and atmospheric water resources, should be developed on the basis of mutual understanding and friendship by means of a common project, which must be elaborated with due regard to the existing rights of the parties concerned.

Being considered a free commodity, water is relatively scarce, compared to other resources, and thus is a limiting factor in the economy of the societies. Therefore it is best to seek for new sources of water supply and other means to increase its availability.

Desalination, long distance conveyance, transbasin transfer, and weather modification present good grounds for research on new sources of water. Economic and advantageous solution of such processes of water production depend mostly on the continuity and persistence in research in these fields until a feasible method is found for large scale production of water. Thus, allocation of more funds to do research in these fields is most desirable and recommended.

## APPENDIX B: DIGEST OF INFORMATION ON WATER RESOURCES AND RELATED DEVELOPMENT PROJECTS IN IRAN

Water, being the most important resource and of limited supply in Iran, has been nationalized in order to enable the county to employ it to the maximum possible extent in the economic development. Therefore it is essential to employ the most advanced and scientific technology in the proper evaluation and efficient exploitation of water resources.

The approximate balance of fresh water in Iran is as follows:

Average precipitation 400 billion cubic meters per year.
Evaporation loss 240 billion cubic meters per year.
Total infiltration 60 billion cubic meters per year.
Total Runoff 100 billion cubic meters per year.

### Policies

The general policies on water development may be summarized as follows:

(A) Nationalization of water resources by:

(1) Taking over the management of water in the water courses and underground water tables.

(2) Supervising the supply and controlling water use in cultivation and orchards.

(3) Establishing water organizations and cooperative institutions for collection, control, supply distribution and proper exploitation of water resources.

(B) Agricultural development within the poles of resources by:

(1) Preventing sub-division of agricultural units.

(2) Forming agricultural cooperatives.

(3) Stopping unsystematic development in small units, and protecting and transferring the farmers.

(C) Development of agriculture in a crop-pattern by:

(1) Programming agricultural production.

(2) Rewarding progressive production.

(3) Protecting and undertaking the marketing of the production.

(D) Adoption of extensive research work by discovering new water resources from desalinization, weather modification, etc.

## Capital Investments

The approximate capital investments in water development projects excluding the town water supply investments (coming within the responsibility of the municipalities) may be summarized as follows:

First Plan period (1948-1955)
Rls. 1.4 billion (USA $18.4 million)

Second Plan period (1955-1962)
Rls. 5.3 billion (USA $70 million)

Third Plan period (1962-1968)
Rls. 21 billion (USA $275 million)

Fourth Plan period (1968-1972)
Rls. 53.15 billion (USA $710 million)

Fifth Plan period (1972-1976)
Rls. 125 billion (USA $1.64 billion)

Total investment to be expended in the next 35 years in water development projects, both for urban water supply and farm irrigation is estimated to amount to Rls. 2,000 billion (USA $26 billion)

## Organization

The water is being managed and organized in the country by:

(1) Ministerial water unit being responsible for the general planning, control of management studies, water resources development and coordination of activities and operation of water authorities.

(2) Nine regional water authorities serving all water installations and water project construction units, as well as the control of use and protection of resources, collection of data, etc.

(3) Exploitation of domestic water supply in a few major cities. Such functions are usually within the responsibility of the town authority and municipalities.

## Employees

There are 19,000 employees engaged in activities related to water development and usage.

## Completed Projects

| | | |
|---|---|---|
| (1) | Mohammad Reze Shah Dam in Khuzestan | Rls. 5,000 million (USA $65 million) |
| (2) | Farah Pahlavi Dam in Sefid Rood | Rls. 5,000 million (USA $65 million) |
| (3) | Shahnaz Pahlavi Dam in Hamadan | Rls. 960 million (USA $12.6 million) |
| (4) | Farahnaz Pahlavi Dam in Tehran | Rls. 3,100 million (USA $41 million |
| (5) | Shah Esmail Dam in Golpaygan | Rls. 90 million (USA $1.2 million) |

| | | |
|---|---|---|
| (6) | Amil Kabir Dam in Tehran | Rls. 5,200 million (USA $68 million) |
| (7) | Koohrang Tunnel and Diversion in Isfahan | Rls. 180 million (USA $2.4 million) |

## Present Development Projects

Major development projects under construction are as follows:

| | | |
|---|---|---|
| (1) | Aras Dam in Azarbaijan | Rls. 3,420 million (USA $45 million) |
| (2) | Daryoosh Kabir Dam in Fars | Rls. 2,150 million (USA $28 million) |
| (3) | Dez Irrigation Project in Khuzestan | Rls. 4,000 million (USA $2.5 million) |
| (4) | Ghazvin Irrigation Project | Rls. 1,550 million (USA $29 million) |
| (5) | Gonjancham Irrigation Project | Rls. 181 million (USA $2.4 million) |
| (6) | Gorgan Irrigation Project | Rls. 1,760 million (USA $23 million) |
| (7) | Jirift and Minab Irrigation Project | Rls. 3,780 million (USA $49.5 million) |
| (8) | Koorosh Kabir Dam in Azarbaijan | Rls. 2,070 million (USA $27 million) |
| (9) | Lar Dam in Tehran | Rls. 7,500 million (USA $100 million) |
| (10) | Moghan Irrigation Project in Azarbaijan | Rls. 2,300 million (USA $30 million) |
| (11) | Reza Shah the Great Dam in Khuzestan | Rls. 10,000 million (USA $130 million) |
| (12) | Sefid Rood Irrigation Project | Rls. 12,000 million (USA $156 million) |
| (13) | Shah Abbas Kabir Dam in Isfahan | Rls. 5,200 million (USA $68 million) |
| (14) | Shahpoor, the First Dam in Azarbaijan | Rls. 1,225 million (USA $16 million) |
| (15) | Shavoor Irrigation Project | Rls. 409 million (USA $5.4 million) |
| (16) | Sistan Irrigation Project | Rls. 7.14 million (USA $9.4 million) |
| (17) | Taleghan Dam and Tunnel in Ghazvin | Rls. 2,876 million (USA $37.5 million) |
| (18) | Varamin Garmsar Irrigation Project | Rls. 200 million (USA $2.6 million) |
| (19) | Voshmgir Dam in Gorgan | Rls. 1,000 million (USA $13 million) |
| (20) | Weather modification | Rls. 137 million (USA $1.8 million) |

Figure 1

# DAMS AND IRRIGATION NETWORKS TO BE CONSTRUCTED IN THE FOURTH PLAN

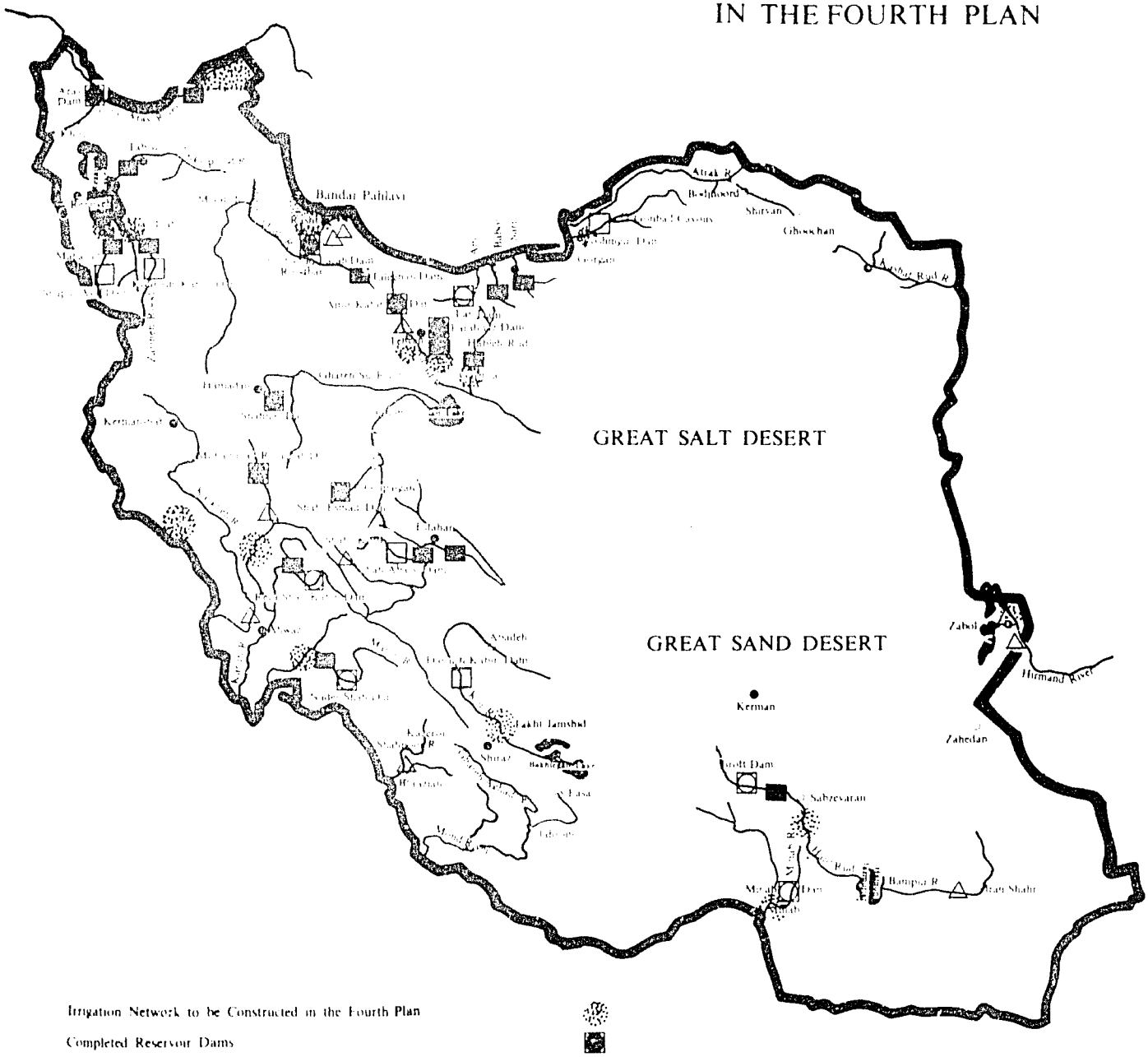
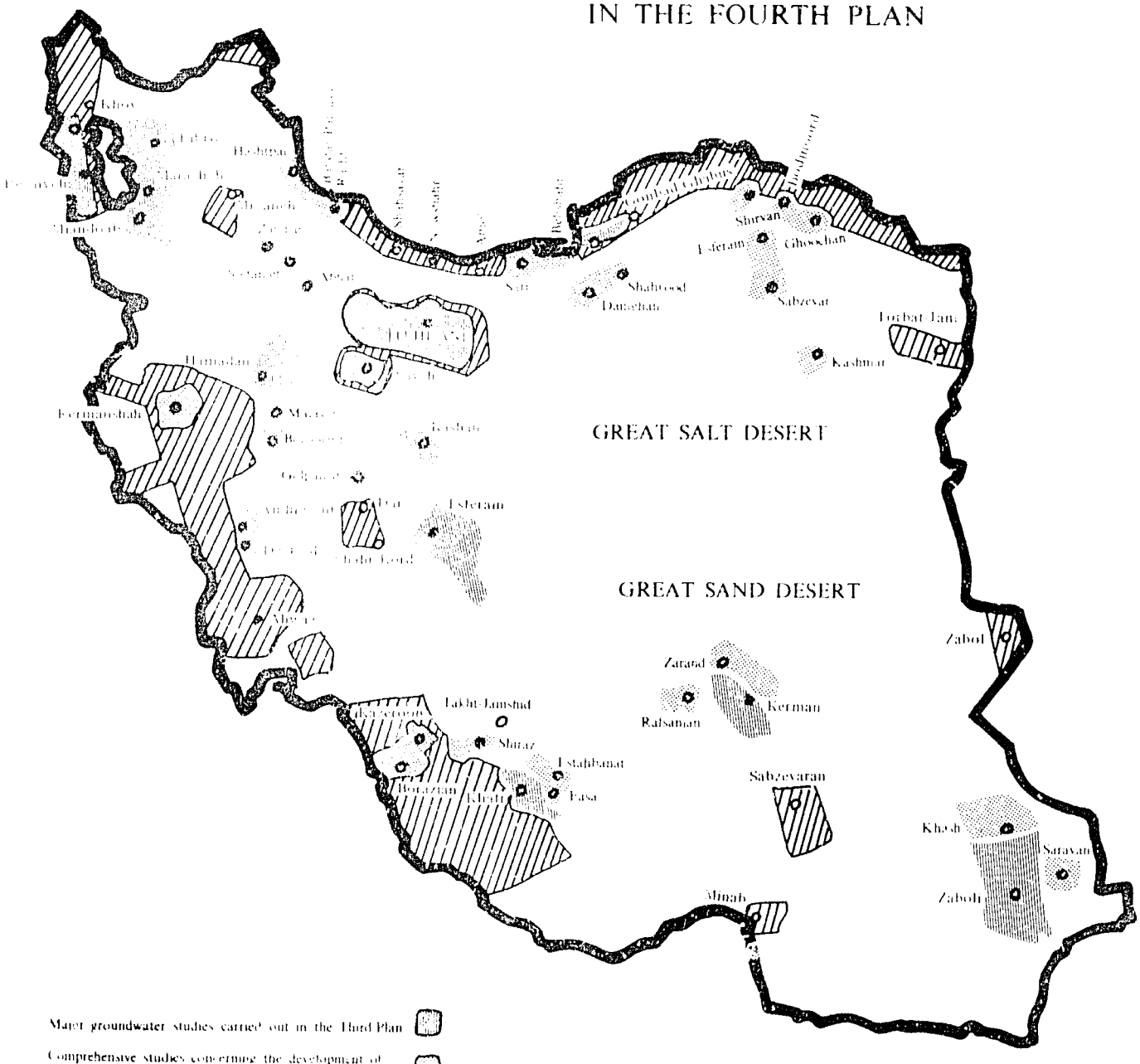


Figure 2

# STUDIES RELATING TO SURFACE WATER AND GROUNDWATER RESOURCES IN THE FOURTH PLAN




Major groundwater studies carried out in the Third Plan

Comprehensive studies concerning the development of water resources

Major comparative and semi-comparative groundwater studies to be carried out in the Fourth Plan

(An evaluation of groundwater resources covering an area of 75 per cent of the country will also take place.)

# PAKISTAN

Pakistan, one of the largest Muslim states in the world, has a population of 125.04 millions and a total area of 365,526 square miles. West Pakistan covers 310,400 square miles and East Pakistan 55,126 square miles. Of the gross national product of Rs.51,038 millions, the value of agricultural produce is Rs.23,101 millions, which is 46.9 per cent of the gross national product at a base factor cost of 1959-60. The per capita income works out to Rs.408. The two wings of the country have different topography, soils, climate, population density and problems of development.

## WEST PAKISTAN

West Pakistan is located in a climatic region of arid and semi-arid conditions. Of the total cultivated area of 48.66 million acres, 30 million acres are canal irrigated. For the development of the total cultivable 73 million acres in the Indus basin, 400 million acre feet of water is required compared to the available surface flows of 142 million acre feet from the Indus system and 45 million acre feet of useable supply that can be exploited from groundwater. At present the total diversions are only 103 million acre feet, and 50 per cent of this supply is delivered at the outlet heads to irrigate 30 million acres. There is thus a net delivery of only 1.7 acre feet per acre, compared to 3.2 acre feet (the actual consumptive use and leaching requirements) which reflects itself in crop yields.

## EAST PAKISTAN

East Pakistan is located in the extreme northern end of the Bay of Bengal. It is a tropical monsoon region in the delta of one of the largest rivers in the world, where roughly 80 percent of the soils are formed of recent alluvium, 10 percent of older alluvium, and the balance are formed directly from the rock. Its area is 35.28 million acres, of which 23.59 million acres are cultivable but only 22.43 million acres are actually cultivated. The annual flow of the rivers Brahmaputra, Ganges and Meghna averages 1,100 million acre feet and the annual rainfall varies from 50 to more than 200 inches, of which 80 percent is concentrated between June and mid-October.

East Pakistan has a variety of problems, including a high rate of population growth and low agricultural productivity. The present population of the east wing is about 75 million and is expected to reach about 100 million by 1980. Food production on about 22 million acres, or 65 percent of the land area, has been deficient and rather static the past ten years. The estimated production for 1968-69 was 11.12 million tons and an import of 1.2 million tons of grain was required. The food requirement for 1980 has been estimated at about 20 million tons. This estimate was based upon an individual requirement of 15.5 ounces per day.

Agriculture is the main activity of East Pakistan and employs 85 percent of the people. Crop yields per acre are low. Part of this is due to primitive cultural practices, lack of improved seeds, scant use of fertilizers, excess of water during the monsoon floods, and drought during the non-monsoon season. Two crops per year are grown on 25 per cent of the land and only five per cent of the land supports three crops. With irrigation, more of the land could produce three crops annually. The deep water rice

grown during monsoon is a low-yielding crop, but with better flood protection higher yielding crops could be produced. The climate is tropical and can support agriculture the year around. There is no killing frost. In the northwest night temperatures do get low enough to affect rice but not wheat, potatoes, tobacco, corn and other crops. During the monsoon cyclones are a hazard to crops, as well as humans and livestock. Floods, an annual phenomenon, have caused damage to crops, property and lives. Rainfall occurs from June through mid-September, but not until mid-October do most of the floods gradually drain off these flat deltaic lands. The total damage, including both direct and indirect losses sustained by the economy, has been estimated at about 800 million dollars (USA) every year.

Rainfall, although excessive during the period June through September, is deficient for crop production during the winter months. No proper estimate has been made of drought damage, but it has been observed that this could amount to 200 million dollars (USA) annually.

## SOILS AND WATER IN WEST PAKISTAN

### Soil and water survey work

The soil and groundwater investigation program has covered a large part of the west wing of Pakistan. During the last two years the survey of the Lower Indus Plains and writing of the report have been completed. The investigation work in the northern region within the command of canal irrigation has also been completed and the action program is now in hand for tackling the problem of salinity and waterlogging for improvement of irrigation. So far eight SCARPS (Salinity Control and Reclamation Projects) in the north and in the lower Indus have been proposed. The scope of these projects has to be confined to the area which has reasonably useable water for irrigation. The area covered by these projects, total number of tubewells proposed and the progress of installation is shown below:

**Progress of Installation**

| | Name of Project | Gross Area in Acres | No. of T/wells | Proposed capacity | No. of T/wells Completed |
|---|---|---|---|---|---|
| 1. | Project No. 1 Central Rechna Doab. | 1,200,000 | 2057 | 5999 | 2059 |
| 2. | Project No. 2 Chaj Doab. | 1,877,000 | 2439 | 9790 | 1750 |
| 3. | Project No. 3 Lower Thal Doab. | 1,105,000 | 1635 | 6268 | 1635 |
| 4. | Project No. 4 Upper Rechna Doab. | 562,000 | 935 | 3714 | 135 |
| 5. | Project No. 5 Lower Rechna Doab. | 438,000 | 568 | 2026 | — |
| 6. | Project No. 6 Panjnad Abbasia Area. | 1,680,000 | 1782 | 6752 | — |
| 7. | Project No. 7 Upper Bari Doab. | 1,140,000 | 1161 | 4437 | — |
| 8. | Project No. 8 Left Bank Sutlej. | 2,332,000 | — | — | — |
| 9. | Khairpur Drainage Project. | 355,000 | 540* | 1380 | 540 |
| 10. | Rohri North F. 6 W Project. | 790,000 | 1269 | 4153 | — |
| 11. | Rohri South F. 6 W. Project. | 480,000 | 1692 | 3700 | — |

* 161 Irrigation wells.
379 Drainage wells.

## Visual salinity survey by Directorate of Land Reclamation

The salinity survey was initiated first in the year 1927 and is still continuing. The statistics of salinity are collected by visual observation in the field, all over the area within the command of canal irrigation. A brief mention of this survey was also made in the previous country report. From the data so collected it was noticed that in the year 1941-42 there was a big increase in the area affected by salinity. The situation was aggravated still further in 1956-57 when the salinity affected rose from 2,051,500 to 3,069,765 acres. From the survey record for seven years (1961-62 to 1967-68) as given below, it will be seen that there was an increase in the salinity-affected area only in two years and decrease in the other five years. There is, however, an overall decrease of 0.7 per cent in salinity if an average is taken for a period of seven years. This works out to 38,060 acres in 38.06 million acres of cultivated area, surveyed in 1967-68. This can be regarded as a trend toward improvement, and if nothing else it shows that the further spread of salinity has been checked to some extent.

### Variation in the salinity during the seven years from 1961-62 to 1967-68

| Year | Total area surveyed | Total Saline | Percentage of saline over total area | Difference in Percentage |
|---|---|---|---|---|
| 1961-62 | 34,692,736 | 5,268,164 | 15.1 | (-) 0.2 |
| 1962-63 | 37,691,573 | 5,616,554 | 14.9 | (-) 0.2 |
| 1963-64 | 37,018,051 | 5,630,443 | 15.2 | (+) 0.3 |
| 1964-65 | 36,977,648 | 5,442,027 | 14.7 | (-) 0.5 |
| 1965-66 | 37,061,855 | 5,444,102 | 14.6 | (-) 0.1 |
| 1966-67 | 37,476,213 | 5,575,838 | 14.9 | (+) 0.3 |
| 1967-68 | 38,066,615 | 5,476,656 | 14.4 | (-) 0.5 |
| | | | Difference | (-) 0.7 |

## UN Soil Survey of Pakistan

The soil survey project of Pakistan was initiated to provide the government with a basic inventory of the country's soil resources and to provide a basis for sound agricultural development planning. Land capability maps together with the maps of land forms and the present land use have been prepared for the area surveyed. The progress of the reconnaissance soil survey so far achieved in East and West Pakistan is given below:

Total area survey (square Miles)

| | A Level | B Level | Total |
|---|---|---|---|
| East Pakistan | 34,350 | 5,000 | 39,350 |
| West Pakistan | 67,414 | 19,312 | 86,726 |
| | 101,764 | 24,312 | 126,076 |

The number of reports that have been issued since the last seminar have gone up from nine to 15 for East Pakistan and from four to 20 for West Pakistan.

## SOILS AND WATER IN EAST PAKISTAN

Presently the government of Pakistan is treating the flood problem at a national level, with some of

the ambitious flood control programs for the province coming outside the aid consortium program. The primary plan envisions control of flood water by building protective dikes to prevent river flooding. Also, there is a program to pump excess rainfall off the land. In addition, there will be a general program of river channel enlargement for better land drainage.

The government of East Pakistan has been doing extensive investigations in the field of soils and water. These studies are for the implementation of short-term and long-term improvement projects that will help intensify food production. Under the East Pakistan Water and Power Development Authority (EPWAPDA) a comprehensive scheme for flood control, drainage and irrigation has been taking shape. This work of information gathering and program development has been implemented through EPWAPDA's personnel with the aid of consultants especially appointed. In addition, EPWAPDA through its office of Land and Water Use Directorate has been conducting soil surveys in many areas.

## WATER RESOURCES IN WEST PAKISTAN

### Surface Water

West Pakistan has the largest contiguous system of irrigation in the world. Now 142 million acre feet of water of three rivers: Chenab, Jhelum and Indus, will be used according to the Indus Water Treaty of 1960. To make use of the flows of the different rivers, one large dam, five barrages and nine inter-link canals have been constructed.

When Tarbela Dam, the largest earth and rock fill dam in the world, is completed in 1974-75 it is expected that water which presently flows into the Sea will be used for cultivation. However, since the last seminar two years ago water use in West Pakistan has risen from 95.7 million acre feet in 1966-67 to 103 million acre feet in 1969-70 and there is a corresponding increase in irrigated area from 28.61 million acres to 30 million acres.

In recent years, attention has been paid to Baluchistan, a region similar to parts of Afghanistan and covering an area of approximately 1,420,000 square miles. This is a vast area equal to almost half of West Pakistan. The whole region is arid and requires huge quantities of water to rehabilitate it. Some short-term schemes as tabulated below were completed:

| Completed schemes | Total No. |
|---|---|
| Small Irrigation Schemes | 327 |
| Flood Diversion weirs | 98 |
| Small storage dams | 13 |
| Delay action dams | 3 |
| Flood bunds | 59 |
| Tubewell borings | 268 |
| Approximate area benefitted from these schemes. | 225,948 acres |

### Small Dams Organization

Twenty small dams were accepted for construction by the Small Dams Organization of the Agricultural Development Corporation for a total capacity of 20,501 acre feet. These small dams are located in ample rainfall areas, and have proved of great utility in supplying water for drinking and irrigation at a time of a paucity of water. Thirteen dams have since been completed.

### Groundwater

The groundwater situation was discussed in detail in the previous country reports. The use of groundwater in the private sector has since then tremendously increased in both wings of the country. The number of tubewells in the country is now 89,050. It will be of interest to state that in 1967 the number of private tubewells in West Pakistan was 53,000. Thus 26,233 were installed in two years' time. All the tubewells in the public sector are run on electricity. Of the 79,233 private tubewells, 30,713 are operated by electricity and 48,520 by diesel engines. The total annual pumpage is about 18.7 million acre feet.

## WATER RESOURCES IN EAST PAKISTAN

Irrigation schemes now in operation can be roughly divided into two categories: (1) Irrigation by diversion or pumping of surface water; (2) Pumping from groundwater.

### Surface Water Irrigation

A limited number of water development projects are now operated in East Pakistan while others are under study or are ready for construction. All the

projects are primarily for development of irrigation facilities but flood control and drainage measures are usually an associated feature. In fact, flood control and drainage cannot be divorced from irrigation or vice versa in the majority of areas of this province.

**Ganges-Kobadak Project** — Phase I & II. First phase of this project is complete and is in operation. Construction of the second phase is in progress. It is anticipated that irrigation water will be made available to farmers in the next Kharif season. The progress achieved so far in this project is summarized below:

| | Commanded area in acres | | Area irrigated during 1968 - 69 | | Area irrigated during 1969 - 70 | | length of canals in miles | length of drainage channels in miles |
|---|---|---|---|---|---|---|---|---|
| | Gross | Net | Crop acres | Land acres | Crop acres | Land acres | | |
| Phase I | 210,000 | 120,000 | 99,320 | 67,933 | 112,049 | 83,400 | 49,431 | 243 |
| Phase II | 291,000 | 230,000 | | | | | 535 | 457 |

**Dacca-Naravanganj-Demra Project.** This project has been in operation since 1967. Experiments are being made for intensification and diversification of cropping practices. In addition, studies are being made on the different losses of water in the main and distributary canals. Since the NESA seminar held in Lahore in 1968, a few new canals and drains have been constructed. Uptodate progress of this project is tabulated below:

| Commanded area in acres | | Area irrigated during 1968 - 69 | | Area irrigated during 1969 - 70 | | Length of main channals in miles | Length of drainage channel in miles |
|---|---|---|---|---|---|---|---|
| Gross | Net | Crop acres | Land acres | Crop acres | Land acres | | |
| 18,840 | 12,740 | 12,788 | 7,953 | 18,094 | 10,056 | 28 | 15 |

During the year 1968-69 a number of drains were either widened or deepened. It was observed that some of them had insufficient capacity to cope with the monsoon rainfall discharges

**Chandpur Irrigation Project.** This project is now under construction. It will provide for flood protection, drainage and irrigation to a gross area of 140,000 acres by peripheral embankment, pumping plants, drainage, channels and a canal system. Seven miles of embankment and part of two control structures have been constructed. The current year's program includes construction of 24 miles of embankment, three miles of irrigation canals, five miles of transmission lines, 12 bridges and completion of two control structures.

Low lift pumps are being used extensively by the farmers to lift water from the drainage channels. These pumps are operated through farm cooperatives or with the help of local administrative units. The farmers are obtaining immediate benefit from this irrigation project simultaneously with the projects construction.

**Diesel low lift pump irrigation schemes.** A number of projects with low lift pumps operated by diesel engines are now working under EPWAPDA. These projects vary in size between 100 and 2,000 acres. The pumps have mostly been installed on smaller streams or drainage channels. The progress made so far since the report to the last seminar is listed on the following page.

Under the Fourth Five-Year Plan, 18 projects for water development and flood control have been selected by the World Bank. All these include both long-term and short-term construction projects which cover a major part of East Pakistan. Investigations and surveys for long-term projects and comprehensive studies on different aspects of the program are also proposed during the period. Long-term project studies include the Brahmaputra and Ganges Barrages,

| Project | Commanded area in acres | | Area irrigated during 1968 - 69 | | Area irrigated during 1969 - 70 | | Length of Canals in miles | Length of drainage channels in miles |
|---|---|---|---|---|---|---|---|---|
| | Gross | Net | Crop acres | Land acres | Crop acres | Land acres | | |
| EPWAPDA | 76,400 | 76,400 | 15,517 | 11,093 | 16,098 | 11,399 | 139 | -- |
| EPADC | | | 113,050 | 113,050 | 314,754 | 314,754 | | |

comprehensive regional studies, flood control model analysis and computer studies.

## Irrigation from Groundwater

Both the EPWAPDA and the East Pakistan Agricultural Development Corporation (EPADC) have launched a vigorous program of groundwater development in East Pakistan. Feasibility studies for some of the projects were made earlier and construction of these projects were completed by EPWAPDA in 1965. These projects are in operation in the northern districts of East Pakistan. Besides, the EPADC has adopted a plan of scattered well development in areas where groundwater is known to be available.

A reconnaissance groundwater survey has been made in this province by the United States Geological Survey. On the basis of these investigations plans have been drawn by the EPWAPDA to construct about 2,400 tubewells in the fourth plan period. Meanwhile the EPADC has installed a total of 948 tubewells, of which some 300 are equipped with pumps. The EPADC has recently negotiated a loan from the World Bank for 3,000 more deep tubewells, each having a capacity of one and a half to two cusecs. The progress made to date by the two different agencies, EPWAPDA and EPADC, is tabulated below:

| Projects | Commanded area in acres | | Area irrigated during 1968 - 69 | | Area irrigated during 1969 - 70 | | Length of Canals in miles |
|---|---|---|---|---|---|---|---|
| | Gross | Net | Crop acres | Land acres | Crop acres | Land acres | |
| EPWAPDA | 91,200 | 91,200 | 66,361 | 57,717 | 94,379 | 61,733 | 212 |
| EPADC | | | | (estimated) 6,000 | | 6,000 | |

In addition to EPWAPDA's program, the EPADC is helping improve agriculture and the farm community by constructing deep medium capacity irrigation wells, providing power pumps for surface water, tractors and other machines for cultivation, supplies of fertilizer and improved seeds. There are 17 seed-producing farms under EPADC management. All this effort is part of the "Grow More Food" campaign directed toward provincial self-sufficiency in food during the fourth plan period. Increased efforts were organized after the crop year 1968-69 as adverse weather caused the loss, mostly by flooding, of about one million tons of the rice crop. All government services are instructed to accelerate irrigation programs and to increase per-acre productivity. All major projects are being handled by EPWAPDA while EPADC is following a policy of scattered irrigation well development where groundwater is known to be available. This activity comes under the Thana Irrigation Program. The thana is the lowest administrative unit of government in the province. EPWAPDA has a well irrigation project in operation and has plans for developing more. EPWAPDA wells are electrically powered, whereas EPADC relies upon individual diesel engines for operation. In addition, EPADC has 17,634 diesel operated centrifugal pumps of two-cusec capacity lifting surface water for rice growing during 1969-70. It proposes 25,000 such pumps during 1970-71. These pumps are rented to groups of farmers organized under the Thana Irrigation Program. In addition, each group must buy fuel and oil for the engine operation from EPADC depots. EPADC also provides maintenance and engine repair service on all units each year during the monsoon season.

## LAND DEVELOPMENT

With the development of planned agriculture, attention is being paid to land leveling and to bringing more area under irrigated agriculture. The total number of bulldozers employed for this purpose is about 1,100. The total area leveled and graded during the period 1965-66 to 1968-69 is 0.87 million acres. Cultivators are now realizing the necessity of leveling for efficient use of the meager available water supply. An age-old method of land leveling is still being employed by cultivators at the time of seed bed preparation, i.e., leveling by means of wooden planks drawn by bullocks and by tractors where possible.

## LAND RECLAMATION

The reclamation of saline and waterlogged land in West Pakistan has been in progress since 1939. Additional reclamation water supply is made available to cultivators for saline land during the flood season when enough water is available in the rivers. The water allowance for reclamation is 22.2 cusecs per 1,000 acres. This supply is allowed for three years. An attempt is made to wash down the salts from the soil profile and the root zone of the crop so as to make the soil fit for growing normal crops. Generally an area of 117,000 acres is tackled annually by making use of 2,500 cusecs of reclamation supply. This affords a temporary relief. For a permanent solution the SCARP (Salinity Control and Reclamation Projects) are planned and executed. Some of the SCARPS have proved very useful and effective. In SCARP Nos. 1, 2, 3 and 9 which have come into operation, the water table has gone down considerably and the crop production has appreciably increased. The pumping of groundwater through private tubewells has also contributed in arresting the rise of the water table, which was one to one and a half feet every year.

One of the world's largest embankment projects is under construction in the coastal districts of East Pakistan to prevent saline tidal inundation from the sea and to reclaim land. During the year 1968-69, 215 miles of embankment, 88 sluices and two polders were completed in the Coastal Embankment Project. Up to June, 1969, 1,832 miles of embankment, 569 sluices and 48 polders protecting 1.506 million acres were completed of a total estimated benefited area of 2.353 million acres. The Coastal Embankment Project, Phase I, would consist of 2,293 miles of embankment, 729 sluices, and 87 polders, with a benefited area of 2.01 million acres.

## EXTENSION SERVICE

There is no change in the setup of Extension Services, as indicated in the country progress report presented in the last seminar. The special staff employed in the Agricultural Department in West Pakistan for extension work consists of three directors, 12 deputy directors, 45 assistant directors, 285 agricultural assistants, and 2,200 field assistants. The research work conducted in the research institutes and laboratories under the control of various departments and universities is published in technical papers and other progress reports, and made available in simple understandable language for the education of the public through radio and television talks and through the extension service staff and other field workers of revenue, irrigation and cooperating departments. Private agencies such as Rural Supply Cooperative Corporation, Pakistan National Oil, ESSO, Dawood and Jaffar, et al, which have been assigned the task of procurement and distribution of the seed and fertilizer, are also helping in disseminating the scientific findings on agriculture. Thus the use of good seed and fertilizers has gained popularity among cultivators. Use of fertilizers has increased from 70,000 nutrient tons in 1965-66 to 245,000 nutrient tons in 1968-69. The indiscriminate use of fertilizers has been arrested and the requisite nutrients are applied according to the crop needs and the nature of the soil, and quality and quantity of water available for irrigation.

Extension services play a dominant role in an irrigation project in East Pakistan. In fact the success of the project depends chiefly on the performance of the extension staff. In all these irrigation projects, extension staff are training farmers in the proper use of irrigation water, improved seeds, fertilizers, and pest control measures, through lectures, pamphlets, direct discussions, etc. A large number of demonstration farms also have been set up in these project areas. The response of the farmers, although not encouraging at the outset, is gradually improving. This is demonstrated by the fact that the demand for fertilizers is on the increase (from 226,000 tons in 1967-68 to 296,000 tons in 1969-70).

## RESEARCH

Research work conducted on problems of irrigated agriculture by the Land Reclamation Directorate, Lahore, during the last four decades has played a vital role in improving the economy of West Pakistan. Research by this directorate regarding the rate of rise of the water table, spread of salinity and the research to combat the salinity menace has provided the basis for the formation of salinity control and reclamation projects.

Research work by the Land Reclamation Directorate, by agricultural universities and by the central Irrigation, Drainage and Flood Control Research Council on consumptive use of crops, water quality standards, irrigation practices, land drainage, salt balance, soil reactions, salt tolerance of crops, plant nutrient requirements of different agricultural crops, seepage and evaporation losses, potential yielding capacity of crops, has added a new chapter in research on soil science.

The government of Pakistan established the Irrigation Drainage and Flood Control Research Council as an autonomous body in 1965 to organize, coordinate and promote research in the various fields of hydraulics, irrigation, drainage, reclamation, tubewells and flood control.

The council decided to give top priority to subjects of national importance and has so far approved the following research schemes:

(1) Determination of field efficiency in irrigation in East Pakistan.

(2) Some basic studies on hydraulic problems.

(3) Lysimeter studies on soil, water and plant relationship for salinity and waterlogging control.

(4) Aid for research and training post-graduate students in hydraulics.

(5) Basic studies on groundwater exploitation.

(6) Aid for research and training post-graduate students in mechanics.

These research schemes are at different stages of execution in the research institutes and universities of East and West Pakistan.

Also in the last years the council has undertaken a bibilographic research on waterlogging and salinity in West Pakistan. After this study is completed, the topics in this field requiring further research work will be undertaken by the council.

The council has also decided to set up mono-discipline institutes to undertake intensive and extensive research on specific problems which have a bearing on the economy of the country. Four such research institutes, one for flood control in East Pakistan, another for land reclamation in West Pakistan, and two for hydrology, one each for East and West Pakistan, are being planned. These institutes are proposed to be established during the Fourth Five-Year Plan (1970-75).

## CONCLUDING REMARKS

With limited land resources in East Pakistan and limited water resources in West Pakistan, it will really be a hard task for this country to cope with the food and fiber requirements of its growing population. Unless scientific land and water use is made very strictly, together with other inputs, viz., fertilizers, pest control and introduction of high yielding varieties, it will be impossible to meet the requirements of the growing population. This country is glad to report that there is, however, general realization on all sides, viz. the government and the cultivators, for the need of scientific irrigation and other agricultural practices.

# TURKEY

Turkey is no newcomer to world history. It has been at the crossroads of many civilizations over past centuries. As is well known, in the great cities of Asia Minor history began with the Hittites and continued with the Phrygians, Lydians, Romans, Seljaks and Ottomans, before the republic of Turkey was established. From the point of view of geography and location, Turkey stands with a foot in Europe and a foot in Asia. A small part of the country, a little over three percent of the total land area, is in Europe and is known as Thrace. The large part of Turkey in Asia known as Anatolia (which means "east") is the land mass which is sometimes called Asia Minor.

Because of the relatively large size of the country, it is not surprising that Turkey has a great variety of landscapes. With a land area of 296,503 square miles, it is approximately the same size as France and England or Texas and Virginia combined.

Anatolia consists of a large plateau surrounded by mountains. Standing in the eastern most part of Turkey is Mount Ararat, the snow covered peak 5,185 meters (16,873 feet) high, where Noah's ark is supposed to have come to rest. Many rivers emerge from Turkey's steep mountains. Among them are two of the world's most famous streams, the Tigris and the Euphrates.

Turkey's climate is greatly influenced by its topography. Along the coasts of Anatolia, in the narrow strips of lowlands, summers are hot and winters cool. As one goes inland over the mountains to the central plateau the climate changes greatly. Winters in the east are very harsh and temperatures fall well below zero centigrade.

Monthly and regional distribution of precipitation is not uniform. Evapotranspiration during the growing season is generally much greater than the precipitation. For this reason water requirements of crops are generally high and indicate great differences from region to region.

Some of the climatological characteristics are shown in Table 1.

**Table 1: Characteristics of Precipitations, Length of Growing Season and Water Requirements**

| | Average Minimum | Average Maximum | Weighted Average |
|---|---|---|---|
| Average annual precipitation (mm) | 315 | 2,441 | 602 |
| Growing season (days) | 128 | 361 | 281 |
| Rainfalls at most critical period (mm) | 15.2 | 485 | 97 |
| Irrigation water requirements (mm) | 75 | 778 | 388 |

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Prepared by Seref Ozgul, Consultant on Soils and Drainage, General Directorate of State Hydraulic Works. (DSI)

Differences in climate, topography and soils through the country influence the growth of crops. Nevertheless a very large variety of crops can be grown successfully. Leading crops in the coastal areas are tobacco, cotton, walnuts, citrus, grapes and fruits. Cereals, sugar beets and rice are produced on the plateau. Due to the lack of rainfall and irrigation one third of the cultivated lands are left fallow. Present land use is shown in Table 2.

### Table 2: Present Land Utilization (1969)

| Type of Utilization | Area (1,000 Hectares) |
|---|---|
| Agricultural lands | 26,068 |
| Cultivated areas | |
| Crop land (15,400) | |
| Fallow (8,692) | |
| Orchards and Vineyards (2,976) | |
| Pastures and meadows | 26,621 |
| Forests | 12,273 |
| Unproductive lands | 13,096 |
| Total Area | 78,058 |

## STATUS OF IRRIGATION IN TURKEY

Irrigation has vital importance for Turkey because agriculture is the principal occupation, yet in most of the country the precipitation is insufficient for normal crop growth.

As a matter of fact, from earliest times the Turkish people have been conscious of benefits to be derived from irrigation and have been in constant investigation of both ways and means of devising irrigation systems.

According to available data 518 billion cubic meters (420.6 million acre feet) of water, corresponding to an annual precipitation of 166 billion cubic meters (134.8 million acre feet), flows into the sea, and it is assumed that about 80 billion cubic meters (64.9 million acre feet) of the remainder can be utilized. With groundwater reserves estimated at about seven billion cubic meters (5.7 million acre feet), overall water potential in the country reaches 87 billion cubic meters (70.6 million acre feet). With this potential, 8.5 million hectares (21 million acres) can be irrigated economically.

The total area under irrigation in 1970 is only 1.8 million hectares (4.5 million acres), which is one fifth of the total area requiring irrigation. Of this total area, one million hectares (2.47 million acres) are irrigated by private enterprizes and the remaining 800,000 hectares (2.03 million acres) by state irrigation systems.

On lands irrigated by state-owned systems 60 per cent of the water is obtained by use of storage dams, 36 per cent by diversion dams and four per cent by tubewells.

As mentioned in previous NESA seminar reports, topographic and soil conditions in irrigated areas are generally favorable for irrigation. These lands are usually flat to gently sloping and need light to medium leveling and they have soils generally of alluvial origin, deep profile and extremely variable texture, with high lime content and base exchange capacity.

The land utilization pattern in Turkey has been and will continue to be determined primarily by physical features and climate. As a result of the variation in climate and soil characteristics, kinds of crops grown on irrigated lands show great variations from region to region. In Table 3, kinds and distribution of irrigated crops are given for 1969.

### Table 3: Kinds and Percentages of Areas of Irrigated Crops in 1969

| Crops | Percent of Total Irrigated Area |
|---|---|
| Cotton | 48.52 |
| Cereals | 19.26 |
| Fruits | 6.62 |
| Sugar beets | 4.55 |
| Vegetables | 4.31 |
| Forage crops | 3.60 |
| Corn | 3.11 |
| Melons | 2.94 |
| Legumes | 2.39 |
| Oil Seeds | 2.19 |
| Citrus and bananas | 1.97 |
| Tobacco | 0.75 |
| Potatoes | 0.46 |
| Poplars | 0.33 |
| Total | 100 |

There is great need in Turkey for farm equipment and mechanization. This need is growing rapidly due to the sharply increased use of fertilizers, expansion of irrigated areas, and reduction of lands in fallow. It will be a long time before all farms are completely mechanized. Nevertheless the present trend in mechanization continues hopefully, as seen in Table 4.

**Table 4: Trends in Farm Mechanization**

| | Number of Machines | | | |
|---|---|---|---|---|
| Farm Machine | 1960 | 1964 | 1967 | 1968 |
| Tractors | 42,160 | 51,784 | 74,103 | 85,475 |
| Tractor plows | 47,080 | 55,100 | 72,900 | 89,900 |
| Tractor-cultivators | 6,134 | 6,500 | 15,300 | 21,100 |
| Grain drills (tractor-pulled) | 8,343 | 9,800 | 12,700 | 15,200 |
| Cotton planters | 11,147 | 16,600 | 20,100 | 22,700 |
| Binders | 3,037 | 3,780 | 6,300 | 6,800 |
| Combines | 5,554 | 6,790 | 7,200 | 8,210 |
| Motor pumps | 22,557 | 45,700 | 66,300 | 69,900 |

With the first five-year development plan (1962-1967) of Turkey, soil and water improvement has entered a planned period. For this period a total sum of 11.3 billion Turkish liras (TL) (1.97 billion USA dollars) was earmarked for improvements in the agricultural sector, of which 45 per cent was allocated to the irrigation of an additional area totaling 515,000 hectares (1.3 million acres), as well as to the reconditioning, repair and maintenance of old installations and equipment. Of the 515,000 hectares scheduled for irrigation, only 441,000 hectares (1.1 million acres) were irrigated.

The second five-year development plan (1968-1972) requires the irrigation of another 392,000 hectares (968,240 acres). In the first two years of this plan the area put under irrigation was 110,000 hectares (271,700 acres), of a total 130,000 hectares in the plan.

It has been estimated that the full development of water resources requires a total investment of 159 billion TL (26.8 billion USA dollars). Taking into consideration that by the end of 1969 the investment reached 13 billion TL (2.3 billion USA dollars), it is seen that at present the implementation covers only 9 per cent. Of this sum of 13 billion, 5.5 billion TL (0.9 billion USA dollars) or 43 per cent, was spent for irrigation and drainage projects.

In irrigation development projects this investment consisted of 12,000 TL (2.02 thousand USA dollars) per hectare on the average, and the resulting increase in annual income has been 2,800 TL (471 thousand USA dollars) per hectare. The overall benefit-cost ratio of the completed project is 2.19.

## ACCOMPLISHMENTS SINCE THE LAST SEMINAR

(1) An additional area of 110,000 hectares (275,000 acres) was provided with irrigation systems built by the state.

(2) A total of 13,158 hectares (32,500 acres) of land was leveled, 23,300 hectares (57,441 acres) of land was drained, and 11,174 hectares (27,600 acres) of land was consolidated. These activities were financed from state funds and the investments thus made will be repaid by water users through water charges.

(3) A total of 106 TOPRAKSU cooperatives were established and 65,047 hectares (160,550 acres) of land put under irrigation by drilling 1,535 wells, to accelerate the utilization of underground waters for irrigation. This was accomplished by joint efforts of three organizations: State Hydraulic Works (DSI), Soil Conservation and Farm Irrigation (TOPRAKSU),

and the Agricultural Bank of Turkey. In this underground water development program DSI drilled the wells and supplied the pumps, and TOPRAKSU constructed pump houses, stilling pools, and distribution systems and provided technical assistance for on-farm activities, while the Agricultural Bank has provided loans. Cost of the wells and pumps is to be repaid in 30 years without interest.

(4) Operation and maintenance on 53 projects were transferred to irrigation associations.

(5) In the irrigation projects operated by DSI, attempts were made to transfer the operation of secondary and tertiary canal systems to groups of farmers. Each group elects a representative from its members, and this representative requests water from DSI on behalf of his group and distributes water to individual plots. These irrigation groups are assisting DSI to a great extent, and a saving in personnel is realized. In cases where water distribution is conducted by irrigation groups, the irrigation charges are reduced by 15 per cent below the normal rate. At present a total of about 150 irrigation groups have been established in 10 projects.

(6) Repayment was started on 15 irrigation projects. The number of such projects will be increased each year.

(7) Twenty-eight state irrigation projects were rehabilitated, at an expense of 24.8 million TL (4.18 million USA dollars).

(8) To meet the needs of farmers in large irrigation projects (mainly state projects) for seeds, fertilizer, insecticides, machinery, tools, livestock, etc., the Agricultural Bank made loans amounting to 49,809,000 TL, as supervised credits.

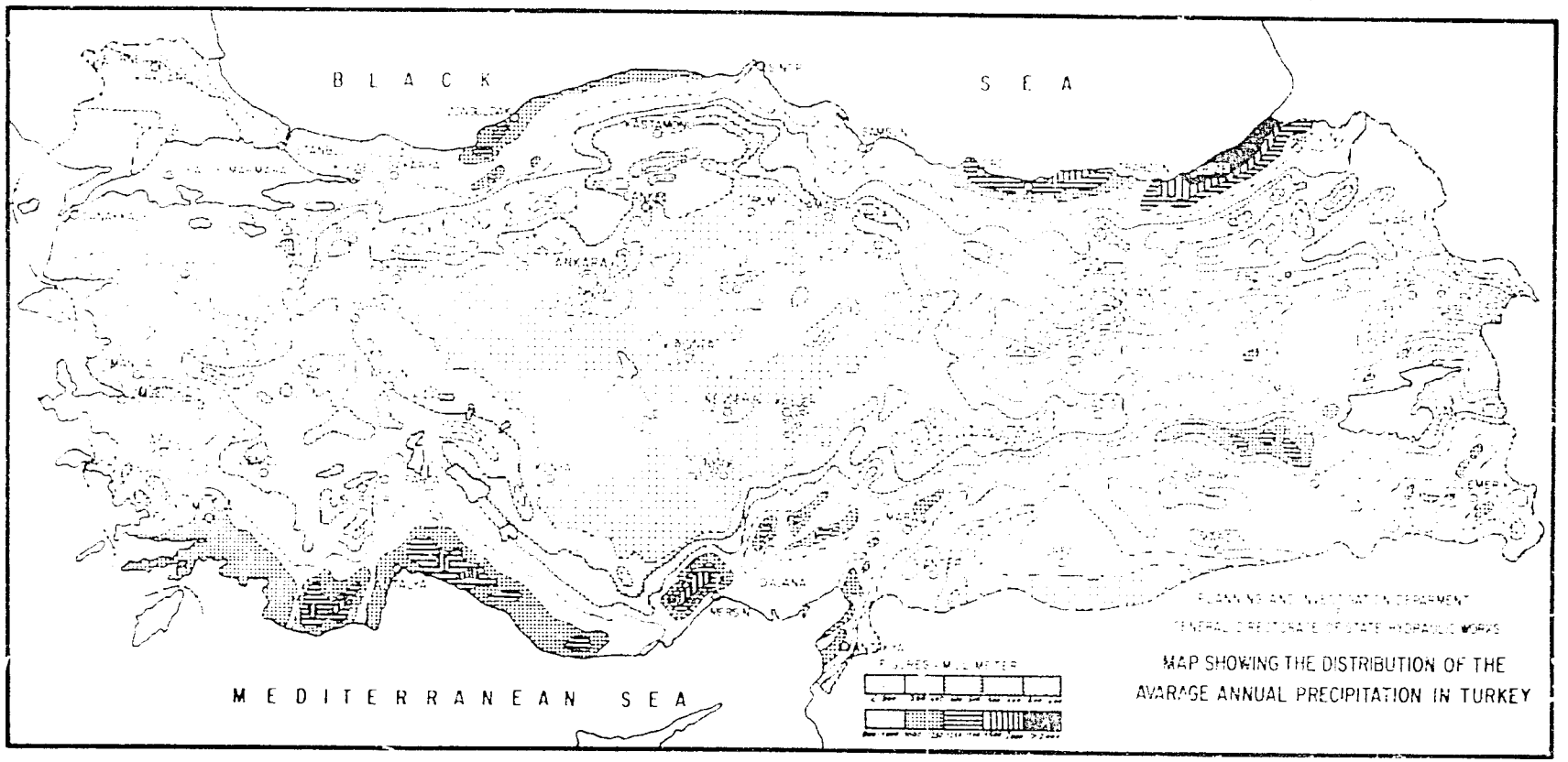
(9) The number of companies occupied in the manufacture of on-farm development equipment such as scrapers, ditchers, listers landplane, etc., increased from six to 37.

(10) Three sprinkler manufacturing factories were established to supply equipment to areas where this type of irrigation is more economical.

(11) Under the "On-Field Irrigation Development Works Program" initiated through the cooperation of TOPRAKSU and other government organizations concerned, the Gediz Irrigation Project was selected as a model. At present the laying of field drains on 23,300 hectares (57,551 acres), land leveling on 7,233 hectares (17,865 acres) and land consolidation on 8,068 hectares (20,170 acres) have been completed. In these areas also other services, such as pest control and extension services, are fully provided, through the related agencies.

(12) DSI and TOPRAKSU arranged courses and seminars in various parts of the country for government technicians and farmers.

(13) Standards for field drainage were prepared by TOPRAKSU.


B L A C K
S E A
M E D I T E R R A N E A N S E A
ANKARA
MAP SHOWING THE DISTRIBUTION OF THE
AVARAGE ANNUAL PRECIPITATION IN TURKEY

# UAR

UAR lies in a virtually rainless zone. But for the Nile, Egypt would have been desert.

Irrigation in Egypt depends mainly on the Nile river. Groundwater has been used in the oases since very ancient times to irrigate about 518,000 acres. The quantity of the groundwater in the oases is 2,340,000 $m^3$. This is a 780-year supply.

The UAR area is one million $km^2$, of which only 3.5 per cent is normally habitable, the rest being desert. The arable area is 10.58 million acres, of which 7.26 million acres are cultivated at present by irrigation.

The basin system continued to be the only means of irrigation in the UAR until about 1820, when the cultivation of cotton and sugar cane was first introduced. Under the basin system the land is divided into basins of 1,000 to 40,000-acre areas by the construction of dikes and flood water let into the compartment to a depth of one or two meters. After 30 to 40 days, when the river has fallen, these lands are drained and a crop is planted. But after construction of the High dam, no basin system continued in the UAR.

In 1826 a system of deep canals was introduced for irrigation of lower Egypt to cultivate cotton in the region. The deep canals silted up yearly and had to be cleared by a system of forced labor. The Delta barrage was built at the head of Rosetta and Damietta branches to improve the irrigation but it could not cope with the increased irrigation requirements of the Delta and it was necessary to build new barrages (Delta barrages) which were completed in 1939.

Other projects undertaken toward converting some basin irrigation schemes into perennial irrigation schemes were conducted at sites on the Nile in the last century. The area under irrigation increased from five million acres in 1879 to 5.1 million acres in 1900. Until 1902 summer cropping depended entirely on the natural discharge of the river. With the extension of perennial areas, the demand for summer water also increased and Aswan dam was constructed in 1902 with the capacity of one billion $m^3$. In 1912 it was raised six meters in height to increase its capacity to 2.5 billion $m^3$ and again eight meters in 1933 to store five billion $m^3$.

Assuit barrage was also constructed in 1902 to raise the summer level of the river and to improve the canalized supplies to the middle of Egypt. Though intended for use during low-river stage and floods, it was remodeled in 1938 to cope with future development and to help in filling the raised Aswan dam reservoir. Zifta barrage was also constructed in 1905 on the Damietta branch at 78 kilometers down the Delta barrage to improve the perennial irrigation in the northern area of the Delta. It was later remodeled in 1954 to increase the head.

Esna barrage was built in 1912 for use in the flood season only. This barrage was remodeled later in 1947 to serve during lower river stages.

Idfina barrage was constructed on Rosetta branch at 210 kilometers down Delta barrage to help in filling Aswan dam reservoir.

In 1925 Sennar dam was constructed on the Blue Nile to store 780 millions $M^3$ of water to

improve the irrigation in the Gizera (Sudan).

The Nagah Hamdi barrage in upper Egypt was completed in 1930 for use both in floods and in summer seasons to take advantage of additional supplies to be obtained from the raised Aswan dam and Gabel-Auiia reservoirs.

Gabel Auiia was constructed in 1937 south of Khartoum for the benefit of the UAR.

The Sadd-el-Aali dam is constructed to store 164,000 millions $m^3$. It is a long-term storage project which will guarantee the necessary water requirements of the present agricultural lands, make available additional water for the cultivation of 1,200,000 acres of new land, enable the conversion of 700,000 acres from basin to perennial irrigation and annual irrigation of more than 1,000,000 acres of rice, improve the drainage condition in the cultivated areas, protect against floods, improve navigation conditions along the river and enhance industrial development through use of the general electric power.

The Sadd-el-Aali is built seven kilometers upstream from the US Aswan dam. It is of the rockfill type, 111 meters above the river bed and with storage capacity of 164 billion $m^3$. Its width is 80 meters at the base, 40 meters at the crest. The lake upstream from the dam is one of the largest in the world. It is 500 kilometers in length and 10 kilometers in width. The hydro-electric power station has 12 Fracis type turbines with an installed capacity of 180,000 kilowatts each.

## PRESENT DEVELOPMENT AND FUTURE PLANS

The irrigation area at present is 7.26 million acres, while the estimated arable area is about 10.38 million acres. Sadd-el-Aali brings 1,500,000 additional acres under irrigation.

The underground water supplies in the oases will increase the cultivated area by 518,000 acres.

In 1952, the UAR and Uganda constructed Owen Falls dam at the exit of Lake Victoria, transforming it into an over-year-storage reservoir for the benefit of irrigation in the UAR and Sudan and for the generation of hydro-electric power for Uganda.

The following schemes are proposed for the full utilization of the Nile water:

(1) Construction of a dam at the exit of Lake Albert to convert the lake into an over-year-storage reservoir.

(2) Construction of a regulator at the exit of Lake Kiaga for its control in order to facilitate the combined over-year storage regulation of Victoria and Albert lakes.

(3) Construction of a diversion canal (Janglia canal) to switch the water of Lake Albert from the swamps of southern Sudan where about 50 per cent is lost by evaporation and transpiration.

(4) Similar investigations on the Sabat river and its branches (now in progress) to find means of increasing their contribution to the main river.

(5) Construction of a dam at the exit of Lake Tana to enable using the lake as an over-year-storage reservoir.

(6) Investigations on Bahr-el-Gazal and its branches to find means of increasing their contribution to the main river.

## DRAINAGE

Under the basin system of irrigation, salts were washed away from the land each year by the flood waters. The introduction of perennial irrigation resulted in gradual accumulation of these salts in the subsoil as well as a general rise in the water table. Due to inadequate drainage the cotton crop failed in 1909 and this led to (a) reducing the amount of water put on land to that required for cropping, and (b) intensive drainage activity. New drainage was provided and many pumping stations were built to arrest further deterioration of the irrigated area.

The development of drainage includes the following:

(1) Construction of main drains not exceeding 30 kilometers long.

(2) Installation of new drainage stations to

increase drainage depths.

(3) Widening and deepening all main drains and branch drains to provide field drainage of 1.25 meters.

(4) Additional construction of drainage stations to provide the depths necessary for all cultivated land in the UAR.

(5) As the public drains are effective only in benefiting a narrow strip extending along their banks, the government policy has been to spread general systems of tile and concrete drains throughout the fields in order to convey the land drainage water to the public drains. Studies have been made to utilize drainage water. As the result of studies, drainage waters of high, medium or low salinity are being used, saving equivalent amounts of fresh Nile water. Highly saline water is used in leaching saline soils for reclamation, while water of medium or low salinity is used for irrigation. This totals 1,500 million $m^3$.

## SOME IMPORTANT PROJECTS

**Aswan Dam.** The area under perennial irrigation was entirely dependent on the natural discharge of the river, which was far below the irrigation requirements in most years, resulting in failure of crops. Aswan dam was built in 1902 to store one billion $m^3$ of water for the protection of the perennial irrigated area and for converting 400,000 acres of basin irrigated land into perennial irrigation. The full reservoir level was reconstructed to R.L. 106 to avoid the submersion of Philae temple.

In 1912, the first heightening of Aswan dam, by six meters, increased its storage capacity to 2.5 billion $m^3$. The additional water stored was used for reclaiming 400,000 acres of new land in lower Egypt. The dam was raised again by eight meters in 1933 to increase its total capacity to five billion $m^3$. The additional water stored enabled converting another 200,000 acres of basin lands to perennial irrigation and reclaiming 200,000 acres of new land. The extra water was used to increase rice cultivation. The dam was grouted in 1953.

**The Sadd-el-Aali** is described above.

**Delta barrages.** Constructed between 1843 and 1863. Were replaced in 1939 by two new barrages at the heads of Rosetta and Damietta branches. These barrages serve the Delta area of four million acres.

## INTERNATIONAL WATER AGREEMENT

The governments of the UAR and Sudan concluded the Nile Water agreement on November 8, 1959, which contains eight articles. Only the first and second articles are listed because they deal with the shares of water for the two republics.

### Article 1

**Paragraph 1.** The amount of the Nile waters used by the UAR until this agreement is signed, shall be her acquired water rights before obtaining the benefits of the Nile Control projects and the projects which will increase its yields. The total of this acquired right is 48 billion $m^3$ per year as measured at Aswan.

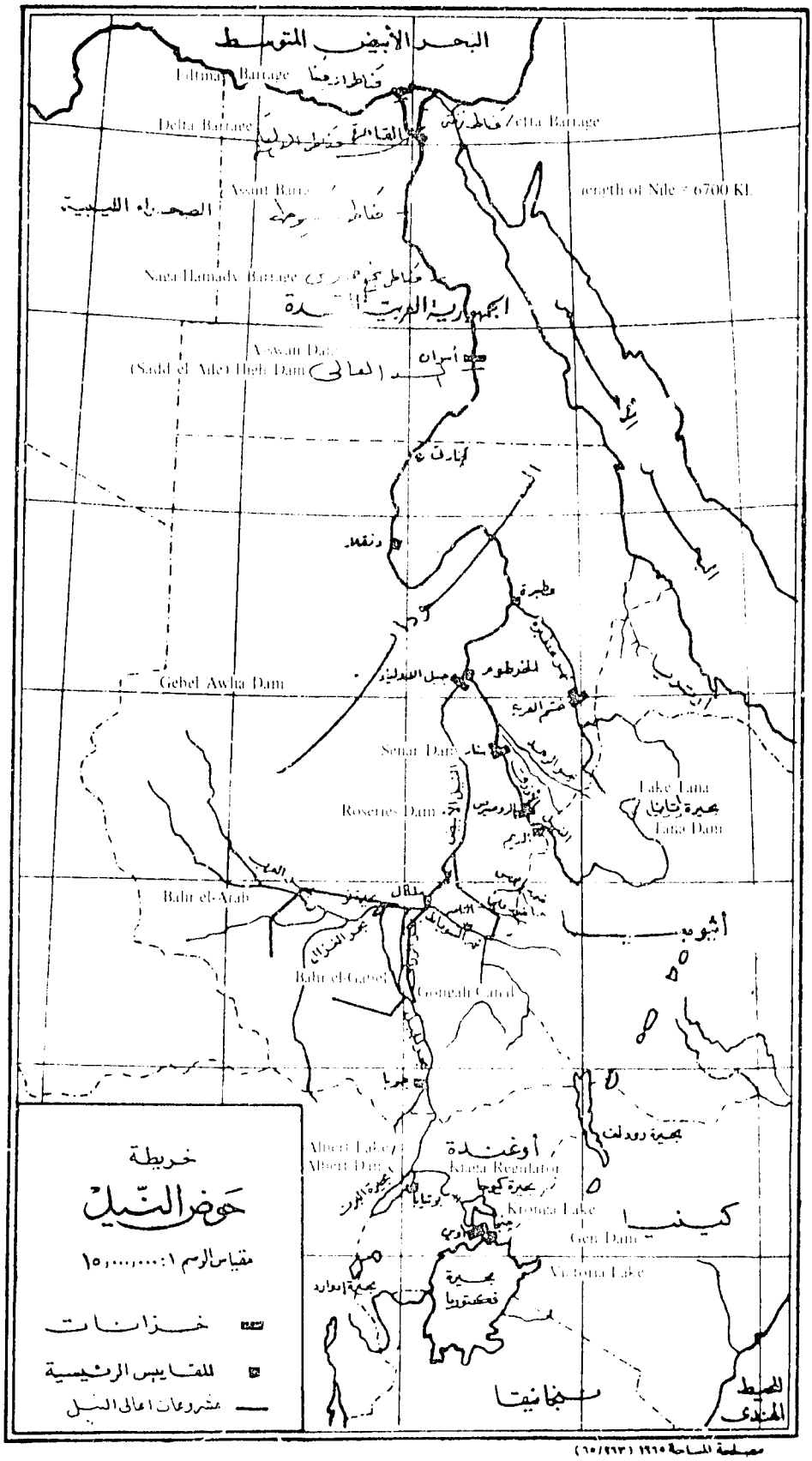
**Paragraph 2.** The amount of waters used at present by Sudan shall be by acquired right, before obtaining the benefits of the projects. The total amount of this acquired right is four billion $m^3$ as measured at Aswan.

### Article 2

**Paragraph 1.** In order to regulate the river waters and control flow into the sea, the two republics agree that the UAR construct the Sudd-el-Aali at Aswan as the first link of a series of projects on the Nile for over-year storage.

**Paragraph 2.** In order to enable the Sudan to utilize its share of the water, the two republics agree that Sudan shall construct the Roseirey dam on the Blue Nile and any other works which the Republic of Sudan considers essential for utilization of its share.

**Paragraph 3.** The net benefit from the Sadd-el-Aali reservoir shall be calculated on the basis of the average natural river yield of water at Aswan in the years of this country, which yield is estimated at about 84 billion $m^3$ per annum. The acquired rights of the two republics referred to in Article 1 as measured at Aswan and the average losses of over-year storage of the Sadd-el-Aali reservoir shall be deduced from this yield and the balance shall be net benefit which shall be divided between the two republics.




مصلحة المساحة ١٩٦٥ (٦٥/٩٦٣)

**Paragraph 4.** The net benefit from the Sadd-el-Aali reservoir mentioned in the previous paragraph shall be divided between the two Republics in the ratio of 14.5 for Sudan and 7.5 for the UAR, so long as the average river yield remains within the limits of the average yield referred to in the previous paragraph. This means that if the average yield remains the same as the average of the previous years of this country, which yield is estimated to be 84 billion $m^3$, and if the losses remain equal to 10 billion $m^3$, the net benefit of the Sadd-el-Aali reservoir shall be (84-48-4-10) = 22 billion $m^3$. The share of the Sudan shall be 14.5 + 4 = 18.5 and of the UAR 48 + 7.5 = 55.5 billion $m^3$. But if the average yield increases, the resulting net benefit from this increase shall be divided between the two republics in equal shares.

**Paragraph 6.** The UAR agrees to pay 15 million pounds to Sudan as full compensation for the damage resulting to the Sudanies' existing properties as the result of the storage in the Sadd-el-Aali reservoir, up to the reduced level of 182 meters.

**Paragraph 8.** It is understood that when the Sadd-el-Aali is fully operated for over-year storage, the UAR will not require storing of any water at Gebel-el-Aulia dam.

# CHAPTER V

# Farm Management of Irrigation Practices

## INDIA

## ON-FARM WATER MANAGEMENT — INDIA'S APPROACH

by

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### SUMMARY

One of the important elements in the new strategy for agricultural development in India is attention to water use and management. It has been recognized in this country that along with the use of the high-yielding varieties and high inputs, proper water control and its effective use are vital to achieve high yields. The tradition of treating irrigation as protection against drought has been changed. Water is now considered one of the most important components for agricultural production and accordingly a policy aiming at optimum return per unit of water has been adopted.

Effective organizations both at the Center and in the states are being developed to plan and execute suitable water management programs. Pilot projects on a regional basis to better demonstrate modern water management practices have been established, while coordinated research has been planned to feed the extension program. Integrated development of the commanded area by provision of infra-structure services and production inputs, as well as giving emphasis on effective and efficient use of water resources, has been the new approach. Water management in existing projects is being streamlined, and in new projects it is seen that the water requirements of crops would be adequately met. Programs to assist the farmers in their water use problems, both technical and financial, have been launched by setting up new agencies as well as utilizing existing soil conservation agencies. Preparation of technical bulletins and manuals for upgrading the technical specifications followed in the country have been undertaken. Training of farmers, technicians and specialists is also programmed. There is still a large gap in the general knowledge and technology required to utilize the water efficiently from the canal systems and the tubewells. This gap has been recognized and efforts are being made to fill it.

### INTRODUCTION

In the last two decades, India has given high priority to the development of irrigation to increase agricultural production. Considerable resources have been expended. Although the irrigation potential which was developed through construction of major and medium irrigation projects mounted systemat-

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ically during these years, its utilization has been lagging behind. The problem of under-utilization of the potential created has been a source of concern ever since the early 1960's. A joint working group of the Ministry of Food and Agriculture and the Ministry of Irrigation and Power, set up in 1963, observed that only about half of the irrigation potential developed was being utilized. State governments were often requested to improve water utilization. By the end of 1968-69, however, the situation had improved and the irrigation utilization was of the order of 81 per cent of the potential created. Even then the unutilized potential was as high as four million acres. Besides, by utilization it is meant that only irrigation water has been applied. It does not show that water has been used efficiently, as agricultural production has not shown any appreciable increase even under irrigation.

The marginal increase in yield per acre in spite of providing irrigation facilities caught the attention of the concerned authorities. Studies were then undertaken by specialists to diagnose the basic causes of only marginal increase. These studies revealed that lack of proper management of irrigation water and its efficient use were primarily responsible. Detailed examination of utilization of irrigation water in a few projects indicated the following lapses on the part of planners:

(1) Failure to conduct pre-irrigation soil surveys.

(2) Failure to construct water courses and field channels for proper conveyance and distribution of irrigation water beyond the turnouts fixed in the public canals.

(3) Failure to develop land for irrigation by shaping, grading and leveling.

(4) Inadequate provision for drainage.

(5) Lack of farmers' education and guidance in changing cropping patterns and adopting improved irrigation practices.

With the introduction of new short-duration high-yielding varieties in the mid-sixties, the need for precision in water application and use assumed importance. For the new varieties using high inputs, there is need for ensuring adequate and timely supply of water, especially at critical periods of their growth. The efficiency with which water is managed by the farmers is the crucial factor in raising the existing marginal yields to optimum levels.

To achieve optimum production under irrigated agriculture, integrated development of the command area, with the provision of all necessary inputs and services, is essential. A policy has been adopted to develop intensive irrigation farming by setting up pilot water management projects as well as undertaking area development programs.

## THE PROBLEMS

Responsibility for development of water for irrigation and its delivery to the farm turnouts for use in irrigation farming has been with the irrigation departments. The inter-farm distribution of irrigation water has been left to the farmers, although it was expected that the state departments of agriculture would give necessary technical guidance to farmers on efficient use of water. However, in practice, this has not always been the case, and in the absence of proper guidance in water management, it has been impossible to attain high irrigation efficiencies. This has led to waterlogging, salinity and alkalinity in a number of irrigation projects.

Water conveyance and distribution systems at the field level are, in general, inadequate for proper division and distribution of water among the irrigators. The cultivators themselves are responsible for getting the water from the turnouts to their individual fields which, in many cases, involves areas from 100 to 200 acres or more divided into many ownerships. Farmers seldom join together to construct water courses and field channels. There is no legal or administrative compulsion for them to come together to plan, finance, construct and maintain group or inter-farm channels. No farmers' associations exist for this purpose. The method of distribution in most of the projects, especially for paddy cultivation, is that of continuous flooding. This usually means water flowing from one field to the next lower down.

Farmers do not have any control over water under this system. When there is shortage of water, the fields in remote areas seldom get water. This results in crop failure.

In the comparatively new projects, absence of water courses and field channels, coupled with uneven land, stands in the way of obtaining efficient water use. Farmers have not been getting adequate technical assistance in construction of water courses and field channels, nor in shaping and leveling fields for proper application of irrigation water. Information on how to irrigate, how much, and when, has not been made readily available to farmers.

Drainage is lacking in most areas. Even natural drains are not maintained. Further, no field drains are connected with these natural drains. Thus irrigated areas get waterlogged. Irrigation without adequate drainage becomes generally a detriment rather than an aid in increasing production, especially for obtaining sustained increases in yield.

## EARLY EFFORTS

The problem of water use and management has been receiving the attention of the agricultural departments in the past. Several agricultural research stations in India have been working on different problems of irrigated agriculture with a view to developing improved practices for recommendation to cultivators.

With the undertaking of an intensive agricultural development program, it was felt that there was a need for helping farmers in their problems of water use and management. Accordingly, demonstrations on individual farmers' lands have been conducted since 1965. This includes helping farmers with proper alignment and construction of field channels, with necessary water control and distribution structures, land grading, provision of adequate drainage, etc. These demonstrations brought out the weaknesses in the irrigation systems and the potential for increasing agricultural production through proper water management. They have also shown that if given necessary technical and financial assistance, farmers are agreeable to undertaking improved irrigation practices on their farms and are willing to invest for such measures. These demonstrations have paved the way for undertaking a large-scale program on water use and management in the command areas of the irrigation projects.

## PRESENT APPROACH

### Organization

The problems of continued under-utilization of the irrigation potential created and the low per acre yield obtained from the irrigated areas, attracted serious attention of the government. The Agricultural Production Board, the highest policy-making body, considered this problem, and it was decided to set up a water management organization under the Union Ministry of Food and Agriculture to examine the problems of command areas with a view to locating the shortcomings in soil and water management and intensifying agricultural production. This unit (now called division) was created in 1967 and has the responsibility of identifying the water management problems in the country as well as planning and coordinating a water management program at the central level. It is also to assist the state governments in developing and implementing water management programs.

It was soon realized that to achieve efficient water management in a large number of projects there was need for similar organizations at the headquarters of each state. The states were, therefore, requested to set up water management units. Some of the state governments have already set up such units, while others are still in the process.

Such existing organizations as soil conservation departments are being utilized by some of the state governments for undertaking programs and giving assistance to the farmers in their water management problems.

Under the soil conservation departments in the states there are divisional soil conservation officers posted at the district level. Each such division has a few sub-divisions headed by a sub-divisional officer who is either a graduate in agriculture or an engineer

trained in soil and water conservation. These officers have a supporting survey crew and an engineering and agricultural supervisory staff. The sub-divisional officer conducts surveys and prepares proposals for land improvement measures for irrigated lands with the cooperation of the farmers, and arranges loans, subsidies, etc., as well as assistance in the execution of the works.

## Water Management Pilot Projects

With realization of the seriousness of water management problems and with the establishment of Water Management Division at the center to deal with this, it was decided to establish regional pilot projects for soil and water management in certain key areas, to study and develop sound methods for efficient water use.

The project areas are selected as representative of a large soil and water resource area of the country and have substantial areas of irrigated land. Compact areas covering about 10,000 acres each are selected for each project. These projects provide an opportunity for bringing together various disciplines of soils, agronomy, engineering and agricultural economics to identify the social and physical problems and needs relating to soil and water management in the particular land and water resource area.

A sampling procedure has recently been evolved for assessing the soil and water resources in an area which can be conveniently used for planning.

The projects are to develop technical guides for application of the improved practices and provide data and experience on the need for alternative methods and techniques as well as cost and returns of carrying out treatment measures. These projects are also to be utilized as training ground for field technicians and specialists in various disciplines. Three such projects have already been established and a few more are in the process of being established.

## Research

Lack of research information and lack of results from successful experiences on scientific irrigation farming limit the widespread undertaking of extension programs to aid cultivators in their water use problems. With the launching of intensive agriculture and the high-yielding varieties program, the problem of providing facilities for assured supply of water and its controlled application became more acute. Unfortunately the country had, until recently, no well planned research program on water management to feed the extension organizations with scientific information on water needs of crops, especially the new high-yielding varieties. A team of USA research scientists were asked to study the problem of water management on the farm and to assist in devising an adequate research program. They found water management to be India's neglected technology and recommended intensification of research on water management.

Realizing the importance and the urgency with which studies on water management have to be conducted, the Indian Council of Agricultural Research has chalked out a well coordinated research program by strengthening a few of the existing agricultural research stations as well as setting up new centers. At these locations an accelerated water use and soil management research program has been launched, to provide information on irrigation water use for the important crops of the country under each of the major soil, climatic and cropping pattern complexes.

## Project Planning for Efficient Water Management

In India, many large irrigation systems were built in the past mainly for protective irrigation. Their primary objective was protection against famine. They were not intended to give sufficient irrigation water for intensive farming of the command areas. This approach resulted in gross inefficiencies in the use of available irrigation water supplies. Water was thinly spread over large areas and could not fully meet needs of the crops. These defects are being avoided in the new projects to be constructed.

The irrigation projects proposed by the state governments are sent for approval of the central government. These schemes are scrutinized by the Water Management Division at the center with special reference to agricultural development in the command area. Different aspects, such as suitability of the soils in the command area for irrigation, adequacy of the water supply for the area proposed for irrigation, capacity of canals to carry the supply during peak demand periods, arrangements for land development, provision for construction of field

distribution systems, suitability of cropping pattern proposed, drainage requirements, development of associated infra-structure, etc., are examined in detail before approval is given.

## Water Management in Existing Irrigation Projects

Water use and management in most of the old irrigation projects are unsatisfactory due to several reasons, such as lack of proper water distribution systems at the field level, absence of land development, lack of modern technology for water application methods and schedules, etc. To streamline these projects and make them effective for sustained agricultural production, detailed studies are being undertaken by the Water Management Division in the Union Ministry of Food and Agriculture. Studies are being conducted to locate the shortcomings and the changes necessary in management of the soils, water distribution, application schedules, etc., as also modifications necessary for cropping patterns and irrigation practices. These studies are undertaken by teams of specialists from the division along with concerned state officials. On the basis of such detailed studies, necessary steps are taken by the concerned state governments to improve soil and water management programs.

## Development of National Standards and Specifications

The Water Management Division at the center prepares technical bulletins, memoranda, etc. The following are the bulletins already prepared:

(1) Technical Series - No. 1 (Cylinder Infiltrometer Method for Determination of Intake Characteristics of Soils).

(2) Technical Series - No. 2 (A Guide for Estimating Irrigation Water Requirements).

(3) Technical Series - No. 3-I (Handbook on Irrigation Water Management - "Soil Survey and Land Classification").

(4) Technical Series - No. 3-II (Handbook on Irrigation Water Management - "Soil-Water-Plant Relationships").

National standards and specifications on various practices are prepared and circulated to the state governments, and the central officers work directly through the state officers to see that standards are upgraded. In states where water management pilot projects are established, there is a continuous exchange of technical information between officers of the division at the center and the states. The division assists the states in soil surveys, computation of consumptive use of crops, etc., and also arranges workshops and seminars on technical subjects. The standards and specifications adopted in different states are brought to uniformity through the above measures.

## Carrying Research to the Farmers

Water use and management, in many respects, is a long-term program because of the complexity of supply and disposal programs and because of the technological requirements of a wide variety in climate, soils and crop practices in a country like India. It, therefore, needs great efforts to give momentum to this program, to get its widespread adoption. First of all, it is necessary to create an awareness among administrators, technical workers and farmers, of the importance of water management in irrigation farming. There is also need to disseminate the available technical information among the large number of field workers and farmers. Demonstrations of improved practices are required. Farmers also need assistance in revamping their farm and land for improved irrigation practices. Accordingly, the following information and educational activities are undertaken by the Water Management Division at the center:

(1) Collection and compilation of technical information for field workers' use.

(2) Preparation of information material, such as films and brochures.

(3) Preparation of material for radio broadcasting, putting up hoardings, etc.

The extension program for water management is the responsibility of state governments. The center assists both for development of the program and its implementation.

Water management is included in the package of practices prepared and distributed to the farmers. Technical specifications are upgraded whenever information becomes available through trials, demonstration, etc.

A program for demonstration of water use and management practices is in operation under the "Intensive Agricultural Program." Under this program a number of water use demonstrations have been conducted on private farms. Similar programs in other areas have also been started by the state governments. In some major irrigation projects special programs have been undertaken to improve water management in the command areas.

As a result of water use demonstrations thus conducted, a large number of farmers have started to take interest in adopting improved practices. They are seeking help, both technical and financial, for such improvements on their lands. Some state governments have responded and have launched programs for farmers' assistance in water management. The state of Andhra Pradesh has set up an independent agency for irrigation development. Other states, including Punjab, Maharashtra, Tamil Nadu and Gujarat, have assigned the existing soil conservation agency to undertake the water management program.

Under this program, the work consists of providing irrigation distribution systems beyond the turnouts with control structures, providing separate drainage channels, remodeling the layout of the plots (replacing existing large size bunds and small size plots with large plots and small bunds) as well as land shaping and leveling. As a result of these improvements farmers can irrigate each field independently of the other fields and can turn off water when not needed. Besides, the drainage of the fields is another gain. It also facilitates the use of tractor-drawn equipment for farming operations. In some cases, there are savings of land to the extent of one per cent by reducing the size of the peripheral bunds. Government assistance through loan and subsidy is given for getting this work done.

Where the water conveyance losses are high in states such as Punjab and Rajasthan, lined channels as well as underground pipelines are also constructed for distribution of irrigation water among the farmers.

Agricultural universities in the various states have also initiated demonstrations and extension programs in water management.

## Area Development

It is well recognized that to gain optimum production with irrigation farming, integrated development of the command area is essential. But the crux of integrated area development lies not only in planning for efficient use of the soil and water resources but also in providing all the infra-structure services and necessary inputs. The infra-structure to be built up includes items such as an adequate research base, extension, farmers' education and training, rural roads, storage facilities, marketing and processing and related items. Inputs like credit, seeds, fertilizers, pesticides and agricultural machinery are also to be provided. Accordingly, emphasis has been laid in our Fourth Five-Year Plan (begun in April, 1969) to develop irrigated areas based on the area development approach. Already a few projects in the major irrigation projects have been launched, each of which is about one million acres.

## Training

The improved practices demonstrated to cultivators all need technical skill for planning and execution. The farmers cannot effect these measures on their farms merely by seeing the demonstrations. Thus, the need arises for training the farmers as well as technicians and administrators. The government of India has recognized this and has initiated training of personnel both in this country and overseas. Practical training is given through water use workshops organized for farmers. Special integrated courses are conducted for the field workers and subject matter specialists. Special courses are conducted in agricultural universities for irrigation engineers, agricultural inspectors, etc.

## CONCLUSIONS

One important element in the new strategy for agricultural development in India is attention to water use and management. It has been recognized that along with the use of the high-yielding varieties and high inputs, proper water control and its effective use are vital to achieve high yields. The traditional policy of treating irrigation as protection against

drought has been changed. Water is now considered one of the most important components of agricultural production, and accordingly a policy has been adopted aiming at optimum return per unit of water.

Effective organizations both at the center and in the states are being built to plan and execute suitable water management programs. Pilot projects on a regional basis to better demonstrate modern water management practices have been established, while coordinated research has been planned to feed the extension program. The new appraisal has been integrated development of the command area by provision of infra-structure services and production inputs as well as giving emphasis on effective and efficient use of water resources. Water management in existing projects is being streamlined and in new projects it is seen that the water requirements of the crops are adequately met. Programs to assist farmers in their water use problems, both technical and financial, have been launched by setting up new agencies and utilizing existing soil conservation agencies. Technical bulletins and manuals have been prepared to upgrade technical specifications. Training of farmers, technicians and specialists is also programed. There is still a large gap in the general knowledge and technology required to utilize the water efficiently from the canal systems and the tubewells. This gap has now been recognized and an effort is being made to breech it.

## IRAN

# IRRIGATION AND DRAINAGE PRACTICES APPLIED IN KHUZESTAN WITH SPECIAL REFERENCE TO THE DEZ IRRIGATION PROJECT

by
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## SUMMARY

The main objective of irrigation, whether in arid, semi-arid or humid areas, is to prevent lack of moisture from limiting crop growth. In arid or semi-arid regions, irrigation permits intensive agricultural operations where food and fiber could not otherwise be produced in sufficient quantities. In less arid climates, irrigation can assure the farmer that his crop yields will not suffer from moisture deficiency and that he will obtain maximum benefit from other cultural operations, such as fertilization, pest control and farm machinery use.

Irrigation needs and practices vary widely. A lack of generally recognized irrigation principles of broad application has added to the complexities in planning new irrigation projects or operating existing irrigation systems and irrigated farms efficiently.

The specific irrigation practices required to produce a desired level of crop production will vary greatly from one situation to another. Since water, especially in arid regions, is a limiting and, usually, a costly resource, it is generally desirable to plan irrigation schemes for "efficiency" in terms of maximizing crop yield per unit of water applied to the crop. However, in other cases it may be preferable to maximize crop yield per unit of irrigated land or to maximize crop yield per unit cost of water or labor, or per unit of initial investment in land preparation or the irrigation distribution system. Thus the most desirable irrigation practice varies with the situation and depends on the proper integration of all the factors involved.

The irrigation practices recommended for a given situation should be based on, and designed specifically in accordance with, prevailing water resources, soil, crop, climate, management and economic conditions.

In the Khuzestan plains, where irrigated cropping is practiced by the native farmers on small holdings, primitive traditional surface irrigation methods are applied, depending on the factors involved. This paper details the improved surface irrigation methods applicable to the Dez Irrigation project in the Khuzestan region of Iran.

So far as the water supply is concerned as one

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of the ruling factors in a successful irrigated agriculture, a brief outline of the recent activities toward water resources development of the Khuzestan region will be forwarded.

## INTRODUCTION

Khuzestan province, located in the southwest of Iran, covers an area of 157,000 square kilometers and comprises one eleventh of the country's total expanse. As to climate, this region has mild winters and extremely hot, dry summers, with temperatures reaching 52° centigrade. Precipitation averages 350 millimeters in a normal year, occuring in the winter months.

The geographical location of the Khuzestan, with its access, through the Persian Gulf, to the free ports of the world, its natural resources and the existence of five major rivers — Dez, Karkheh, Karoon, Jarrahi and Hindijan — makes it an ideal place to launch ambitious development programs to serve the needs of the people and to raise their standard of living.

Each year an estimated 35 billion cubic meters of much needed water flows from the rivers, uncontrolled and unused, into the Persian Gulf. At the same time drought problems and shortage of agricultural production have, for many years, prevented the attainment of self-sufficiency in foodstuffs, resulting in the general deterioration of a fertile land and consequent economic decline. The construction of 14 multi-purpose dams on the Khuzestan rivers will harness this water, making possible the irrigation of one million hectares of land and the generation of six million kilowatts of hydroelectric power.

We are well aware that the industrial strength of a nation can develop effectively only when combined with advancement in agriculture. The provision of food has to be safeguarded to meet the requirements of the steadily increasing population of the Khuzestan, now exceeding 2,500,000.

Under the auspices of His Imperial Majesty, the Shahanshah Aryamehr, the government of Iran gave top priority to the development of the Khuzestan region. Prolonged studies and investigations, in cooperation with internationally known agencies, indicated the course of action for a program to revolutionize the agricultural and industrial standing of Khuzestan.

As a first step toward the development of Khuzestan, the government of Iran in 1957 approved the following projects:

(1) The construction of a dam on the Dez river, for flood control, generation of 520,000 kilowatts of electricity, and the regulation of Dez river water for irrigation of the fertile land in the Dez Irrigation project.

(2) Establishment of a high-voltage power line between the major cities of the Khuzestan

(3) Establishment of a sugar cane plantation and refinery.

(4) Extensive fertilizer research in the Khuzestan.

The Khuzestan Water and Power Authority was established in 1960, and was assigned the management and execution of the designed program.

Since initiation of the development, activities on the primary projects have progressed and many phases have been completed. The activities associated with these developments are:

## THE DEZ MULTI-PURPOSE PROJECT

### Mohammad Reza Shah Pahlavi Dam

Construction of the Pahlavi dam on the Dez river (Picture No. 1) was the first step toward achievement of the planned results to derive full benefit from development of the water resources. This multi-purpose arch-type dam, highest in the Middle East and sixth highest in the world, was completed in 1962 and has a potential generating capacity of 520,000 kilowatts.

Prior to construction of Pahlavi dam, the Dez river flow was, at its lowest ebb, 50 cumecs during the summer. This often reached 3,000 cumecs in the rainy season, resulting in serious flood damage and inundation. The Pahlavi dam has served to stabilize the Dez river flow (Figure 1). The 3.3 million cubic

meters of water stored behind this dam can assure sufficient year-round regulated flow for the irrigation of 125,000 hectares of the Dez Irrigation project lands.

## The Dez Irrigation Project

Construction of the Dez Pilot Irrigation project (DPIP), a program to place [illegible],000 hectares of land under modern irrigation practices, began in 1959. Regulated Dez river water was first delivered to DPIP lands late in 1963.

### *Physical Features*

The general topography of the project is formed by several broad alluvial fans extending south from the northern foothills. These fans were formed by minor outwashes from the foothills and by flood deposits of the Dez river and several seasonal water courses. These alluvial fans have been partially eroded by entrenchment of minor streams, tributary to the main river. The slope of agricultural lands, present and potential, ranges from 1.0 to 0.5 per cent at the northern portion of the project down to less than 0.2 per cent in the southern half of the project. Side slope to entrenched drainage channels ranges from one to six per cent for short distances. In a few areas, severe erosion along the channels has rendered such lands unusable except for permanent pasture.

An important characteristic of the project is the widespread flood plains of the three main rivers bounding or passing through the project, namely the Karkheh, Dez and Shaur.

The project is divided internally by a series of north-south drainage ways with broad, low ridges between. The occurrence of fairly well entrenched drainage ways contributes importantly to the generally good drainage of both surface and sub-surface waters, but also tends to require more costly canal construction to serve narrow, elongated irrigation areas.

Two low out-cropping anti-clinical ridges run in a general east-west direction within the project area.

### *Climate*

From mid-June to mid-September, maximum temperatures in the Dez Irrigation project (DIP) often approach 50° centigrade and minimum temperatures drop to 20 to 25° C. at night. No precipitation falls during this period, but dust storms are frequent and dust haze is almost continuous. During August, winds occasionally bring moist air from the Persian Gulf causing hot, humid periods of one or two days. During the fall and spring, the days are fairly hot and the nights cool. Winters are pleasant, but have some rainy periods occuring intermittently from mid-November to early May. Frosts occur occasionally from early December through February. The intensity of the frosts relates to the micro-topography and the lowest temperatures occur in low-lying areas along the main rivers.

Most of the precipitation in the area occurs as rain storms. Hail sometimes occurs in April and May, and causes damage to crops. Wind velocities have been observed thrice daily at the project's agricultural research center at Safiabad, where a meteorological station has been established. During 1966, wind velocities were below four kilometers per hour during 78 per cent of the year, from five to 13 kilometers per hour during 19 per cent of the year, and from 14 to 27 kilometers per hour during three per cent of the year.

The average climatological conditions are summarized in Table 1.

### *Hydrology*

**Precipitation** in the project area occurs as rain and hail, and has been recorded, at the Dezful Climatological station since 1951, at the Haft Tapeh cane sugar project since 1959 and at other stations since the fall of 1961. Monthly precipitation is presented in Table 2.

For the five-year period ending June 30, 1966, the mean annual rainfall was 248 millimeters with the exception of Haft Tapeh. During individual years, the rainfall at each station correlates with that at the others. For the project area, the range in mean annual rainfall is from 111 millimeters in 1964 to 309 millimeters in 1963. Low rainfall in the project area means low rainfall in the mountains and thus a low runoff in the Dez river.

**Water Supply.** *Surface Waters:* The Dez river runoff is characterized by high monthly runoff in the

rainfall and snowmelt seasons of the year, with mean maximum runoff occurring in April, and by a recession period, fairly easily forecast at a date in May, extending to a seasonal low flow usually in October.

The natural discharge of the Dez river is presented in Table 3, prior to and after the Pahlavi dam operation.

The electrical conductivity of Dez river water prior to construction of Pahlavi dam ranged from about 350 micromhos per centimeter (EC x $10^6$ at 25°C.) in April-May to about 800 micromhos per centimeter in the October-November period. Since construction of the dam, the water has been consistently rated as medium in salinity hazard and at all times been rated as low in sodium (alkali) hazard. The calcium and magnesium ions always exceed those of carbonate and bicarbonate, and the water is safe with respect to residual sodium carbonate. The concentration of boron has ranged from 0 to 0.3 ppm and thus is not hazardous.

*Groundwater:* Studies of groundwater movement in the Dez Pilot Irrigation project since 1960, when many wells were installed, showed that water levels increased during the summer rice irrigation season each year, but receded rapidly during the winter months, despite rains and winter irrigation of grain. This annual fluctuation ranged from two meters to nearly five meters in the middle portion of the DPIP, demonstrating the inherent rapid drainability of much of the project lands.

Further evidence of good drainability in the DPIP is demonstrated in the yearly water balance studies made since 1960. These studies show that of the total yearly water input to the project, 36 per cent was identified as deep percolation (primarily from irrigation of rice) and that this volume of water was removed yearly by natural drainage into the water-bearing strata and, hence, to natural channels and finally to the Dez river below the project.

A network of groundwater observation wells was also established in 1965-66 in the project area, in addition to those already established in the DPIP. These wells have been concentrated in potential drainage problem areas, and observations and analyses will continue during the years of project development.

### *Soils*

Soils in the project area are calcareous. Generally, they are free from, or have only slight, salt accumulations. Those soils having salt accumulations are readily leached after drainage facilities have been provided. There are no alkalinity problems. The project water is of good quality and no special provisions are required for salinity control. A salt balance study of the DPIP area for the year ending May 15, 1962, concluded that the area was either in balance or was favorable in salt balance.

### *Land Use*

The gross area within the Dez Irrigation project boundaries is approximately 160,000 hectares. Non-agricultural lands, such as flood plains and river beds, hilly and eroded wastelands, urban development, roads and government installations, constitute almost one third of the area. Of the net irrigable area of about 100,000 hectares, almost all is under cultivation, either dry farmed in some years with winter crops or irrigation farmed with winter and summer crops. The total irrigated farms comprise approximately 65 to 75 per cent of the area. Run-of-the-river water is used for irrigation as a supplement to precipitation. Approximately 20 per cent of the irrigated lands were devoted to summer crops. Because of the lack of double cropping, all of the lands lie fallow during the off-season.

### *Crops*

The principal winter crops are wheat and barley, either dry farmed or irrigated. In the summer, rice is the principal crop, with lesser amounts of sesame and vegetables. The total amounts and type of cropping depend on water availability. Over the greater Dez project, the yields have been generally low, primarily due to low fertility of the soils and the deficiency in the availability of a firm water supply the latter in turn being due to dependence on natural, uncontrolled sources. Also, farming operations remain very primitive.

The Dez Pilot Irrigation project includes 20,000 hectares of the total within the DIP. Since 1963, the DPIP has had a full, regulated water supply from the Pahlavi dam and through the new project canals. Applied agricultural research is conducted at the Field Trial farm at Safiabad. New varieties of crops

are tested and evaluated for their adaptability and commercial feasibility for the region.

Results of the new development were discussed in detail by the Iranian delegate to the Sixth NESA Seminar in 1966.

### *Project Facilities*

**River structures.** A dam constructed on the Dez river, about 4.5 kilometers upstream from the bridge over the river at the city of Dezful will re-regulate the varying release from Pahlavi Dam reservoir, caused by peaking of the power generation. The concrete re-regulating dam is 17 meters high: with an ogee-type spillway, having a low level outlet for releases at a minimum reservoir pool elevation, and six flood gates. The spillway capacity of 6,000 cumecs equals that of the Pahlavi dam spillways. A diversion dam, constructed about one kilometer downstream from the Dezful bridge, will incorporate the existing DPIP sluiceway, diversion canal intake and headworks structure which were constructed in 1963. The diversion dam will also include a spillway 400 meters long, designed to pass the design flood discharge, a right bank sluiceway and a right bank intake structure for the main west canal.

**Conveyance facilities.** Most of the project will be served by gravity from two main canals originating at the diversion dam. The west main canal will serve all irrigation units between the Karkhoh and the right bank of the Dez river. Pump facilities will be provided to serve several small areas which cannot be served by gravity from the west main canal system. The east main canal, built originally to serve the DPIP and the Dahli east areas only, will be enlarged to convey to full water requirements for the east side of the project, except the Dezful bench, which will be served by a pumping plant.

The design capacity of the east main canal is 67.5 cumecs, including the Dahli east area of 12.5 cumecs diversion capacity. The design capacity of the west main canal at the diversion from the Dez river is 146 cumecs, which includes diversion capacities of 33 cumecs for the Haft Tapeh sugar plantation, 16.5 cumecs to be diverted to the Karkheh river and, 12.7 cumecs to the Karkheh flood plains.

## LAND PREPARATION FOR IRRIGATION

Development of the project has been planned in two stages. The lands of the Stage I development program will be prepared for irrigation to the extent required to meet the agricultural production program. This program will consist of the minimum land leveling necessary to provide reasonably uniform irrigation grades, eliminate ponding and obliterate old canals, silt ridges and tapehs. Some land planning will be required to remove the irregularities after the rough leveling operation. The design and construction of the on-farm distribution and drainage facilities are also a part of this program. Shallow soils and topographic conditions in some of the area will preclude land leveling and require sprinkling. A minimal area is to be irrigated by sprinkler irrigation.

Except for 3,000 hectares on the DPIP, the land preparation will be by contract on all lands of Stage I. Work on approximately 1,500 of the excluded 3,000 hectares has been completed. The remaining 1,500 will be prepared by KWPA forces.

The schedule is predicated on the contractor's ability to prepare approximately 1,000 hectares per month. A period of one month per year was assumed to be too wet for leveling operations. A machine efficiency of 80 per cent was used for determining the rate of earthmoving.

## IRRIGATION METHODS

As part of the training course on water regulation and water management, some irrigation tests have been carried out also with the aim to evaluate the border, furrow and corrugation methods.

### Tests

**Irrigation tests of furrows, corrugations and borders.** Tests have been run at Haft Tapeh, Shamsabad and Kutyan (the last two being villages within the DPIP) in 1961, 1962 and 1963, to determine relationships between volumes and rates of irrigation applications; lengths, spacing and slopes of furrows; corrugations and borders; soil textures; and irrigation efficiencies.

Water balances and field efficiencies for furrows, corrugations and borders derived from these

tests are summarized in Table 4. It is evident that field irrigation efficiencies can be achieved in the range from 60 to 80 per cent. Evaluations of irrigation methods as to on-farm efficiencies at the Field Trial farm since 1963 have confirmed this, where proper water control practices and proper land preparation are employed.

**Irrigation tests of puddled rice paddies.** Numerous tests were run on plots and fields of rice in the Dez Pilot Irrigation project in 1962 and 1963. These tests indicated that the water duty to rice under the puddling method was as low as two liters per second per hectare. For the DPIP, however, rice was alloted a field application of four liters per second per hectare, at an irrigation efficiency of 33 per cent and with limited hectarages for any given headgate unit.

In the Dez Irrigation project, Stage I, rice is planned only for areas of very heavy soils; therefore, an on-farm irrigation efficiency of 45 per cent was calculated as being a more realistic percentage, assuming proper land preparation and annual puddling of those soils. Under this efficiency figure, the field application of water is 2.7 liters per second per hectare for rice areas.

## Irrigation Methods Proposed for Stage I

Two methods of irrigation are proposed for Stage I of the Dez Irrigation project to determine land leveling costs. These are the "level bench method" and the "cross-slope method." They are described below:

**Level bench method of irrigation.** It is planned to employ the level bench method of irrigation for rice in the Dez Irrigation project, and for pasture, vineyards and orchards, where soil depth and microtopography are appropriate and costs are within the economic limits of total unit costs allowed for land preparation. Figure 2 illustrates the method and sets forth general criteria. In recent years this method has gained prominence in the desert areas of the southwest United States for several reasons, some of which are:

(1) Provides for more uniform depth of water application over entire fields.

(2) Provides for maximum water depth in furrow for salt control for vegetables and other low-salt-tolerant crops.

(3) With proper water application practices, the method can effect highest attainable efficiencies of surface irrigation and can eliminate tailwater from crops.

(4) With good water depth control and tailwater control, level benches are the most effective surface irrigation method to accomplish periodic deep irrigation for leaching or control of salt balance.

(5) With proper control facilities and border height, benches will retain winter rains, thereby substantially reducing or eliminating surface runoff from prepared areas. General criteria for this method, in addition to those shown in Figure 2 are:

(1) Width of benches between border and risers needs to be sufficient to make use of modern farm machinery on an efficient and economic basis. Where possible, width should be a multiple of widths of cultivation tools, such as combines and mowers (Table 4 A). Width of benches can be increased up to 100 meters where dominant slopes are low. Benches wider than 100 meters will be difficult to level to zero cross-slopes.

(2) Length of benches will be governed by soil type, with the shortest lengths employed on soils with highest intake rates and the longest lengths on heavier soil types. In areas having relative uniform microtopography, where 100-hectare farm units are regular in shape or nearly square, 250-meter lengths provide a logical layout for the farm distribution and drain systems and will provide sufficient length for practical farm machinery operations.

(3) Borders and risers need to be constructed with slopes, to permit easy crossing with farm machinery between benches. Reasonable compaction is required to avoid washouts where dominant slopes approach one per cent.

**Down and cross-slope surface method.** Greater microtopography, shallow soil depths and dominant slopes exceeding one per cent will require the use of the down-slope border irrigation method as shown in Figure 3, for close-growing field crops, and the use of corrugations or sprinklers to establish seed stands.

For irrigation of row crops and especially bed-planted crops such as vegetables, land will be prepared and irrigation systems designed so that such crops can be irrigated on cross-slope grades, as near to optimum grade as is practical.

Border strips will be graded to zero cross-slope between borders and with uniform irrigation grades below one per cent where possible. Borders will be constructed to permit seeding and harvesting of forage crops. The variation in border strip widths will not exceed five per cent of the strip width. Land leveling will be so designed as to minimize point of fill rows when fields are in cross-slope furrows.

**General criteria.** In addition to the criteria specified under irrigation methods, the minimum requirements for first stage land preparation are:

(1) The field unit will be graded, so far as practical, to a single plane, moving the minimum amount of earth. Should a single plane be impractical, due to slope within the field, the field will be graded to several planes to fit the lay of the land.

(2) Fields will be laid out to contain 15 to 20 hectares, with a minimum of 10 hectares. Field layouts will be regular shapes designed to minimize point and fill rows and to provide for efficient machinery operations.

(3) Land leveling earthworks will include the construction of ditch pads, ribbon fills, field access road embankments and excavation of drains. These features will be so constructed as to meet the requirements for ultimate capacity development.

(4) Maximum and minimum grades will vary according to soil texture and irrigation method. The maximum permissible grades for close growing crops such as alfalfa and grains will be two per cent on heavy soils to three per cent on coarse soils. The minimum permissible grades may be reduced somewhat with increases in head of water available and to reduce the length of run.

(5) Permissible grade variations within a run depend on type and conditions of the soil and irrigation method. The maximum change in a grade increasing from top to bottom shall not exceed one-half the initial slope or five per cent, whichever is smaller. The maximum change in a grade decreasing from top to bottom shall not exceed one-fourth the initial slope or three per cent, whichever is smaller.

(6) A construction tolerance of three centimeters up or down from the accepted design grade will be allowed, provided no negative slopes occur.

(7) After the bulk of the rough land leveling is completed, the land will be sub-soiled to a depth not less than 70 centimeters where needed. Borders made for pre-irrigation of the land will be disced and land planed, with towed equipment (not less than 60 feet in total length) sufficiently to obtain a reasonably uniform slope.

(8) The fields will be checked after the land leveling to ensure conformity to the design. Upon completion of the above, the fields may be released for agriculture.

(9) Interior on-farm irrigation systems will be designed to serve each project farm unit. The on-farm systems will be designed for the capacities required for pre-irrigation or for operational flexibility.

(10) On-farm distribution systems will include structures for measuring and controlling distribution of water to fields within the headgate unit, erosion control structures and gate controlled turnouts for field ditches or distributing basins.

## Consumptive Use

The Blaney-Criddle method for determining consumptive use of various crops gives reliable results for this semi-arid area. This method utilized data obtained at the DPIP and at the Field Trial farm at the agricultural headquarters of the project at Safiabad. Additional data from recent studies by the USDA made in the desert areas of the southwestern United States, having very similar climatic conditions, were also used in the re-evaluation of different methods which included Blaney-Criddle coefficients. Consumptive use of some representative crops computed by this method is shown in Table 5.

## Irrigation Efficiency

To date the field irrigation efficiencies achieved by farmers in the DPIP have been low. These low irrigation efficiencies have resulted from such factors as:

(1) Lack of education and proper training of the farmers.

(2) Lack of proper land leveling in most of the area.

(3) Water being supplied in the canal system 24 hours a day whereas irrigators apply water during daylight hours only. These factors will be corrected in a relatively short time after land leveling is completed and better control of water on the fields is made possible and training program on water management implemented. Projected irrigation efficiencies are shown in Table 4 applying new irrigation methods.

## Drainage facilities

The project drainage system will collect and remove all natural runoff. Irrigation return flows and agricultural drainage water will be similarly collected. The drainage system will include a network of collection ditches serving each headgate unit to assure prompt removal of water from the lands.

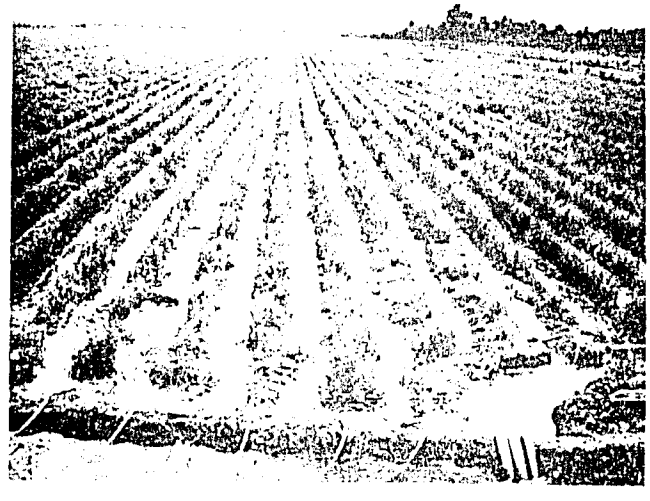
Full utilization of natural channels will be made. Many have sufficient capacity to remove major storm accumulations and are deep enough to serve as outlet channels for open ditch and tile collectors. Where such capacity is not available, necessary improvements will be made. On-farm agricultural drainage will, on the majority of the project, be provided by the open ditches. Increased depth of drains beyond that required for surface drainage, will be necessary in some areas to assure maintenance of a lowered water table.

Tile drains may be needed in certain soils, depending on the cropping, and will be installed as the need arises. Rice is planned in the very heavy soils, eliminating the need for immediate tiling of these lands. If the cropping of the lands is deemed desirable in the future, tile may be placed at that time. Cropping other than rice on some heavy soils is assumed in the early years and tiling of these lands so cropped will only be provided as deemed necessary.

Surface drainage ways and deep drains will be designed to pass the 10-year frequency storm without flooding the fields. Drop structures will be used where required to prevent erosion. All depressions where surface waters might accumulate will be drained. Map No. 4 shows the layout of a headgate unit, fields, on-farm water distribution and drainage systems.

1. Mohammed Reza Shah Pahlavi Dam

2. Old Irrigation Method



3. New Irrigation Method

**Table 1: Climate of the Dez Irrigation Project Area**

| Month | Average Temperature at Safiabad C° | Precipitation Mean of 10 Stations in DIP - mm. | Relative Humidity at Safiabad % | Type (A) Pan Evaporation at S/abad mm | Wind Movement at Safiabad M/Sec. |
|---|---|---|---|---|---|
| Jan. | 11.2 | 60.2 | 73.0 | 81.0 | 1.09 |
| Feb. | 13.6 | 42.6 | 70.0 | 84.0 | 1.20 |
| March | 16.1 | 22.6 | 62.0 | 140.0 | 1.21 |
| April | 20.5 | 28.5 | 56.0 | 179.0 | 1.33 |
| May | 27.6 | 18.8 | 35.0 | 300.0 | 1.34 |
| June | 32.4 | – | 24.0 | 373.0 | 1.36 |
| July | 33.8 | – | 28.0 | 415.0 | 1.28 |
| Aug. | 33.6 | – | 32.0 | 370.0 | 1.02 |
| Sept. | 29.2 | – | 28.0 | 289.0 | 0.98 |
| Oct. | 24.2 | 5.0 | 47.0 | 221.0 | – |
| Nov. | 17.8 | 34.4 | 60.0 | 129.0 | 1.05 |
| Dec. | 12.6 | 39.1 | 72.0 | 84.0 | 1.13 |
| Year | 22.7 | 248.2 | 60.0 | 2665.0 | – |

Table 2: Summary of Yearly Precipitation in Dez Irrigation Project Area Millimeters

| Year Ending June 30 | Andimeshk | Dezful | Ghaleh Sheikh | Shahabad | Ghaleh Nov Ask. | Safiabad | Shush | Boneh Enayeb | Shamoun |
|---|---|---|---|---|---|---|---|---|---|
| 1952 | | 301.0 | | | | | | | |
| 1953 | | 427.7 | | | | | | | |
| 1954 | | 543.8 | | | | | | | |
| 1955 | | 456.5 | | | | | | | |
| 1956 | | 232.0 | | | | | | | |
| 1957 | | 367.4 | | | | | | | |
| 1958 | | 265.7 | | | | | | | |
| 1959 | | 302.0 | | | | | | | |
| 1960 | | 271.5 | | | | | | | |
| 1961 | | 472.5 | | | | | | | |
| 1962 | 295.0 | 262.2 | | 269.5 | 267.5 | 281.5 | 258.5 | 235.0 | 246.0 |
| 1963 | 346.0 | 328.5 | 315.0 | 351.0 | 354.5 | 302.5 | 302.5 | 263.0 | 297.5 |
| 1964 | 125.0 | 115.5 | 110.0 | 125.0 | 104.0 | 85.0 | 85.0 | 96.0 | 133.0 |
| 1965 | 311.0 | 317.0 | 325.0 | 349.1 | 284.5 | 287.3 | 287.3 | 304.5 | 345.8 |
| 1966 | 305.6 | 281.5 | 297.5 | 318.0 | 271.5 | 245.0 | 245.0 | 254.0 | 243.5 |
| Mean 1962-66 | 276.5 | 260.9 | 254.7 | 282.3 | 252.4 | 235.6 | 235.6 | 230.5 | 237.2 |
| Total mean | 276.5 | 328.0 | 254.7 | 282.3 | 252.4 | 235.6 | 235.6 | 230.5 | 237.2 |

Table 3: Natural Discharge of Dez River
(Cubic Meters Per Second)

| Year Ending Oct. 31 | N | D | J | F | M | A | M | J | J | A | S | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dezful Gauges 300m and 375m upstream from bridges | | | | | | | | | | | | |
| 1954 | | | | 453 | 807 | 977 | 626 | 338 | 214 | 141 | 98 | 86 |
| 1955 | 125 | 447 | 267 | 169 | 464 | 508 | 478 | 225 | 137 | 100 | 83 | 89 |
| 1956 | 120 | 163 | 170 | 314 | 459 | 556 | 395 | 238 | 165 | 100 | 82 | 72 |
| 1957 | 71 | 94 | 160 | 290 | 531 | 811 | 841 | 408 | 211 | 128 | 93 | 107 |
| 1958 | 170 | 207 | 261 | 227 | 455 | 362 | 214 | 138 | 91 | 72 | 59 | 52 |
| 1959 | 55 | 294 | 154 | 178 | 401 | 573 | 324 | 182 | 123 | 88 | 65 | 58 |
| 1960 | 64 | 70 | 175 | 108 | 171 | 371 | 294 | 154 | 98 | 68 | 53 | 48 |
| 1961 | 79 | 90 | 497 | 298 | 305 | 483 | 469 | 214 | 136 | 93 | 66 | 58 |
| 1962 | 67 | 109 | 198 | 323 | 195 | 417 | 361 | 181 | 120 | 84 | 62 | 54 |
| SUMMARY OF ULTIMATE WATER REQUIREMENTS FOR DIP IRRIGATION AND OTHER DOWNSTREAM USE STUDY OF 1967 | | | | | | | | | | | | |
| TOTAL | 56 | 49 | 46 | 42 | 96 | 142 | 195 | 237 | 241 | 230 | 200 | 115 |

**Table 4: Irrigation Tests of Furrows, Corrugations and Borders**

| Net Application to root zone mm. | Average Unit Stream requirement, $M^3$/meter width/Min | Gross Application, mm. | Water balance, percent Surface run-off | Deep percolation | To root zone |
|---|---|---|---|---|---|
| (a) Furrows on 0.2 to 0.3% Slope: loam and Clay loam 4.5 mm/hr. basic infiltration rate | | | | | |
| 50 | 0.0120 | 74 | 21 | 11 | 68 |
| 75 | 0.0095 | 103 | 21 | 6 | 73 |
| 100 | 0.0080 | 130 | 19 | 4 | 77 |
| 125 | 0.0065 | 149 | 11 | 5 | 84 |
| 150 | 0.0060 | 185 | 17 | 2 | 81 |
| (b) Furrows on 0.10 to 0.15% Slope: Silt loam and silty Clay loam, 2.5 mm/hr. basic infiltration rate. | | | | | |
| 50 | 0.0075 | 78 | 31 | 5 | 64 |
| 75 | 0.0055 | 120 | 34 | 4 | 62 |
| 100 | 0.0040 | 159 | 35 | 2 | 63 |
| 125 | 0.0035 | 206 | 38 | 1 | 61 |
| (c) Corrugations on 0.7 to 1.0% Slope: silt loam; 4 mm/hr. basic infiltration rate | | | | | |
| 60 | 0.0055 | 94 | 32 | 4 | 64 |
| 100 | 0.0037 | 158 | 34 | 3 | 63 |
| 150 | 0.0027 | 238 | 36 | 1 | 63 |
| (d) Borders of 200-m length; 4.5 mm/hr. basic infiltration rate | | | | | |
| 50 | 0.023 | 64 | 16 | 6 | 78 |
| 75 | 0.016 | 102 | 24 | 2 | 74 |
| 100 | 0.011 | 133 | 24 | 1 | 75 |
| 125 | 0.008 | 160 | 21.5 | 0.5 | 78 |
| 150 | 0.008 | 241 | 38.1 | 0.4 | 61.5 |
| (e) Borders of 200-M length; 4.0 mm/hr. basic infiltration rate | | | | | |
| 50 | 0.020 | 64 | 16 | 6 | 78 |
| 75 | 0.014 | 109 | 29 | 2 | 69 |
| 100 | 0.010 | 150 | 32 | 1 | 67 |
| 125 | 0.008 | 204 | 38.2 | 0.8 | 61 |
| 150 | 0.008 | 324 | 53.5 | 0.5 | 46 |

**Table 4A: Cultivation and Irrigation Methods**

| Crop | Cultivation & Irrig. Methods | Size in meters width - length | Remarks |
|---|---|---|---|
| Wheat | Border | 9.00 x 200 | combine width is 3 meters |
| Barley | Border | 9.00 x 200 | |
| Alfalfa | Border | 9.00 x 200 | |
| Milo | Furrow | 0.75 x 200 | |
| Soy beans | Furrow | 0.75 x 200 | |
| Sun flower | Furrow | 0.75 x 200 | |
| Peanut | Furrow | 0.75 x 200 | |
| Sorghum | Furrow | 0.75 x 200 | |
| Sugar beets | Furrow | 1.00 x 200 | Two rows on one bed |
| Sesame | Furrow | 1.00 x 200 | Two rows on one bed |
| Vetch | Furrow | 1.00 x 200 | Two rows on one bed |
| Kenaf | Furrow | 1.00 x 200 | Two rows on one bed |
| Cotton | Furrow | 1.00 x 200 | Two rows on one bed |
| Vegetables | Furrow | 1.00 x 150 | Two rows on one bed |
| Vegetables | Furrow | 0.75 x 150 | |
| Sudan grass | Corrugation | 0.25 x 200 | |
| Broad beans | Furrow | 0.75 x 200 | |
| Rice | Basin | 3.00 x 4 | Varies |

Traditional method, depending upon the topographical condition of the fields.

Table 5: Consumptive Use of Crops
(millimeters)

| Crops | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food Grains | | | | | | | | | | | | |
| Wheat | 56 | 99 | 144 | 183 | 155 | | | | | | | 50 |
| Rice | | | | | | 110 | 307 | 315 | 225 | 144 | | |
| Food Grains | | | | | | | | | | | | |
| Barley | 42 | 73 | 126 | 150 | 89 | | | | | | | 25 |
| Oats | 42 | 73 | 126 | 150 | 89 | | | | | | | 25 |
| Milo | | | | | | 131 | 343 | 290 | 220 | 104 | | |
| Corn | | | | 66 | 148 | 286 | 320 | 269 | | | | |
| Forage Crops | | | | | | | | | | | | |
| Alfalfa | 66 | 91 | 156 | 192 | 272 | 300 | 284 | 260 | 236 | 150 | 92 | 68 |
| Berseem | 34 | 49 | 67 | 86 | 103 | 81 | | | | | | |
| Pasture | 27 | 37 | 70 | 115 | 201 | 250 | 277 | 252 | 182 | 121 | 61 | 34 |
| Fiber Crops | | | | | | | | | | | | |
| Cotton | | | | 30 | 71 | 142 | 264 | 284 | 200 | 121 | 55 | |
| Kenaf | | | | | | 54 | 135 | 244 | 178 | 92 | | |
| Oil Crops | | | | | | | | | | | | |
| Safflower | 22 | 49 | 108 | 178 | 245 | 109 | | | | | | |
| Soybean & Misc. | | | | | 60 | 112 | 217 | 286 | 159 | | | |
| Misc. Field Crops | | | | 66 | 148 | 286 | 320 | 269 | | | | |
| Edible Legumes | | | | | | | | | | | | |
| Blackeye Beans | | | | | 160 | 270 | 308 | 212 | 113 | | | |
| Broadbeans | 62 | 52 | 71 | | | | | | | | 53 | 56 |
| Peanuts | | | | | 56 | 93 | 162 | 239 | 214 | 113 | | |
| Chick Peas | 60 | 73 | 92 | 99 | | | | | | | 52 | 50 |
| Lentils | 60 | 73 | 92 | 99 | | | | | | | 52 | 50 |
| Sugar Crops | | | | | | | | | | | | |
| Sugar Beets | 57 | 76 | 119 | 162 | 245 | | | | | 77 | 54 | 50 |

(continued on next page)

Table 5: (continued)

| Crops | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green Vegetables | | | | | | | | | | | | |
| Lettuce | 45 | 37 | | | | | | | | 61 | 72 | 51 |
| Onions | 45 | 37 | | | | | | | | 61 | 72 | 51 |
| Tomatoes (Spring) | 29 | 52 | 99 | 126 | 179 | | | | | | | |
| Tomatoes (Fall) | | | | | | | | 128 | 147 | 158 | 76 | |
| Carrots | 45 | 37 | | | | | | | | 61 | 72 | 51 |
| Melons | | 31 | 62 | 111 | 174 | 193 | | | | | | |
| Egg Plant (Spring) | | | | | | | 111 | 178 | 163 | 127 | 69 | 35 |
| Egg Plant (Fall) | 37 | 51 | 80 | 103 | 125 | | | | | | | 23 |
| Cucumbers | 27 | 72 | 110 | 142 | | | | | | | | |
| Asparagus | 45 | 37 | | | 107 | 132 | 144 | 132 | 102 | 61 | 72 | 51 |
| Misc. Vegetables | | | | | | | | | | | | |
| Winter | 45 | 37 | | | | | | | | 61 | 72 | 51 |
| Summer | | | | | 89 | 215 | 246 | 222 | 122 | | | |
| Fruits & Nuts | | | | | | | | | | | | |
| Grapes | 11 | 15 | 30 | 67 | 158 | 220 | 240 | 210 | 128 | 76 | 32 | 14 |
| Citrus | 35 | 43 | 65 | 95 | 158 | 193 | 214 | 197 | 147 | 104 | 61 | 40 |
| Deciduous Orch. | 35 | 48 | 83 | 132 | 240 | 306 | 334 | 294 | 207 | 138 | 71 | 41 |
| Walnuts | 5 | 8 | 22 | 60 | 154 | 250 | 294 | 244 | 144 | 75 | 28 | 9 |
| Woodlots | 39 | 52 | 86 | 132 | 230 | 292 | 330 | 201 | 206 | 138 | 73 | 44 |

Figure 1

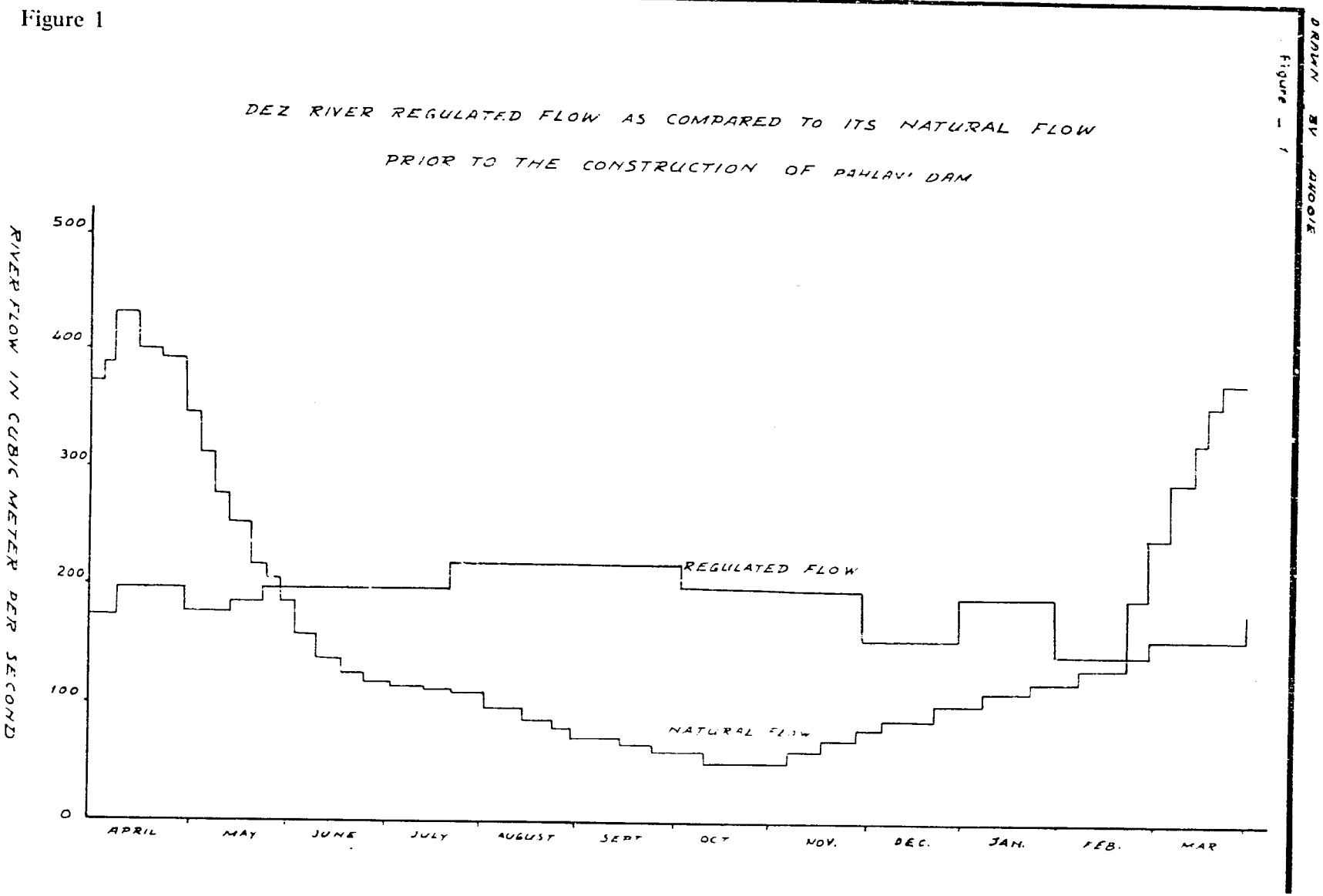



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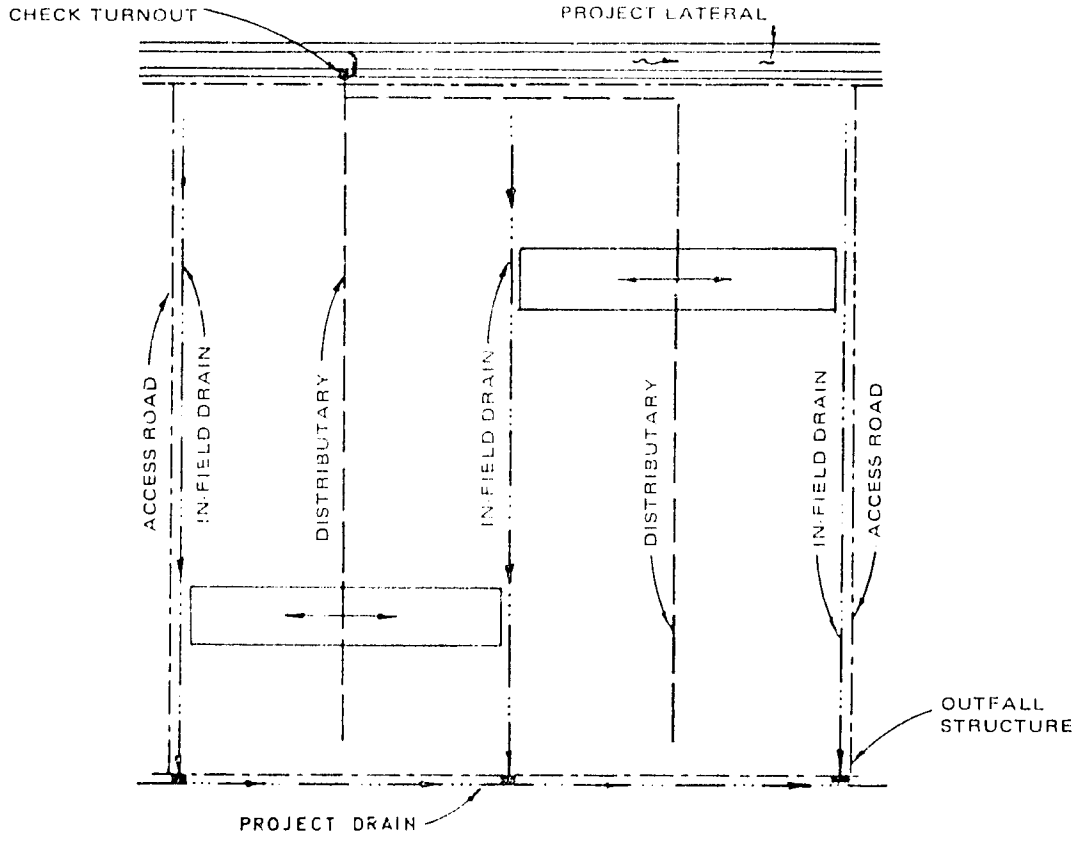
Figure - 1

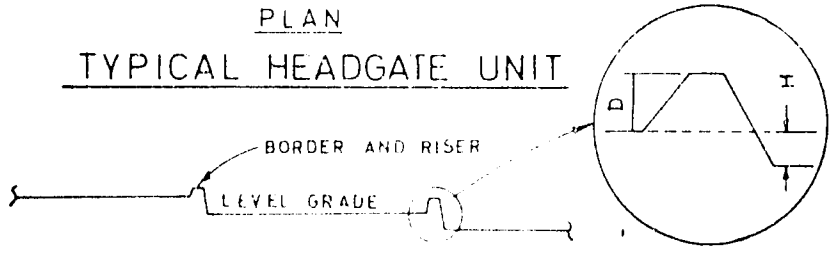
Figure 2

# LEVEL BENCH IRRIGATION




PLAN

## TYPICAL HEADGATE UNIT




## TYPICAL BORDER AND RISER

| DIMENSIONS | | | |
|---|---|---|---|
| DOWNSLOPE | BENCH WIDTH | RISER - H | BORDER - D |
| 1.0% | 30 m | 30 cm. | 30 cm |
| 0.5% | 50 m | 25 cm. | 30 cm |
| 0.3% | 67 m | 20 cm. | 30 cm |
| 0.2% | 100 m | 20 cm. | 30 cm. |
| 0.1% | 100 m | 10 cm. | 30 cm. |

Figure 3

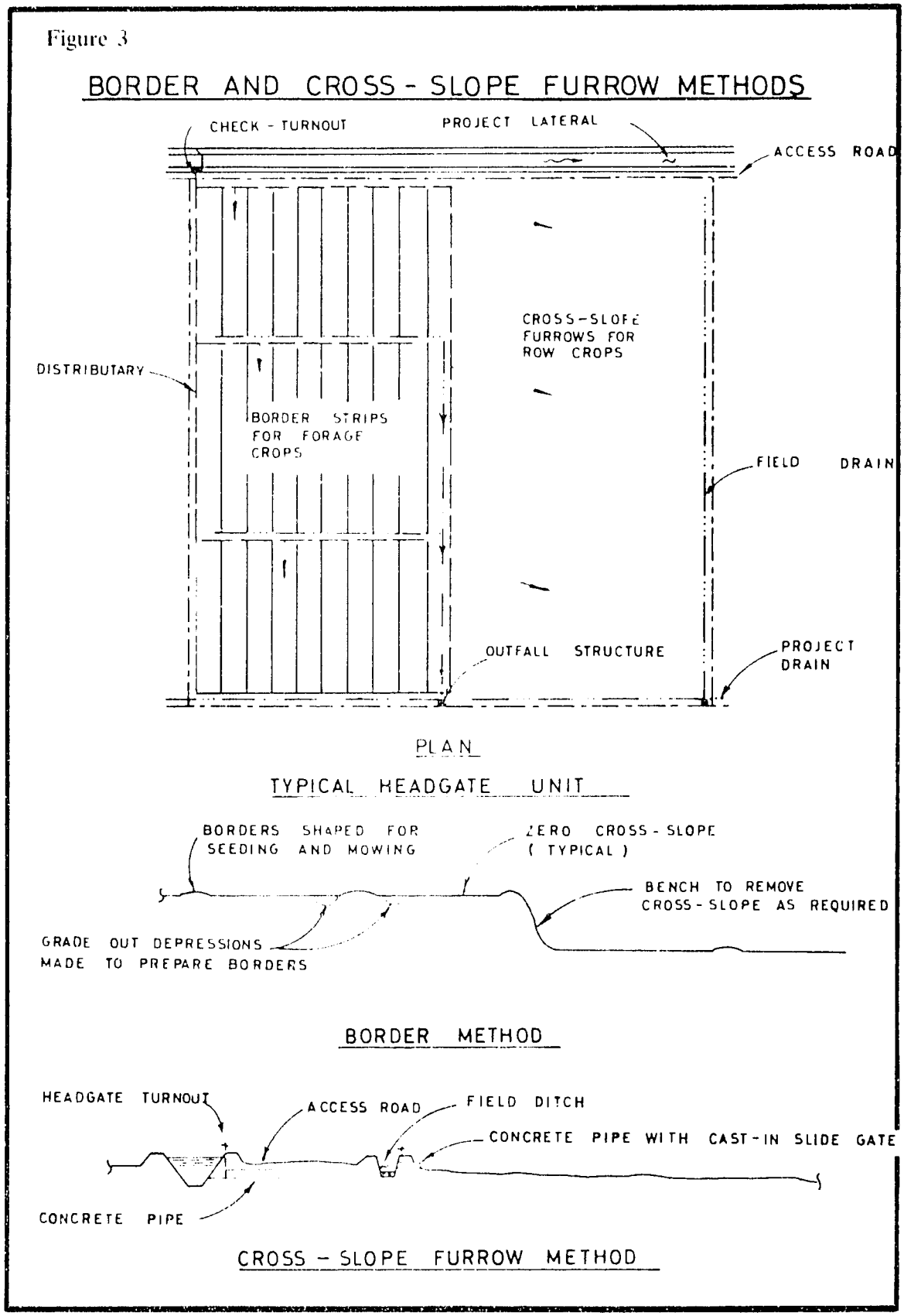



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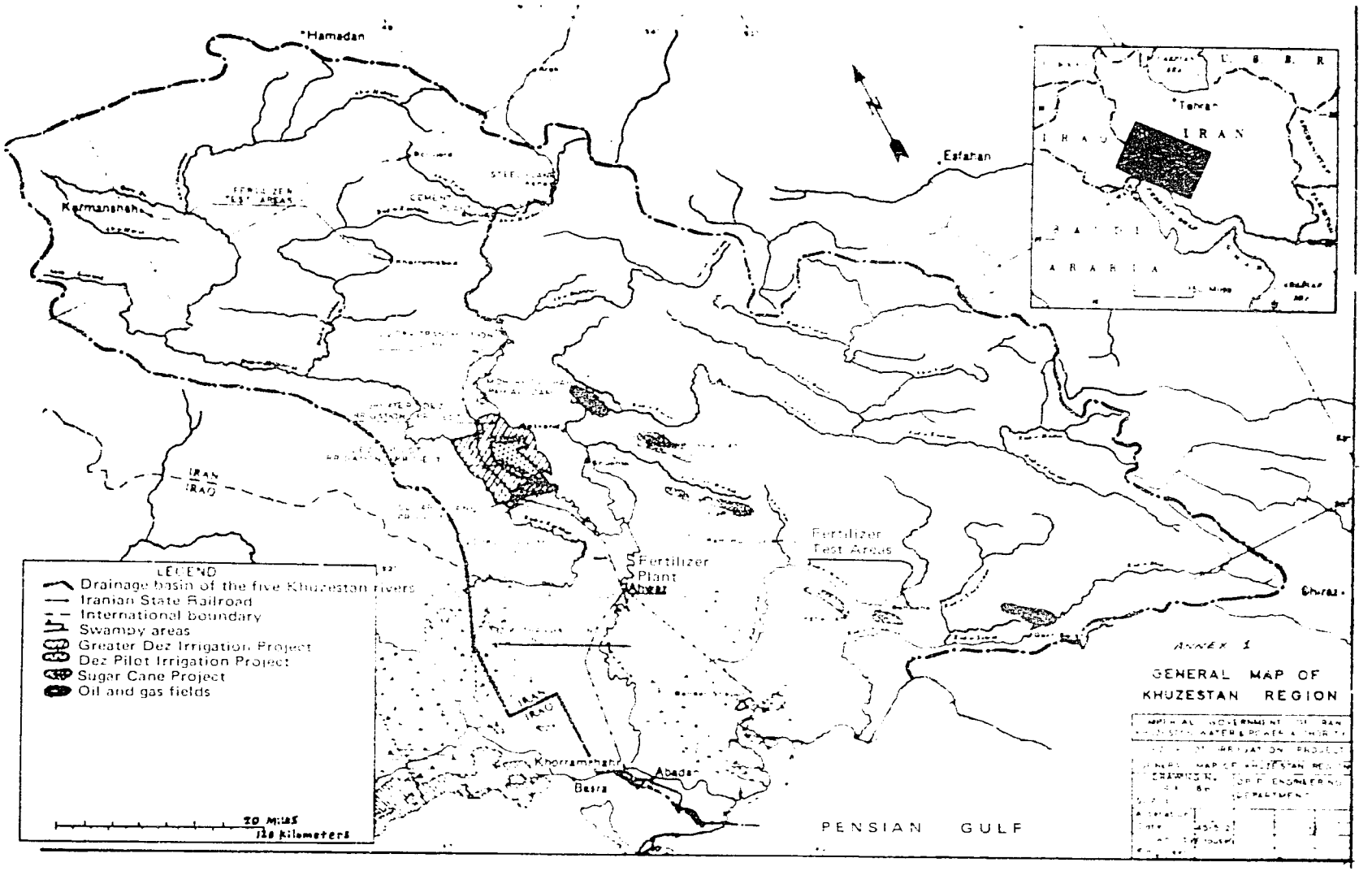
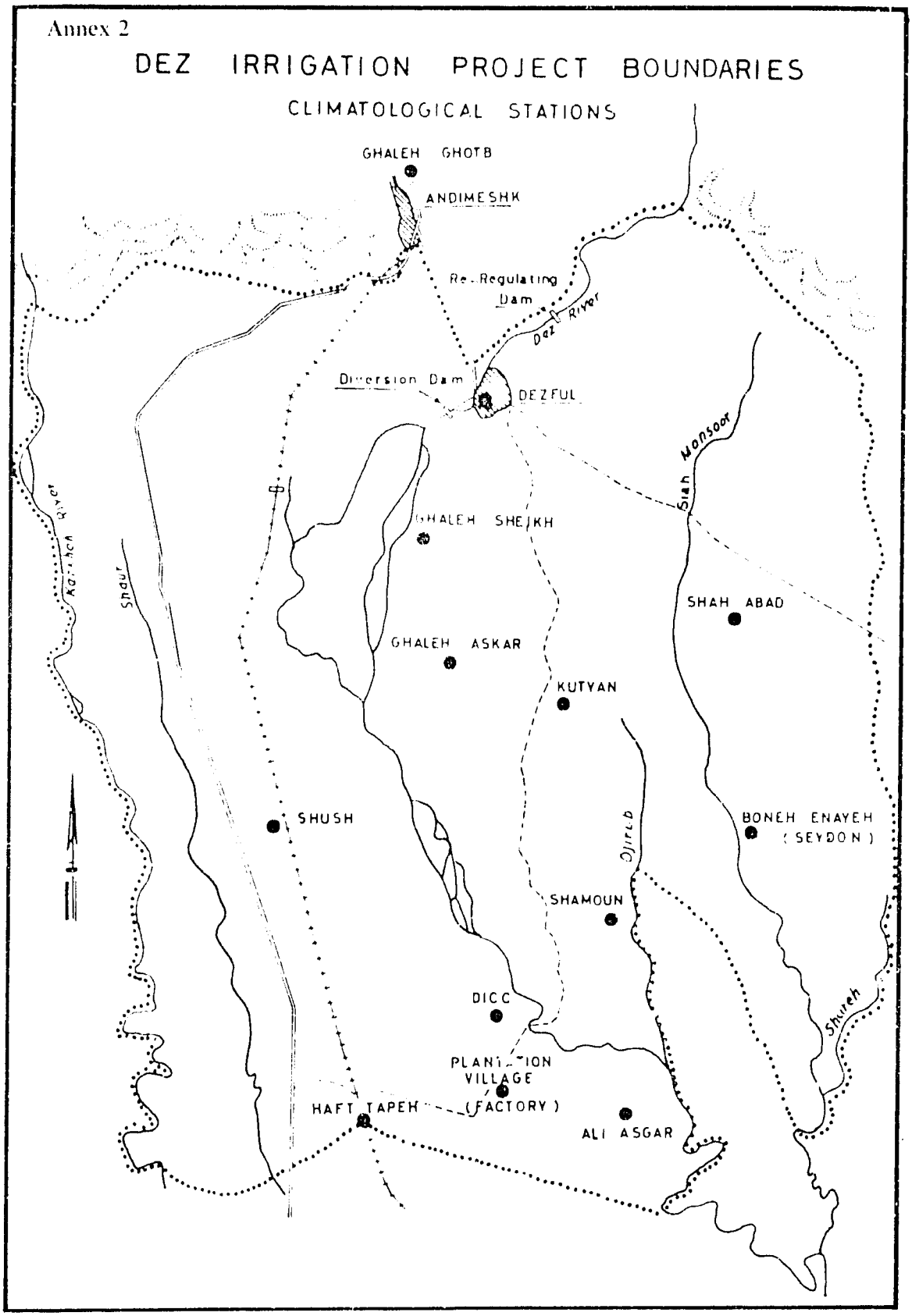
Figure — 3

Annex 1

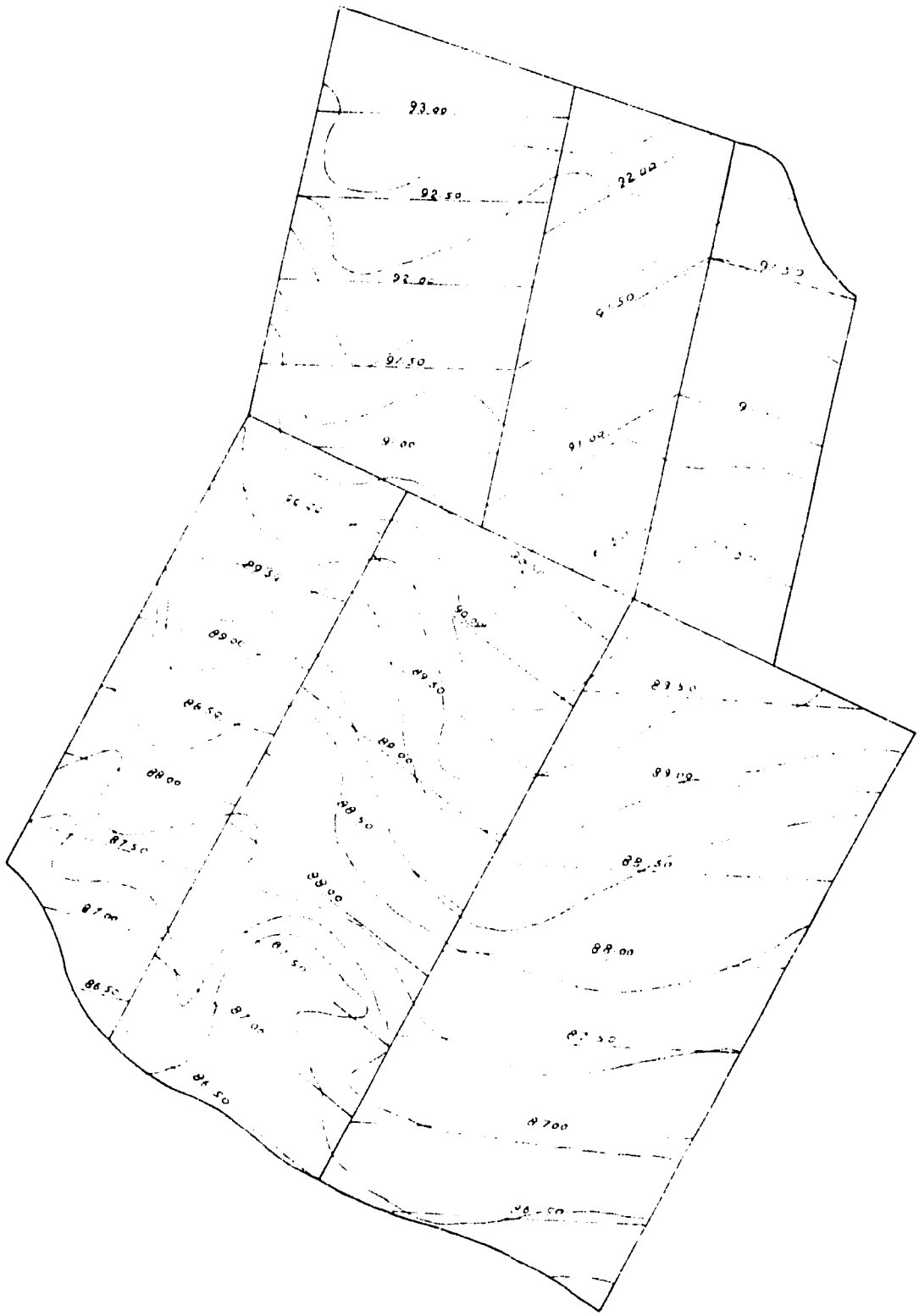

Hamadan
Kermanshah
Esfahan
Tehran
IRAN
IRAQ
ARABIA
U. S. S. R.
IRAN
IRAQ
Fertilizer Plant
Ahwaz
Fertilizer Test Areas
Shiraz
Khorramshahr
Abadan
Basra
PENSIAN GULF
LEGEND
Drainage basin of the five Khuzestan rivers
Iranian State Railroad
International boundary
Swampy areas
Greater Dez Irrigation Project
Dez Pilot Irrigation Project
Sugar Cane Project
Oil and gas fields
20 Miles
120 Kilometers
ANNEX 1
GENERAL MAP OF KHUZESTAN REGION

Annex 2


DEZ IRRIGATION PROJECT BOUNDARIES
CLIMATOLOGICAL STATIONS
GHALEH GHOTB
ANDIMESHK
Re-Regulating Dam
Dez River
Diversion Dam
DEZFUL
Siah Mansoor
GHALEH SHEIKH
SHAH ABAD
GHALEH ASKAR
KUTYAN
SHUSH
BONEH ENAYEH (SEYDON)
SHAMOUN
DICC
PLANTATION VILLAGE (FACTORY)
HAFT TAPEH
ALI ASGAR
Shureh

Annex 3

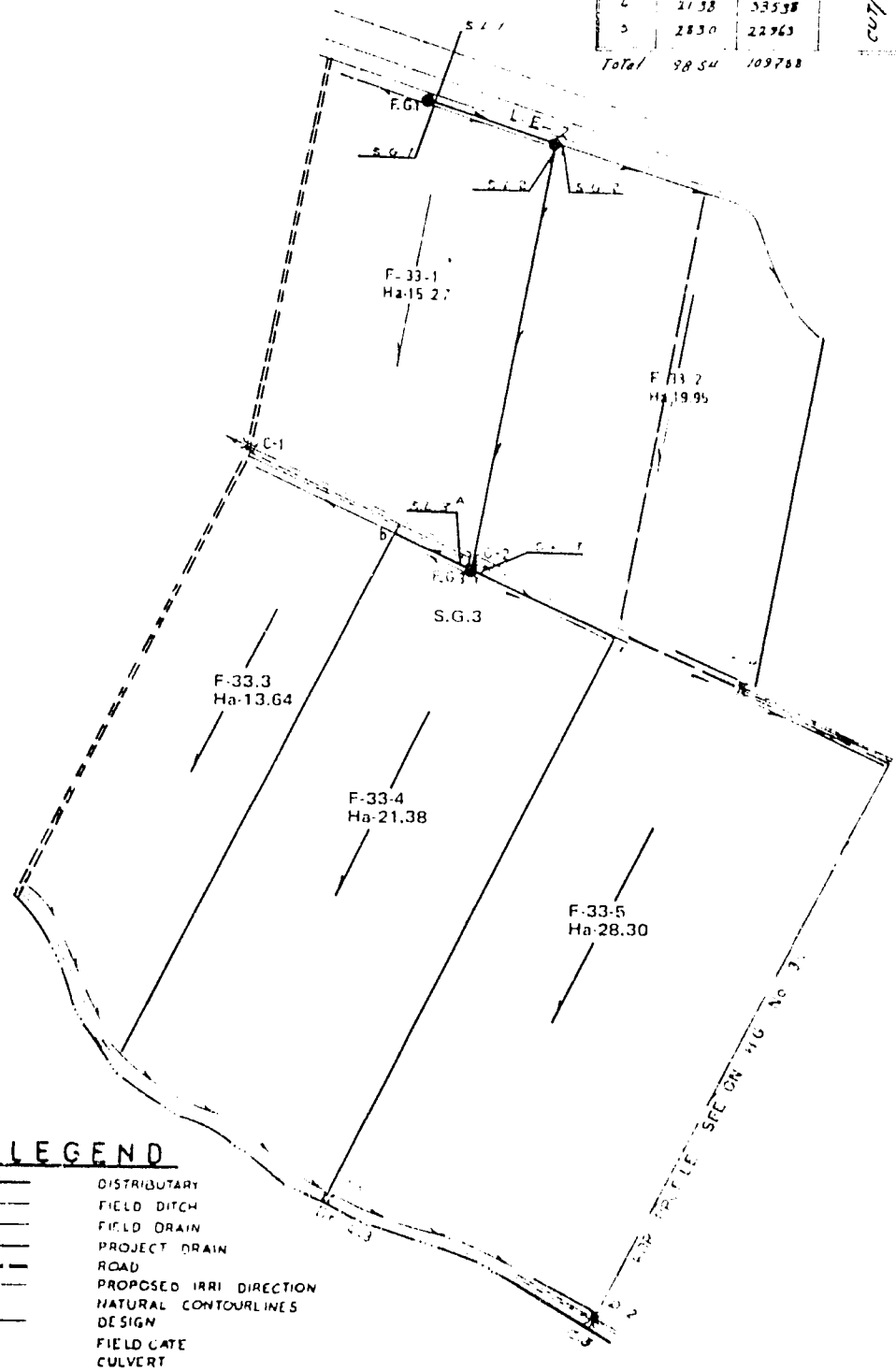
TOPOGRAPHICAL LAYOUT OF A HEAD GATE UNIT



Annex 4

| field No | Ha | cut m3 | Remarks |
|---|---|---|---|
| 1 | 15.27 | 17050 | cut/Ha = 11m |
| 2 | 19.95 | 13838 | |
| 3 | 13.64 | 16369 | |
| 4 | 21.38 | 33538 | |
| 5 | 28.30 | 22963 | |
| Total | 98.54 | 109768 | |

FIELD LAY OUT OF A HEAD GATE UNIT




LEGEND

- DISTRIBUTARY
- FIELD DITCH
- FIELD DRAIN
- PROJECT DRAIN
- ROAD
- PROPOSED IRRI DIRECTION
- NATURAL CONTOUR LINES
- DESIGN
- FIELD GATE
- CULVERT

## IRAN

# IRRIGATION AND DRAINAGE PRACTICES IN HAFT TAPPEH CANE SUGAR PROJECT

by

S. Hajrasuliha, PhD*

## ABSTRACT

Khuzestan is one of the oldest irrigated areas in the world. For many centuries, the Khuzestan was a land of sugar cane. In all this great area there was no place in which sugar cane did not grow. Then the cane disappeared completely. Today, after an absence of nearly 700 years, sugar cane is again being cultivated in the Khuzestan. The sugar cane plantation is in an area called Haft Tappeh. The area receives an average annual precipitation of 260 millimeters (November to May), while the annual evaporation exceeds 2,900 millimeters. Since the Khuzestan rainfall is so scanty, sugar cane cultivation must rely entirely upon irrigation. The source of irrigation water for the area is Dez river. Water is pumped from an intake canal to a primary canal, then is distributed to secondary and tertiary canals, and finally to head ditches where it can be siphoned into the cane furrows. The Dez river water is of medium salinity hazard, and safe as to residual sodium carbonate. The ratio of Ca to Mg, and the concentrations of B, Cl and $SO_4$ are also within safe limits. The furrow method of irrigation, using aluminum siphon tubes to apply water, has become standard practice for the plantation. Based on experimental data and also on results obtained from sheath moisture measurements, different fields may require from 15 to 30 rounds of irrigation during each growing season. An average of 30,000 cubic meters of water is applied per hectare annually.

Most of the plantation soils are heavy, with low organic matter content, low permeability, two to six meters deep, and show lack of structure and profile development. There are also a great many indications of salinity and some alkali spots. Since salt pockets were visible throughout all the area, with some exceptions, and since the water table was rising due to heavy summer irrigation of cane fields, it was of interest to consider an extensive tiling and leaching program.

Open drains were initially used, and effective in lowering the water table. However, because of their disadvantages, they have more recently been used only as main drains of large capacity, to carry off water flowing from the tiles. Tile drains with 80 and 100-meter spacings, depending on the soil differences, work well and lower the water table to within safe limits. In areas of complete growth failure which were subsequently tiled, leached and replanted, cane now grows beautifully. At present over 4,000 hectares of

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the plantation have been tiled, and more than 134 kilometers of open drains and 470 kilometers of tile lines have been installed. Due to the leaching program, the salinity has been reduced to a safe limit for a great number of fields.

## INTRODUCTION

Khuzestan is one of the oldest irrigated areas in the world. Many believe that the earliest settlements of man and his first agriculture were in this vicinity along the foot of the Zagros mountains. The village Shush (Suza) is built at the base of a great mound, comprised of layer upon layer of the dust and debris of civilizations from antiquity. For example, the biblical city of Suza, where Daniel interpreted the handwriting on the wall, has been uncovered by archaeologists who have been working on that particular mound for three quarters of a century. But biblical Suza is not at the bottom of the mound. There were other cities there before that time (5). Sometime in the twelfth century BC Haft Tappeh was known as Elkar. (4). The size of this great city was more than 600 hectares. An archaeologist told me, "It will take us over 500 years to uncover the whole city."

A series of 14 dams in all the rivers of Khuzestan province has been proposed by consulting agencies. Construction of a high dam on the Dez river and irrigation of more than 120,000 hectares of dry land in the Dez project area are steps forward to a return of prosperity in the area. There is possibility for a new foundation in this area, for a future civilization that may again bloom as did its predecessors under Cyrus, Darius and Xerxes, and again hundreds of years later under Shapur I and his Sessanian successors and again after the Islamic era. The historian Al Istakhri wrote, in the twelfth century AD (6), "I have traveled on the river Karun by way of Ahwaz . . . of its waters, not a drop is lost, and it is all used for watering groves, grains and sugar cane fields. In all this great area there is no place in which sugar cane does not grow."

For many centuries, the Khuzestan was the land of sugar cane. Then the cane disappeared completely. One may ask himself, why did this disappear? Great water projects have failed in the past for one or a combination of the following reasons:

(1) Lands have become salty due to lack of knowledge in soil and water management. Khuzestan is not the only place in the world encountering saline soils. Many of the best agricultural lands of the ancient world lost their productivity due to accumulation of salts in irrigated soils. This problem has been disastrous for these areas, and many of the great empires of ancient times have vanished. Many glorious civilizations were destroyed, thousands of towns and villages died; happy rich farmers turned miserable, the population of humans and animals decreased, and the plant population was confined to a few salt resistant species.

(2) Complex water systems have been disrupted, by earthquake and/or invasions, and the service areas have dried up.

(3) Irrigation canals have filled by siltation.

(4) The elaborate institutions needed to operate and maintain the complex water system have been destroyed or have broken down, the project area fallen into ruins, and the people driven off or starved out.

Many believe that the project or irrigation systems that supported the ancient civilization in the Khuzestan plain fell into disuse because the human institutions that managed them were destroyed. Khuzestan has suffered 13 invasions since the time of Alexander. Perhaps there simply was not enough energy or engineers in the surviving population to cope with the problems then confronting the people of the area.

Today, after an absence of nearly 700 years, sugar cane is again being cultivated in the Khuzestan. To accomplish this, irrigation was introduced, a modern drainage system was established, and salty areas were leached.

### Area and Climate

**Location.** The Haft Tappeh sugar cane plantation is in the Khuzestan plain, 45 kilometers south of Dezful near the biblical city of Suza (Shush), latitude 32°04'N, and longitude 48°21'E, between the Karkheh and Dez rivers. The elevation above sea level is between 43 and 82 meters. The present plantation has an area of 10,000 hectares, from which a little over 5,200 hectares have been put under cultivation. The area under cultivation will be doubled by the year 1972.

**Rainfall.** The average monthly rainfall from 1961 to 1969 at the central weather station is given in Table 1. The data indicate that most of the rainfall occurs between November and April, and for nine years no precipitation has been recorded for July, August and September. Most of the rainfall occurs during the harvest. On the other hand, very little precipitation occurs during the growing season.

**Temperature.** The average monthly maximum and average monthly minimum temperature at a weather station in the center of the plantation is presented in Table 1 for the years 1961 to 1969. Data on absolute temperature show extremes of 52°C and -7.3°C for July and January, respectively.

**Relative humidity.** The average daily maximum and minimum percent relative humidity for the central weather station from 1961 to 1969 is presented in Table 1. The data show a daily average maximum percent relative humidity in December; whereas the minimum falls to nearly 14 during May to October.

**Evaporation.** The average monthly pan evaporation from 1961 to 1969 is presented in Table 1. Figure 1 shows that pan evaporation reaches a peak in the months of June and July when the amount of rainfall is practically zero. The average pan evaporation for nine years has been 2,900 millimeters.

**Sunlight.** The average daily radiation from 1961 to 1968 was 447 gram calorie/cm$^2$ day at Haft Tappeh. However, the daily range was 203 in January to 692 in June. Sunlight data for the years 1961-68 are given in Table 1. Although the energy reaching the earth is low in some winter months, fortunately during the growing season (May, June, July, August and September), sunshine is very ample.

## IRRIGATION PRACTICES

As mentioned before, the area receives an average annual precipitation of 258 millimeters (November to May), while the annual evaporation exceeds 2,900 millimeters. Since the Khuzestan's rainfall is so scanty, sugar cane cultivation must rely entirely upon irrigation. As the growing season is in the hot, dry summer months, large-scale cultivation would not be possible without a substantial increase in normal flow of the Dez river during this critical period. This increase became possible by construction of the high Dez dam.

To minimize the complexity of the subject it is convenient to describe different aspects of irrigation practices separately.

### Source of Irrigation Water

The plantation's comprehensive irrigation systems takes water from the Dez river by means of a simple diversion structure leading into an intake canal 650 meters in length, having a capacity of 12 m$^3$/sec. From here the water is lifted about 14 meters by 10 diesel pumps, each having a capacity of about 90 m$^3$/min., to the primary canal that swings across the plantation in a rough semi-circle from the northern boundary to the southwestern corner of the project lands. The length of the primary canal is about 13 kilometers, of which 2.6 kilometers have been lined. There is an irrigation canal about 2,500 years old, constructed at the time of Emperor Darius. About 800 meters of this have been put to use as a part of the primary canal. Despite the accumulated silt of centuries of idleness, in some areas the Darius canal is still 20 meters deep and 100 meters wide at the top. The Darius canal is about three kilometers in length today. At one time it formed part of a canal 80 kilometers long, which carried water from the Karkheh river at Pay-i-Pol southward to the Shahour river area. The diversion works on the Karkheh river are still visible today, but most of the canal itself has long since been filled in and plowed over for agricultural use.

Secondary canals carry water to all parts of the plantation. The length of the secondary canals is 31 kilometers, of which 3.4 kilometers have been lined.

Tertiary canals carry water from the secondary canals to the supply ditches, where water is siphoned to the irrigation furrows. The length of the tertiary canals is 39 kilometers, of which 22 kilometers have been lined.

### Quality of Dez River Water

The Dez river water is of medium salinity hazard, but can be used with no danger if the fields are adequately drained so salt does not accumulate (8). The ionic concentration of Dez river water varies

throughout the year and is usually higher in the winter and lower in the summer. Table 2 indicates the analysis of Dez river water throughout the year 1967. The average electrical conductivity (EC x $10^6$) for the year 1967 was 650 micromhos per centimeter, with an SAR of 1.5, placing it in the $C_2S_1$ class (8). $S_1$ water implies no sodium hazard, while $C_2$ water implies medium salinity water. Since over-irrigation is practiced at Haft Tappeh for salt balance, there should be no problem with continuous use of Dez river water for irrigation. The sum of the Ca and Mg ions exceeds that of the carbonate and bicarbonate ions, placing the water in a safe category as far as the "residual sodium carbonate" is concerned (8). The ratio of Ca to Mg, and the concentrations of B, Cl and $SO_4$ are also within safe limits, and thus are not hazardous.

## Methods of Irrigation

The furrow type system of irrigation, using aluminum siphon tubes for applying water, has become standard practice at Haft Tappeh plantation. Generally it is well developed and quite satisfactory. Irrigation furrows 1.5 meters apart and 40 centimeters deep are used, and the irrigator irrigates 18 to 90 lines at a time, depending on the slope of the head ditch. Early problems with grade and length of furrows have been overcome with experience, improved land leveling, and better field layouts. Through training and experience, both irrigators and supervisors have developed an ability. For uniform application of water, land is leveled with irrigation furrows laid on a slope of 0.025 per cent to 0.05 per cent depending on length of furrow.

Farm hydraulic structures and portable devices for uniform distribution of water in the field (their functioning and results of performances) are as follows:

(1) Portable frames for canvas checks (Figure 2) are used in irrigation head (supply) ditches to raise the water surface siphons or to control the flow.

(2) Removable checks fabricated from 200 liter oil barrels (Figure 3) are removed for harvesting operations and are placed again in the head ditch at the beginning of the irrigation season.

(3) In slopes where erosion occurs in the head ditch, concrete check-drop structures with a steel plate gate have been installed (Figure 4). They work very well, however, they do create problems for harvesting.

(4) Aluminum siphons, 5.0 and 7.5 centimeters in diameter, are used to convey water from the head ditch (Figure 5) to the irrigation furrow. It is common practice to employ crews of two to three men to each head ditch. Two laborers at the head construct canvas checks in the ditch and install siphons, while the third man works near the end of the furrows and signals for removal of siphons as the water approaches the end of the lines.

## Amount of Water Used for Irrigation

The total amount of water pumped annually is over 200 million cubic meters, from which about 150 million cubic meters is used for pre-irrigation, irrigation and leaching. Sugar cane is very sensitive to high soil moisture tension. Tensiometers installed in the cane plots, at a depth of 45 centimeters, indicated that sufficient water was taken up during the hot summer months as long as soil tension did not exceed 0.25 atmosphere. Though the use of tensiometers furnishes a good check on the requirements of irrigation, the routine two-week sampling of sheath moisture (crop logging) gives a fairly good picture of the moisture status of the cane plant and is a relatively good method in setting intervals of irrigation at Haft Tappeh.

Measurements of water flow, by parshal flumes, in a number of strategically located areas in the Shush and elevated Haft Tappeh soil series, show that an average of 1.5 centimeters of water per day is given from approximately the first of April until the last round before harvest.

An irrigation experiment was conducted in field 311 during the months of May to October 1965 to evaluate the applications of 0.5, 1, 1.5 and 2 centimeters of water per day. Treatments were replicated four times and the size of each plot was approximately one-third of a hectare. Data given in Tables 3 and 4 show that the effect of inadequate irrigation was considerable. There was 14 per cent more growth in 1.5 and 2 centimeters over 0.5 centimeters and 6x per cent more growth over the 1 centimeter treatments.

Unfortunately most of the rain in Haft Tappeh falls during the winter months, when the growth of

cane is very slow. Frequent irrigations are needed during the period when weather is hot, growth is fast and the rate of evapotranspiration is highest. Based on results obtained from sheath moisture measurements, different fields may require from 15 to 30 rounds during each growing season. In each round 1,200 to 1,300 cubic meters of water per hectare is applied. As a result, an average of about 30,000 cubic meters of water is applied per hectare annually. Considering the average yield of sugar per hectare to be 12.4 tons, about 2,420 liters of water are applied to the field, for the production of one kilogram of refined sugar.

## SOILS, DRAINAGE AND LAND RECLAMATION

### Soils

In general, three soil series have been recognized in Haft Tappeh plantation, as shown by Figure 6. These are:

(1) The Shush series located at the northern section of the plantation, running eastward from field 400 to field 122.

(2) The Haft Tappeh series, comprised of fields at the south, running eastward from field 403 to 413 and to some extent 309, 310, 311, and 125.

(3) Fields 130, 131 and 132 are flood plain soils where gravel can be found two to three meters below the ground surface.

Most of the soils of the Haft Tappeh plantation are heavy, with low organic matter content, two to six meters deep, and lack of profile development. A mechanical analysis of soil samples, collected from 0 to 50 centimeters depth from selected fields, is presented in Table 5 and shows that Shush series are silty clay loams and clay loams, whereas the Haft Tappeh series are loams, and silt loams, and the flood plain soils are mostly loam.

Due to a high clay content, low organic matter, and lack of structure, the permeability of most of the soils in the plantation is low. Table 6 shows the hydraulic conductivity and the permeability of several soil profiles in the plantation.

Although there are some nonsaline-nonalkali soils in the plantation, a great number of the soil samples of the plantation are saline. The electrical conductivities of the saturated extracts of a large number of soil samples are above the range of the tolerance of sugar cane (Table 7).

Determination of cations and anions in saturated soil extracts, taken in April 1961 from several locations in fields 250 to 252, are given in Table 8. The depth of samples was approximately 45 centimeters.

There are also some saline-alkali spots present in the plantation. Exchangeable bases, determined on samples taken at different depths from several fields, indicate the presence of alkali spots in the plantation (Table 9).

### Drainage

Soil surveys of 1958 indicated the existence of a water table in the Shush soils at 1.5 meters below the soil surface; also water analysis showed that the water at this level and below was salty, and thus, undesirable for domestic or irrigation supplies. The high salt concentration of the soil and underground water in this area seems to have the following origins:

(1) Parent materials high in salt were laid down in the bottom of ancient seas in early geological ages and/or were transported by water and deposited in the area. Under weathering of these materials, soluble salts were formed in the place.

(2) Soluble salts were transported from higher locations to the lower drainage area where the water evaporated and the salt accumulated.

(3) Irrigation of poorly drained lands in the past followed by evaporation from the soil surface and transpiration from the plants caused the salt to be accumulated in the area.

(4) Transportation of some salt by dust storms and deposition to the area caused high salinity.

It seems that among the above mentioned factors, irrigation in the past had a fairly good share in salinizing the poorly drained, lower lands of this area.

With the water requirement of sugar cane being relatively large, continuous irrigation under conditions of high water tables and salinity would ultimately cause the area to become virtually unproductive, especially if no effort was made to provide drainage. Since salt pockets were visible throughout all the area, with some exceptions, and since the water table was rising due to heavy summer irrigation of cane fields, it was essential to consider an extensive tiling and leaching program.

**Open drains.** These were first considered as a means of lowering the water table, because drainage ditches are relatively cheap to construct, particularly where drains of large carrying capacity are required. Open drains were installed in 1962 in field 106 at 150, 200 and 300 meters spacing and at 1.75 meters depth. These drains, with a slope of 0.2 per cent, were connected to a main drain 2.5 meters deep. The actual measurement of water table was at 0.75 to 1.0 meter at midpoint between drains, which was very helpful. However, ditches require regular maintenance to remove weeds, rubbish, and soil which has sloughed or eroded into them. Another disadvantage of open drains is the area they occupy, and they are likewise a danger and inconvenience in farm operations. For these reasons open drains were later constructed to a depth of three to four meters only as main drains of large capacity, to carry off the water flowing out of the tiles (Figure 5).

**Mole drains.** An experiment with mole drains in 1962 proved them to be unsatisfactory as a means of underground drainage. The drains collapsed in project soils.

**Tile drains.** In the summer of 1963 the present system of installing tile drains, at approximately two meters depth, was initiated. In areas where complete growth failures had occurred and which were subsequently tiled, leached and replanted, canes grew beautifully. To select a reasonable spacing between the tile lines, the formula $S = \frac{4P(b^2 - a^2)}{Q}$ was used (2). Where:

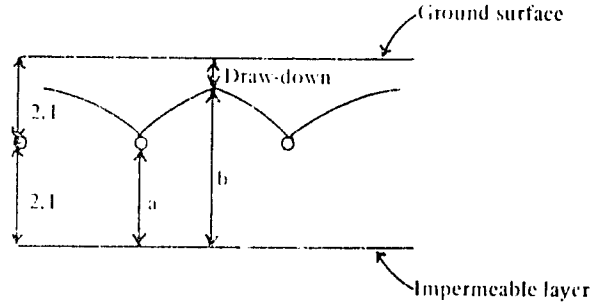
S = Spacing of the tile lines.

P = Co-efficient of permeability, gallons/ft$^2$/day.

a = Distance from the average tile depth to barrier stratum (feet).

b = Distance from draw-down curve to barrier stratum at the midpoint between the tile lines (feet).

Q = Quantity of water discharged from one tile line in gallons per day per foot of tile line.




Assuming:

Q = 0.0272 gal/ft/day or 10 per cent of the water applied to the field. Depth of tile line = 2.1 meters = 6.89 feet.

a = 2.1 meters = 6.89 feet.

b = 3.2 meters = 10.5 feet, for a one-meter draw-down.

P = 0.05 gal/ft$^2$/day*.

To obtain a one-meter draw-down, S was calculated at 102.9 meters. So the initial spacing of tile lines in Shush soils was selected at 100 meters. Since it takes local experience as well as trial and error to design a successful drainage system (5), tiling was installed in field 251 and field 115, with a spacing of 100 and 80 meters respectively. This was to compare water table levels at the two tile line spacings. As indicated by Figure 8, the 80-meter spacing improved draw-down considerably, so that the water table was kept at least one meter from the ground surface during the summer, and dropped to below two meters late in August. Although draw-down was improved after tiling at 100-meter spacing, the water table fluctuated between 0.25 and 1.0 meter during the irrigation season and did not fall to the two-meter level until late in the season when irrigation rounds were stopped. One reason for this

* This value was suggested by Donnan (3) for silty clays and may be applied to Shush soil series.

discrepancy may have been the seepage from the adjacent irrigation ditches. Consequently, an 80-meter spacing has been scheduled for Shush soils since 1966. This permits the drawdown level to fall below 1.75 meters at harvest time.

Tiles are made of fired clay, are 40 centimeters long, and are butted together to form a continuous buried pipe line within a 10-centimeter envelope of gravel at a slope of 0.2 per cent. The joints are not sealed, and a crack spacing of 1.6 to 3.2 millimeters permits the entrance of water into the tile line. On lines shorter than 300 meters, tiles with a 5-meter of 10 centimeters are employed. When the tile line has to be longer, e.g., 500 meters, 15 and 20-centimeter diameter tiles are employed. Figures 9 and 10 show typical tile drainage installation.

## Land Reclamation

At the start, as mentioned before and indicated in Table 7, 42 per cent of the plantation's soils had EC x $10^3$ over 2. After approximately six years of leaching and irrigating, salinity was reduced in the Shush and flood plain soils, which were either artificially or naturally drained. However, the salt content of Haft Tappeh soils increased because drainage was insufficient to cope with the slope of the land. This shows that a proper drainage system is required before any leaching program is initiated.

Preliminary studies on soil salinity have shown a marked reduction in cane yield when electrical conductivity of saturated extract of the soil exceeds three millimhos/cm. The effect of salinity on yield of sugar cane is shown by the following figures:

| EC x $10^3$ | TNC/Ha | No. of plots |
|---|---|---|
| < 2 | 101.9 | 7 |
| 2.1-3 | 92.0 | 6 |
| 3.1-4 | 76.0 | 6 |
| 4.1-5 | 64.9 | 10 |
| >5.1 | 48.2 | 31 |

Earlier investigations in the Khuzestan (1) indicated that soils of the area could be leached and the total soluble salts reduced from unsafe to safe levels without any need for drains if the water table was below five meters. Dez river water, which has a low SAR value and a high Ca + Mg content (Table 2) was used for leaching purposes. Field 130 was selected for the leaching studies. No drainage system was established for this field. The average soil conductivity for the area was 14.85 millimhos/cm and the piezometers indicated no water table.

A total of 230 centimeters of water, applied during a period of 25 days, caused EC x $10^3$ to drop from 14.85 to 2.27 millimhos/cm in the first meter of soil depth. Before leaching, growth failure of cane occurred in portions of this field, whereas a very fine crop was produced after the field was leached.

Unfortunately, as mentioned before, a great majority of fields in the plantation have slow permeability and poor internal drainage. Obviously, under such conditions, leaching of excess salt was not possible and, as a result, establishment of a modern drainage system was necessary. Heretofore, as also mentioned before, open drains were installed in field 106 (area 78 hectares) at 150, 200 and 300-meter spacing and at 1.75-meter depth. The actual water table at midpoint between drains spaced at 150 meters was at 0.75 to 1.0-meter depth.

Complete analyses of waters were made to determine the relationship between the salt deposited by irrigation and that removed by the drains. A total of 169,000 $m^3$ of water was applied in 10 rounds from July to October 1962, and more than four times as much salt was leached out as was brought in by the irrigation water (Table 10).

Another leaching experiment was installed in field 118 $B_2$ (area 15 hectares). Tiles were placed at a spacing of 100 meters. Approximately 410 centimeters of water was applied in 180 days. Table 11 shows a considerable decrease in salt content in the first meter of soil depth.

After the above successful experiments were terminated, a leaching program was established for the plantation as a whole. At the beginning, the criterion for leaching was based on an average EC x $10^3$ 4. As increases in yield were reflected on leaching excess salt, standards were raised to an average of 3.0 mmhos/cm. Soil samples are taken from 0 to 50 centimeters and although the soil survey is still conducted on an 80-meter grid, it is changed to a 40-meter grid if the salinity conditions are very different in the area and some portions do not require leaching. To estimate the salinity condition of the field under leaching without any need for drying

them, the effluent at the outlets of tiles are sampled for analyses, continuously. When the average conductivity of the effluent water reaches three or less, leaching is discontinued. Soil sampling after drying has shown that the above method is a relatively good measure for estimating the salinity status of the soil, even though salt diffusion from a depth below the tile lines into the tiles may occur.

On the average it takes about 300 centimeters of water and 80 days to correct the salinity of Shush soils, while it takes less water with an average of about 25 days for correction of salinity of flood plain soils.

At present, over 4,000 hectares of the plantation have been tiled, and in excess of 134 kilometers of open drains and 470 kilometers of tile lines have been installed.

Since the start of the project in 1961, tremendous improvement has been achieved. Yield of cane has increased from 77.4 to 120.4 tons per hectare. Much of this success must be attributed to the work done in drainage and land reclamation as well as intensive research in crop-logging and soil-water-plant relationships.

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Table 1: Climatological Data for Central Weather Station, Haft Tappeh Cane Sugar Project.

| 1961-1969 | Rainfall (mm) | | Daily max. temp. (°C) | | Daily min. temp. (°C) | | Daily %RH | | Daily pan evaporation (mm) | | Radiation * (g cal/cm²/day) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Range | Ave. | Ave. | Abs. | Ave. | Abs. | Max. | Min. | Ave. | Range | Ave. | Range | | |
| Jan. | 4-285 | 81.0 | 22.4 | 28.0 | 40.3 | -7.3 | 96 | 28 | 2.29 | 2.81-1.94 | 249.7 | 293.3-203.2 | | |
| Feb. | 12-66 | 38.6 | 25.2 | 28.0 | 1.1 | -3.0 | 96 | 27 | 2.95 | 4.18-1.82 | 326.2 | 379.9-290.5 | | |
| March | 6-37 | 18.9 | 30.7 | 33.8 | 3.9 | 0.5 | 93 | 19 | 5.56 | 7.19-3.72 | 441.0 | 473.4-378.8 | | |
| April | 3-78 | 28.2 | 35.8 | 37.8 | 8.4 | 4.5 | 98 | 21 | 7.57 | 10.00-5.46 | 549.6 | 558.2-460.0 | | |
| May | 1-56 | 12.5 | 45.6 | 46.0 | 12.8 | 7.0 | 88 | 14 | 11.80 | 14.96-9.68 | 583.4 | 669.0-545.7 | | |
| June | - 3 | 0.3 | 47.0 | 49.0 | 17.3 | 10.5 | 83 | 12 | 15.77 | 18.30-13.50 | 647.0 | 691.8-601.5 | | |
| July | 0 | 0 | 49.6 | 52.0 | 21.0 | 20.9 | 77 | 13 | 15.02 | 16.64-12.81 | 615.7 | 640.9-573.3 | | |
| Aug. | 00 | 0 | 47.6 | 49.4 | 20.2 | 17.0 | 90 | 12 | 13.72 | 14.90-11.29 | 568.9 | 602.1-525.2 | | |
| Sept. | 0 | 0 | 45.4 | 46.5 | 15.2 | 11.5 | 80 | 14 | 10.59 | 11.83-7.87 | 510.8 | 553.9-447.8 | | |
| Oct. | 3-23 | 7.2 | 39.7 | 41.5 | 11.7 | 7.0 | 84 | 13 | 6.82 | 7.48-5.48 | 338.5 | 443.7-290.6 | | |
| Nov. | 13-80 | 38.2 | 33.0 | 38.8 | 3.6 | 0.0 | 93 | 22 | 3.48 | 4.30-2.07 | 280.8 | 317.4-244.5 | | |
| Dec. | 4-96 | 32.8 | 25.0 | 28.5 | 0.8 | -2.2 | 94 | 29 | 2.20 | 2.87-1.48 | 241.3 | 265.9-227.2 | | |

* Data is the average of 1961-68.

Table 2: Water Analysis of Dez River, 1967.

| Date | pH | EC mmho/cm | SAR | Na % | Concentration, meq/l | | | | | | | | Baron ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^{-}$ | $CO_3^{=}$ | $SO_4^{=}$ | $Cl^{-}$ | |
| January 15 | 7.7 | 0.68 | 1.50 | 32.8 | 3.03 | 1.42 | 2.20 | 0.04 | 2.65 | Nil | 1.73 | 2.10 | 0.03 |
| February 15 | 8.2 | 0.78 | 1.80 | 37.7 | 3.11 | 1.20 | 2.64 | 0.05 | 2.65 | Nil | 2.15 | 2.30 | 0.03 |
| March 15 | 7.9 | 0.72 | 1.47 | 32.6 | 3.03 | 1.48 | 2.21 | 0.05 | 2.85 | Nil | 2.03 | 2.00 | 0.03 |
| April 15 | 7.8 | 0.70 | 1.50 | 33.4 | 3.07 | 1.48 | 2.26 | 0.05 | 2.90 | Nil | 1.87 | 2.00 | 0.02 |
| May 15 | 7.8 | 0.62 | 1.37 | 31.5 | 3.23 | 1.16 | 2.04 | 0.04 | 2.80 | Nil | 1.73 | 1.80 | 0.02 |
| June 15 | 7.7 | 0.58 | 1.60 | 36.9 | 2.50 | 1.10 | 2.13 | 0.04 | 2.55 | Nil | 1.54 | 1.75 | 0.01 |
| July 15 | – | 0.55 | 1.28 | 31.3 | 2.63 | 1.20 | 1.77 | 0.03 | 2.80 | Nil | 1.20 | 1.60 | 0.01 |
| August 15 | – | 0.65 | 1.60 | 34.8 | 2.71 | 1.48 | 2.26 | 0.04 | 2.70 | Nil | 1.70 | 1.90 | 0.02 |
| September 15 | – | 0.62 | 1.30 | 30.3 | 3.19 | 1.44 | 2.04 | 0.04 | 3.00 | Nil | 1.70 | 1.70 | 0.04 |
| October 15 | 8.0 | 0.62 | 1.20 | 29.4 | 2.83 | 1.52 | 1.83 | 0.04 | 2.80 | Nil | 1.60 | 1.75 | 0.02 |
| November 15 | 7.9 | 0.65 | 1.00 | 25.1 | 3.27 | 1.48 | 1.61 | 0.04 | 2.65 | Nil | 2.09 | 1.60 | 0.02 |
| December 15 | 8.2 | 0.64 | 1.40 | 32.1 | 3.11 | 1.44 | 2.17 | 0.03 | 2.80 | Nil | 1.84 | 1.90 | 0.01 |
| Average | 7.9 | 0.65 | 1.42 | 32.3 | 2.98 | 1.37 | 2.10 | 0.04 | 2.76 | Nil | 1.77 | 1.87 | 0.02 |

**Table 3: Effect of Amount of Water Applied for Irrigation on Growth of Sugarcane (variety NCo 310)**

| cm $H_2O$ per day | $m^3$ $H_2O$ per ha | Average intervals (Days) | Cane length (cm) | | | |
|---|---|---|---|---|---|---|
| | | | June 22 | Aug. 2 | Aug. 30 | Oct. 17 |
| ½ | 4686 | 14.7 | 106 | 202 | 234 | 267 |
| 1 | 8989 | 8.1 | 107 | 202 | 236 | 292 |
| 1½ | 13761 | 5.3 | 109 | 227 | 270 | 310 |
| 2 | 18072 | 3.9 | 103 | 230 | 283 | 312 |

**Table 4: Effect of Amount of Water Applied for Irrigation on Yield of Cane and Sugar.**

| cm $H_2O$ per day | $m^3$ $H_2O$ per ha | Average intervals (Days) | Per hectare | | |
|---|---|---|---|---|---|
| | | | Tons net cane | Tons pol | Tons sugar |
| ½ | 4686 | 14.7 | 116.4 | 15.50 | 12.40 |
| 1 | 8989 | 8.1 | 134.1 | 17.67 | 14.14 |
| 1½ | 13761 | 5.3 | 142.5 | 19.41 | 15.53 |
| 2 | 18072 | 3.9 | 144.1 | 19.22 | 15.38 |

**Table 5: Mechanical Analysis of Some Project Soils.**

| Field & block | Series | Percent | | | Texture |
|---|---|---|---|---|---|
| | | Sand | Silt | Clay | |
| 100 M | Shush | 22 | 50 | 28 | Clay loam |
| 105 $B_2$ | Shush | 20 | 48 | 32 | Clay loam |
| 106 D | Shush | 22 | 45 | 33 | Silty clay loam |
| 204 F | Shush | 18 | 48 | 34 | Silty clay loam |
| 250 A | Shush | 18 | 47 | 35 | Silty clay loam |
| 300 E | Shush | 20 | 50 | 30 | Silty clay loam |
| 402 A | Shush | 19 | 52 | 29 | Silty clay loam |
| 125 D | Haft Tappeh | 34 | 47 | 19 | Loam |
| 309 $D_2$ | Haft Tappeh | 31 | 49 | 20 | Loam |
| 403 $B_1$ | Haft Tappeh | 31 | 47 | 22 | Loam |
| 408 F | Haft Tappeh | 40 | 39 | 21 | Loam |
| 413 B | Haft Tappeh | 33 | 47 | 20 | Loam |
| 415 C | Haft Tappeh | 24 | 53 | 23 | Silty clay |
| 116 B | Haft Tappeh | 22 | 51 | 27 | Silty clay |
| 132 A | Flood plain | 36 | 48 | 16 | Loam |

Table 6: Permeability of Several Fields at Different Depths.

| Field & block | Depth (cm) | Hydraulic conductivity (cm/hr) | Permeability * class |
|---|---|---|---|
| 114 B Stat. No. 2 | 25 | 3.62 | Moderate |
| " | 50 | 1.35 | Moderately slow |
| " | 75 | 3.74 | Moderate |
| " | 100 | 1.42 | Moderately slow |
| 114 B Stat. No. 4 | 25 | 3.08 | Moderate |
| " | 50 | 0.18 | Slow |
| " | 75 | 2.06 | Moderate |
| " | 100 | 0.95 | Moderately slow |
| 204 A | 25 | 6.30 | Moderately rapid |
| " | 50 | 1.26 | Moderately slow |
| " | 75 | 2.82 | Moderate |
| " | 100 | 4.80 | Moderate |
| 300 A | 25 | 0.0 | Very slow |
| " | 50 | 0.538 | Slow |
| " | 75 | 0.0 | Very slow |
| " | 100 | 0.374 | Slow |
| 300 F | 25 | 4.65 | Moderate |
| " | 50 | 1.84 | Moderately slow |
| " | 75 | 0.78 | Moderately slow |
| " | 100 | 3.75 | Moderate |

* Classification from: Methods of soil analysis (7).

**Table 7: Salinity Status of Haft Tappeh Sugar Project Area*.**

| Soils | Percent | | |
|---|---|---|---|
| | $EC \times 10^3 < 2$ | $EC \times 10^3 = 2$ to 4 | $EC \times 10^3 > 4$ |
| | First sampling (1963-65) | | |
| Shush | 54 | 26 | 20 |
| Haft Tappeh | 69 | 31 | 0 |
| Flood plain | 73 | 0 | 27 |
| Whole plantation | 58 | 26 | 16 |
| | Last sampling (1969-70) | | |
| Shush | 66 | 28 | 6 |
| Haft Tappeh | 53 | 47 | 0 |
| Flood plain | 100 | 0 | 0 |
| Whole plantation | 66 | 30 | 4 |

*Waste areas are not included.

Table 8: Ionic Determination in Saturated Extracts of Soil Samples from Fields 250, 251, and 252.

| Sample No. | EC x $10^3$ | meq/l | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $HCO_3$ | $SO_4^{=}$ | Cl |
| 6 | 2.5 | 16.8 | 3.6 | 4.4 | 0.5 | 4.0 | 14.6 | 4.0 |
| 7 | 2.5 | 16.8 | 4.0 | 4.0 | 0.5 | 4.0 | 14.5 | 4.0 |
| 8 | 2.9 | 16.0 | 5.2 | 7.7 | 0.3 | 4.0 | 15.8 | 8.0 |
| 9 | 3.0 | 18.0 | 4.8 | 7.4 | 0.5 | 4.0 | 16.3 | 8.0 |
| 10 | 2.0 | 12.0 | 3.6 | 4.5 | 0.3 | 4.0 | 8.9 | 5.0 |
| 11 | 5.5 | 33.6 | 10.4 | 9.9 | 0.8 | 4.0 | 34.6 | 16.0 |
| 12 | 5.7 | 35.2 | 10.4 | 10.7 | 0.6 | 4.0 | 24.7 | 22.0 |
| 13 | 5.7 | 32.8 | 10.0 | 15.8 | 0.4 | 4.0 | 26.4 | 24.0 |
| 14 | 2.1 | 13.6 | 3.6 | 4.5 | 0.3 | 4.0 | 9.5 | 6.0 |
| 15 | 3.0 | 18.4 | 5.2 | 8.2 | 0.4 | 4.0 | 15.8 | 8.0 |
| 16 | 2.6 | 15.6 | 3.6 | 7.4 | 0.3 | 5.0 | 9.6 | 8.0 |
| 17 | 3.3 | 22.4 | 5.6 | 6.5 | 0.4 | 4.0 | 24.0 | 4.0 |
| 18 | 3.9 | 26.4 | 6.8 | 8.0 | 0.6 | 5.0 | 26.4 | 6.0 |
| 19 | 6.7 | 40.0 | 11.2 | 20.7 | 1.4 | 4.0 | 36.0 | 26.0 |

**Table 9: Exchangable Cations in Several Fields.**

| Field & block | Depth (cm) | EC x $10^3$ | meq/100 g soil | | | | | ESP |
|---|---|---|---|---|---|---|---|---|
| | | | CEC | Ca | Mg | Na | K | |
| 252 B | 0- 5 | 6.0 | 15.1 | 8.3 | 5.1 | 1.3 | 0.4 | 8.6 |
| | 5- 25 | 6.5 | 14.0 | 8.5 | 3.8 | 1.3 | 0.4 | 9.2 |
| | 25- 55 | 5.0 | 11.9 | 4.8 | 5.5 | 1.3 | 0.3 | 10.9 |
| | 55-100 | 5.5 | 10.2 | 3.6 | 5.2 | 1.1 | 0.3 | 10.7 |
| 203 H | 0- 5 | 2.0 | 14.1 | 6.1 | 6.6 | 0.8 | 0.6 | 5.6 |
| | 5- 25 | 5.0 | 14.1 | 3.8 | 8.8 | 0.9 | 0.6 | 6.3 |
| | 25- 55 | 7.0 | 18.5 | 9.0 | 7.3 | 1.5 | 0.7 | 8.1 |
| | 55-100 | 10.0 | 16.3 | 3.8 | 7.3 | 4.6 | 0.6 | 28.2 |
| Waste area | 0- 5 | 200.0 | 8.0 | 3.6 | 1.7 | 2.1 | 0.6 | 26.2 |
| next to | 5- 25 | 40.0 | 8.6 | 3.8 | 2.5 | 1.9 | 0.4 | 22.0 |
| 309 G | 25- 55 | 18.0 | 7.8 | 3.5 | 2.3 | 1.8 | 0.4 | 20.5 |
| | 55-100 | 9.0 | 8.7 | 4.9 | 2.6 | 0.9 | 0.3 | 10.3 |
| 311 F | 0- 5 | 1.2 | 12.6 | 8.1 | 3.8 | 0.4 | 0.3 | 3.1 |
| | 5- 25 | 0.7 | 11.3 | 8.5 | 2.2 | 0.4 | 0.2 | 3.5 |
| | 25- 55 | 0.6 | 11.7 | 7.9 | 2.9 | 0.6 | 0.3 | 5.1 |
| | 55-100 | 0.6 | 11.7 | 9.8 | 1.2 | 0.4 | 0.3 | 3.4 |

Table 10: Total Input and Discharged Ions, Field 106

| Ion | Tons | |
|---|---|---|
| | Input | Discharged |
| $SO_4$ | 17.3 | 237.5 |
| Cl | 47.7 | 115.8 |
| $HCO_3$ | 29.1 | 22.5 |
| Ca | 11.4 | 39.1 |
| Na | 10.2 | 70.1 |
| Mg | 7.0 | 38.3 |
| $NO_3$ | 0.2 | 0.7 |
| B | 0.0 | 0.1 |
| Total | 122.9 | 524.2 |

Table 11. Electrical Conductivity of Soil Saturated Extract, Before and After Leaching, Field 118.

| Depth (cm) | EC x $10^3$ | |
|---|---|---|
| | Before leaching | After leaching |
| 0- 20 | 18.4 | 4.7 |
| 20- 40 | 5.3 | 3.8 |
| 40- 60 | 8.9 | 3.1 |
| 60- 80 | 8.6 | 3.4 |
| 80-100 | – | 3.9 |

Figure 1: Average Monthly Rainfall and Evaporation (Haft Tappeh - 1961 to 1969) (9).

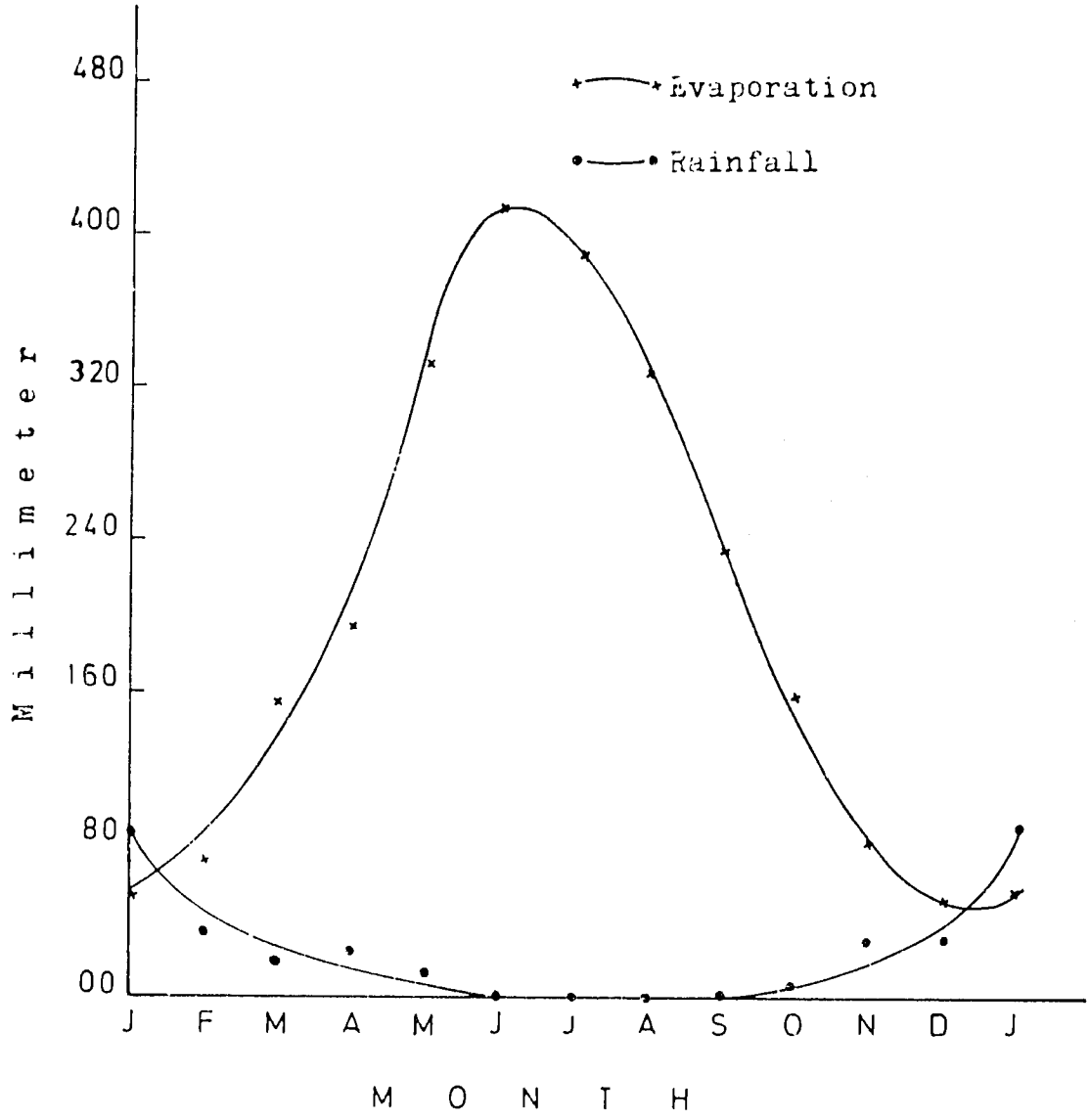


Figure 2: Drawing of a Portable Metal Frame for Canvas Checks in Irrigation Head Ditches

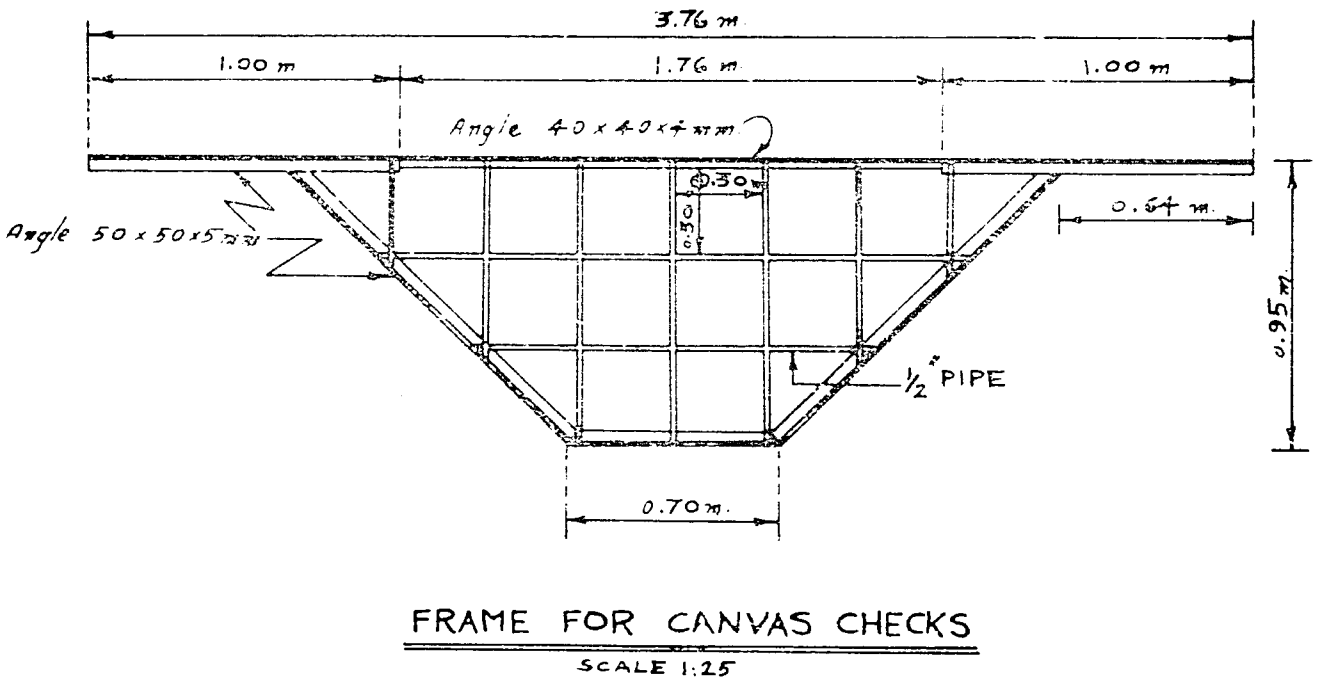


Figure 3: Drawing of Removable Checks for Irrigation Head Ditches, Fabricated From Oil Barrels

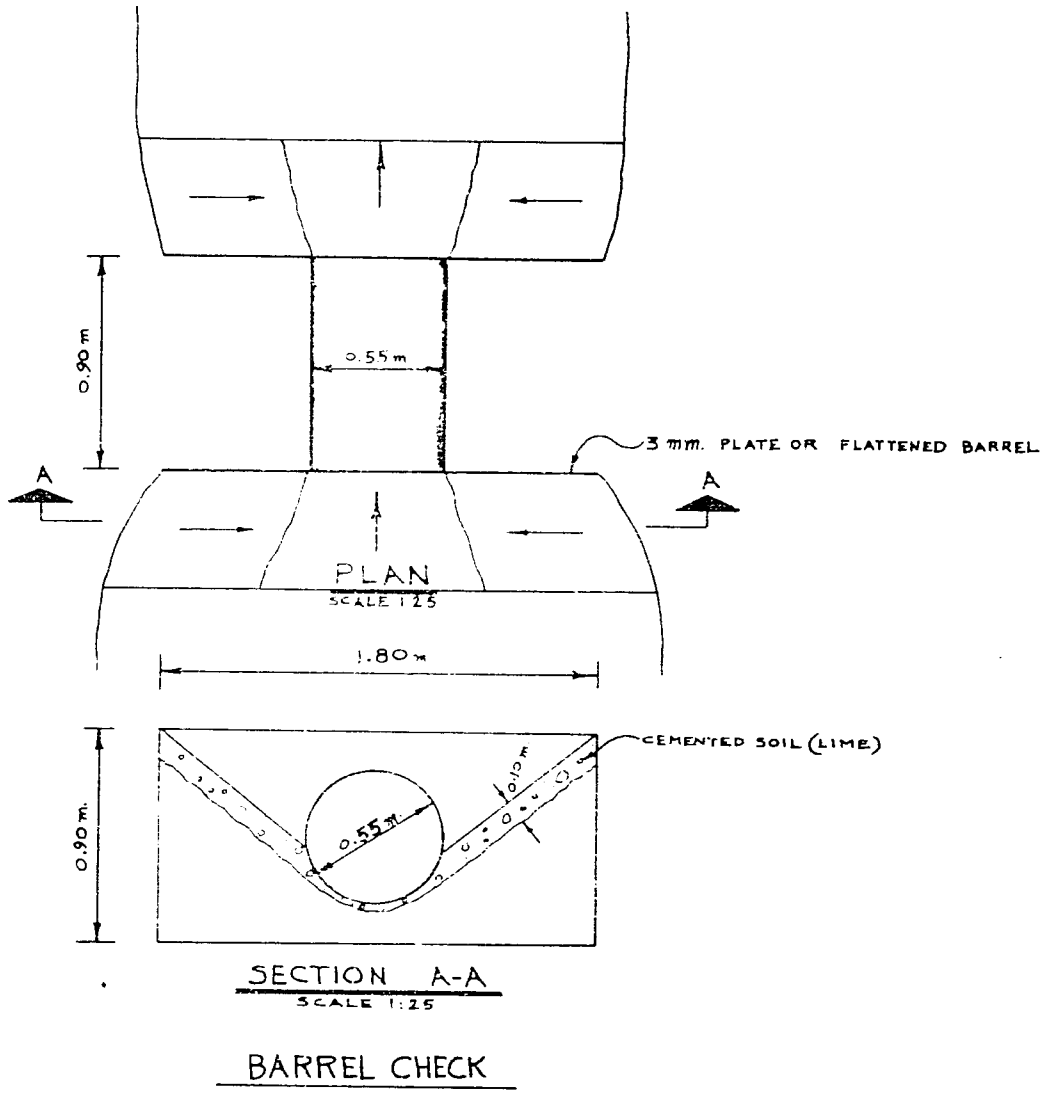


Figure 4: Drawing of a Concrete Check-Drop Structure in Irrigation Head Ditches

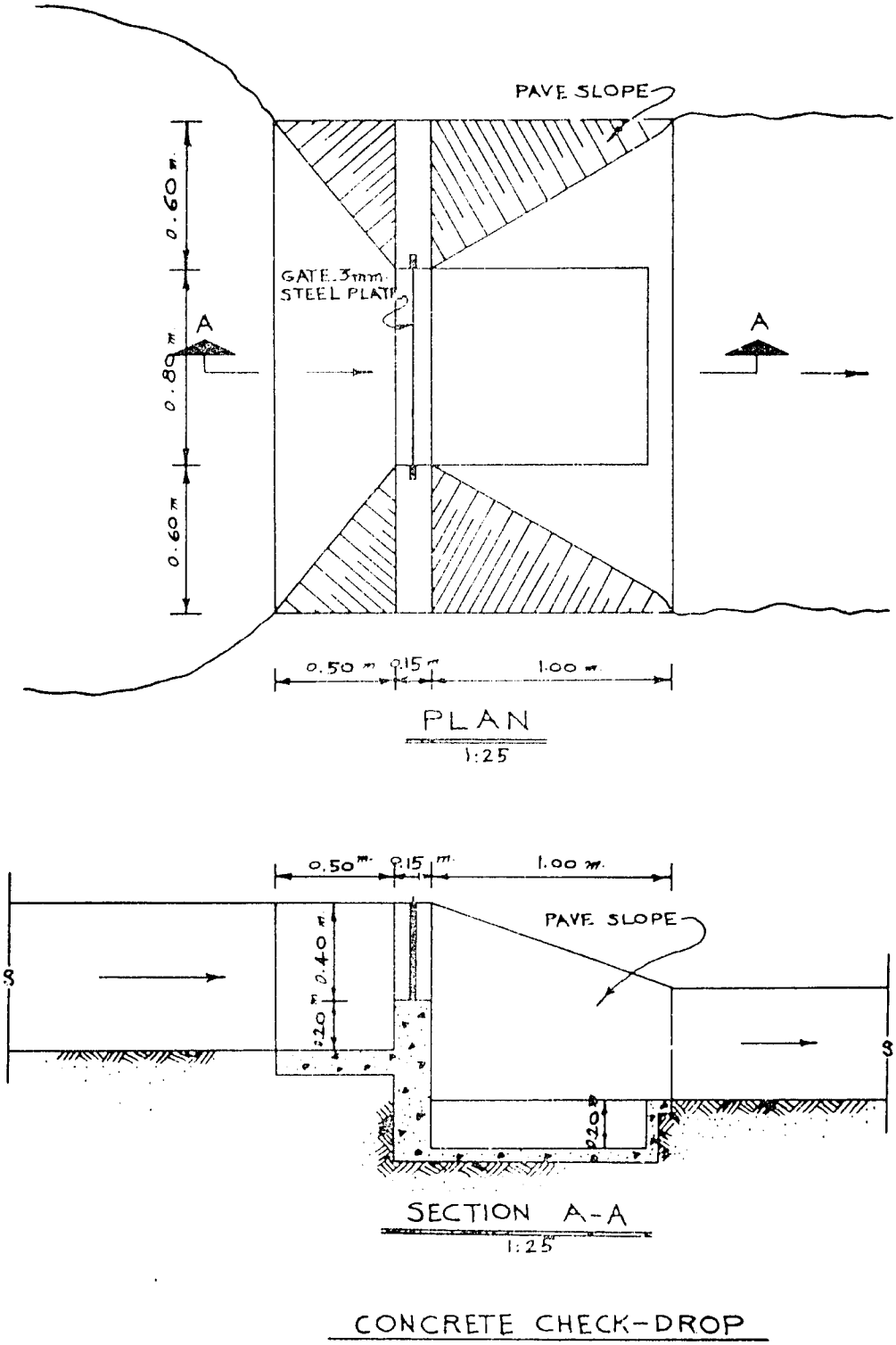


Figure 5: Drawing of Cross Section of a Head Ditch

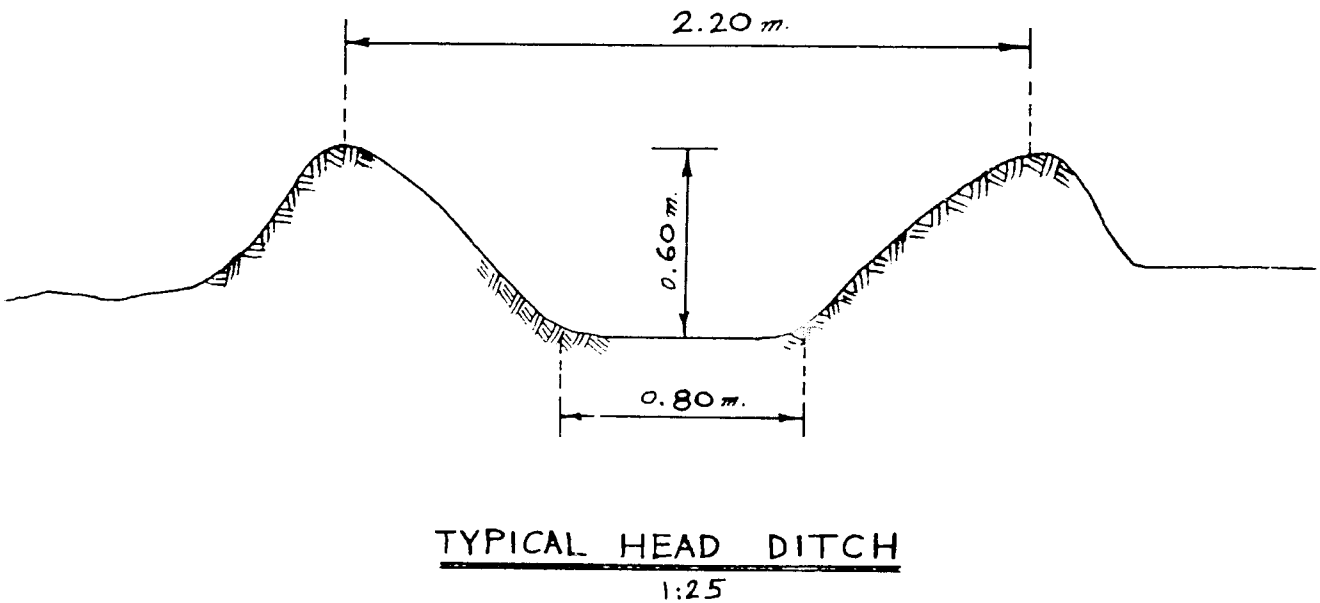


Figure 6: Map of the Haft Tappeh Plantation, 1969.

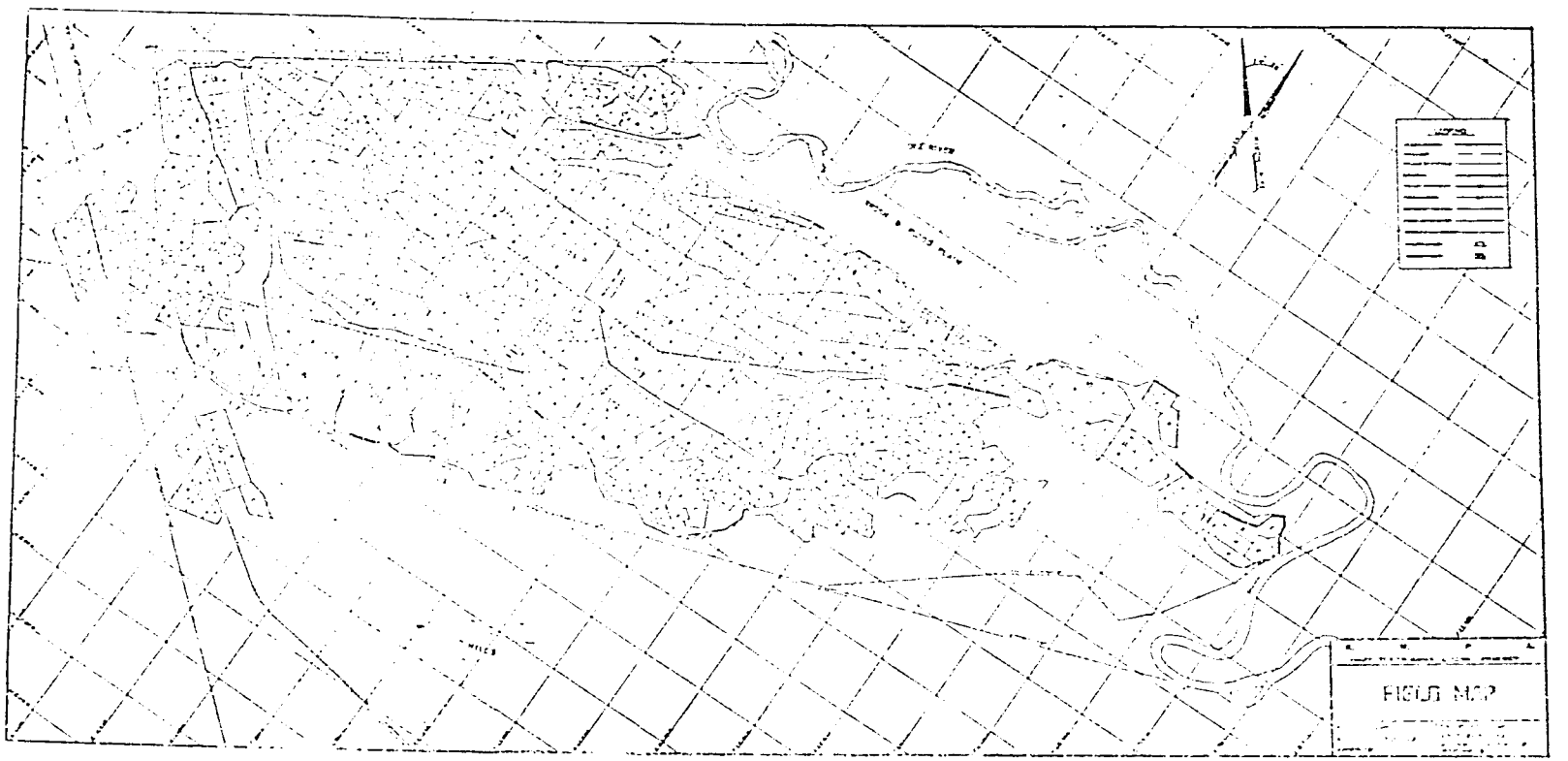


Figure 7: Drawing of Cross Section of a Typical Collector Drain

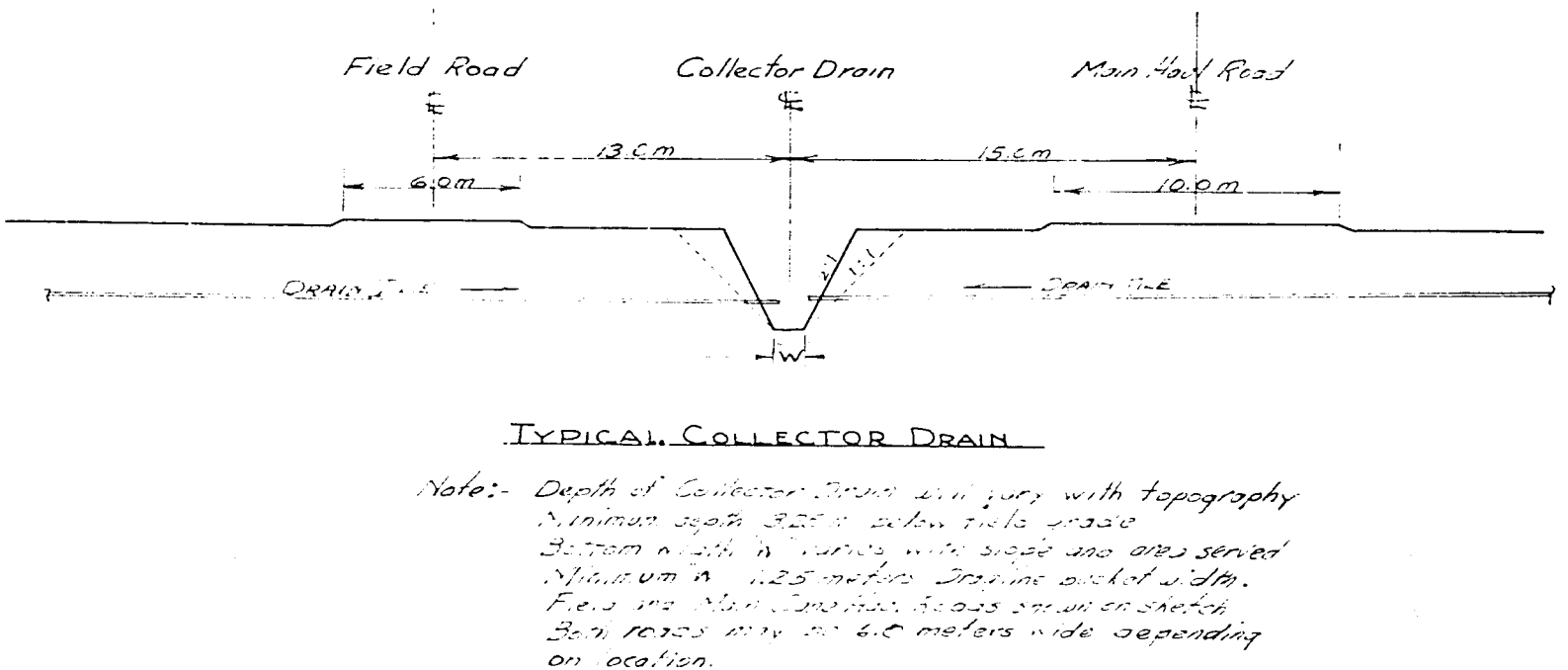


Figure 8: Water Tables Before and After Tiling at 80 (Field 115 $B_1$, above) and 100 (Field 251 $B_1$, below) Meter Spacings (9).

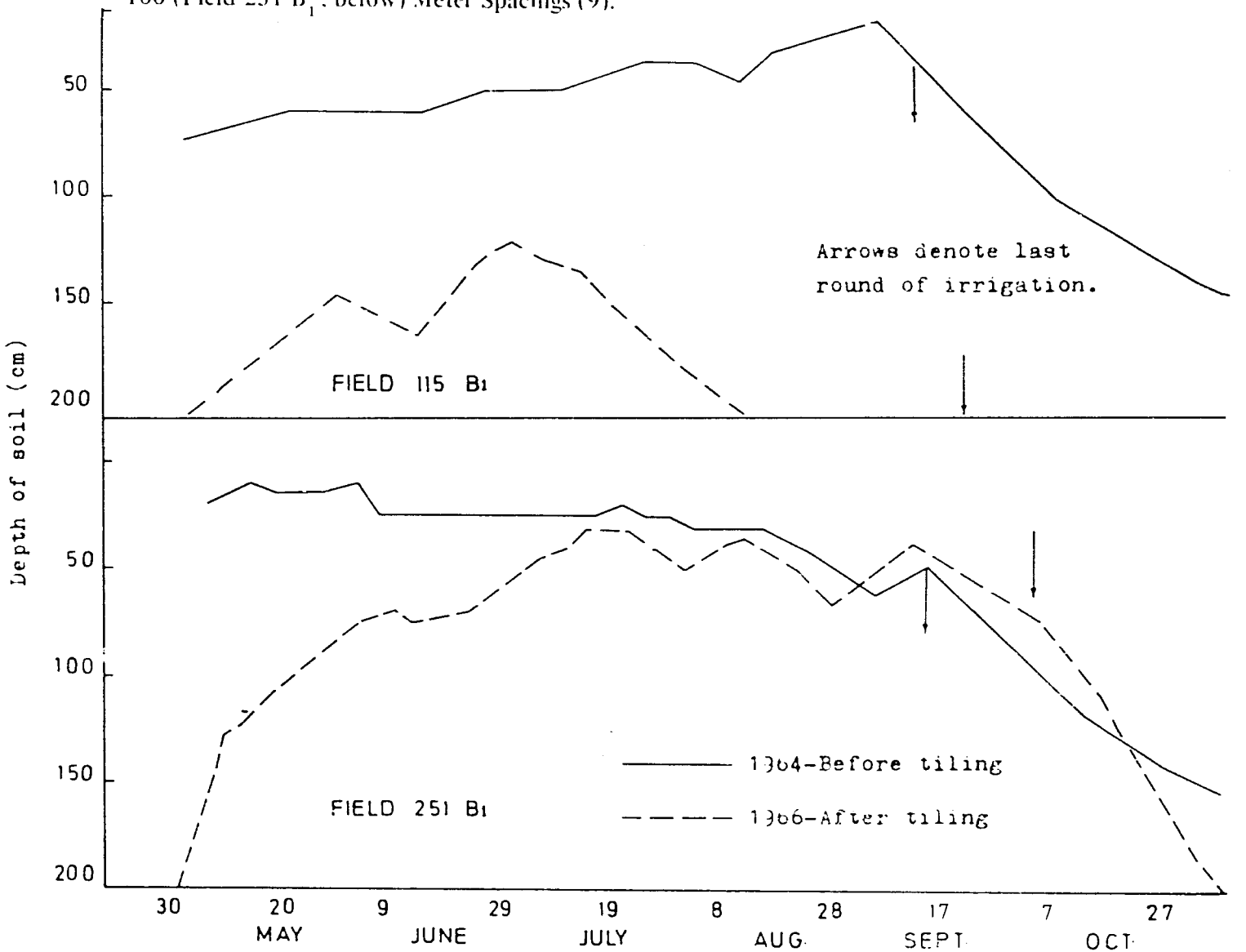
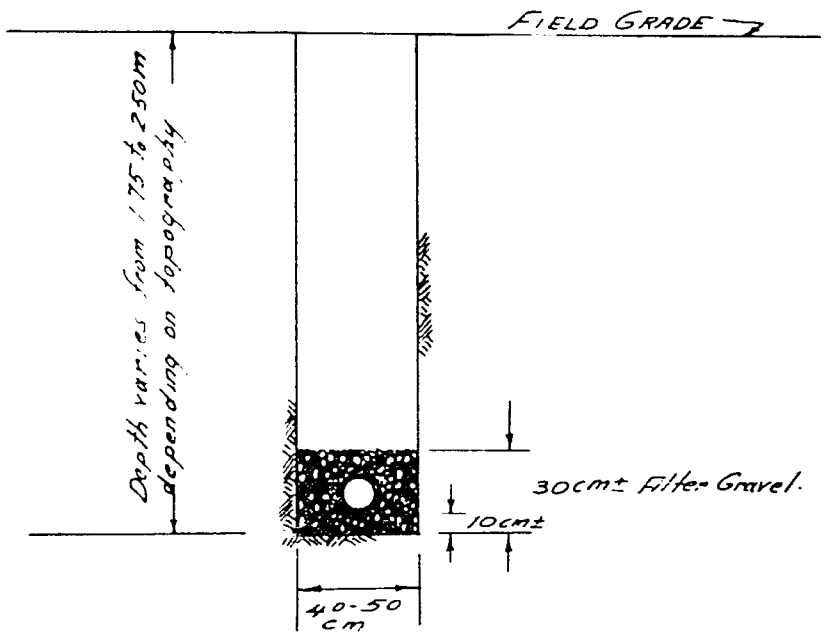


Figure 9: Drawing of Cross Section of a Typical Drain Tile Installation

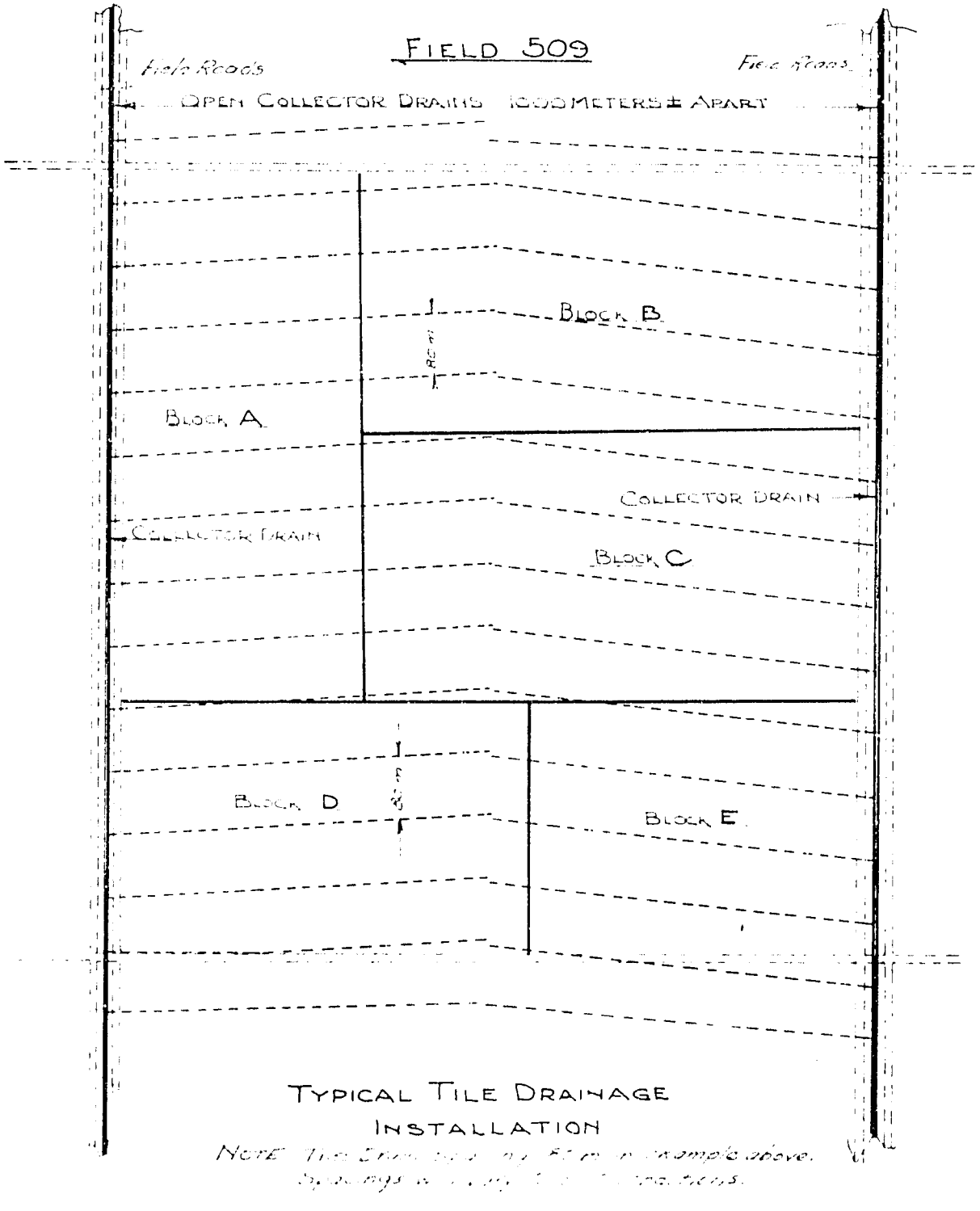
TYPICAL DRAIN TILE INSTALLATION

10 -15 & 20 cm dia tile used




Maximum tile line slope 0.20% where possible. Greater slopes used where topography permits. Filter gravel around tile is same for the 3 diameters used. Where possible tile line lengths limited to 500± meters with angle points in the line.

**Figure 10: Plan of a Typical Tile Drainage Installation**



# PAKISTAN

## IRRIGATION PRACTICES IN EAST PAKISTAN

by

**Aolad Hossain, B.E.C.E.M.I.E. Pakistan***

### INTRODUCTION

East Pakistan has an area of about 55,100 square miles and a population of more than 70 million. Only about five per cent is urban population. This indicates the dominant position of agriculture in the economy of the province. A vast majority of population depends entirely on agriculture for a living.

The province is deficient in food and has to depend on the import of food grains from West Pakistan and abroad. Average size of a farm is too small to support an average family of five to six members. Due to lack of adequate irrigation facilities, agricultural pursuit is seasonal, confined to the wet season, and optimum use of land has not been possible. The agricultural population, weighed down by a recurring load of debt, is able to maintain only a meager existence. Any crop failure means famine and starvation. Feeding of an ever increasing population has thus become a pressing problem.

### PRESENT WATER USE

Agriculture in East Pakistan receives its water requirement mainly from two sources, rainfall and rivers. Conventional irrigation by diversion or pumping of surface water or tapping groundwater is still in its infancy. Local diversion for flood irrigation through channels or old stream beds exists on a small scale. In the saline areas of the coastal belt embankments have been and are being constructed to prevent the ingress of salt water, and sluices have been constructed to control drainage. A limited amount of irrigation, both by human labor and by small diesel low lift pumps from adjacent channels and depressions, is practised in the boro (winter) paddy growing areas of the Meghna depression and haor (depression) areas of Sylhet district. Mechanical pumping, although started a few years ago, is still in the experimental stage. Thus agriculture in East Pakistan is almost wholly dependent on natural supplies of water; artificial irrigation on a major scale has not yet developed.

Major crops, viz. rice and jute, must therefore be grown when water is naturally available in adequate quantities. Although annual rainfall is as high as 80 inches, it is concentrated in the five monsoon months from June through October. River overflows generally occur between mid-July and mid-September. Thus total water supplies are ample in the rainy season and gradually deficient in the winter. The western part of the province is generally drier than the east, not only because of less rainfall but also because it is higher in elevation and subject to less flooding. In the northeastern part of the province, especially in Sylhet, Mymensingh and Comilla

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districts, the combination of heavy rainfall, river flooding and low elevation in the extensive haor (depression) areas prohibits cultivation in the rainy season.

At present there are about 22.6 million acres available for cultivation in the province, of which less than six million acres yield two crops and about one million yield three crops. Apart from a small acreage of unirrigated rabi (winter) crops and about 0.55 acres now under systematic irrigation, double cropping is tied closely to the monsoon.

## NECESSITY OF IRRIGATION

There is a belief that East Pakistan does not require irrigation, or that drainage is a greater necessity. This is hardly true.

The figures below show comparative yields of rice in different countries, in pounds per acre:

| | |
|---|---|
| Western Europe | 4,569 |
| Japan | 4,324 |
| Korea | 3,647 |
| China Taiwan | 3,242 |
| Malaya States | 2,375 |
| India | 1,356 |
| East Pakistan | 1,330 (aus) |
| | 1,515 (aman) |

It may be seen from these figures that the yield of rice in East Pakistan is one of the lowest. What might be the causes of such low production?

East Pakistan soil is very fertile so far as its content of soil nutrient is concerned. Therefore, poor fertility cannot be the cause of low production. Total rainfall varies from 60 to 120 inches, with the average being 80. Of this total quantity about 80 per cent falls during the five months from June to October. Considering the April-to-October period, the rainfall in these seven months is about 94 per cent of the total. Thus it is clear that in the rabi season from November to March the average rainfall is about five inches, whereas the average evaporation during these months is more than 20 inches. The rainfall in this period is inadequate for the crop requirements and is the main cause of low production of rabi crops.

The kharif crops are grown in the monsoon when the country gets abundant rainfall which far exceeds evaporation. Therefore, water can hardly be the reason for low production. Yet aus rice and jute which grow on comparatively high land suffer from drought. These crops and long stem aman paddy are sown after the middle of May when the pre-monsoon shower has fallen to moisten the soil. It often happens that sufficient rain does not fall in time for preparation of the lands. Sowing, therefore, is very late with consequent result of possible submersion of the young plants by the rise of the water level. Also, the young plants are very sensitive to drought and at this stage a drought of a week or two may be sufficient to cause total loss. Drought at planting time has become practically an annual occurrence in East Pakistan.

The yields of paddy fluctuate greatly and are more frequently below normal. Aus especially shows great fluctuation and is a more risky crop than aman. Crop failure due to drought after sowing seems to occur more frequently than failure caused by flooding. Even aman cannot be regarded as a safe crop and is liable to be damaged by early or late flooding as well as drought.

The main causes of low production are:

(1) Lack of water in dry season for rabi crops.

(2) Drought after sowing of aus and aman.

(3) Too early flood and too fast rise of water level in case of aman paddy.

(4) Late floods when aman paddy is already in the generative stage.

For timely sowing and to safeguard the plants until they are sufficiently high, irrigation is essential.

## BENEFITS OF IRRIGATION

Experiments have been conducted in various agricultural research stations in East Pakistan, to study the effect of irrigation on yields of different crops. The results are very encouraging. It has been established that:

(1) With the aid of irrigation, it is possible to grow transplanted aus, which gives a much higher yield (about 30 per cent more) than the broadcast variety,

especially when transplanting is done early in the season.

(2) Early transplanting of aus enables a second crop to grow in the same field.

(3) Irrigation eliminates the harmful effects of droughts.

(4) After a second paddy crop it is possible to grow a third crop and thus three crops can be obtained from the same field in one year.

(5) High water-consuming, high-yielding, improved varieties of crops such as IRRI paddy, can be grown.

(6) Irrigation alone increases yields appreciably.

In recent years systematic irrigation has been introduced in some of the project areas completed by East Pakistan Water and Power Development Authority. Crop cutting experiments have been made to determine the extra yield obtained by irrigation. Yields in mounds per acre in 1968-69 for some of the principal crops are given below:

| | G.K. Project Kushtia Unit Phase I | | Buri-Teesta | | Tubewell in Dinajpur Dt. | | Low-lift pumps | | Dacca-Demra Narayanganj | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Irrigated | Non-irrigated | Irrigated | Non-irrigated | Irrigated | Non-irrigated | Irrigated | Non-irrigated | Irrigated | Non-irrigated |
| B. Aus | 27 | 12 | | 12 | 25 | 13 | 24 | 16 | 17.7 | |
| T. Aus | 30 | 16 | | | 28 | 18 | 30 | 19 | 23.75 | |
| Sugar cane | 500 | 400 | | | 800 | 300 | 525 | 330 | 400 | |
| Vegetables | 80 | 50 | | 60 | 115 | 50 | 100 | 60 | 95 | |
| B. Aman | 25 | 14 | | | 25 | 12 | 20 | 16 | 14 | |
| T. Aman | 26 | 15 | 31 | 22 | 30 | 18 | 33 | 33 | 25.5 | |
| Local Wheat | 15 | 8 | | 10 | 20 | | 15 | 9 | 13 | |
| Maxi Pak Wheat | 20 | 10 | | | 30 | 15 | 24 | 13 | 20 | |
| Potato | 150 | 80 | | 44 | 200 | 50 | 107 | 62 | 85 | |
| Barley | 10 | 6 | | 10 | 8 | 5 | 15 | 8 | | |
| Tobacco | 8 | 4 | 12 | 5 | 8 | 3 | 10 | 5 | | |
| Jute | 13 | 12 | | | 15 | 7 | 17 | 12 | 15.2 | |
| Onion | | 40 | | 40 | 75 | 30 | 90 | 56 | 90 | |

With irrigation facilities available, the growing of IRRI has been possible in the project areas. Large areas were planted with IRRI as aus, aman and boro in all of the above project areas. The average yields per acre are given below.

| Name of project | Av. yield in mds/acre of IRRI | | |
|---|---|---|---|
| | Aus | Aman | Boro |
| G.K. first phase | 43 | 30 | 60 |
| Buri Teesta | | | 77 |
| Tubewell | 60 | 30 | 60 |
| Low-lift pump | 63 | 53 | 65 |
| D-N-D | 47 | 26 | 60 |

The higher yields as indicated in the above tables are the combined result of irrigation, use of fertilizer, better seeds, pesticides and better farming methods. Fertilizer is one of the main factors contributing to higher yields and its use is only possible with irrigation.

## POSSIBLE METHODS OF IRRIGATION IN EAST PAKISTAN

Of all the methods of irrigation, gravity or flow irrigation and lift irrigation are generally possible in

East Pakistan. This is mainly due to the extreme flatness and deltaic nature of the country. Small storage reservoirs are possible on a limited scale only in the small hill streams in the eastern districts of Sylhet and Chittagong where the catchment areas of these streams lie within Pakistan. With the dependable dry weather flow of these streams being quite small, the scope of storage is very much limited.

As most of the rivers flowing through East Pakistan originate from India, gravity diversion is limited to the rivers whose waters cannot be diverted by India for her own use and to a few rivers having appreciable discharge whose catchment areas lie entirely inside East Pakistan. The Teesta and the Sangoo fall in the first category and the Matamuhuri in the latter category. Irrigation projects of the Teesta and the Sangoo have already been prepared by East Pakistan Water and Power Development Authority, and it plans to prepare a Matamuhuri project.

Lift irrigation projects may be classed into (1) pumping surface water from rivers, beels, haors, depressions, etc. and (2) tapping the underground reservoir.

Pumping surface water from major rivers poses an unavoidable problem. Because of the shifting nature of the bed and banks as well as silting, construction of permanent pumping stations is subject to the problems of erosion and silting. Because of these problems, pumping from the Brahmaputra-Jamuna and the Ganges is difficult. The Ganges Kobadak pump house has been stationed on the Ganges, taking advantage of the protective works constructed by the railway for the protection of the Hardinge bridge. Even then, silting of the intake has become a problem and a huge amount is being spent every year for dredging to keep the intake channel open.

A number of small pumping stations have been established by East Pakistan Water and Power Development Authority on streams in the districts of Dinajpur, Rangpur, Bogra and Rajshahi. East Pakistan Agriculture Development Corporation also rents several thousand small diesel-driven mobile pumps of one to two cusecs capacity to the farmers for irrigation in the winter season.

Pumping groundwater is possible only through tubewells. No surveys to determine the groundwater potential of the province have been done. However, the East Pakistan Water and Power Development Authority has recently completed a tubewell project in the northwestern part of the province where 377 tubewells have been sunk, and it is planned to sink another 1,000 tubewells in the districts of Rangpur and Dinajpur. East Pakistan Agriculture Development Corporation has also sunk a large number of tubewells for irrigation and will continue to sink more in future years.

## IRRIGATION PROJECTS COMPLETED

According to its charter East Pakistan Water and Power Development Authority will plan and construct large projects costing more than Rs 50 lakhs and after completion turn them over to the Irrigation Directorate of the government of East Pakistan for operation and maintenance. Some pertinent data concerning completed irrigation projects transferred to the Irrigation Directorate are given below:

### Groundwater Development and Pump Irrigation Project in the Northern Districts of East Pakistan

The project consists of four distinct parts:

(1) Tubewells: It was proposed to install 380 10-inch diameter tubewells in and around Thakurgaon to irrigate 91,200 acres. Actually 365 tubewells with good aquifer have been installed. Others have been discarded due to low yields, or not constructed. Of these 365, three are being used to supply cooling water to a diesel power plant constructed to supply power to the tubewell pumps and 362 tubewells have been handed over to the Irrigation Directorate for operation and maintenance. These tubewells with a total rated discharge of 1,035.46 cusecs (average discharge per tubewell about three cusecs) supply an area of 70,925 acres.

During the agricultural year 1968-69 (from March 1968 to February 1969) the following results were achieved:

Command area, in acres 70,925
Net land acreage irrigated 57,717
Net cropped acreage irrigated 66,316

This project produced the following additional quantity of food grains in addition to rabi crops:

| | |
|---|---|
| Paddy | 1,943,223 mounds |
| Wheat | 71,012 mounds |
| | 2,014,235 mounds |

(2) Sixty electrically driven low-lift pumps: These pumps, each with 4.5 cusecs rated discharge, will pump water from the Karotoya river to irrigate 19,200 acres. The work on this part of the project has not been completed. So far 60 pumps, located in six stations, have been installed. Transmission lines have been built and pumps connected with the power line. Canals have been constructed. Canal lining and cross-drainage works are yet to be constructed. The project is not yet ready for supplying water to the fields.

(3) Power plant and transmission line: A power station with seven (1,500 kilowatt each) diesel engine-driven generating units has been built to supply power to the tubewells and 60 electrically driven low lift pumps. Transmission lines have also been built and all the tubewells and low lift pumps connected.

(4) Eight hundred diesel driven low-lift pumps of one to two cusecs capacity placed throughout the districts of Dinajpur, Bogra and Rajshahi: These pumps were designed to irrigate 76,400 acres. During the agricultural year 1968-69 the position of this scheme was as follows:

| District | No. of diesel low lift pumping Stations | No. of pumps installed | No. of pumps worked Max. | Min. |
|---|---|---|---|---|
| Dinajpur | 40 | 197 | 102 | 72 |
| Rangpur | 19 | 133 | 68 | 34 |
| Bogra | 10 | 82 | 42 | 34 |
| Rajshahi | 20 | 182 | 83 | 69 |
| Total | 89 | 594 | 295 | 209 |

All the installed pumps did not work, because farmers were not inclined to use irrigation water and because of a mechanical breakdown of pumps, which had to be removed for repairs.

The following results were achieved during the agricultural year 1968-69.

| District | Command area, in acres | Net land area irrigated in acres | Net cropped area irrigated in acres |
|---|---|---|---|
| Dinajpur | 20,617 | 5,721 | 7,165 |
| Rangpur | 10,424 | 1,098 | 1,300 |
| Bogra | 4,350 | 1,629 | 2,569 |
| Rajshahi | 6,817 | 2,645 | 4,442 |
| Total | 42,208 | 11,093 | 15,476 |

## Dacca-Demra-Narayanganj (D-N-D) Project

Estimated cost: Rs 22.9 million.

This is a pilot project for flood protection, drainage and flood control in a deeply flooded area.

The D-N-D project is located in the southeast suburb of Dacca city. This project commands an area of 18,840 acres of land, of which 15,000 are cultivable. The project is surrounded by four rivers: the Lakhya, Buriganga, Balu and Dholai Khal. Historically these rivers have flooded every year, inundating the project area to a depth of five to 15 feet.

The project area is divided into two parts: Area I and Area II. Area I is a triangle enclosed by road and railroad embankment and contains 10,100 acres of arable land. Area II is outside the embankments and contains 4,900 acres of arable land.

Flood protection to Area I is effected by the embankments around it, and drainage and irrigation by four axial flow propeller type pumps of rated capacity of 128 cubic feet per second each. Area II is unprotected from floods, but irrigation water is supplied by the above pumps.

The project has a twofold objective:

(1) Introduction of new and high yielding variety crops through flood protection, drainage and well regulated irrigation in Area I.

(2) Production of different crops in winter with the help of irrigation water only in Area II.

During the agricultural year 1968-69, the following results were obtained.

Net command area, in acres 15,000
Net land acreage irrigated 7,953
Net cropped acreage irrigated 12,788

The project has contributed the following quantity of food grains in addition to rabi crops:

| | |
|---|---|
| Paddy | 588,480 mounds |
| Wheat | 445 mounds |
| | 588,925 mounds |

## Buri Teesta Project (Teesta Sub-project)

Estimated cost: Rs 6.0 million.

Due to the long construction period estimated to be required for the completion of Teesta barrage project it was decided to construct the Buri-Teesta or Teesta sub-project in such a way that this would ultimately fit in with the Teesta barrage main project. The object of this sub-project is to train farmers in the use of irrigation water. This is mainly a monsoon-season irrigation project, as the dry weather discharge is only sufficient to irrigate about 500 acres in the rabi season. The project consists of a barrage across the Buri-Teesta river, a spill channel of the Teesta river to divert its flow through the canal system. The project was started in 1968. During that year the following results were obtained:

Command area, in acres 33,000
(monsoon season only)
Net land acreage irrigated 2,720
Net cropped acreage irrigated 2,720

During the first year, irrigation was confined mostly to rice. The project has contributed an additional 92,549 mounds of paddy during the year.

## Ganges-Kobadak Project, Kushtia Unit, Phase I

The Ganges-Kobadak project is the first large scale irrigation development of the province. It provides for pumping of water from the Ganges river below the Hardinge bridge for irrigation of 1.2 million acres in the districts of Kushtia and Jessore. The first unit of the project, known as the Kushtia unit, has a net command area of 350,000 acres. The second unit is the Jessore unit.

The project includes an intake canal from the Ganges, a steam power plant of 8,500 kilowatts to run the pumps, two pumping plants and a canal system. The pumping plants consist of a battery of 12 medium size pumps of 120 cubic feet per second each and three big pumps each with 1,300 cubic feet per second capacity. The 12 small pumps were installed a few years back and are now supplying water to the project area. Installation of the three big pumps has recently been completed and the pumps have just been put into operation.

Kushtia unit of the project has been divided in two phases. Phase I is likely to be completed shortly. Phase II is still under construction and will require a couple of years for completion.

Although Phase I of the Kushtia unit has not yet been fully completed, the project has been under operation for a number of years and irrigation was started a few years back.

During the past year the following results have been achieved:

Command area, in acres 116,000
Net land acreage irrigated 58,341
Net cropped acreage irrigated 62,882

The project has contributed the following additional quantity of food grains during the year:

| | |
|---|---|
| Paddy | 1,285,395 mds. |
| Wheat | 26,073 mds. |
| Total | 1,311,468 mds. |

Estimated cost of G. K. Kushtia Unit Phase I: Rs 228 million.

## DIFFICULTIES EXPERIENCED IN INTRODUCING IRRIGATION

Every irrigation project needs a considerable period of development. Farmers must be taught the use of irrigation water along with the use of fertilizer, better seed, plant protection and better farming.

Even in arid regions, where no crop can be grown without irrigation, farmers are shy in the use of water. East Pakistan is a tropical and humid country, where crops have been grown for centuries without irrigation water. Irrigation here is supplemental. As such, the introduction of irrigation is a formidable task. We have seen canals flowing full and water not utilized, as no farmer comes forward to take water. We have talked to the farmers to ascertain

the reason for their not taking water. Briefly, a few of the reasons are listed below:

(1) **Superstition.** Farmers have a false belief that water coming out through the pump as well as underground water contains some elements injurious to crops.

(2) **Idleness.** Irrigation needs hard labor in initial leveling of land, use of better farming methods, use of fertilizer, etc., which the farmers are not willing to undertake.

(3) **False contentment.** Depending upon God, farmers remain content with whatever they got from their land with conventional agricultural methods.

(4) **Large holdings.** Specially in tubewell areas, where the holdings are large and cultivation is generally done through share-croppers, the owners are not interested in double or triple cropping because they get enough produce even with one crop under existing conditions.

(5) **Ignorance.** As irrigation is new in the province, farmers are reluctant to use water because of their ignorance of the know-how.

(6) **Poverty.** To get good results from irrigation, better farming methods should be applied along with good seed, fertilizer and pesticides, which they cannot afford.

(7) **Adverse propaganda.** Adverse propaganda was made against the irrigation projects, stating that huge taxes would be levied if the water is used from canals.

(8) **Antagonism toward project.** Vast areas of lands were acquired for construction of canals and other structures. Farmers were deprived of their land, which remained fallow for a long time. This made them antagonistic toward such projects.

Under the circumstances we had to initially face tremendous odds in the introduction of irrigation. An irrigation extension service was opened in 1961 with a view to bring home to the farmers, the uptodate findings of agricultural experiments and research, educate them about the practicability of these findings in their own lands, by lectures as well as demonstrative methods, persuade them to apply this knowledge on their own farms, and above all, help them in the actual field work at the time of their adoption of new practices.

## EXTENSION WORK

To help develop the projects for a successful irrigated agriculture, extension methods were followed as outlined below:

**Ganges-Kobadak Project** was the first project where water could be made available to the farmer's plot for irrigation. There a demonstration block was initiated and an irrigation experimental farm was started. In the demonstration block, covering approximately 500 acres, farmers were invited to see the results of irrigated agriculture with better farming practices. Here they were trained in relaying water from the canals through the field and plot channels to the lands. The first crop demonstration was on transplanted aman rice which was hitherto unknown to the farmers of the project area. After one season's demonstration in this block, scattered demonstration plots were set up throughout the project area, while of course the main demonstration block continued and the farmers were brought there to watch and learn the methods and the results of irrigation. The demonstration plots were started on farmers' own lands with a guarantee that if there was a loss, the loss would be made good but in case of profit it would belong to the farmers.

A training center was also established near this demonstration block where both farmers and the field workers were trained in irrigated agriculture and other related subjects. Theory courses and practical training were given at the demonstration block. It was felt at that time that as soon as the farmers knew how to grow new crops under irrigated conditions they would progressively be given training in program building and diversification of crops.

A number of rural centers were established at key points near the concentrated village areas and covering a command of approximately two to three thousand acres. An experienced and trained extension overseer was placed in charge of each of these rural centers. These rural centers were called "Chashi (Farmers) Clubs." Leading and enthusiastic farmers constituted a committee to conduct the affairs of the Chashi clubs. These clubs provided recreational facili-

ties for the farmers after the day's work and in the process of recreation the extension overseer chalked out the seasonal program of cropping and explained the suitability of the program for the command of his jurisdiction. He presented understandable technical data to the farmers. Each season the farmers know plot by plot their program of cropping. In the process of this cropping program the requirements of fertilizers, arrangement of pesticides, etc., were also taken into consideration. At one time it was felt that the time lag between one crop and the following crop was too small for land preparation by indigenous means. An improved plow was therefore devised, three times more efficient than the indigenous plow so long used by the farmers. Tractors were also made available on a rental basis. These Chashi clubs worked as nerve centers for the local community where, in addition to the recreational facilities, all the problems related to agriculture were discussed and decision arrived at for solution. In the area of the command of a Chashi club there was always a small demonstration center with improved cultural practices, new crops, farm machinery, good seeds and fertilizers. In many cases the seeds of various kinds of vegetables were provided through the courtesy of a free gift from the CARE organization.

One of the major problems in the G. K. project was the excavation of the required field channels, because the farmers were reluctant to dig these channels. Accordingly, the East Pakistan Water and Power Development Authority agreed to dig 1,778 field channels in Phase I. The land required for the canals and ditches was donated by the farmers.

This system of extension work continued for a period of approximately five years, and approximately 60 per cent of the areas could be covered in G. K. project Phase I by irrigation in this period.

Lately it has been felt that such methods, viz., demonstrations, audio-visual propaganda, etc., give results slowly and leave many major difficulties. The farmer's holdings in most of the projects are not only small but also the parcels of land are scattered, and to implement an agricultural development program credit and marketing facilities are needed. To meet this important problem, rural cooperatives have been introduced and farmers encouraged to form primary cooperatives at the village level. This primary society consists of 30 to 40 members. A number of primary cooperatives form a central cooperative association at the thana level. This central cooperative borrows money for credit purpose mainly from the Provincial Central Cooperative banks and lends out money to the primary cooperatives, from which the farmers borrow the money required for their purpose. Normally, at least 80 per cent of the loans from the primary societies are given in kind such as fertilizers, seeds, implements, etc. The cash loan is never more than 20 per cent. This loan is repayable immediately after the harvest of the seasonal crop for which the loan was made. In many cases storage facilities have been provided so that farmers can store their produce after the harvest when the market price is low and hold it until the market prices rise to the desired level. This stored produce acts as a security for the loan issued to the farmer. The members of each primary society also have to make weekly thrift deposits, the minimum amount being .50 paisa, which accumulate to their credit.

This system of cooperative extension work was first introduced in 1965 in the tubewell project in Thakurgaon. Almost 100 per cent of the area has been covered by irrigation in the last four years.

## TRAINING OF FARMERS

From each of the primary societies, a manager and a model farmer is selected by the society to come to the Thana training center every week. The manager gets training in the procedures of cooperative activities while the model farmer is trained in agricultural works. Trainers are either appointed or borrowed from various national building departments of the government at the thana and the sub-divisional level. The manager and the model farmer get traveling allowance and daily allowance to meet their expenses. The model farmers go back to their villages, grow desired crops using the methods given to them and train other local farmers. The manager with his training organizes the cooperatives, collects the thrift deposits, arranges the loans, etc. The extension overseer with his hierarchy of trained officers supervises the activities of the manager and the model farmer in such field operations as land leveling, land preparation, digging of field and plot channels, rotation of irrigation, application of fertilizer, pest control measures, etc.

There is a Central Coordination committee consisting of WAPDA officials, officers of Agricultural Development Corporation, Agricultural Devel-

opment Bank of Pakistan and Cooperative and Animal Husbandry Departments of the government headed by the deputy commissioner of the district. This committee meets every fortnight at the project level to solve bottlenecks to efficient development of irrigated agriculture in the project.

## APPLICATION OF WATER

At present only two methods are being followed for application of irrigation water, viz., flooding, and ridge and furrow method. Flooding is the most common method of irrigation because the major crop is transplanted rice, both in the summer and the winter seasons.

The ridge and furrow method is sometimes used, but mostly for vegetables, in the rabi season, especially for potato, ground-nut and other vegetables.

## BOOKING OF IRRIGATION WATER

Under the existing act, East Pakistan Irrigation (Imposition of Water Rate) Ordinance 1963, a water rate assessment, not exceeding 10 percent of the gross increased benefits accruing to the owners of the land as a result of supplying irrigation water, can be realized from the owners. To make the water rate assessment, booking of irrigation water both cropwise and plotwise is essential.

A number of initial records as maintained in this connection. The "Permanent Field Book for Chakbandi" and "Plotwise Irrigation Registers" are the two initial records to be maintained for booking irrigation water. A chak is a block or a part of a block whose area falls within the command of one outlet fixed in the canal for delivering water. The Permanent Field Book for Chakbandi consists of two parts, viz.: (1) Chakbandi map showing the plots of land within, and a chak that can be irrigated along with the classification of the land according to its productivity, land elevation, soil fertility etc., and (2) A list of those plots, with area, name of owner, address, and the class of land. This information is entered in the register known as the "Permanent Field Book for Chakbandi."

In the plotwise irrigation register one page of the register is allotted to one plot and the dates of irrigation are recorded therein cropwise. While recording the first irrigation, the signature of the owner-occupier is taken as a proof that irrigation water has been supplied to the plot of land.

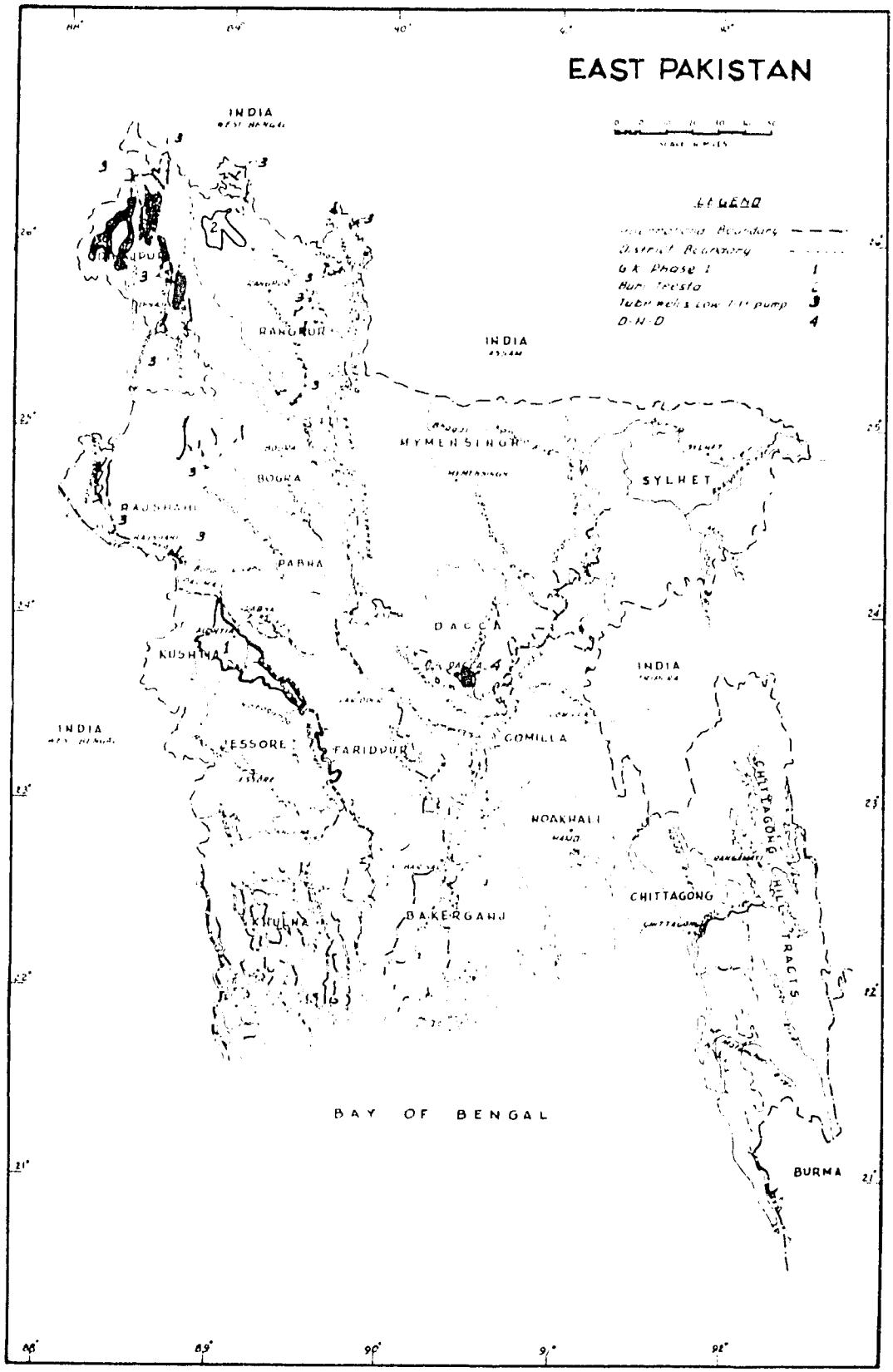
## ASSESSMENT OF WATER RATE

For the purpose of assessment each chak is divided into three assessment circles, depending on the classification of lands. Assessment circle I is comprised of first class lands; Circle II, of second class lands, and so on. An assessment is based on gross increase in yield. Crop cutting has to be done both for pre-irrigation and post-irrigation periods. The results are compiled in a register known as the "Crop-cutting Register." Crop cutting is generally done in a few plots in every assessment circle and an average is determined. Where such crop cutting to determine the pre-irrigation yields is not possible in the area of command, crop cutting is carried out on similar lands outside the irrigated areas.

The annual benefit is calculated and entered in the "Register of Annual Benefit." The act provides that in determining the benefit in terms of money value, 10 years' average price of crops should be taken. Information on the market price of crops is collected from the Directorate of Agricultural Marketing, under the government.

After all the information noted above is available, it is compiled in the "Assessment Register" and preliminary assessment rates are calculated. Preliminary assessment notices are then served on the beneficiaries and objections are invited. After hearing the objections final assessment is made. Demand notices are then issued on the beneficiaries on the basis of final assessment.

The water rates under the present act do not even cover the operation and maintenance charges, no such annual costs as replacement reserve, amortization, interest, etc. All farmers do not take water even though their lands are situated within the area of command. The government is, accordingly, considering amendment of the act, making provision of three flat rates, depending on the classification of lands, to realize the cost of operation and maintenance for the next five years, irrespective of whether a farmer takes water or not. After that period of five years, total annual costs, including amortization and interest, should be realized.


EAST PAKISTAN
INDIA
INDIA
RANGPUR
MYMENSINGH
BOGRA
SYLHET
RAJSHAHI
PABNA
DACCA
KUSHTIA
INDIA
INDIA
JESSORE
FARIDPUR
COMILLA
NOAKHALI
CHITTAGONG
CHITTAGONG HILL TRACTS
KHULNA
BAKERGANJ
BAY OF BENGAL
BURMA

## LOCAL TERMS AND ABBREVIATIONS

(1) **Acre**: 4,840 square yards = 0.40468 hectare.

(2) **Aman Broadcast or B. Aman**: A rice broadcast in March-April and harvested in November.

(3) **Aman Transplanted or T. Aman**. A kind of rice transplanted in August and harvested in November-December.

(4) **Aus**: A kind of rice generally broadcast or transplanted in March-April and harvested in July-August. When transplanted it is called transplanted Aus or T. Aus and when broadcast it is called broadcast Aus or B. Aus.

(5) **Beel**: Shallow depression

(6) **Boro rice**: A winter rice, transplanted in December-January and harvested in April.

(7) **EPADC**: East Pakistan Agricultural Development Corporation.

(8) **EPWAPDA**: East Pakistan Water and Power Development Authority.

(9) **Haor**: Deep depression.

(10) **Kharif crops**: Crops grown in summer and monsoon, including rice, jute, etc.

(11) **Maund**: 82.286 pounds.

(12) **Rabi crops**: Crops grown in winter from November to March, including mustard, pulses, wheat, barley, potato, tobacco, brinjal, chilli, onion, garlic, vegetables, etc

(13) **Rupees**: Re = $0.21

## PAKISTAN

# A MODIFIED CONCEPT OF THE CONSUMPTIVE USE OF WATER IN CASE OF RICE

by

**Ch. Mohammad Hussain***

Water is the limiting factor in the expansion of irrigated agriculture. Knowledge of consumptive use and irrigation water requirements is necessary so that only optimum requirements are supplied and any wastage avoided. The determination of consumptive use and irrigation water requirements involves consideration of water supply, both surface and underground, as well as those of the management and general economics of irrigation projects.

The accurate determination of consumptive use requirements of crops and its intelligent use is of utmost importance in the formulation and implementation of irrigation projects. The consumptive use requirements for some crops as in the case of rice may be quite different at the same place, when determined under different water table conditions, irrigation and agronomic practices. As such the consumptive use co-efficient 'K' derived according to the emperical formula, commonly in use, will give misleading estimates of the consumptive use requirements of the same crop at some other place having different water table conditions and agronomic practices.

Lysimeter studies give a good approximation of the consumptive use requirements and seepage losses in case of dry crops, while the field studies using tanks are suitable for wet crops like rice under high water table conditions. The results arrived at from the various experiments by different methods in both wings of Pakistan are discussed here.

## REVIEW OF PREVIOUS DATA

Lying as it is in an arid to semi-arid area, West Pakistan will always have a greater demand for water than available supplies. With limited water supplies and growing demands, a careful inventory must be made to assure its best possible use. Faced with this situation, great strides have been made in the past to arrive at some firm statistics of the water requirements of plants on scientific lines. Systematic studies accordingly were undertaken by the Directorate of Land Reclamation at Lahore in specially constructed lysimeters with various crops in 1947. At 10.5 feet deep water table the consumptive use requirement of rice was worked out to be 43.18 inches (1). Results are based on the average data of 10 years, 1947 to 1957. The growing period of the rice was 105 days (3.5 months).

To compare these results with those at Amla Experimental Station in East Pakistan on the Aman

*Director, Land Reclamation, (Punjab).

variety of rice having a growing period of 104 days, almost equal to the growing period of some of the rice varieties of West Pakistan, the two sets of data were considered. The consumptive use at Amla was estimated as 37.08 inches (2). The variation in the results from the two areas may be largely due to the difference in soil, water table conditions and such metereological factors as humidity, air temperature, wind movement, solar radiation and day length. West Pakistan lies between 24° and 37° north latitude and 61° and 76° east longitude, whereas East Pakistan lies between 21° and 26° north latitude and 88° and 92° east longitude. Accordingly it was decided to conduct some other experiments in West Pakistan on the consumptive use of rice by eliminating the dissimilar factors as far as possible. One of the factors involved in these studies was the water table. The experiments in East Pakistan were under high water table conditions whereas in the lysimeter studies in West Pakistan the water table was 10.5 feet from ground surface. Incidentally, high water table conditions as existing at Amla Experimental Station also prevailed at Chakanwali Experimental Station of the Directorate of Land Reclamation in West Pakistan. The water table at this station during the growing period of rice varied between one and two feet from the ground surface, more or less similar to that of Amla Station. Chakanwali Experimental Station lies at 32° north latitude and 73.6° east longitude, whereas Amla Experimental Station is situated at 24° north latitude and 89° east longitude.

## LAYOUT OF THE EXPERIMENT AT CHAKANWALI EXPERIMENTAL STATION

The layout pattern of the experiment conducted at Chakanwali Experimental Station was similar to the one conducted at Amla Experimental Station. Twelve metal tanks, half with bottoms and half without bottoms, were used for the experiment. The length of each tank was 80 centimeters and the diameter 56 centimeters. These tanks were buried to a depth of 64 centimeters, leaving a rim of 16 centimeters above ground level. These 12 metal tanks represent three replications each consisting of four treatments as follows:

| Treatment | Description |
|---|---|
| A | Transplanted rice in tank with bottom |
| B | No rice in tank with bottom |
| C | Transplanted rice in tank without bottom |
| D | No rice in tank without bottom |

In tank A with bottom and tank C without bottom four hills of rice with five seedlings per hill were transplanted. The spacing between the hills was nine inches. To create true rice field conditions the empty space around all sides of the embedded tanks was also transplanted with rice. The layout arrangement is shown in Appendix I.

After transplanting of rice the water level in the tanks was raised to six centimeters above the soil surface. Daily readings were taken at 8 a.m. Every morning simultaneously with the observations the water level in the tanks was again raised to six centimeters above the soil surface. To maintain the accuracy of the water level a plastic scale was attached with the rim of the tank above soil surface as a staff gauge and also an indication needle was set with the tip exactly six centimeters from the soil surface. Any addition from precipitation was counted toward water applied to the crop. The rainfall was recorded from a rain gauge installed close to the experimental area.

### Method of Computation

Rice (Basmati) was transplanted on the 7th August 1969, and water measurements started from next morning at 8 a.m. Addition of water was continued until the 18th October 1969. Irrigations were then discontinued and the plants utilized the remaining moisture available in the soil profile. The crop was finally harvested on 15th November 1969. Ignoring the last 15 days, which were used in drying of the seeds and the plants, the effective irrigation season may be taken as 7th August 1969 to 31st October 1969 (86 days). The results compiled, therefore, pertain to this period. A proforma was devised to record daily the amount of water added, any rainfall received, and in case of excessive precipitation any water taken out, and the total or net water added to the soil profile under experimentation.

The amount of water lost by evaporation and transpiration can be calculated directly as below:

**Transpiration:** Reading from tank A minus reading from tank B (A-B), or reading from tank C minus reading from tank D (C-D).

**Evaporation:** Reading from tank B or reading from tank A plus reading from tank D minus reading from tank C (A + D - C).

It has been observed, however, that the two sets of data, both in case of transpiration and evaporation, are quite close to each other. However, under practical conditions rice is grown in fields where there are no bottoms at all. In view of this the second set of data, viz., reading of tank C minus tank D, has been adopted.

Similarly in case of evaporation, instead of taking the direct data from tank B, the data arrived at by adding readings of tank D to A and subtracting that of C has been taken into consideration.

## RESULTS AND DISCUSSION

The term "Consumptive Use" is defined as the total water transpired and evaporated from a given area of vegetation for a unit time divided by the area.

The Division of Irrigation of the U.S. Department of Agriculture and the National Resources Planning Board, however, defined consumptive use as follows (3).

> "Consumptive use is the sum of the volume of water used by the vegetative growth of a given area in transpiration or building plant tissues and that evaporated from adjacent soil, snow or intercepted precipitation on the area in any specified time. It may be expressed in acre-inches per acre (depth in inches) or acre-feet per acre (depth in feet)."

The results of transpiration and evaporation, the sum total of which indicate the consumptive use for the entire growth period of the crop, are given in Table 1 below:

**Table 1: Consumptive Use of Water by Rice**

| Month & Date | Transpiration Cm(T) | Evaporation Cm(E) | Consumptive use Cm(E+T) |
|---|---|---|---|
| August | | | |
| 7th to 10th | 0.20 | 0.40 | 0.60 |
| 11th to 20th | 0.92 | 2.98 | 3.90 |
| 21st to 31st | 3.33 | 6.48 | 9.81 |
| Monthly Total: | 4.45 | 9.86 | 14.31 |
| September | | | |
| 1st to 10th | 6.03 | 8.75 | 14.78 |
| 11th to 20th | 6.18 | 8.08 | 14.26 |
| 21st to 30th | 6.15 | 10.31 | 16.46 |
| Monthly Total: | 18.36 | 27.14 | 45.50 |
| October | | | |
| 1st to 10th | 5.83 | 11.57 | 17.40 |
| 11th to 18th | 7.72 | 8.99 | 16.71 |
| 19th to 31st | – | – | – |
| Monthly Total: | 13.55 | 20.56 | 34.21 |
| Total: | 36.36 cm | 57.56 cm | 93.92 cm |
| | 14.31 inches | 22.66 inches | 36.97 inches |

The results of seepage average 5.38 centimeters (2.12 inches) only. The consumptive use of water by rice comes to 36.97 inches. These results compare favorably with the data arrived at Amla where it was calculated as 37.08 inches. Although two stations are not situated exactly the same latitude, yet these represent similar water table conditions.

## CO-RELATION OF CONSUMPTIVE USE DATA WITH CONSUMPTIVE USE FACTOR (K)

Under Chakanwali metereological conditions, the consumptive use factor has also been derived by the use of the Blaney-Criddle formula commonly in use.

Mathematically this is expressed as under:

$$U = KF$$

where U = Consumptive use of crop in inches for a given time period.

F = Sum of the monthly consumptive factors for the period

(Sum of the products of mean monthly temperature and monthly percentage of annual day time hours).

K = Consumptive use co-efficient for the given crop for the growth period determined empirically from field research

The monthly and seasonal values of co-efficient (K) as determined are given in Table 2 below:

**Table 2: Showing Consumptive Use and Co-efficient Values (K) as Derived by Blaney Criddle Formula**

| Month & Date | Transpiration Cm(T) | Evaporation Cm(E) | Consumptive use E + T = U | $\frac{T \times P}{100} = F$ | K = U/F |
|---|---|---|---|---|---|
| August | | | | | |
| 7th to 10th | 0.20 | 0.40 | 0.60 | 7.88 | 0.07 |
| 11th to 20th | 0.92 | 2.98 | 3.90 | 7.74 | 0.50 |
| 21st to 31st | 3.33 | 6.48 | 9.81 | 7.91 | 1.24 |
| Monthly Total | 4.45 | 9.86 | 14.31 | 23.53 | 0.60 Average |
| September | | | | | |
| 1st to 10th | 6.03 | 8.75 | 14.78 | 6.93 | 2.14 |
| 11th to 20th | 6.18 | 8.08 | 14.26 | 6.91 | 2.06 |
| 21st to 30th | 6.15 | 10.31 | 16.46 | 7.02 | 2.34 |
| Monthly Total | 18.36 | 27.14 | 45.50 | 20.81 | 2.18 Average |
| October | | | | | |
| 1st to 10th | 5.83 | 11.57 | 17.40 | 6.51 | 2.67 |
| 11th to 18th | 7.72 | 8.99 | 16.71 | 11.98 | 1.36 |
| 19th to 31st | – | – | – | – | – |
| Monthly Total | 13.53 | 20.56 | 34.21 | 18.49 | 2.01 Average |
| Total: | 36.36 cm or 14.31 inches | 57.56 cm or 22.66 inches | 93.92 cm or 36.97 inches | | Average K 1.60 |

The data indicate that the seasonal co-efficient (K) of the Basmati variety of rice with 80 days as its irrigation period comes to 1.6 as compared to 1.58 at Amla Experimental Station East Pakistan, which is similar.

## VARIATION IN CONSUMPTIVE USE REQUIREMENTS AT DIFFERENT WATER TABLES

In another set of experiments at the Directorate of Land Reclamation, Lahore, rice was grown in 1968 in lysimeters at water tables of five feet, seven feet and nine feet. The lysimeters have been provided with arrangements for measuring the irrigation water, accretion or depletion occuring at the sub-soil water level and for recording the natural precipitation. The data for different water tables are given in Table 3.

**Table 3: Showing Consumptive Use Data of Rice At Different Water Tables**

| Water table depth (Feet) | Irrigation (Inches) | Precipitations (Inches) | Total application (Inches) 1968 | Accretion to watertable (Inches) | Consumptive use (Inches) | K |
|---|---|---|---|---|---|---|
| 5 | 34.0 | 11.60 | 45.60 | 25.57 | 20.03 | 0.7 |
| 7 | 32.0 | 11.60 | 43.60 | 23.47 | 20.03 | 0.7 |
| 9 | 40.0 | 11.60 | 51.60 | 28.46 | 23.14 | 0.8 |

In lysimeters water was applied according to soil moisture conditions and crop symptoms and the irrigations reported are, therefore, somewhat different from those normally practiced by cultivators in the fields. Under field conditions in high water table areas or in areas where sowing of rice is done after thorough "puddling" — locally called "kaddu" — there is more evaporation. In the "kaddu" system of cultivation the seed bed is prepared by plowing and planting the land in standing water. In this way finer soil particles settle below the plow sole depth, and the percolation losses are reduced. During the irrigation period the water is constantly kept standing on the soil surface. In the lysimeter studies the water table is maintained at a desired depth under free drainage conditions. The irrigation water does not necessarily stand at the surface all the time during the growing period of the crop. Losses due to evaporation are more under high water table condition and the "kaddu" system of cultivation where the soil surface is kept covered with water. Under deep water table and free drainage conditions the losses due to evaporation become somewhat less. Otherwise the water lost through seepage under free drainage conditions in case of wet crops like rice correspondingly increases. The data presented above indicate that approximately 52 per cent of the surface application has been lost through seepage in lysimeter studies, compared to 5.5 per cent in such seepage losses under high water table conditions at Chakanwali Experimental Station. The actual water transpired through the plant should, however, practically remain the same under any system of cultivation and water table conditions. This is illustrated in Table 4 below:

**Table 4: Showing the Transpiration Losses at Different Water Tables**

| Water table (Feet) | Total application of water (Inches) | Accretion to water table (Inches) | Total consumptive use (Inches) | Evaporation from free water surface (Inches) | Water transpired through plants (Inches) |
|---|---|---|---|---|---|
| 5 | 45.60 | 25.57 | 20.03 | 7.24 | 12.79 |
| 7 | 43.60 | 23.47 | 20.03 | 7.13 | 12.90 |
| 9 | 51.60 | 28.46 | 23.14 | 9.26 | 13.88 |

In the table above the water lost through evaporation has been estimated on the assumption that it was equal to the actual evaporation from an adjacent evaporation pan. By deducting these evaporation losses the transpiration losses are estimated to be 13.88 inches in the lysimeter where the water table was maintained at nine feet depth. These compare favorably with the transpiration losses of 14.31 inches as determined at Chakanwali under high water table conditions.

The consumptive use co-efficient for rice under deep water table (nine feet) and free drainage conditions works out to be 0.8 compared to 1.6 under a high water table condition at Chakanwali Experimental Station. In both cases the consumptive use is based on evaporation and transpiration losses in accordance with the accepted concept, which however is open to question under these circumstances. In both cases as shown above the transpiration losses are practically the same but there is great variation in the evaporation, viz., 22.6 inches in a high water table condition and approximately 9.26 in deep water table and free drainage conditions. In the latter case there are other losses due to seepage which could have added to evaporation losses.

In another study at Lahore (4) it was observed that the evapotranspiration and the consumptive use co-efficient varied with varying water table, although the surface application and irrigation practices are the same. The results are reproduced in Table 5 below:

**Table 5: Showing Evapotranspiration at Different Water Tables by Keeping the Water Constantly Standing During Growing Period**

| Watertable (feet) | Rainfall (inches) | Surface irrigation (inches) | Total irrigation (inches) | Percolation (inches) | Evapo-transpiration (inches) | K |
|---|---|---|---|---|---|---|
| 1 | 1.75 | 95.66 | 97.41 | 30.34 | 67.07 | 2.3 |
| 8 | 1.75 | 95.05 | 96.80 | 36.51 | 60.29 | 2.05 |

The obvious reason for the low consumptive use in case of deep water table is much percolation and comparatively less evaporation loss.

For calculating the water requirements, the losses due to evaporation and percolation should be considered in accordance with the prevailing water table, soil conditions and other agronomic practices. However, much research is needed to ascertain evaporation losses from a free water surface and the seepage losses, in relation to the water requirements at different places with varying water tables.

## SUMMARY

Unlike dry crops, the consumptive use of water in case of rice, when worked out under high water table conditions with water constantly standing on the soil surface, gives quite different results than under free drainage and deep water table conditions. The quantity of water actually applied, however, may be approximately the same. In the former case the losses due to evaporation are greater than in the latter case, wherein there are more seepage losses which are not accounted for in accordance with the prevailing consumptive use concept. This has been demonstrated in the experiment conducted in the Directorate of Land Reclamation, Lahore (West Pakistan). As such, this may require modification to avoid any controversial issues.

## ACKNOWLEDGEMENT

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# TURKEY

## THE FINANCIAL PROBLEMS OF ON-THE-FARM OPERATIONS IN SEYHAN IRRIGATION PROJECT STAGE-I

by

Ethem Özsoy*

### SYNOPSIS

Irrigation projects are developed in two stages in Turkey. The first stage is planning and construction, accomplished by the General Directorate of State Hydraulic Works (DSI) and the second stage is on-the-farm operation, accomplished by the General Directorate of Farm Irrigation and Soil Conservation (TOPRAKSU) and by the farmers.

Generally, the first stage and the first part of the second stage are well done. But the last part of the second stage is only fairly done. With even a small difference between the quality of the two stages optimum benefits cannot be obtained and some parts of the investment may be in vain. It is a challenge to find the financial resources to implement an irrigation project, and especially so for small farmers in a project area.

In this paper the financial problems and procedures in a certain irrigation project area are discussed.

### INTRODUCTION

The Seyhan Irrigation project, fed by Seyhan river water, is designed to irrigate an area of 180,000 hectares in the Adana plain, which is between Berdan and Ceyhan rivers in the southern part of Turkey. Stage I has 56,000 hectares of irrigable land, out of the total 180,000 hectares, and these 56,000 hectares were almost completely irrigated in 1968.

Calculations show that the average cost (adjusted to present day prices) per hectare of the Seyhan Irrigation project will total 13,500 TL or $1,500 per hectare (nine TL equals one dollar). Of this cost, an average of 2,500 TL or $220 per hectare is required for on-the-farm improvements. TOPRAKSU at present subsidizes the farmer to the extent of 1,250 TL or $110 per hectare through the use of its equipment for leveling and drainage operations, in accordance with its principle of cost-sharing. Thus, the farmer is required to invest only 1,250 TL or $110 per hectare in the improvements on his land, while the government covers the balance of 12,250 TL or $1,390 per hectare. The government's share in the project is about 91 percent and the farmer's investment is only nine percent of the total cost. If Stage I of the Seyhan project is taken alone the farmer's investment is only about seven percent.

The farmer's reluctance or inability to finance his share of on-the-farm improvements was a major stumbling block in the implementation of the project.

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It resulted in the state's investment either lying idle or being used in a manner likely to harm the land. There is certainly no justification for keeping idle or misusing 93 percent of the total investment for even one year, while awaiting a mere seven percent in farmer participation.

## CREDIT FACILITIES: APPLICATION PRINCIPLES AND PROBLEMS

To solve the problem it was necessary to find financial resources for the farmers. Farm credits are granted by the agricultural bank, ZIRAAT BANKASI, a government agency, responsible to the Ministry of Commerce. Three branches of the bank, located in Adana, Tarsus and Karataş, process the loans to individual farmers and local cooperatives for the whole Adana plain, including the project area.

The agricultural bank extends short, medium and long-term credits to farmers. Loans for on-the-farm development for land leveling, irrigation and drainage facilities (designated as TOPRAKSU loans) fall into the latter category. Three types of loans are applied by the bank:

(1) **Conventional loans.** The Bank law (1937), article 10-2, specifically mentions long-term loans for irrigation development. In this case, extension offices of the Ministry of Agriculture in the provinces and towns develop loan projects and the bank finances them. This method is not completely successful because of incomplete loan projects. Generally, offices of the extension services are too busy and they are not specialists in this field.

(2) **TOPRAKSU loans.** These loans have been granted since 1960 for the execution of works in accordance with plans prepared by TOPRAKSU on behalf of the individual applicant. Credit is granted at five percent interest for a period of up to 20 years, with the understanding that on-the-farm improvements, cropping patterns, fertilizer applications and methods of cultivation will be under the supervision of TOPRAKSU. The bank has large financial resources for this type of credit, but in the beginning only a few loans were actually applied for by farmers. This was probably due to the farmer's natural disinclination to bear the cost of on-the-farm improvements. Furthermore, the rate at which these loans were disbursed was very slow: credits granted within Stage I total 706,000 TL or $73,500 for 21 farmers' 555 hectares of land in the first five years, from 1961 to 1965. It was difficult to find guarantors acceptable to the bank, especially for small farmers. The situation in the second five years, from 1966 to June 16, 1970, was better, with credits granted within the Stage I area amounting to 7,760,000 TL or $862,000 for 293 farmers.

(3) **Supervised credits** These loans depend on inter-ministerial project agreements. This is a complete project method approach. It has been in operation since 1964 in pilot areas. It is not only an irrigation loan, but includes soil conservation, land consolidation, farm machinery, livestock development, farm building construction, etc. The bank now employs 176 agricultural technicians at 203 branches in the country for this program. These technicians prepare farm and work plans and supervise the implementation of the plan and utilization of credit.

A TOPRAKSU loan project in the supervised credit system becomes a part of the farm and work plans. It may also contain work plans developed by other agencies related to agriculture. The bank decided to expand the supervised credit system for Stage I area in 1970.

## RELATION BETWEEN COOPERATIVES AND CREDIT AGENCIES

On-the-farm development requires the cooperation of farmers with TOPRAKSU. At this stage, associations, cooperatives and other groups play an important role between government agencies and individual farmers. They eliminate many problems created when working with individuals. However, the cooperative approach has not yet been developed as a successful system in Turkey. In Stage I area loans amounting to about 432,000 TL or $48,000 were made in 1968 and 1969 to 17 farmers with 235 hectares land, representing eight TOPRAKSU cooperatives.

## PRESENT CREDIT APPLICATION FORM IN STAGE I AREA

The establishment and functions of a coordinated extension service for Stage I area were explained

in the previous NESA seminars. The agricultural bank and the extension service cooperatively undertook comprehensive action to facilitate financing. They reached agreement on payment and arranged for every farmer who has adequate securities within the project area to receive 1,000 TL or $110 in cash and 900 TL or $100 in merchandise for every hectare he cultivates. To make sure that the money and materials would really be well spent and not wasted, the loan was divided into four stages in the growth period: (1) One or two months before sowing; (2) after germination; (3) after the first irrigation; (4) two or three weeks before harvesting.

The four forms used for this are shown on the following pages.

It was necessary to convince the farmers to go into this program and repay the debt after the crop harvest. A special technician from the bank and the foreman in the village would check to see that at each stage the required operations had been performed satisfactorily, then they would sign a report to this effect and the money for the next agricultural stage was granted. This system ensures the performance of all necessary operations in the most efficient fashion.

In the project area during the 1969 season, loans amounting to 5,190,000 TL or $557,000 were made to 192 farmers with 4,411 hectares of land. Of this 2,729,000 TL or $303,000 was loaned as cash.

**Credit Report – I**

VILLAGE _____

| FARMER'S FIRST AND LAST NAME: | |
|---|---|
| SIZE OF THE FIELD | OWNER BENT PARTNER TOTAL |
| CROP | |
| FOREMAN'S NAME | |

ONE OF TWO MONTHS BEFORE SOWING

| THE KIND OF AGRICULTURAL ACTIVITY | CONDITION OF THE AGRICULTURAL ACTIVITIES | | |
|---|---|---|---|
| DEEP PLOWING | GOOD ☐ | MID ☐ | LOW ☐ |
| FERTILIZATION | GOOD ☐ | LOW ☐ | NEVER DONE ☐ |
| SEED BED PREPARATION | GOOD ☐ | MID ☐ | NEVER DONE ☐ |
| APPLICATION OF INSECTICIDE | GOOD ☐ | LOW ☐ | NEVER DONE ☐ |
| CONDITION FOR SEEDING | GOOD ☐ | MID ☐ | NOT GOOD ☐ |
| RECOMMENDED CREDIT SUBJECT AMOUNT TL | | | |

SIGNATURE _____

**Credit Report – II**

VILLAGE_____

| FARMER'S FIRST AND LAST NAME: | |
|---|---|
| FARMER'S FATHER NAME | |
| FOREMAN'S NAME | |

AFTER GERMINATION

| | | | | | | |
|---|---|---|---|---|---|---|
| STAND CONDITION | GOOD | ☐ | MID | ☐ | LOW | ☐ |
| WEED CONTROL | GOOD | ☐ | SAT.[x] | ☐ | NOT SAT. | ☐ |
| INSECT CONTROL | GOOD | ☐ | SAT. | ☐ | NOT SAT. | ☐ |
| PREPARATION FOR IRRIGATION | DONE | ☐ | NOT DONE | ☐ | | |
| PREPARATION OF FERTILIZER | DONE | ☐ | NOT DONE | ☐ | | |
| LAND PREPARATION | GOOD | ☐ | SAT. | ☐ | NOT SAT. | ☐ |
| RECOMMENDED CREDIT<br>SUBJECT AMOUNT TL | | | | | | |

SIGNATURE_____

[x] SAT. = SATISFACTORY

**Credit Report – III**

VILLAGE _____

| FARMER'S FIRST AND LAST NAME: | |
|---|---|
| FARMER'S FATHER NAME | |
| FOREMAN'S NAME | |

AFTER FIRST IRRIGATION

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FIRST IRRIGATION | | GOOD | ☐ | SAT. | ☐ | NOT SAT. | ☐ |
| | PLANT PROTECTION A.P.P. APPLICATION | SAT. | ☐ | NOT SATISFACTORY | | | ☐ |
| | B.USEGA OF FERT. CHEM. TIMING | SAT. | ☐ | NOT SATISFACTORY | | | ☐ |
| HARVEST CONDITION | | GOOD | ☐ | SAT. | ☐ | NOT SAT. | ☐ |
| WEED CONTROL | | GOOD | | SAT. | ☐ | NOT SAT. | ☐ |
| GENERAL CONDITION OF THE FIELD | | PERFECT | ☐ | VERY GOOD | ☐ | SAT. ☐ | NOT SAT. ☐ |
| RECOMMENDED CREDIT<br>SUBJECT AMOUNT TL | | | | | | | |

SIGNATURE _____

**Credit Report – IV**

VILLAGE _____

| FARMER'S FIRST AND LAST NAME: | |
|---|---|
| FARMER'S FATHER NAME | |
| FOREMAN'S NAME | |

TWO OR THREE WEEKS BEFORE THE HARVEST

| | SATISFACTORY | | | | | NOT SATISFACTORY | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| IRRIGATION<br>NUMBER OF IRRIGATION | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| PLANT PROTECTION<br>NUMBER OF SPRAYING | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| CULTIVATION<br>NUMBER OF CULTIVATION | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| PREPARATION BEFORE HARVESTING | WELL PREPARED ☐ | | | | | NOT PREPARED ☐ | | | | |
| GENERAL CONDITION | PERFECT ☐ | | GOOD ☐ | | | SAT. ☐ | | NOT SAT. ☐ | | |
| RECOMMENDED CREDIT<br>SUBJECT AMOUNT TL | | | | | | | | | | |

SIGNATURE _____

# CHAPTER VI

## Irrigation Institutions - Farm Relationships

## AFGHANISTAN

### IRRIGATION INSTITUTIONS AND WATER MANAGEMENT ASPECTS

by
Ahmad Farid Issaq*

### ABSTRACT

This paper deals with the water resources of Afghanistan, their present use and future uses. After describing the special physical features of the country, its meteorological and hydrological aspects, the paper gives details of water resources in the three main drainage areas. It describes in the latter part the customary systems of water management in the old irrigation systems and also gives an idea of what the country proposes to do for water management and water legislation in the future.

### PHYSICAL CHARACTERISTICS

Afghanistan is a land-locked country situated in central Asia at the junction of the Himalayas, Kunlun, Hindu Kush and Pamir mountains. The Hindu Kush, a compound mountain system, is the country's main climate factor and landscape boundary. This range crosses the country from northeast to southwest and reaches heights of 6,000 meters in the northeast. The total area of the country is 645,000 square kilometers. The area above 5,000-meter elevation is only about two percent; from 5,000 to 3,000-meter elevation is six percent; 3,000 to 1,000-meter elevation is 59 percent, and below 1,000-meter elevation is 33 percent. (See Figure 1) Precipitation varies from 100 to 700 millimeters. Precipitation isobars are shown in Figure 1. The country is divided into 28 provinces, each headed by a governor. Precipitation is highest in Southern Salang and lowest in Kandahar. See Figure 2. Usually precipitation above 4,000-meter elevation is mostly in the form of snow; 4,000 to 1,500-meter elevation is sometimes snow and sometimes rain, depending on the season. Below 1,500 meters it is largely rain.

The country can be divided into three main drainage basins: (1) areas and rivers draining into Amu; (2) areas and rivers draining into the Indus and (3) areas and rivers draining into the southern and southwestern Seistan deserts and salt lakes. See Figure 3. There is an adequate covering of river gauging stations, as shown in Figure 3.

### AGRICULTURAL AND IRRIGATION ASPECTS

Afghanistan is an agricultural country. Agriculture is based on irrigated farming, though livestock

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breeding (including karakul for pelts) is also well developed. Figure 4 shows generally the areas covered by deserts, river irrigation, karez, dry farming areas, etc. Figure 5 shows diagramatically the distribution of irrigated areas by various means such as canals, springs, Karezes (called ghanats in Iran) or wells. It also shows distribution of land under various categories such as pastures, forests and sown areas. The diagram also shows distribution of sown land under various crops such as wheat, barley, etc. The main crop is wheat. About half of this is irrigated, and half is by dry farming. In 1967 the Ministry of Agriculture and Irrigation undertook a census of land in Afghanistan. Preliminary data of this work are given in Table 2.

One of the main tasks of the Third Five-Year plan in Afghanistan is the realization of an ambitious program in the development of irrigated farming. It is planned to achieve the following targets of production: wheat, 2.8 million tons; rice, 0.4 million tons; cotton, 0.18 million tons, sugar beets 0.19 million tons. To increase yield in other crops like barley, maize, citrus, tobacco, etc., the government also plans to construct a number of water resource development works for better utilization of its most valuable and natural resource, water.

Figure 6 gives details of the existing and future works.

The major part of Afghanistan is mountainous and unsuited for crop cultivation. The potential cultivable area is estimated to be 14 million hectares (22 per cent of the land area). Of this, only 5.3 million hectares is presently under irrigation. Due to the lack of proper facilities and want of proper water management, only 2.3 million hectares is irrigated every year. Of this, about 1.2 million hectares is in wheat. Another 1.1 million hectares is under wheat by dry land farming. Of the irrigated area, more than 95 percent is under canals, karezes and wells owned by the landowners. These works are operated and maintained by the landowners and farmers in a cooperative manner, although their societies are not registered and there are no laws or bylaws governing their actions. Water regulation, sharing the cost of operation and maintenance, is done in a collective manner by the farmers. This is in accordance with Islamic law (Shara) and tradition.

## WATER RULES AND LAWS

The basic rules for water distribution between the water users have been outlined in the Sharaiat. Some of the principles in the water usage laws are handed down from generation to generation and are more or less identical in all provinces of Afghanistan. During the flood period the farmers and landowners receive a constant flow of water. During the low water period, there is strict adherence to turn systems between irrigation systems, villages, individual farms and holdings.

Local administrators helped by 'mirabs' supervise the distribution of water and the repair and maintenance of the irrigation systems. There is a permanent supervisor (bandban) at the headwork of an irrigation system on main canals and he is paid by the landowners whose land is watered by the given system or canal. There is another supervisor (mardicar) at the head of each main distributory.

Water is distributed among the water courses in proportion to the area of land to be irrigated on a time basis. Special supervisors (saatchi) regulate the time during which water is delivered to a village and they are also paid by the landowners. Sequence of irrigation through water rotation is very strictly adhered to. All the population is involved in cleaning canals. For want of earth digging and moving machinery, this work is done by hand.

It should be stated that legal adoption and coordination of Moslem laws (sharat) on water utilization is of high importance in Afghanistan at present.

Laws on water utilization run as follows: "Imam is in charge of dead (virgin) lands." "Imam. . . can withdraw the land and hand this land to another person." Shariat laws are distinguished for their adaptability. For example, "water is not a subject for sale and purchase and cannot be used for paying debts." But on the other hand, if there is no land in possession of the owner of water, in this case Imam has the right to purchase land, which does not have water on account of the debtor's property, and sell together with water in order to obtain means for covering the debts.

All disputes over water should be settled on the basis of the amount of land possessed by the parties, because the major principle of the Shariat is "the right of land for water." The Shariat says "the basis for water distribution is the area of arable land" and "the land belongs to a man who has irrigated it."

Following are interesting details on distribution and utilization of water in the regions of karez irrigation in eastern Afghanistan: Water for irrigation is taken strictly by turn from the karez, during each day assigned to every village and the hours determined for every farmer. In the Pashtoon region the day when water is given is called "kolba." This is divided into four "shangolas" — six hours each, which in turn divide into "sels" (1.5 hours) and further into smaller irrigation time units. In provinces where Dari is spoken the irrigation period of 24 hours is called "shab-i-ruz," divided into four "charaks" (six hours each). "Charaks" are subdivided into "pau" (1.5 hours each) and khords (20 to 25 minutes each).

The usual order of distribution and utilization of water for irrigation is as follows: if the karez belongs to a big landlord who grants his land on lease to farmers, he establishes the sequence of watering among the farmers and he determines the amount of water for their use according to the area of plots and sown crops. The amount of water varies from a shab-i-ruz or kolba to several khords or sels. If the karez is the property of a group of farmers a strict sequence of water utilization between the farmers is adhered to, because each has equal rights in respect to the karez. If a farmer chooses to relinquish his share of water or to pass a watering turn, he has the right to sell his portion to another farmer. The land irrigated from karezes or springs, even when other conditions are similar, always is valued higher than the land of river irrigation, because karezes and springs during the whole year have more or less stable supplies of water. Especially is this so for the eastern regions of Afghanistan, where due to constant water supply it is possible to get two harvests a year and to cultivate valuable crops which have long vegetative periods such as sugar cane, cotton, citrus plants, etc. Small land owners having two to five sels each usually cultivate their land jointly in order to reduce labor expenses. When such a joint system of land cultivation is employed the harvest is divided according to the number of sels.

Besides the water charges which are paid to the owner of the canal in proportion to the number of sels and khords taken by a farmer, the farmers are bound to keep the irrigation canal in good order and to clean it and to protect the banks.

Presently Afghanistan is thinking of codifying customary laws and enacting legislation in order to have better control. The need for these laws is becoming more and more apparent as water is put to more and more consumptive use. A draft bill on water legislation is being prepared. The draft bill has the following chapters:

(1) Water Ownership
(2) Underground Water
(3) Groundwater and Ways of Distribution
(4) Construction and Maintenance of Irrigation Systems
(5) Irrigation Supervisors
(6) Irrigation Cooperatives
(7) Water Reservoirs
(8) Timings
(9) Miscellaneous

The central idea is that water, surface as well as underground, is a part of the country's national wealth and is owned by the public and all Afghans are entitled to its use. All persons have a right to use water for drinking from a public source, but if it is a private source, permission of the owner is necessary. A plot owner who may wish to dig a well or a karez on his plot may do so only after obtaining permission from the government. The laws also deal with the method of construction and maintenance of irrigation works by joint cooperative effort, and give rules regarding sharing the costs.

The proposed laws take into account and recognize the customary laws and give them legal status and backing. The chapter on irrigation supervisors deals with the qualifications of the general mirab and mirabs, methods of election and duties. It also defines the duties of chackbashi (dam supervisor) and darakban, etc. The existing societies of farmers will be strengthened and given legal status. The method of election of the board of directors by the general body is specified and their finances are subject to control by the government.

Restrictions on use of water for industrial purposes or for production of power are enunciated.

Limits of protected or prohibited areas around wells, karezes and canals are specified where digging for water or tapping water is prohibited.

## WATER RATES

In the concept of Islamic law, the water cannot be sold, because it is the property of the community. To utilize the flow water, there is need to construct storage works, diversion works, conveyance works and cross-drainage works. Either the people could contribute in advance to finance the construction or the government could construct the work and recover the cost over a long period. Sometimes the government can recover only the interest on the investment. Other charges are for operation and maintenance. Both of these charges would be payable by the beneficiaries either in proportion to the land irrigated or to the quantity of water used. Where measurement of water is difficult, charges can best be collected in relation to the area irrigated. This could vary with different crops, as their water consumption varies considerably. For instance, water required for winter wheat is only 4,100m$^3$ hectare, while water required for rice is nearly ten times as great: 40,000 m$^3$ hectare. Cotton is in between, at about 11,000 m$^3$ hectare. It is therefore reasonable that charges for capital works and operation and maintenance be related to the water consumption. Also, when the government spends money on these works it should not be a burden on the general tax payer. Since the primary, direct benefits will be realized by only a limited community, these beneficiaries should pay for the facility.

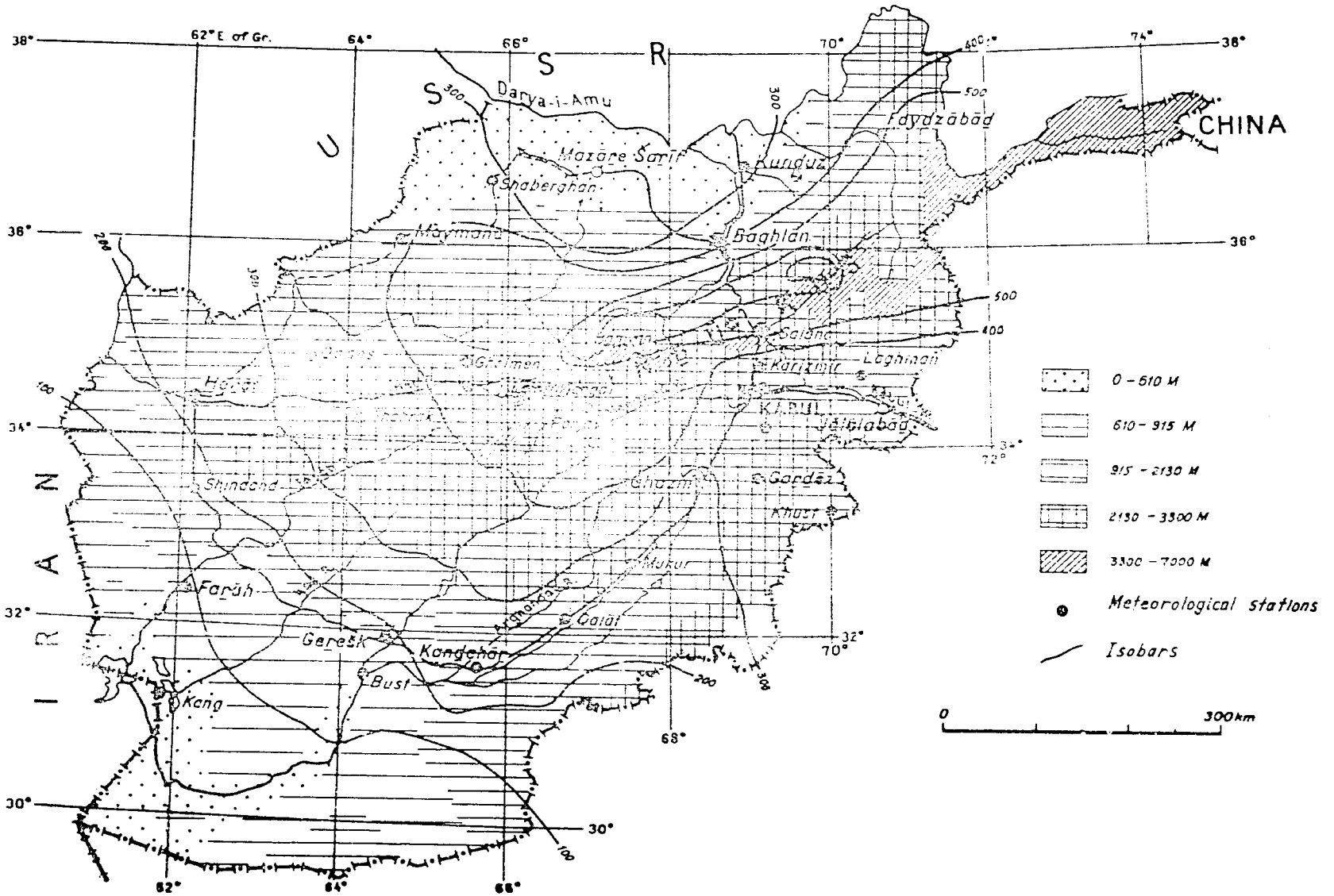
In addition to the above, the land owner pays a sort of land tax or property tax whether the land is under dry farming or irrigated. In many countries what is termed as a betterment charge is payable by the farmer when his once dry farm is provided with assured water supply. This facility increases the market value of this land and there is appreciation or betterment of the capital value of his land. The government may collect, after passing suitable legislation, a part of the difference in original price and appreciated price. This may be called the betterment fees, which can be collected in easy installments. The possibility of applying this regulation in Afghanistan should be considered.

## SUMMARY

For orderly development of water resources a master plan and a national water code (or water legislation) is necessary. In preparation of a master plan, water resources and water rights should be inventoried. Existing traditions and customs should be taken into account and a water code drafted. Also, for an orderly development of water resources with due regard to national priorities, a coordination authority should be set up.

Other duties of the water authority should include: (1) examining all projects in the water resources field recommended for construction or modification, to determine whether they are economically feasible and technically sound, whether they fit within the overall needs of the country, and do not interfere with the operation or duplicate the function of the existing projects, or require the use of a previously committed water supply; and (2) recommending the study of new projects of the same nature.

Figure 1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915 - 2130 M
2130 - 3300 M
3300 - 7000 M
Meteorological stations
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Figure 2: Annual values of precipitation in (mm) according to the data of the main meteorological stations of Afghanistan.

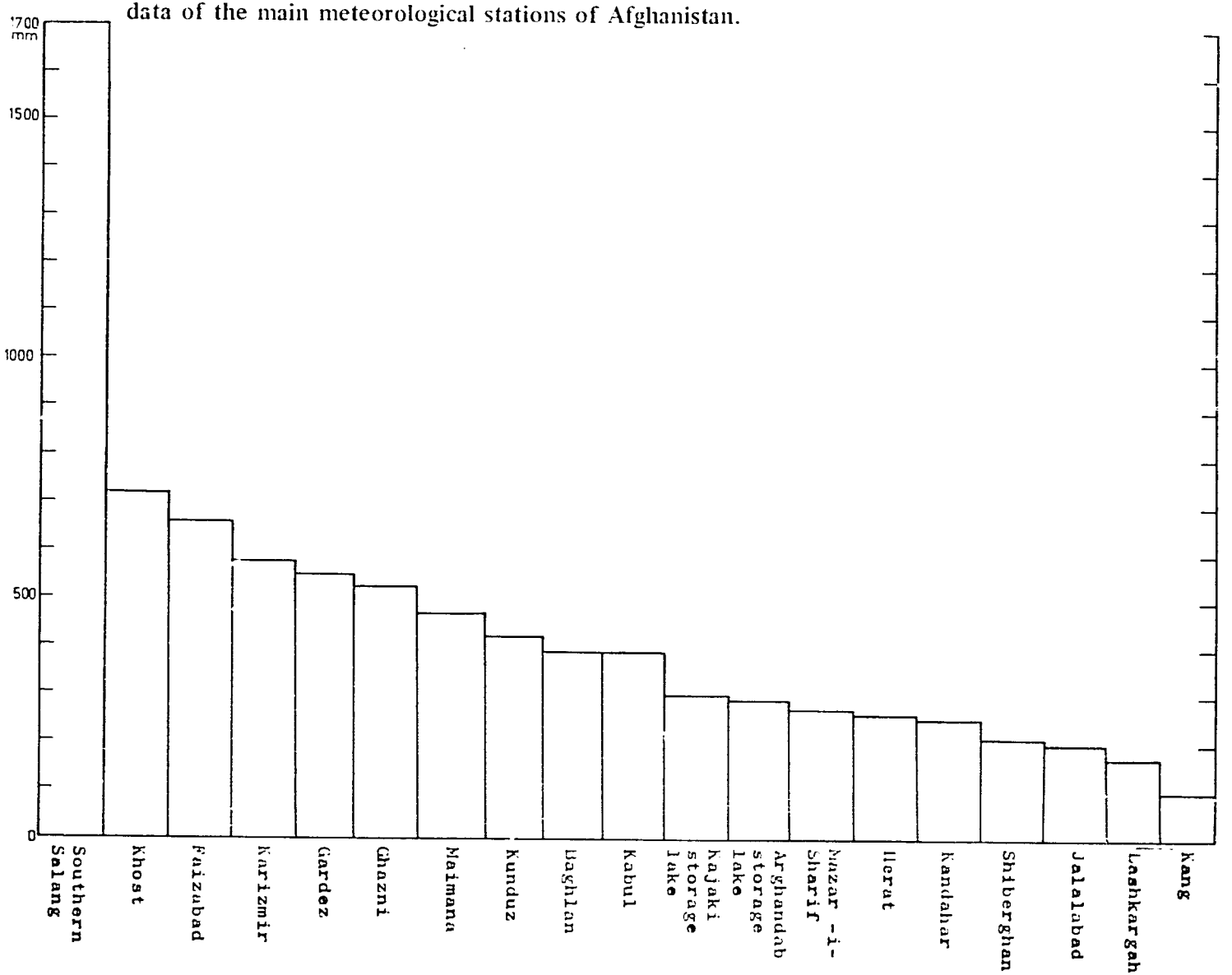
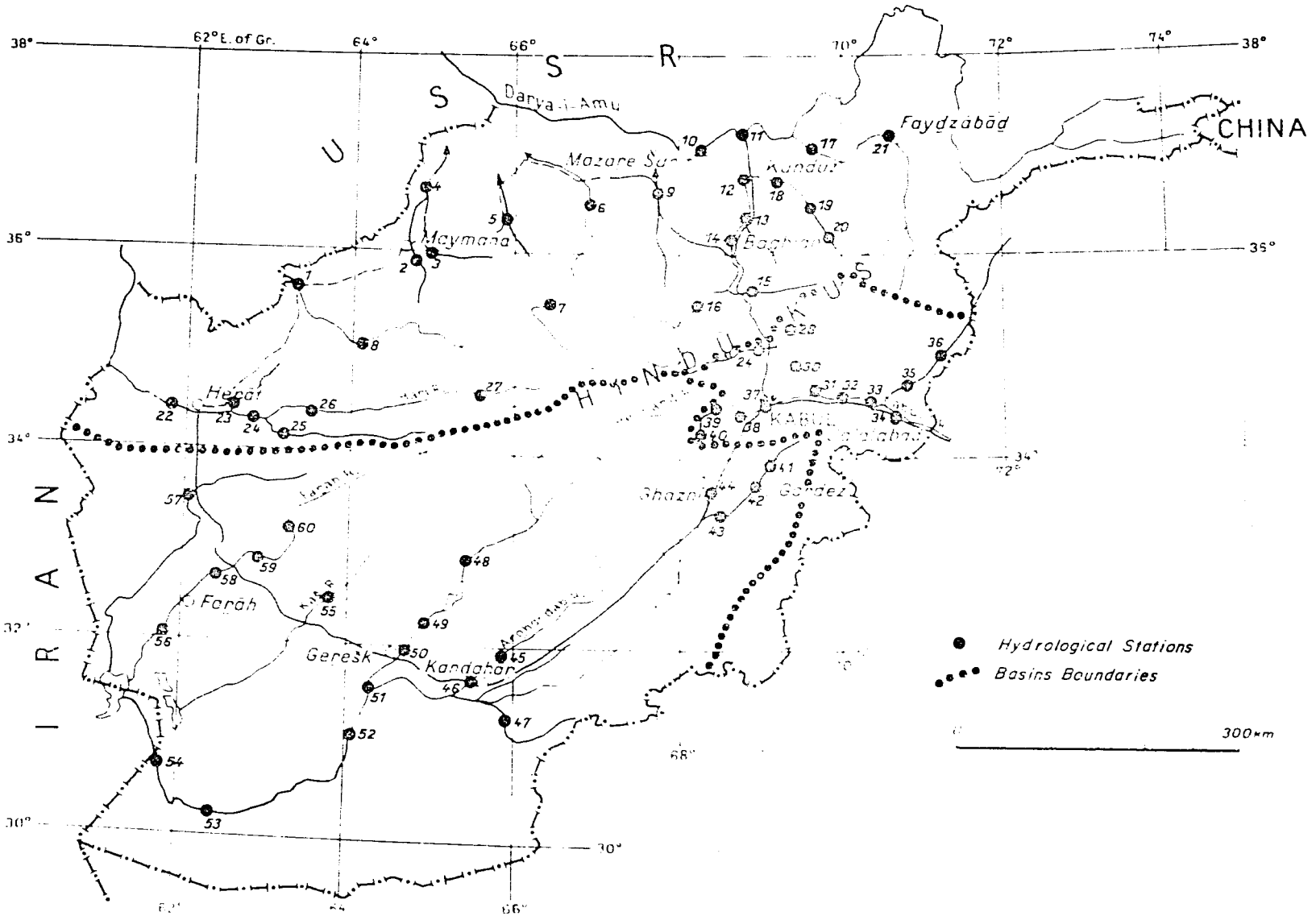


Figure 3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Hydrological Stations
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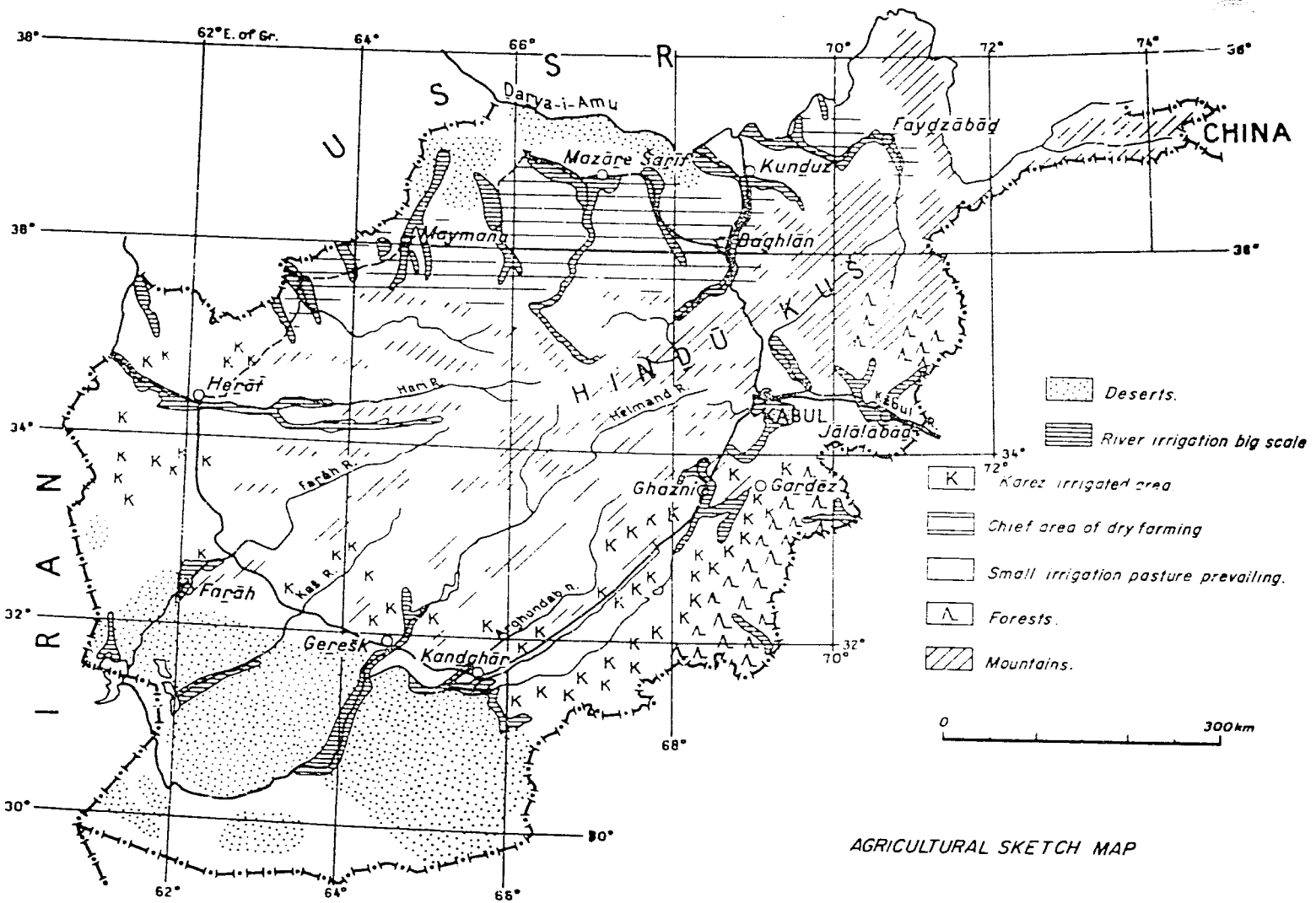
Figure 4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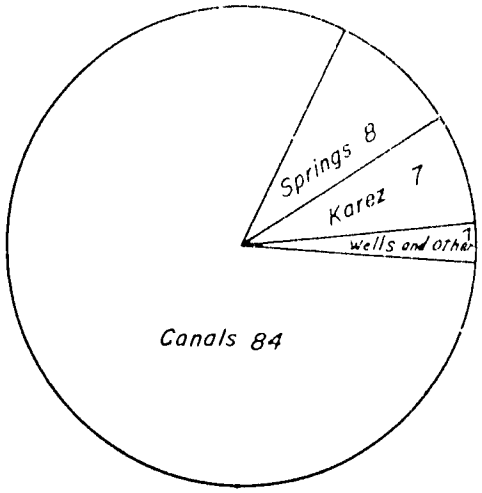
Helmand R.
KABUL
Kābul R.
Jālālābād
Farāh R.
Ghazni
Gardez
Farāh
Kaš R.
Ghundab R.
Gereš
Kandahār
Deserts.
River irrigation big scale
Karez irrigated area
Chief area of dry farming
Small irrigation pasture prevailing.
Forests.
Mountains.
0
300km
AGRICULTURAL SKETCH MAP

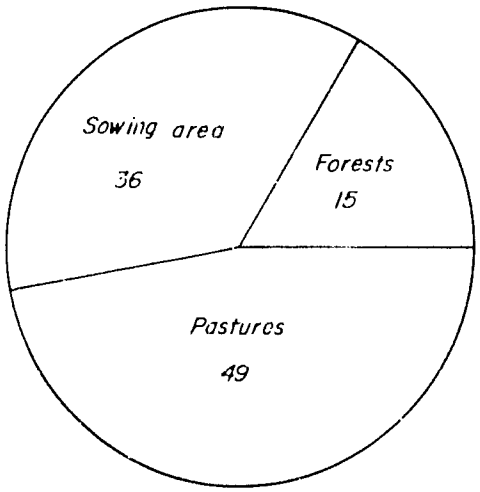
Figure 5

*Area of the country irrigated by means of various sources, suchas: canals, springs, Karez and others*

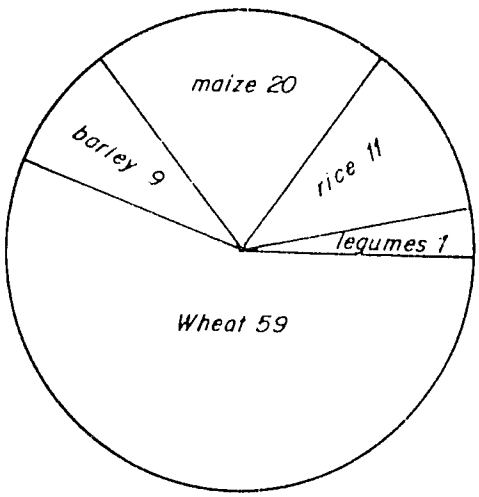
*Note: In Iran a Karez is referred to as a ghanat.*




*Distribution of country's land stock*




*Cereals and legumes production in the country*




*Distribution of agricultural crops in the country*

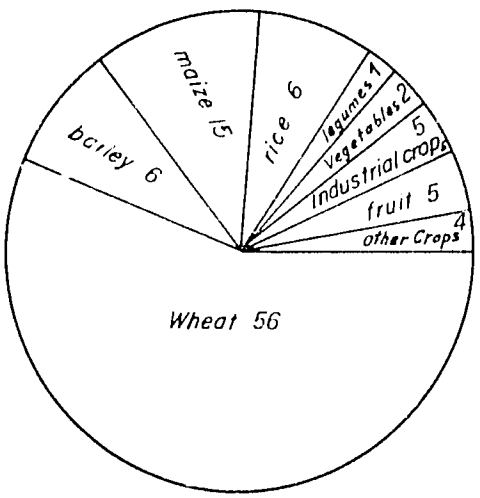
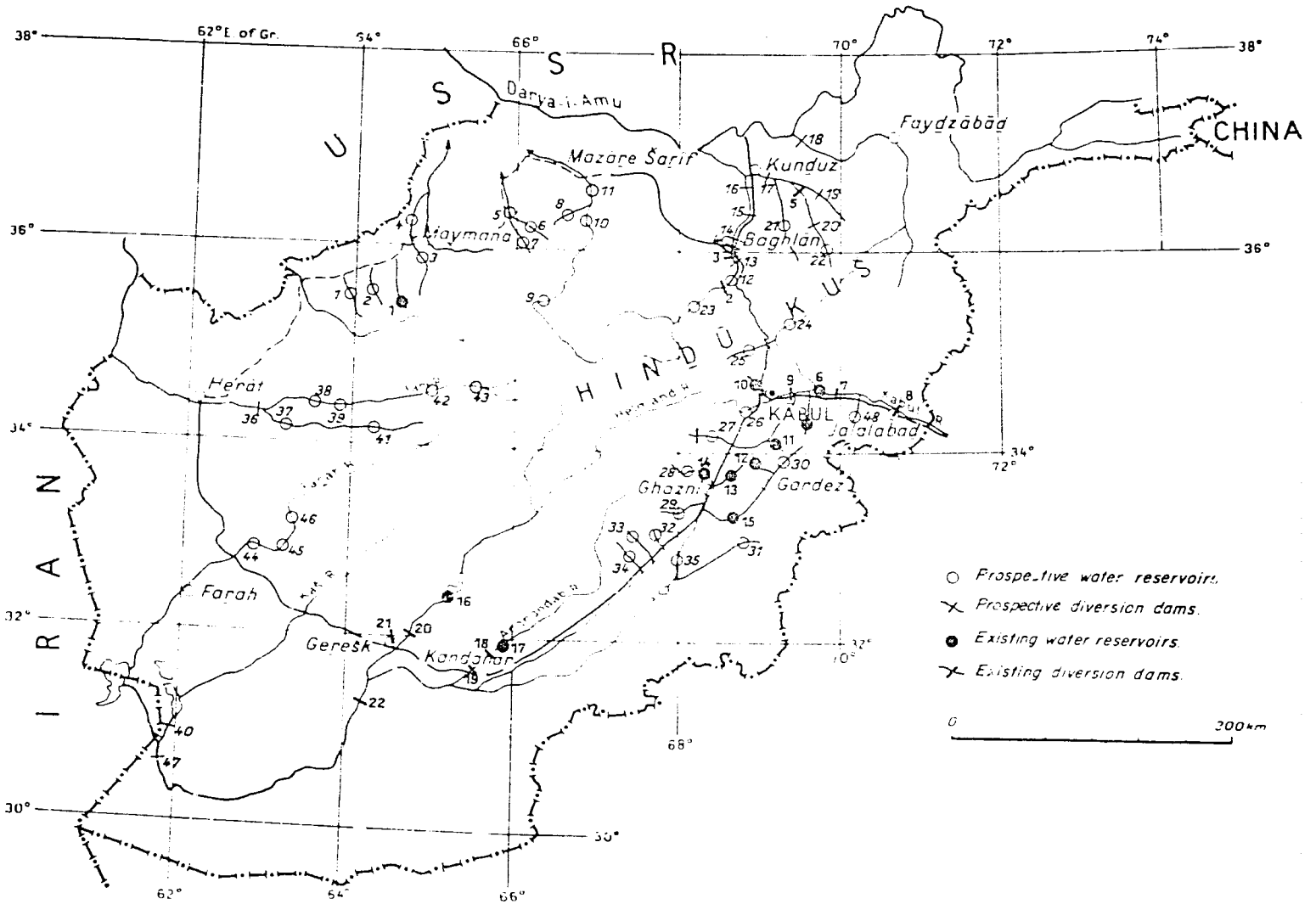


Figure 6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Herat
KABUL
Jalalabad
Ghazni
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Prospective water reservoirs.
Prospective diversion dams.
Existing water reservoirs.
Existing diversion dams.
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# INDIA

## WATER CHARGES IN RELATION TO BENEFITS DERIVED FROM IRRIGATION AND WATER CHARGING SYSTEMS, RULES AND REGULATIONS

by

J. P. Naegamvala* and H. J. Desai**

### INTRODUCTION

Agriculture provides about 50 percent of India's national income, engaging about 75 percent of its population. It is thus the major economic activity of the country and is likely to remain so for years to come.

The erratic monsoon with its wide variation with respect to rainfall, in both incidence and duration, has made provision of irrigation facilities a vital necessity in India's development plans. In the context of these plans, a study of the financial returns from large investments in irrigation projects assumes great significance.

### FINANCING OF IRRIGATION PROJECTS

According to the scriptures, the kings and others of the rich class were enjoined to build wells, tanks, etc., for the welfare of the community. In ancient India, therefore, construction of these works owed their existence to the munificence of kings and philanthropists.

In the beginning of the British rule in India, irrigation works were the responsibility of the military engineers under the control of a military board. This continued up to 1854 when the Public Works Department came under the purview of the government of India with similar departments in the provinces. Irrigation formed one of the branches of these departments. By 1858, pressure was brought on the government of India to provide irrigation facilities through private companies with an assured return of five percent on the capital invested. This, however, did not meet the anticipated success. In 1866 it was felt necessary for the government to take up extensive irrigation works by raising loans earmarked solely for this purpose. Sanction to raise such loans, however, was subject to the irrigation works being remunerative. Following the great famine of 1877-78, the government decided to raise special funds for famine relief and for the construction of protective works.

Until 1921 funds for all major irrigation works were found by the central government, with the loans

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raised in the United Kingdom. The expenditure in unprotective and minor irrigation works was met from the general revenue of the provinces or by grants from the central government. After 1921, all protective works were also financed by the state governments either from the general revenues or from loans.

## FINANCING OF IRRIGATION PROJECTS IN THE POST-INDEPENDENCE PERIOD

Planned development of the country since 1951 envisages balanced improvement in the various areas and extension of benefits of economic progress to the less developed regions. Agriculture, irrigation and power have the widest coverage and aim at providing basic facilities and services to people in all regions. Water resources development thus [illegible] is an important segment in the plans of several states, and large investments have been made in the various irrigation projects. The expenditure incurred on major and medium irrigation projects alone since the commencement of the first plan in 1951 exceeds Rs. 18,000 millions. Irrigation being a state matter in India, the funds for these projects are provided by the state governments from their own resources and by loan assistance from the center. The loan carries interest and is repayable in equated installments over a specified number of years. In the context of such a heavy investment, the question of appropriate return from irrigation projects assumes great significance.

## FINANCIAL RETURN

The financial policy of the government of India pertaining to irrigation projects could be traced back to 1866 when the Secretary of State expressed his willingness to sanction the raising of loans necessary for the construction of such works which could reasonably be expected to be remunerative.

The Select Committee on Indian Public Works, inter-alia, reported in 1879 as follows:

"The financial results of works of irrigation are, in the opinion of your committee, the best test of their utility. The construction of new works from borrowed money for the future should be limited to those schemes [illegible] one which upon the responsibility of the government are estimated to be productive by yielding an annual income equal to the interest on the capital expended on their construction, including such capital interest during construction."

The Irrigation Commission (1901-03) defined productive work as that which yielded a net revenue, 10 years after completion, sufficient to cover interest charges on the sum-at-charge at that date. The sum-at-charge indicates the total direct and indirect capital cost plus excess if any, on interest charges to date over net revenue. The productivity rate of irrigation projects is assessed with reference to the rate of return on the capital invested. This varies from time to time, the present rate being 6.5 percent.

Even the Taxation Enquiry Commission in 1953-54 expressed the view that the water rates on productive works should include a charge for supply of water which will primarily cover debt charges, overhead expenses, etc.

## IRRIGATION REVENUE

Charges for water supply for irrigation from government canals and works are levied differently in different states. Generally such charges comprise one or more of the following elements:

(1) Water rate depending on the kind and the extent of crop.

(2) Increment in land revenue based on increased benefit derived annually from providing irrigation facilities.

(3) Betterment levy, representing the government's share in the increase in land value accruing with the provision of irrigation facilities.

(4) Irrigation cess, being the annual charge per acre of the irrigable area, whether water is actually taken for irrigation or not.

## FIXATION OF WATER RATES

Water rates in India vary from state to state and even from project to project in the same state. In the past these rates were more or less fixed on an ad hoc basis.

It is generally felt that higher yields with the use of improved seeds, pesticides, etc., and the higher prices now obtained for agricultural produce, have increased the paying capacity of the farmers. An urgent need was felt, therefore, for a scientific inquiry into the entire structure of water rates now

prevailing so as to put it on a fair and rational basis. The method usually suggested for this is based on costs and benefits.

Measuring the quantum of additional net benefit precisely available to the farmers is a difficult task. The following formula could be suggested for deriving this additional net benefit: Additional net benefit owing to canal irrigation = $(R_2-R_1)-(C_2-C_1)$ where $R_1$ is the value of crop before introduction of irrigation; $C_1$, the cost of cultivation before irrigation; $R_2$, the value of crop after introduction of irrigation, and $C_2$, the cost of cultivation after irrigation but before paying the water rates.

Since the entire net benefit could not be attributed to irrigation alone, the cost of expenses ancillary to the investment on irrigation should be deducted from the gross value of the produce from the land.

Another question that arises in the fixation of water rates is the portion of the net benefit to the farmers that should be recovered.

## STUDIES FOR FIXING WATER RATES

The question was studied by the National Council of Applied Economic Research. The principal conclusions of their report in 1959 were as follows:

(1) The water rates should be fixed on additional net benefits derived due to irrigation. This is to be measured by the excess of net benefit after irrigation over net benefit before irrigation.

(2) Water rates should in no case exceed 50 per cent of the additional net benefit to the cultivator and should vary from 20 to 50 per cent.

(3) The water rate should be split into compulsory and voluntary rates where the demand fluctuates widely. The compulsory rate should be from five to 10 per cent of the additional net benefit and should be charged on all cultivators who are assured of water supply whenever they need it. The voluntary rate should be from 15 to 30 per cent of the additional net benefit.

(4) Revision of water rates is desirable after every five years or earlier if the price rise of the farm produce is more than 15 per cent after fixation of last water rates.

(5) The principle of fixing water rates on the cost of the project is not justified.

(6) The principle of fixing water rates on the value of crops is also not justified.

(7) For fixing water rates, Water Rate Boards should be set up for each system or state.

The principle of fixing water rates was also examined by the Irrigation Commission set up by the government of Maharashtra in December, 1960. The principal suggestions made by the commission were as follows:

(1) Water rates should be based on the annual cost (interest charges plus recurring expenses) of irrigation water required by the crop per average acre.

(2) It should be related to the level of average gross income obtained from the crop under the usual conditions of fertility, supply of manure, supply of water, level of efficiency of cultivation, prices, etc.

(3) The average water rate should be the same as the annual cost (interest charges plus recurring expenses) of water per average acre. For the state of Maharashtra, the committee calculated this to be Rs.57 per acre. Also the gross income per average irrigated acre was calculated to be Rs.575. Comparing the two figures, the commission suggested that 10 per cent of the gross income may be appropriated as water rate.

(4) The range of percentage of gross income from the different crops, which should be charged as water rate, may be fixed from six to 12 per cent with an average of 10 per cent.

(5) Water rates may be revised every six years.

(6) Concessional water rates during the initial period of irrigation development are worth continuing.

(7) There is no need for continuing the irrigation assessment as the surcharge on water rates, since the entire recurring cost on irrigation works can be recovered through water rates.

(8) Betterment levy and depreciation may be charged as 14 per cent and six per cent surcharge over the water rates. This surcharge of 14 per cent and six per cent is to be charged on all lands irrigated whether new or old, the period of recovery being unlimited.

The problem was also examined by a committee appointed by the government of India in 1964 to suggest ways and means of improving the financial return from irrigation projects. After studying various factors in water rates the committee considered it reasonable to adopt water rates equal to 25 to 40 per cent of the additional net benefit derived per acre of crop irrigated by farmers. Keeping in view such factors as rainfall, water requirements, yield and value of crop, etc.

The committee also examined the problem of assessing the additional net benefit. The data required for such assessment are production of crops per acre before and after irrigation and the cost of production. In the absence of the latter it may not be possible to compute correctly the additional net benefit derived from irrigation in the commands of various irrigation projects. The committee felt that where such data are not available, water rates may be initially fixed as a suitable percentage ranging from five to 12 per cent of the gross income to the farmers to start with and in the meantime the required data should be collected to revise the water rates on the basis of additional net benefit.

Table 1 gives the prevailing water rates in different states in India and Table 2 gives the percentage of these rates to the average value of gross income per acre from rice and wheat, based on the available data and some assumptions. It will be seen that this percentage varies from 1.1 to 19.4 per cent for rice and from 1.22 to 7.7 per cent for wheat. This study is made for yield of crops per acre of both irrigated and unirrigated areas together. Compared to gross income from irrigated crops alone, these percentages would be still lower.

The committee also recommended that water rates be reviewed periodically after, say, five years on the basis of assessment of additional net benefit from time to time.

## ASSESSMENT OF WATER RATES

Various systems of assessing water rates prevailing in India are broadly discussed below:

(1) **Occupiers rate.** This system is in vogue in the greater part of the country. The charge for the use of water under this system is made on the area irrigated at specified rates. The rules under the Irrigation Act specify the charges for preliminary watering, mixed crops, crops grown separately in the same field, fields resown, fields partly irrigated from canals and partly irrigated from wells or other sources, etc.

Under the Northern India Canals and Drainage Act, as applicable to the states of Haryana, Punjab and U.P., the rate called "Owner's rate" may be imposed in addition to the occupier's rate on the owners of canal-irrigated land in respect of the benefit which they derive from such irrigation.

(2) **Seasonal rate.** This system is in vogue in the states of Bihar, Gujarat and Maharashtra. The charge is levied in the form of a rate per acre of land irrigated, fixed with reference to the crops grown, the season of the year during which and the period for which water is supplied and the method of application of water to the land. According to the prevailing acts, water rates are payable for the whole area in which sanction to supply has been given, whether water is actually taken or not, provided that water for such supply was available.

(3) **Agreement rate.** Under this system the water charge is levied more or less on the same basis as under the occupier's rate except that a special agreement or contract is executed for supply of water for a period of year or years and is paid whether the water is actually used or not. This system is in vogue in the states of Madhya Pradesh and West Bengal.

(4) **Block rate.** Under the block system, prevalent in the state of Maharashtra, water rate per acre is worked out and charged for the entire cropped area.

(5) **Consolidated rate.** Under this system, prevailing in the southern states of India, viz., Andhra Pradesh, Kerala, Tamil Nadu, etc., the water charge is

joined with land revenue to form a consolidated rate. This system is suitable only where a single category of crop is grown, i.e., where the benefit derived from irrigation does not vary to a large extent among irrigators. Under the localization scheme practised in this part of the country, the area irrigated from year to year is fairly constant and each irrigator gets approximately the same average benefit per acre from year to year, owing to the uniform cropped pattern on all holdings.

(6) **Volumetric rate.** This system is generally in vogue in case of lift irrigation and tubewells in different states. The charge is levied on the basis of the quantity of water used for raising the crops.

(7) **Occasional rates.** These are charges levied for use of water in an unauthorized manner, or for wastage of water. These charges are recovered as water rates in addition to any penalty incurred on account of such use or wastage.

(8) **Percolation rate.** Bombay Irrigation Act as applicable in the states of Gujarat and Maharashtra empowers the canal officer to enforce the water rates to any cultivated land within 200 yards of any canal which receives by percolation or leakage from such a canal an advantage equivalent to that which would be received by direct supply of canal water for irrigation. Such water rate is even levied for the use of percolation water for non-irrigation purposes.

(9) **Irrigation cess.** In some states, a cess called the "Irrigation Cess" is levied in respect to land under irrigable command of a canal, in addition to the water rates or other charges leviable under the provision of the irrigation acts.

## CONCESSIONAL RATES

In a country changing from rain-fed cultivation to irrigated agriculture, an incentive is necessary for farmers to adopt the changing pattern of water supply and to meet expenses on land leveling, etc. Such an incentive in most of the states, in the case of food grains and fodder crops, is provided by giving free water in the first year after a distributary is open. In the second and third year of irrigation, the water rate is only one-third and two-thirds respectively of the normal rate. The full normal rate is charged from the fourth year onward.

## TWO-PART TARIFF

In many states water rates are optional and are charged only when farmers avail themselves of irrigation water. Irrigators take water in the kharif (summer) season only in case of inadequate rainfall. This results in reduction in revenue and in infructuous expenditure on the project. It is considered obligatory for the cultivators to pay for the facilities created to the extent of covering maintenance and operation charges. This could be done by adopting a two-part tariff, viz., compulsory water cess leviable on the entire culturable command area for which irrigation facilities are provided irrespective of whether the cultivators take water or not. Payment for facilities charged could be deducted from the total irrigation dues when the farmers actually avail themselves of the facilities.

The recommendations of the committee set up by the Ministry of Irrigation and Power have been commended to the state governments for implementation. As a first step, it has been decided to effect a uniformity in water rates in different zones in which the country has been divided for this purpose. Discussions are in progress at the highest level to make decisions in this direction.

**Table 1: Water Rates for Principal Crops Under Irrigation Canal System in Various States in India**

| S. No. | Name of State | Water rates in rupees per acre | | | | | |
|---|---|---|---|---|---|---|---|
| | | Rice | Cotton | Wheat | Jawar, Bajra millets, etc. | Sugar Cane | Garden Orchards etc. |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
| 1. | Andhra Pradesh | 15.00 | | | 10.00 | 22.50 | |
| 2. | Assam | | | | | | |
| 3. | Bihar | 15.00 | | 9.00 | | | – |
| 4. | Gujarat | 18.00 to 25.00 | 10.00 Kharif 18.00 | 18.00 to 25.00 | 7.00 to 9.00 | 140.00 | – |
| 5. | Haryana | 9.75 | 6.75 | 2.75 to 5.81 | 3.75 to 4.81 | 13.50 to 16.50 | 8.25 |
| 6. | J & K | 5.28 to 6.48 | – | 2.64 | 2.64 | 6.48 | 5.04 |
| 7. | Kerala | 5.00 to 10.00 | | | | | – |
| 8. | Madhya Pradesh | 8.00 to 10.00 | 8.00 | 4.00 to 10.00 | 8.00 | 20.00 to 30.00 | 20.00 to 30.00 |
| 9. | Maharashtra | 15.00 | 54.00 | 9.00 | 6.00 | 120.00 to 180.00 | 70.00 to 120.00 |
| 10. | Mysore | 16.00 | 8.00 | 8.00 | 8.00 | 30.00 to 45.00 | |
| 11. | Crissa | 1 to 8 | 10.00 | 2.00 | 5.00 | 14.00 | 8.00 |
| 12. | Punjab | 9.75 | 6.75 to 7.88 | 2.75 to 5.85 | 3.75 to 4.88 | 13.50 to 16.50 | 8.25 |
| 13. | Rajasthan | 8.50 to 9.00 | 12.25 to 13.00 | 5.25 to 10.00 | 4.0 to 7.0 | 19.50 to 27.0 | 13.25 to 17.00 |
| 14. | Tamil Nadu | 16.00 to 20.00 | 20.00 to 25.00 | | 7.50 to 10.00 | 20.00 | 15.00 to 20.00 |
| 15. | Uttar Pradesh | 5.00 to 17.50 | 2.50 to 5.62 | 5.00 to 15.00 | | 12.50 to 50.00 | 8.45 to 18.75 |
| 16. | West Bengal | 5.50 to 12.50 | – | 6.00 15.00 | – | 9.00 | – |

**Table 2: Relation of Prevailing Water Rates to Gross Income Per Acre**

| S. No. | Name of State | Rice | | | Wheat | | |
|---|---|---|---|---|---|---|---|
| | | Calculated gross income per acre 1966-67 | Prevailing water rates per acre | Percentage of prevailing water rates | Calculated gross income per acre 1966-67 | Prevailing water rates per acre | Percentage of prevailing water rates |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
| 1. | Andhra Pradesh | 436 | 15.00 | 3.44 | – | – | – |
| 2. | Bihar | 173 | 15.00 | 8.68 | 199 | 9.00 | 4.52 |
| 3. | Gujarat | 156 | 18.00 to 25.00 | 11.53 to 16.20 | 424 | 18.00 to 25.00 | 4.25 to 5.90 |
| 4. | Haryana | 322.5 | 9.75 | 3.02 | | 2.75 to 5.81 | |
| 5. | Kerala | 454 | 5.00 to 10.00 | 1.10 to 2.20 | – | – | – |
| 6. | Madhya Pradesh | 131.3 | 8.00 to 10.00 | 6.08 to 7.61 | 130.5 | 4.00 to 10.00 | 3.08 7.70 |
| 7. | Maharashtra | 336.0 | 15.00 | 4.47 | 191.0 | 9.00 | 4.72 |
| 8. | Mysore | 348 | 16.00 | 4.60 | 44.0 | 8.00 | 1.82 |
| 9. | Punjab | 330 | 9.75 | 2.95 | 419 | 2.75 to 5.85 | 0.66 to 1.40 |
| 10. | Rajasthan | 125.8 | 8.50 to 9.00 | 6.75 to 7.07 | 276 | 5.25 to 10.0 | 1.90 to 3.64 |
| 11. | Tamil Nadu | 512 | 16.00 to 20.00 | 3.13 to 3.91 | – | – | – |
| 12. | Uttar Pradesh | 91.6 | 5.00 to 17.50 | 5.46 to 19.10 | 328 | 4.00 12.00 | 1.22 to 3.66 |
| 13. | West Bengal | 388 | 5.50 to 12.50 | 1.42 to 3.22 | 226 | 6.00 to 15.00 | 2.66 to 6.65 |

# TURKEY

## LAND CONSOLIDATION ACTIVITIES AND REGULATIONS


### SUMMARY

Land consolidation activities commenced in 1961, were continued in 1962, then temporarily ceased until 1964. Land consolidation started on a large scale in 1966.

Consolidation projects have been conducted primarily by the TOPRAKSU General Directorate under Law No. 7457. However, consolidation efforts could not be carried out on a large scale due to the technical and especially legal characteristics imposed by consolidation procedures, and a new regulation was required to govern such efforts. For this purpose, a bylaw for land consolidation was drafted in 1965. The bylaw became valid through the publication in the official gazette July 26, 1966.

From then until the end of 1969, a total of TL 17,533,979 has been spent for 21 consolidation projects covering an area of 11,175 hectares. In addition, surveys and planning for seven consolidation projects covering 3,650 hectares have been accomplished, but these projects have not been implemented due to the opposition of farmers. Under the provision set forth by the land consolidation regulations, a consolidation project can be finalized only with the consent of two-thirds of the land owners who own more than half of the project area.

The scope of land consolidation project planning studies includes consolidation of several fragments belonging to any farmer and the possibilities of gathering together the land fragments registered to different members of a farm family. Project planning takes into account the benefits of irrigation systems and field roads to all parcels. Lands within the consolidation project area have been leveled and drainage systems constructed. Beneficiaries total 5,820 land owners and 4,067 farm families. The number of parcels has decreased by 39.62 percent, and the consolidation ratio is about 60.77 percent. On-field roads have increased to 37.1 meters from 25.9 meters per hectare.

In the land consolidation project areas, development activities have been realized at a lower cost; actual irrigation ratios have increased to a maximum, and an average of 36.70 percent saving has been secured in investment costs.


### INTRODUCTION

Land consolidation programs include the consolidation and rearrangement of scattered parcels, the expansion of small land holdings by allocating new lands, irrigation, drainage and land improvement on lands within the projected areas; construction of on-field roads, establishment of village settlement

centers, re-settlement activities, village electrification; culinary water; and other social and cultural improvements such as schools and hygenic facilities.

Land consolidation is conducted by the General Directorate of TOPRAKSU, under the Ministry of Village Affairs. With consolidation the farmers are able to secure maximum benefit from the project and increase their agricultural production and income per unit area, thus improving the operational units and rights of land tenure. Land consolidation is not yet fully implemented. But progress includes construction of on-field road systems, irrigation and drainage systems, land leveling, and re-allocation of scattered plots.

Land consolidation began in 1961 in Karkin village of Cumra town of Konya province. The Karkin project, covering an area of 319 hectares, was discussed in the Fifth NESV seminar. Land consolidation activities were discontinued from 1962 to 1964 due to the lack of efficient regulations and technical staff necessary to meet the technical and legal requirements.

In 1964, Land consolidation was included in a project conducted mutually by the State Planning Office and the United Nations Food and Agricultural Organization (UNFAO). The project was in the Antalya region, covering the Antalya, Burdur and Isparta provinces. Studies were made of measures to be taken in developing the area's agricultural structure. Consolidation surveys were made on a large scale to guide planning.

In 1967, the Lower Gediz Irrigation project, financed by the European Investment bank, envisaged the implementation of land consolidation on 61,000 hectares in addition to irrigation development for increased productivity on Salihli, Turgutlu, Manisa and Menemen plains.

Twenty-one land consolidation projects covering a total of 11,175 hectares have been handled from 1961 to 1969, as listed in Table 1:

## REGULATIONS

Land consolidation works are regulated under Law No. 7457 on the "Organization and Functions of the Soil Conservation and Farm Irrigation General Directorate." Paragraph (J) of article 2 of the law is as follows: "Upon the proposal of the Ministry of Agriculture, to realize land consolidation under related regulations, provided that land consolidation is required by the soil conservation and farm irrigation techniques in areas approved by the Council of Ministers."

In light of Article 52 of the constitution dated May 27, 1961, and based on the above provision and also Article 678 of the civil law, regulations for land consolidation have been enacted. Article 52 of the constitution and Article 678 of the civil law state as follows:

"Constitution, Article 52. The state takes necessary measures to provide the people with efficient food stuffs, to increase agricultural production to meet the needs of the community, to prevent soil loss and to evaluate agricultural products and labor of the farm, and producers." "Civil Law: Article 678. Works such as improvement of soil and waterways, drying-up of marshlands; forestation, road construction, and consolidation of parcels are realized by the mutual consent of beneficiaries. Therefore, decision should be taken by the group which, in number, forms two-thirds of the land owners who own more than half the total lands within the areas."

These provisions do not set forth clearly the procedure to be followed in land consolidation surveys, planning and implementation. Therefore, preparation of regulations was started in 1965 to accelerate the consolidation works and to implement them in accordance with the laws. A bylaw for land consolidation was drafted by the TOPRAKSU General Directorate and submitted for review to the Supreme Council of Ministers. By decision of the council July 11, 1966, Law No. 6/6706 was enacted titled "the Bylaw for Land Consolidation." At present, land consolidation projects are carried out in accordance with the provisions of this bylaw.

Table 1

| Year | No. of Projects | Area in hectares | Amount in TL |
|---|---|---|---|
| 1961-1962 | 2 | 319 | 785,230 |
| 1964 | 1 | 134 | 472,012 |
| 1966 | 2 | 754 | 1,486,636 |
| 1967 | 2 | 1396 | 1,225,098 |
| 1968 | 7 | 3471 | 4,977,297 |
| 1969 | 7 | 5101 | 8,587,706 |
| Total | 21 | 11,175 | 17,533,979 |

The following paragraphs will interpret the provisions of the law in various phases of surveying, planning and applying.

## SURVEY, PLANNING AND APPLICATION OF LAND CONSOLIDATION

**Application areas and priority.** According to Article 1 of the bylaw, land consolidation in Turkey is permitted in cases where "the Council of Ministers approves the land consolidation, and soil conservation and farm irrigation techniques make the consolidation necessary." Priority is given to lands within the irrigation development project areas of high agricultural potential and efficiency.

**Compulsory measures for land consolidation.** Land consolidation is applied in project areas where one or more of the following conditions are found:

(1) Small, misshaped and scattered parcels that make difficult the application of irrigation methods, taking of soil conservation measures and cultivation of arable lands.

(2) Topographical conditions require land leveling within the project area, without taking into consideration the boundaries of plots.

(3) Roads and canals not reaching some parcels of land in the project area.

(4) An irrigation or soil conservation project which necessitates the fragmentation of parcels because of new canals and service roads.

**Preliminary surveys.** Preliminary surveys are commenced when land consolidation is decided in an area where a soil conservation and farm irrigation project is to be applied.

Preliminary discussions are held with farmers in the project area concerning land consolidation practices. All details of the work involved are explained. If the discussions reach a positive result, then the procedures are outlined as follows:

(1) An application form jointly signed is requested from the farmers.

(2) Studies are made on the cadastral surveys of the project area.

(3) Characteristics of parcels are issued from the logs of local land registry offices and maps.

(4) Additional problems, if any, to those already found in the project area are studied with regard to irrigation, drainage and soil conservation requirements.

(5) A preliminary survey report, including land consolidation requirements and compulsory measures, is prepared and submitted to the ministry, together with a cadastral map of the project area.

**Approval by the Council of Ministers.** If the ministry approves the implementation of land consolidation in the project area, based on the preliminary survey reports, a proposal is made to the prime-ministry for approval by the Council of Ministers, in accordance with article 4 of the bylaw as follows:

"A report including one or more compulsory measures for land consolidation practices that should be implemented as required by soil conservation and farm irrigation techniques in TOPRAKSU project areas is submitted to the ministry, and if approved, a proposal is made to the Council of Ministers for final decisions, under the paragraph (J) of Article 2 of Law No. 7457."

Detailed surveys are commenced in the project area only after the final decision is made by the Council of Ministers.

**Cadastral procedure.** Land consolidation practices are conducted in areas where the cadastral surveys have been made. This is stated in Article 5 of the bylaw as follows:

"Land consolidation is implemented in areas where the cadastral surveys are available. In case these surveys are not available The TOPRAKSU General Directorate requests the General Directorate of Land Registry and Cadastre and State Planning Office to include the area within the cadastral program."

Land consolidation practices are closely related to the property rights of land owners. Ownerships should be based on official records. Therefore, cadastral surveys of the areas to be consolidated should necessarily have been made. In the areas where the land register is lacking, the property rights cannot be based on any official records and therefore the amount of land that will be allocated to the farmers cannot be definitely determined.

**Provision of cadastral maps.** The cadastral maps of the project area are supplied from the General Directorate of Cadastre and Land Registry. Graded photogrammetric maps are preferable. Otherwise, remeasurement of the boundaries of the project area is necessary. The cadastral maps of the area are of 1:2,500 or 1:5,000 scale. These maps are checked with respect to the general land situation by using air photographs.

A basic map is prepared to show the available structures (wire fence, vineyard, wood, canal, well, etc.) and land use situation. This map serves as a basis for future activities.

**Ownership surveys.** An "Ownership Registry card" is arranged for each person having land in the project area, after obtaining the proprietorship lists for the parcels in the project area from the local Land Registry office. Ownership registry cards are put in alphabetical order according to the surnames and then numbered. The alphabetical list of land owners is prepared in accordance with the number of the ownership registry cards.

**Land classification.** Classification maps for land use capability and for irrigated farming are prepared for the project area. Article 6 of the Land Consolidation Regulations prescribes that "the project administration prepares the classification maps for land use capability or irrigated farming with regard to the project area."

**Land grading and determinination of replacement values.** Land consolidation planning, as it is known, is made by re-allocation of the parcels. In making the planning of the parcels, parcel grades with regard to soil characteristics should be known. Therefore, parcel grades (classes), values and equivalents (replacement values) are determined in accordance with Article 7 of the Land Consolidation Regulations which prescribes that "parcels in the project area are graded on the basis of factors such as fertility and location," and the equivalent of each grade to other grades is determined following the preparation of classification maps for land use capability in irrigated farming.

Grading procedures are undertaken by grading commissions. A grading commission is set up, under the supervision of an engineer from TOPRAKSU, by three principal and two reserve members nominated by the land owners in the project area and by the village bailiff. In cases where the project area covers more than one village, a separate commission is set up for each village. If a municipal organization exists in the project area, one principal and one reserve member is selected by the municipal committee from its own members to participate in the grading commission.

Commission members cannot undertake grading of lands which are owned by themselves, their wives, their children, fathers-in-law, mothers-in-law, sons-in-law, daughters-in-law nor their grandchildren. Reserve members are taken into the commission during the grading of such plots.

The procedures for selecting the principal and reserve members from among landowners to participate in the grading commissions and also the number of meetings etc., for the commissions, will be prescribed in the regulations to be prepared by the ministry.

The commission undertakes the grading of each parcel and determines the score and equivalent to other parcels. If necessary, land classification maps are used in the grading.

During the selection of commission members, farmers are also asked to choose three sample parcels in the project area representing good, medium and bad conditions, and these are marked on the map. Other parcels are graded on the basis of these sample parcels. The current purchase and sale prices for parcels of different grades, the costs, yield and net income per decare of the crops are determined.

A grading map is prepared following completion of the field works. This is advertised in the village for 20 days together with the alphabetical list of land owners. On this subject, Article 8 of the Land Consolidation Regulations says:

"The lists and tables showing the grade of each parcel and the equivalent of each grade to other grades defined by the commission set up under Article 7 are advertised for 20 days by hanging them in places where they can easily be seen by landowners, and in addition, the related persons are informed. The fact that the lists and tables have been advertised by hanging should be confirmed by minutes.

"Interested persons can raise objections by writing to the commission within 35 days from the advertising date. The commission considers these objections and informs the interested persons about the decision taken.

"Those who have objections to the decision of the commission can apply in writing to the project administration within 15 days from the day of notice. The ministry is informed of such objections by the project administration. The necessary investigations are made by the ministry locally and the interested persons are informed on the final decision. Thus, the grading becomes definite."

**Discussions with land owners.** For the formulation of re-allocation plans, family members and the inventory of families are determined by having an interview with each farm family in the project area. At the same time, wishes of the landowners with regard to land consolidation are written down in minutes. The related Article 9 of the Land Consolidation Regulations is as follows:

"After the grades of parcels and the equivalent of each grade to other grades are finally determined, the subjects to be considered during the application of land consolidation are recorded in minutes by the project administration in a meeting which is attended by the older men or the member to be selected for the town council, the land owners or their agents, and the project administration. A second meeting is arranged for those who have not attended the first meeting, and the relevent persons are informed on the location and date of the meeting. Those who do not attend the second meeting in person or by their agents are assumed to have no wish with regard to land consolidation."

**Establishing the blocks.** Planning activities are commenced following the completion of irrigation, drainage and ownership surveys. The irrigation, drainage and road systems are marked on the basic map and the blocks including new parcels are thus established.

**The principles to be followed in land consolidation:** Article 10 of the Land Consolidation Regulation is as follows:

"Land consolidation is undertaken in accordance with the following principles:

"(1) Parcels owned by each farmer in the project area are consolidated as a single parcel or several parcels having the same size and grade. If it is not possible, farmers are given land of a grade equivalent to the grade of their own land.

"(2) In reparceling, the parcels covering permanent structures such as house, stable, strawshed, barn, storehouse, greenhouse and artesian well, and also oliveyards, vineyards, and orchards are given to those who are the old proprietors of these areas.

"(3) Wishes of land owners with regard to land consolidation will be realized as much as possible.

"(4) Land loss due to roads, irrigation and drainage canals and joint structures will be replaced by land exclusive of ownership. The area that cannot be met, will be reduced from the land to be given to farmers in proportion to the size of the land."

Wishes of land owners should be taken into consideration during the planning of land consolidation. New parcels will be regularly shaped and provided with irrigation and communication facilities. Relationship of the owners is taken into consideration in land consolidation.

**Final approval of the project.** "The New Ownership map" is made by replacement of the new parcels. "The New Ownership list" and "The New Alphabetical list for Land Owners" are prepared according to this map.

The new ownership map and the lists are advertised for 15 days as required by Article 11 of the Land Consolidation Regulations which prescribes that:

"The land consolidation project and its attachments finalized by the execution of Articles 7, 8, 9 and 10 are advertised for 15 days, and in addition, the land owners are given information by letter, and the fact that the project has been advertised is confirmed by minutes."

"Approval of the land owners for the project is requested by the project administration.

"In accordance with Article 678 of the civil law, in case those who own more than half of the area and constitute two-thirds of the land owners approve,

the others should agree with the project requirements.

"The project is finally approved by the ministry and applied in accordance with the annual programs.

"One copy of the project approved by the ministry is sent to the local land registry office, and the parcels in the project area are marked in the land registry log."

For the consolidation of lands covering areas such as vineyards and orchards all of the landowners should consent. Article 12 of the Land Consolidation Regulations is as follows:

"Lands such as oliveyards, vineyards and orchards can be consolidated after the written approval of all of the land owners is secured."

**Project application and new registries.** Irrigation and drainage activities, the construction of on-field roads and the repareeling practices covered by the project are undertaken following the approval of the project by the ministry. Concrete markers are put in the corners of each parcel. After the project is completed, the new ownership map, the lists and the written approval of the land owners are given to the land registry office, which cancels the old registries and makes the new ones in accordance with Article 13 of the Land Consolidation Regulations.

## LAND CONSOLIDATION ACTIVITIES TO THE END OF 1969

**Characteristics and sites of work.** Surveying and planning studies had been conducted on an area of 14,824 hectares in 11 provinces and 25 villages by the end of 1969. As a result of these studies, 21 projects have been prepared and implemented in seven provinces and 18 villages covering an area of 11,175 hectares. A total of TL. 17,533,979 has been spent for these projects. The execution of seven projects covering 3,650 hectares of land has not been possible due to the fact that the consent of land owners could not be secured.

Sites and characteristics of some of the land consolidation projects implemented are shown in Table 2.

**Table 2: Characteristics of Some of the Consolidation Projects Implemented in Turkey**

| Site Province-Town-Village | Area Hectare | Estimated Cost TL | Number of Parcels Before | Number of Parcels After | Number of Holdings | Number of Persons | Road intensity meter/Hectare Before | Road intensity meter/Hectare After | Number of Shares Before | Number of Shares After |
|---|---|---|---|---|---|---|---|---|---|---|
| Antalya-Merkez-Alayli | 134 | 472,012 | 146 | 78 | 75 | 132 | 3.7 | 19.2 | 428 | 351 |
| Burdur-Bucak-Incirdere | 614 | 1,166,636 | 630 | 465 | 415 | 507 | 29.8 | 46.2 | 1,454 | 1,096 |
| Manisa-Merkez-Tilkili | 920 | 540,648 | 2,210 | 876 | 174 | 306 | 32.0 | 22.0 | 3,223 | 1,233 |
| Konya-Cumra-Karkin | 437 | 773,879 | 286 | 206 | 174 | 278 | 31.0 | 71.0 | 379 | 297 |
| Erzincan-Merkez-Gulluce | 371 | 923,566 | 516 | 271 | 115 | 156 | 25.6 | 28.0 | 851 | 389 |
| Burdur-Tefenni-Yuva | 529 | 1,561,185 | 1,003 | 624 | 397 | 500 | 15.0 | 40.0 | 3,580 | 2,939 |
| Manisa-Merkez-Tekeliler | 385 | 465,438 | 626 | 267 | 127 | 192 | 24.9 | 19.9 | 788 | 411 |
| Manisa-Merkez-Selimsahlar | 1818 | 2,242,426 | 1,205 | 729 | 297 | 390 | 27.0 | 37.0 | 1,449 | 924 |

The projects implemented have benefited 4,067 farm families and 5,820 land owners. The total number of parcels has decreased from 12,161 to 7,342. The consolidation rate is 60.77 percent in projects implemented up to the end of 1969. The rate is expected to increase as more efforts are made and the experience and knowledge of farmers increase.

Problems in regard to communications in project areas have been solved by the implementation of land consolidation projects. The total length of on-field roads has increased from 275,739 meters to 370,470 meters. Roads which were non-passable during rainy days or seasons have been stabilized. The road intensity in the project areas was 3.7 to 61.7 meters

per hectare (approximately 25.9 meters average) before the implementation of projects. This amount has been increased from 7.4 to 71.0 meters per hectare (approximately 37.1 meters average).

**Project benefits.** The benefits derived from land consolidation projects can be summarized into three groups:

*(1) Rationalization of land ownership:* In the project areas, the number of parcels has been decreased at a rate of 39.62 percent. Jointly owned parcels have been eliminated, to bring together the shares of a land owner on different parcels under a single title deed. This condition facilitates the farm activities regarding land cultivation, conservation and bettering soil fertility.

*(2) Savings from labor force, time and investment costs, and development of the cultivation techniques:* According to research by instructors of the faculty of agriculture of the Ataturk university in the village of Gulluce within the Erzincan province, the labor force requirement has decreased by 3.4 to 4.5 percent due to the reshaping of parcels and the increase in their area. This rate will rise if other related factors are realized. Studies are being made to determine the increase in agricultural production in the project area as a result of land consolidation activities.

In addition, land consolidation practices reduce land development costs in the project areas. The area actually irrigated has raised to a maximum level, and a saving at a rate of 10 to 50 percent (approximately 36.70 percent average) has been secured from the investment costs of various projects.

*(3) Preventing juridical disagreements:* Juridical problems in the project areas are eliminated and as a result a social and moral ease is secured by the application of land consolidation. Each new parcel is provided with irrigation and communication facilities, and boundaries are marked with concrete stakes to prevent disputes between farmers.

**Project costs.** Project costs depend on the size, shape and fragmentation of the parcels. According to estimations made in 1966, the per hectare cost is TL 128.13 only for the consolidation of parcels. Of this amount, TL 65.33 is for surveying and planning, TL 47.80 for the application of new plans on lands, and TL 15.00 for reshaping of boundaries. This amount of TL 128.13 covers, of course, the costs for surveying and planning, and for the application of re-allocation plans (except for roads, irrigation, drainage and leveling) as well as the personnel and material costs.

The total of TL 17,533,979 spent on an area of 11,175 hectares covered by 21 projects mentioned above gives a cost per hectare cost of TL 1,570.

# CHAPTER VII

## Farm Irrigation and Drainage System

## AFGHANISTAN

### KARZ-ZAKIR EMERGENCY OUTLET DRAINS

### Report on Investigation, Design, Construction and Performance

by

**Mohammed Wali Audin**

### DESCRIPTION OF THE AREA

The Karz-Zakir outlet drainage system serves an area of about 24,000 acres, part of the 143,000 acres of land in the Central Arghandab project. The area called the Karz-Zakir area is to the south of Kandahar city. Before the drains were excavated the land in the area was classified as follows: Class I, 647 acres; Class II, 4,535 acres; Class III, 6,561 acres, and Class VI, 12,134 acres. Under proposed project conditions, which include additional lateral drainage, improvement of irrigation facilities and soil rebuilding, the land classification would be as follows: Class I, 12,414 acres; Class II, 4,253 acres, Class III, 2,962 acres, and Class VI, 4,298 acres.

The general topography is fairly uniform, with minor channeling by historical surface flood flows from the surrounding mountains upthrusted over the past centuries. The Karz-Zakir area contains some of the best vineyards in the Central Arghandab area.

### HISTORY OF IRRIGATION

The water supply for the area originates primarily from the Arghandab river; however, a limited amount of the irrigation supply is provided by a series of deep wells known as karizes. In the past water was also diverted from the Tarnak river for short periods of time during the spring runoff season.

Many of the existing juis (canals) in the area apparently have been in use for over 200 years. The major juis have as their source of supply the Arghandab river, with exception of the karizes. Several small juis derive their water from the return flow, surface waste and drainage flows which originate from irrigated lands situated at higher elevations within the area. Since construction of the Arghandab diversion dam and the Zahir Shahi canal in 1955 the juis in the Karz-Zakir area receive water from turnouts located along the Zahir Shahi canal.

## PROBLEMS OF THE AREA

The current 200-year-old irrigation system is a combination of juis constructed parallel to each other, that divide into additional paralleling small juis. The flow is distributed by means of proportional dividers. The paralleling and duplicating juis have caused an excessive amount of seepage loss.

Prior to construction of the drainage system, there were actually no adequate drains within the Kanz-Zakir area. Several landowners had attempted to get drainage relief by digging shallow hand-dug drains. The result they obtained was only minor temporary relief for lands situated at the highest point on the holdings. The old axiom that a drainage system is no better than its outlet was amplified in all of these attempts to get drainage relief.

Since the construction of the Arghandab diversion dam and the Zahir Shah canal, water has been available for irrigation practically all year long except for a 10-to-20-day shutdown period required to accomplish the necessary maintenance on the distribution facilities. The improved facilities brought considerable additional water into the area and resulted in rapid rising of unconfined groundwater tables. The rising water table began to have visible effects during 1964, 1965 and 1966 and caused a decline in crop production, loss of vineyards and forced some land completely out of production.

## INVESTIGATIONS

Investigations involving detailed land classifications, permeability determinations, groundwater elevations, water distribution analysis, crop census, etc., in the Central Arghandab started during the summer of 1967 by the U.S. Bureau of Reclamation's Project Development Planning team in cooperation with the Helmand-Arghandab Valley Authority's Engineering and Technical department. As information was gathered for the Central Arghandab report it was obvious that immediate action should be taken to provide drainage relief for the area. In addition to recommendations by the Helmand-Arghandab Valley authority, petitions were submitted from the landowners of the area to His Majesty the King through their legislative representatives during his visit on January 13, 1968. His Majesty issued a directive to determine the most feasible means of providing drainage relief to the area as soon as possible. Field surveys of the proposed drain were started by the Planning division of the Bureau of Reclamation on January 17, 1968. A report on the preliminary quantities and location of the drains was turned over to the Helmand-Arghandab Valley authority in April 1968. The report recommended a drainage system of 27.3 kilometers of open type drains. This system consisted of a main outlet drain of 10 kilometers, Zahir spur drain of [illegible] kilometers, Kandahar spur drains of 2.6 kilometers, Manzel Bagh spur drain of 3.3 kilometers, and Sherab Wash spur drain of 3.5 kilometers, with a total excavation of 526,000 cubic meters.

The report also recommended a gravel surfaced six-meter-wide roadway and an ungraveled four meter-wide roadway on the embankment of the drains. The estimated construction cost including the canal crossings, road crossings and roadways was $376,000.

## REVISION AND MODIFICATIONS OF THE PRELIMINARY PLAN

The report submitted by the planning team was revised by the Helmand-Arghandab Valley authority and the Kandahar provincial government authorities. It was recommended that an additional area be covered by the drain system. As a result the 2.7 kilometer Shekarpur spur was also constructed and Manzel Bagh spur extended to provide drainage for the Manzel Bagh camp area.

## DESIGN ACTIVITIES

All field surveys with respect to location, alignment, profile, grades, etc., were accomplished by the Project Development Planning team located in Kandahar. The team also made excavation computations, cost estimates and preliminary layouts. The Engineering division of the Helmand-Arghandab Valley Authority's Engineering and Technical department prepared all of the final designs and revisions. The hydraulic properties as designed for the drains are as shown in Table 1.

## CONSTRUCTION

After acceptance of the proposed plan and its modifications for drainage in the area, the Technical and Engineering department of the Helmand-

**Table 1: Hydraulic Properties - Karz-Zakir Outlet Drains**

n = 0.025 ss = 1.25:1

| Drain | Discharge CFS | Discharge CMS | Depth (M) | Bottom width (M) | Velocity (Ft/Sec) | Velocity (M/Sec) | Slope S |
|---|---|---|---|---|---|---|---|
| Main Outlet | | | | | | | |
| 0+000 to 2+682 | 111 | 3.14 | 1.0 | 2.0 | 3.16 | 0.963 | 0.0011 |
| 2+682 to 3+929 | 110 | 3.11 | 0.92 | 2.0 | 3.52 | 1.073 | 0.0015 |
| 3+929 to 7+420 | 77 | 2.18 | 0.85 | 1.5 | 3.27 | 0.997 | 0.0015 |
| 7+420 to 10+165 | 48 | 1.36 | 0.62 | 1.5 | 3.12 | 0.951 | 0.0019 |
| Zakir Spur | | | | | | | |
| 0+000 to 1+111 | 27 | 0.76 | 0.45 | 1.0 | 3.40 | 1.036 | 0.0034 |
| 1+111 to 3+100 | 20 | 0.57 | 0.45 | 1.0 | 2.63 | 0.802 | 0.0021 |
| 3+100 to 6+511 | 16 | 0.45 | 0.43 | 1.0 | 2.04 | 0.622 | 0.0013 |
| 6+511 to 7+925 | 6 | 0.17 | 0.21 | 1.0 | 1.98 | 0.604 | 0.0026 |
| Shekarpur Spur | | | | | | | |
| 0+000 to 2+650 | 10 | 0.28 | 0.40 | 1.0 | 1.60 | 0.488 | 0.0009 |
| Kandahar Spur | | | | | | | |
| 0+000 to 2+000 | 10 | 0.28 | 0.40 | 1.0 | 1.60 | 0.488 | 0.0009 |
| Manzel Bagh Spur | | | | | | | |
| 0+000 to 1+600 | 16 | 0.45 | 0.48 | 1.0 | 1.95 | 0.594 | 0.0010 |
| 1+600 to 3+270 | 9 | 0.25 | 0.24 | 1.0 | 2.72 | 0.829 | 0.0045 |
| 3+270 to 3+975 | 5 | 0.14 | 0.17 | 1.0 | 2.17 | 0.661 | 0.0040 |
| Shorab Wash Spur | | | | | | | |
| 0+000 to 3+450 | 21 | 0.59 | 0.39 | 1.5 | 2.46 | 0.750 | 0.0019 |

Arghandab Valley authority negotiated a construction contract with the Helmand-Arghandab Construction unit and preconstruction commenced on September 11, 1968. All construction surveys and inspection were done by the Helmand-Arghandab Valley Authority's Engineering division. During the excavation of the drains the first half to one and one half meter depth for the first three kilometers was accomplished by draglines. In areas where the water table was too high, timber mats were used under the dragline tracks to provide floatation. The as-built construction quantities and costs are shown in Table 4 and the as-built excavation quantities for each drain are as shown in Table 2.

**Table 2: Excavation Quantities for Each Drain**

| | Drain Designation | Length Excavated (meters) | Volume of Excavation (Cu.M.) |
|---|---|---|---|
| (1) | Main Outlet Drain | 10,105 | 241,094 |
| (2) | Zakir Spur Drain | 7,925 | 165,228 |
| (3) | Shekarpur Spur Drain | 2,660 | 49,830 |
| (4) | Kandavar Spur Drain | 2,025 | 43,431 |
| (5) | Manzel Bagh Spur Drain | 4,315 | 71,053 |
| (6) | Shorab Wash Spur Drain | 3,450 | 65,992 |
| | Totals | 30,480 | 636,616 |

Some of the problems encountered are as follows:

(1) Extreme waterlogged conditions of the ground made it mandatory to work off of timber mats in several places.

(2) Hydrostatic pressure on the exposed faces of the newly excavated channel caused sloughing in some areas.

(3) Newly excavated drainage channels generated large flows that made culvert construction difficult.

(4) Preliminary plans had called for a free flow uncontrolled outlet discharge into the Tarnak river. Excessive erosion of the Tarnak river bed downstream from the discharge end of the drain required construction of a control structure in the main outlet drain to stabilize the drainage channel in this area.

## PERFORMANCE OF THE DRAINAGE

The Karz-Zakir drainage system was designed as an outlet drainage system only. However, the effectiveness of this system surpassed all expectations. The approximately 200 in-place pump-out auger hole permeability tests in the area indicated permeabilities ranging from two to 16 meters per day. The average permeability for the zone extending from the ground surface down to a depth of 1.40 meters (4.59 feet) was 6.3 meters per day (10 inches per hour). The average permeability determined for the zone from 1.40 meters to 2.40 meters (4.59 to 7.87 feet) was 7.6 meters per day (12.5 inches per hour) and for the zone from 2.40 meters to 3.40 meters (7.87 to 11.15 feet) was 7.2 meters per day (11.8 inches per hour).

These permeabilities would indicate the need for drains spaced approximately 800 meters apart to provide adequate drainage to the land, depending upon the type of crop grown and the irrigation efficiencies attained. It was anticipated that drainage relief would be attained for a distance of 250 to 400 meters on each side of the drainage channels. However, the relief that was attained was in excess of 500 meters in some instances.

The physical appearance of the land, and especially the crops together with yield data obtained from the farmers, portrayed a remarkable, almost immediate recovery of crop production within the area of influence of the drain. Vineyards that yielded small, sour, unmarketable grapes in 1968 produced large, sweet grapes, with an increase in yield of about 25 percent in 1969. Alfalfa production was nearly doubled from 1968 to 1969. Lease prices for land farmed by tenant farmers were more than doubled because of anticipated increased yields. Sale price of land affected by the drainage system soared overnight. Water table levels dropped as much as one meter within one week after the drainage excavation passed pre-set observation wells. Drainage relief was so intense in some reaches that water boils developed in the bottom of the drains initially and persisted for several days.

Cross-drain groundwater observation wells were established across the proposed centerline of the drainage channels prior to construction at 28 different locations. The purpose of these observation wells was to determine pre-construction water table conditions, rapidity of draw-down after construction

passed the points of observation and to determine the overall effectiveness of the drain. Some selected observations on a few of these observation well lines appear in Plates 1 and 2 in this report.

Drainage outflow from this system began on October 20, 1968, at which time, a discharge measurement and quality analysis program was initiated and has continued to the present time. The effluent of the drainage system discharges into the Tarnak river, approximately 12 kilometers south of Kandahar. From October 20, 1968, through July 31, 1970, a total of 42,682 acre-feet of water has been discharged from this system, carrying with it 99,807 tons of salines. The composite quality of the effluent had variations in EC x $10^6$ @ 25° C ranging from 2,200 to 4,600 and an average of about 2,530 or 1,960 parts per million total dissolved solids. The average discharge contains about 63 percent sodium, two to three parts per million of boron, has a sodium adsorption ratio (SAR) of 7.95, an exchangeable sodium percentage (ESP) of 9.20, and no residual sodium carbonate (RSC). An interesting sidelight to this new drainage system is the drainage outflow from a recently constructed hand-dug shallow farm drain which discharges into the Zakir spur of the drainage system. This drain discharges water from land that has been irrigated for an untold number of years from Kareez. The EC x $10^6$ @ 25° C was 12,600, resulting in a salt concentration of 8,110 parts per million, 88 percent sodium and 11.8 parts per million boron. This situation represents the serious nature of some of the problem areas of this basin.

The overall effectiveness of the Karz-Zakir drainage system is best illustrated by three depth-to-water maps that were prepared showing conditions before construction, during construction and about six months after the drainage excavation was completed. The depth-to-water maps were prepared, utilizing depth-to-groundwater data gathered from over 250 observation wells and pits that are located within the area of influence of this drainage system. These depth-to-water maps appear as Plates 3, 4, and 5 in this report.

The data in Table No. 3 gives a breakdown of the acreage affected by various depths-to-water under pre-project and post-project conditions.

It is interesting to note that when a survey of drainage-deficient land was made in the Central Arghandab area during the period between June 1955 and January 1956, it was determined that about 15,200 acres out of 87,500 acres of land were in need of drainage. In the February-March 1968 period, as to the pre-project conditions, it was determined that out of about 99,000 acres in the Central Arghandab area, 52,000 acres had a water table less than 1.5 meters below the ground surface and over 64,300 acres had a water table less than two meters below the ground surface. Of this total acreage, approximately 24,000 acres are in the Karz-Zakir drainage system service area, 17,800 acres of which had a water table less than 1.5 meters and 19,700 acres of which had a water table less than two meters — in the February-March 1968 period.

When a comparable groundwater evaluation was made under post-project conditions, it was determined that the acreage that was plagued with a water table less than 1.50 meters below the ground surface had been reduced to about 6,700 acres and the acreage with a water table less than two meters below the ground surface had been reduced to about 9,500 acres. This tremendous improvement can probably be attributed to construction of the Karz-Zakir drainage system.

There is still considerable acreage that is in need of drainage in this area. The solution to the remaining drainage problems will be in the construction of additional farm and lateral type drains to tie into this outlet system, through the implementation of efficient irrigation practices, and the reduction of seepage losses in the present irrigation distribution system.

**Table 3: Acreages in the Karz-Zakir Drainage System Service Area Affected by Various Depths of Water**

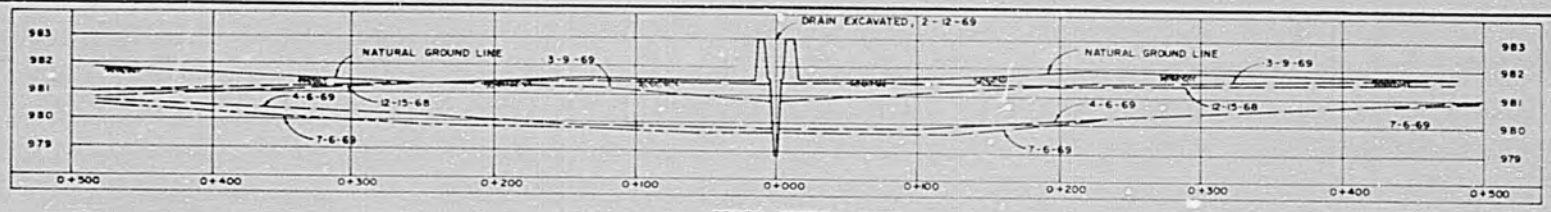
| Condition | Depth to Water in Meters | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.0 - 0.50 | 0.50 - 1.00 | 0.0 - 1.00 | 1.00 - 1.50 | 0.0 - 1.50 | 1.50 - 2.00 | 0.0 - 2.00 |
| | Acres | Acres | Acres | Acres | Acres | Acres | Acres |
| Pre-project Feb-Mar 1968 | 5,418 | 8,054 | 13,472 | 4,359 | 17,831 | 1,889 | 19,720 |
| Intermediate Feb-Mar 1968 | 1,202 | 4,834 | 6,036 | 5,137 | 11,173 | 3,551 | 14,724 |
| Change Between Pre-project and Intermediate | -4,216 | -3,220 | -7,436 | + 778 | - 6,658 | +1,662 | - 4,996 |
| Pre-project Feb-March 1968 | 5,418 | 8,054 | 13,472 | 4,359 | 17,831 | 1,889 | 19,720 |
| Post-project Feb-Mar 1970 | 252 | 1,794 | 2,046 | 4,624 | 6,670 | 2,847 | 9,517 |
| Change Between Pre-project and Post-project | -5,166 | -6,260 | -11,426 | + 265 | -11,161 | + 958 | -10,203 |

## Table 4: Karz – Zakir Outlet Drains

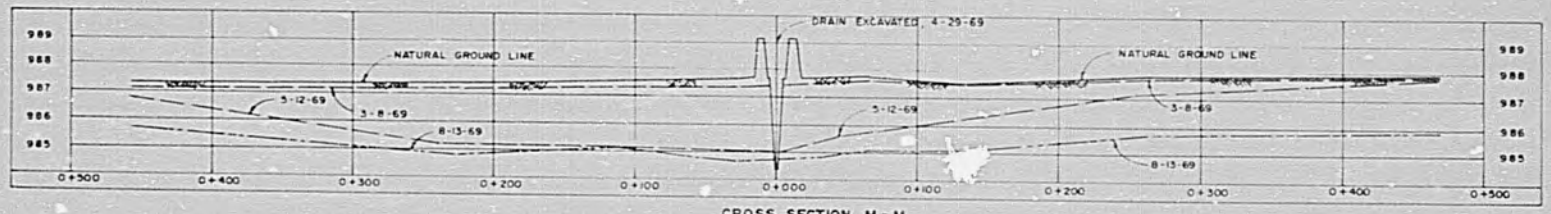
### Constructed Quantities and Costs

| Item No. | Work Description | Unit | Quantity | Unit cost (Afghanies) | Amount (Afghanies) | Amount (Dollars) |
|---|---|---|---|---|---|---|
| 1 | Excavation dry | Cu.M. | 263,117 | 27 | 710,415 | 94,722.00 |
| 2 | Excavation wet | Cu.M. | 373,501 | 43 | 16,060,543 | 214,140.00 |
| 3 | Overhaul | Cu.M. | 144,699 | 14 | 2,025,786 | 27,010.00 |
| 4 | Furnishing & Installing 36" Reinforced Concrete pipe | L.M. | 507.85 | 2,952 | 1,499,173 | 19,988.00 |
| 5 | Furnishing & Installing 48" Reinforced Concrete pipe | L.M. | 418.77 | 3,936 | 1,648,278 | 21,977.05 |
| 6 | Compacted Backfill & Embankment | L.M. | 6,423 | 70 | 449,610 | 5,994.80 |
| 7 | Riprap | Cu.M. | 84 | 700 | 58,800 | 784.00 |
| 8 | Gravel Surfacing | Cu.M. | 17,645 | 41 | 723,445 | 9,645.93 |
| 9 | Dozing 4 meter road | L.M. | 30,140 | 27 | 813,780 | 10,850.40 |
| 10 | Shaping & Compaction | L.M. | 30,140 | 88 | 2,652,320 | 35,364.26 |
| 11 | Furnishing & Installing 24" Reinforced Concrete pipe | L.M. | 428.97 | 1,650 | 707,800.50 | 9,437.34 |
| 12 | Furnishing & Installing 18" Concrete Pipe | L.M. | 262.85 | 800 | 210,280.00 | 2,803.73 |
| 13 | Structural Excavation | Cu.M. | 3,397 | 45 | 152,865.00 | 2,038.20 |
| 14 | Concrete Abutment | Ea. | 8 | 6,500 | 52,000.00 | 693.33 |
| 15 | Barjoist Truss - walkway for 22" Barrels | L.M. | 67.20 | 5,850 | 393,129.00 | 5,241.60 |
| 16 | Barjoist Truss - walkway for 30" Corrugated metal pipe | L.M. | 15.20 | 6,550 | 99,560.00 | 1,327.46 |
| 17 | Furnishing & Installing ½ of 36" Reinforced concrete pipe | L.M. | 26.84 | 1,520 | 40,796.80 | 543.96 |
| 18 | Furnish & Install 1/3 of 36" Reinforced concrete pipe | L.M. | 63.44 | 1,050 | 66,612.00 | 888.16 |
| 19 | Concrete footing including riprap | L.M. | 21 | 1,200 | 66,612.00 | 336.00 |
| 20 | Furnishing & Installing of 1/3 of 24" Reinforcement Concrete pipe | L.M. | 20.74 | 500 | 12,029.20 | 160.39 |
| 21 | Furnishing & Installing 12" non-reinforced concrete pipe | L.M. | 78.96 | 280 | 22,108.80 | 294.78 |
| 22 | Borrow | Cu.M. | 1,295 | 27 | 34,965.00 | 466.20 |
| 23 | Riprap (plain) | Cu.M. | 298.25 | 800 | 238,600.00 | 3,181.33 |
| 24 | Riprap (grouted) | Cu.M. | 93 | 1,100 | 102,300.00 | 1,364.00 |
| 25 | Reinforced concrete | Cu.M. | 57 | 1,500 | 256,500.00 | 3,420.00 |
| 26 | Bypass excavation | Cu.M. | 4,200 | 38 | 159,600.00 | 2,128.00 |
| | | | | | 35,610,232.22 | 474,803.06 |

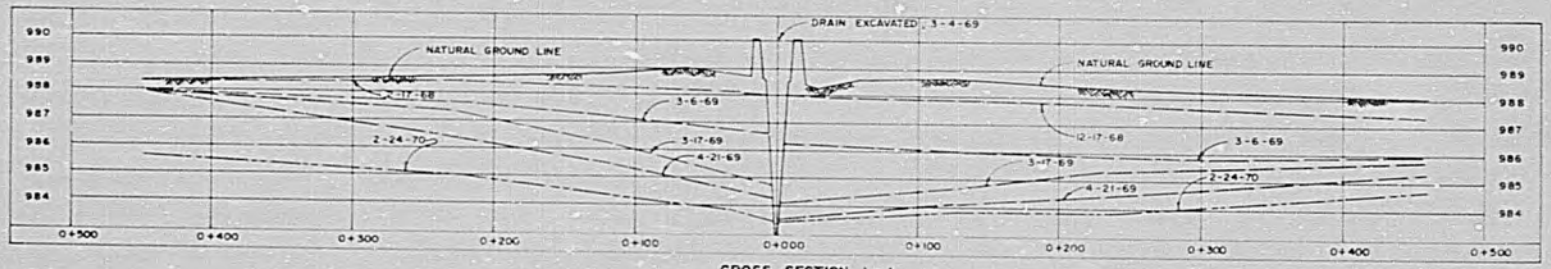
*One Dollar equals approximately 75 Afghanies.



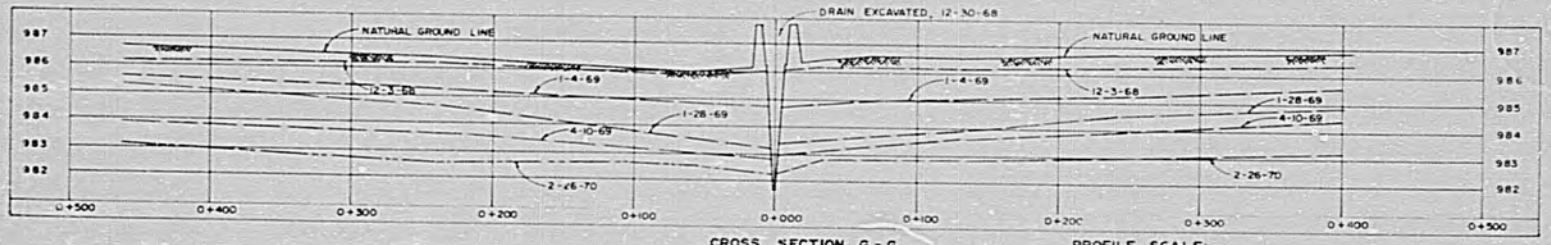

CROSS SECTION O - O
(STA. 2+000 SHEKARPUR SPUR)




CROSS SECTION M - M
(STA. 1+565 KANDAHAR SPUR)




CROSS SECTION I - I
(STA. 0+530 SHORAB WASH SPUR)




CROSS SECTION G - G
(STA. 9+830 MAIN DRAIN)

PROFILE SCALE:

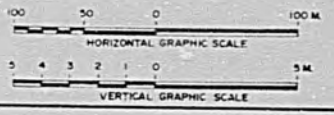
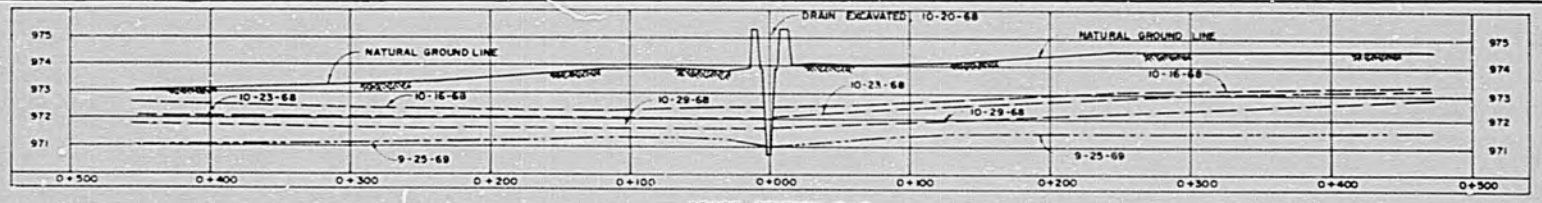


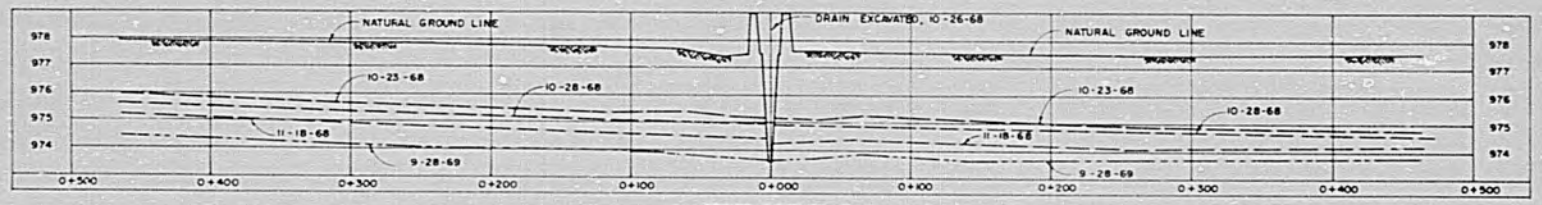

PLATE NO. 1

SHEET 1 OF 2

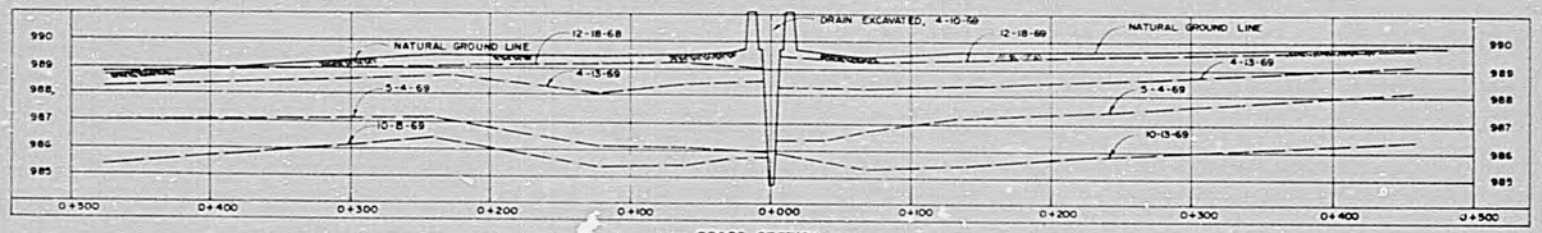
CENTRAL ARGHANDAB VALLEY UNIT
KARZ - ZAKIR
CROSS DRAIN PROFILES



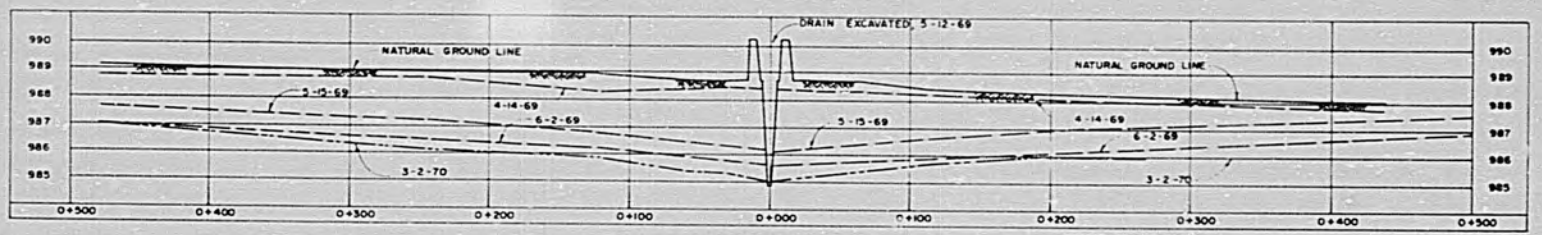

CROSS SECTION E-E
(STA. 3+260 MAIN DRAIN)




CROSS SECTION F-F
(STA. 0+560 ZAKIR SPUR)




CROSS SECTION J-J
(STA. 0+305 MANZEL BAGH SPUR)




CROSS SECTION S-S
(STA. 6+485 ZAKIR SPUR)

PROFILE SCALE:

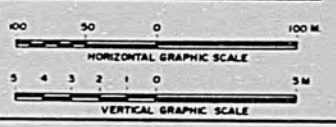
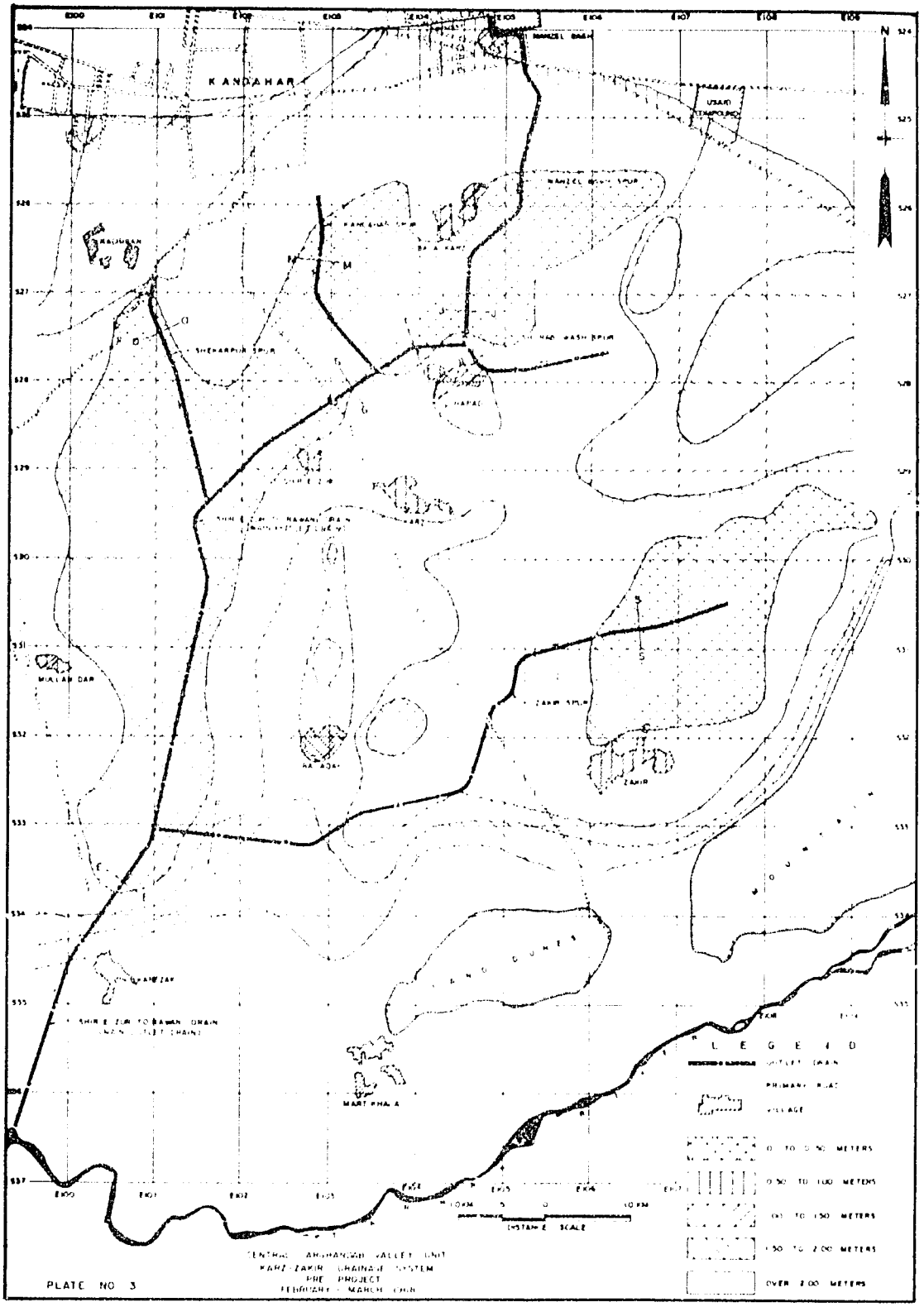
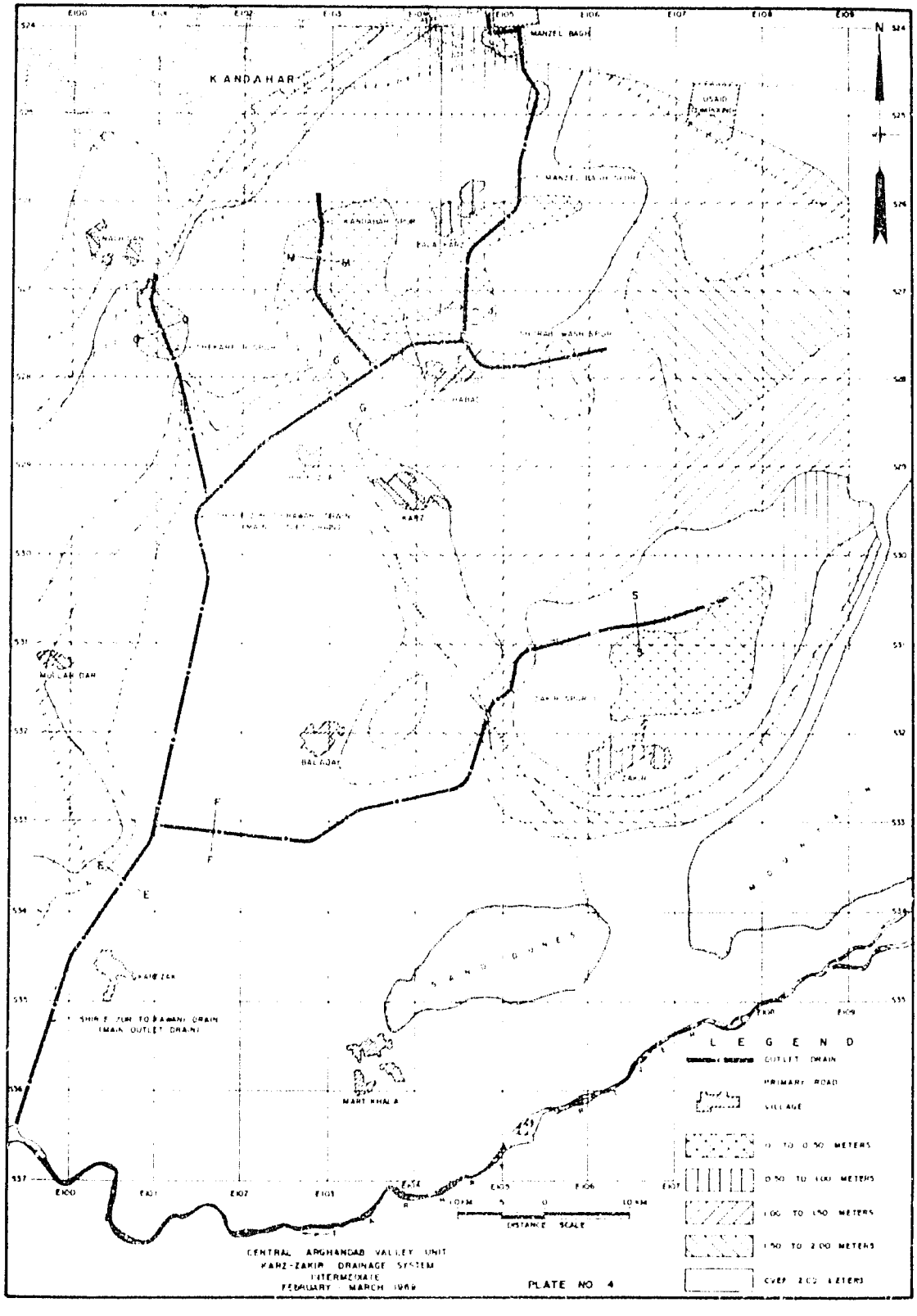


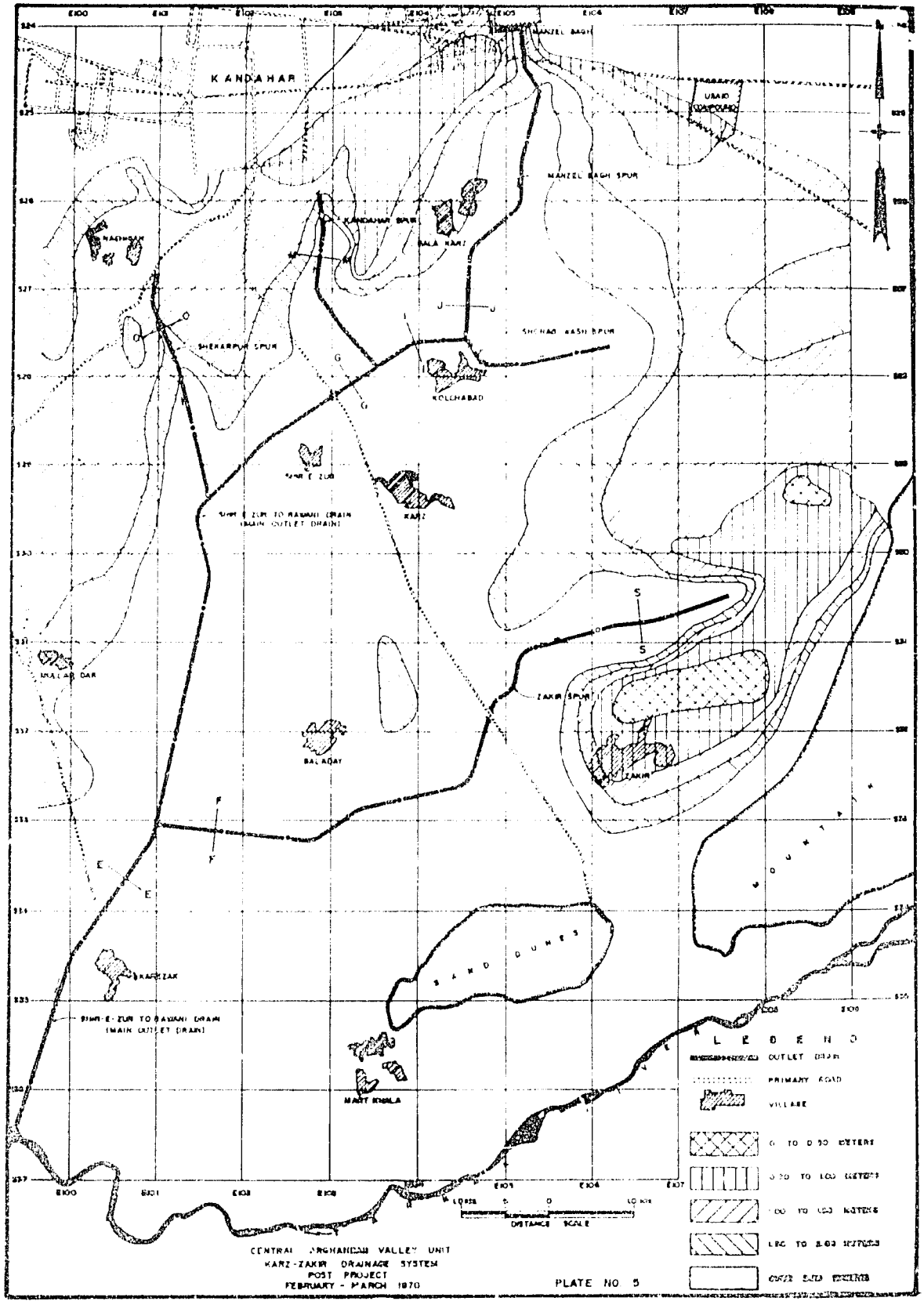

PLATE NO. 2

SHEET 2 OF 2

CENTRAL ARGHANDAB VALLEY UNIT
KARZ - ZAKIR
CROSS DRAIN PROFILES


KANDAHAR
USAID
MALAR DAR
ZAKIR
MARTPHALA
LEGEND
VILLAGE
0 TO 0.50 METERS
0.50 TO 1.00 METERS
1.00 TO 1.50 METERS
1.50 TO 2.00 METERS
OVER 2.00 METERS
DISTANCE SCALE
PLATE NO 3


KANDAHAR
MANZEL BAGH
USAID
MULLAH DAM
BALADAK
MART KHALA
SHIRE ZUR TO DAMANI DRAIN
(MAIN OUTLET DRAIN)
SAND DUNES
N
LEGEND
OUTLET DRAIN
PRIMARY ROAD
VILLAGE
0 TO 0.50 METERS
0.50 TO 1.00 METERS
1.00 TO 1.50 METERS
1.50 TO 2.00 METERS
OVER 2.00 METERS
DISTANCE SCALE
CENTRAL ARGHANDAB VALLEY UNIT
KARZ-ZAKIR DRAINAGE SYSTEM
INTERMEDIATE
FEBRUARY MARCH 1988
PLATE NO 4


KANDAHAR
MANZEL BAGH
MANZEL BAGH SPUR
KANDAHAR SPUR
BALA KARZ
SHEKARPUR SPUR
SHEHAD BASHI SPUR
KOLCHABAD
KARZ
ZAKIR SPUR
ZAKIR
BALADAY
SAND DUNES
LEGEND
OUTLET DRAIN
PRIMARY ROAD
VILLAGE
DISTANCE SCALE
CENTRAL ARGHANDAB VALLEY UNIT
KARZ-ZAKIR DRAINAGE SYSTEM
POST PROJECT
FEBRUARY - MARCH 1970
PLATE NO 5

## AFGHANISTAN

# WATER MANAGEMENT, METHOD OF APPLICATION; MEASUREMENT AND CONTROL

by

**A. G. Shuja***

## ABSTRACT

The principal objective of all irrigation projects is to deliver the proper amount of irrigation water to the water user at the time needed. A water dispatching system was developed and used on a small irrigated area in the Helmand valley near Darweshan. The results of this experiment indicate that the system could be used beneficially on any area, and it is planned to expand it to larger areas. Under this system the ditchrider collects all water orders and delivers them to the dispatcher who schedules them for delivery. The dispatcher gives the delivery schedule to the watermaster and ditchriders for delivery. The record of deliveries is returned to the dispatcher's office where water accounting records are kept on a current basis. This system gives the overall control of water scheduling to one person who can schedule deliveries so that all water users, no matter where they are located on the system, will be treated fairly.

*Director General, Operations and Maintenance Division, Helmand Arghandab Valley Authority.

## INTRODUCTION

The success of any irrigation project depends to a large extent on the proper operation of the facilities and the cooperative efforts of the operation's personnel and the water users. No matter how sophisticated and well constructed, no project can be successful unless the farmers are successful. The success of an irrigation project is therefore measured by the number of successful farmers in the project.

To be effective an irrigation project must be properly staffed with operating personnel and capable of delivering the proper amount of water to the farmers at the time needed. To accomplish this, the operating organization must be backed by a firm set of laws and regulations governing the use of water. Another prime requisite is a charge for the water, preferably on a volumetric basis. If there is no charge for the water, then it seemingly has no value and wasting it is not a deterrent to the water user. If he is required to pay for all of the water delivered through his turnout, he will husband and make the most

beneficial use of the water and avoid waste that would be charged to his account.

Dependable transportation, good communication, and access roads are of great importance in proper management of an irrigation project. Consulting operation and maintenance personnel during the design and construction of an irrigation project will greatly help in smooth and efficient operation of the project. The design and construction engineers are chiefly concerned with the economics of construction features, and frequently overlook certain aspects important to the operation and maintenance of the project. It would be well to have a conference prior to the design of any section of a project. The conference should include representatives of operations and maintenance, agricultural officials and, if possible, the water users themselves. Each entity would then be represented and the entire project would be a cooperative undertaking with a complete understanding of what is to be accomplished.

The present system of water management in the Helmand project has served a purpose for many years. It has been improved year after year, but it is not yet satisfactory. After the construction of the Shamalan and Central Arghandab irrigation systems, it will be possible for HAVA to control the water down to the farmer turnouts.

Keeping in mind a better and more efficient method of water management in future operations, a new system was developed and put into operation two seasons ago for Block 2F-2 of Darweshan, totaling about 900 acres. This system, discussed in the latter part of this paper, seems to be practical and simple and can be used for projects that are designed and constructed accordingly.

## HISTORY OF IRRIGATION

The Helmand valley and the Chakhansur-Siestan areas were first irrigated prior to any written history. Investigation of some of the archaeological ruins reveals that irrigated agriculture can be traced back to 3,000 BC. The ruins of the old cities indicate that a very prosperous and extensive irrigation and agricultural system existed in these areas. There is some evidence that some forested areas also existed in what is now a desert, with practically no vegetation. Enterprising operators are still hauling the dried up timbers into Lashkar Gah and selling the logs, roots, and branches for firewood. The present condition of the desert area would indicate the possibility of extensive agriculture, much of which has now reverted back to the desert. This could be attributed to inadequate drainage, poor land and water use, and the salinity problem aggrivated by the high evaporation rate in this desert area. The operation of this extensive irrigated area must have required the services of considerable manpower. All of these old systems were probably destroyed by conquerors. These events probably resulted in the lower production and, possibly, final abandonment of irrigated agriculture in large portions of this area.

## HELMAND VALLEY DEVELOPMENT PROJECT

This project thus was not undertaken solely for the development of a new area. There is probably only a small portion of the proposed project lands that would be virgin soil. To farm and resettle these areas in the Helmand valley it would be necessary to develop a new system of canals, drains, and access roads, along with a good system of communication. Consideration should also be given to reclaiming some of the areas that are presently not irrigable due to salinity and water logging caused by the present irrigation system.

The major works of Helmand Valley Development project are briefly described as follows:

**Kajakai storage dam.** Earth dam located on the Helmand river; 94 meters high; 273 meters long; base width 410 meters, with 3,225,000 cubic meters embankment. Storage capacity of 1,495,000 acre-feet, with a possible increase in capacity of 800,000 acre-feet by installation of gates.

**Arghandab storage dam.** Earth dam located on the Arghandab river; 50 meters high; 520 meters long; base width 226 meters, with 2,490,000 cubic meters embankment. Storage capacity about 388,000 acre-feet.

**Boghra canal.** Seventy-five kilometers long, 2,600 cubic feet per second capacity.

**Shamalan canal.** Sixty-five kilometers long, 750 cubic feet per second capacity.

**East Marja canal.** Twenty kilometers long, 450 cubic feet per second capacity.

**Darweshan diversion.** Concrete weir and headworks on Helmand river.

**Darweshan canal.** Fifty kilometers long, 1,100 cubic feet per second capacity.

**Zahir Shahi diversion dam.** Rockfill dam on Arghandab river; 800 meters long; seven meters high; rock spillway.

**Zahir Shahi canal.** Forty-four kilometers long, 1,500 cubic feet per second capacity.

**Nad-i-Ali area.** About 13,000 acres, Boghra canal water, settlement of 1,300 families.

**Marja area.** About 27,000 acres, Boghra canal water, settlement of 908 families at present.

**Darweshan area.** About 45,000 acres, Darweshan canal water, old farms, 275 families.

**Central Arghandab.** About 99,800 acres, Zahir Shahi canal water, old farms.

**North Arghandab.** About 40,000 acres, North Arghandab intake structure, old farms.

**Tarnak area.** About 42,000 acres, Tarnak canal water, settlement and old farms.

The above facilities were constructed starting in 1939 with the Boghra diversion dam, followed by about 60 kilometers of the Boghra canal. The Shamalan canal and Marja canal systems, along with Kajakai and Arghandab storage dams, were built between 1950 and 1954. The Arghandab Zahir Shahi diversion dam and canal, the South Arghandab canal, the Tarnak branch and Darweshan diversion dam and canal system, along with the drainage facilities for all of these systems, have been completed since 1954.

## Operation of the Present System

Construction of the project facilities appears to be an extensive development, but when the situation is analyzed one finds that the main accomplishments to date have been the building of proper storage facilities — diversion dams that are permanent structures to replace the old brush mattress dams that were lost each time the river flow got above normal stage, and the main canals which form the backbone necessary to deliver water to the old jui ditch systems that have been in existence almost since time began.

In most instances, when the irrigation water is delivered into the old jui ditches, HAVA does not have any further control of the water. There are no access roads into these areas on which a ditchrider can travel. Most of these old canals have no measuring devices except the headgate and very few turnouts exist. In most cases, the water is delivered by cutting a hole through the side — the old jui and filling it in with soil when the irrigation is completed. The delivery of water to the farmers is actually handled by the village mirab, who in turn requests water to be turned on or off at the main canals by the HAVA ditchriders who patrol the main canal system.

In the Marja and Nad-i-Ali areas there is a limited lateral system. In many cases, the land is not adequately leveled and does not have access roads and proper drainage. Both of these areas have been greatly improved in the past few years.

As to recent times, these areas were first settled and developed in 1952. The majority of the settlers were nomadic people without experience in irrigated farming. The soil is a typical low productive type, overlaying a hard conglomerate two or three meters deep. When this area was first irrigated it was started with small sections which utilized a minor portion of the main canal capacity, and the Boghra canal, with its large capacity, was actually used more as a reservoir than as a flowing canal. The farmers and their agricultural advisors were allowed to turn the water on and off almost at will. There were no charges for water and it was often allowed to run onto the farmed areas far in excess of requirements.

After two or three years of this type of operation, a considerable portion of the developed area was either waterlogged or salted up to the extent that some of the settlers abandoned their land holdings and reverted back to their nomadic life of raising sheep, goats, and cattle.

To correct this condition, the management of the irrigation system down to the farm turnouts was transferred to the Operations and Maintenance division of the Technical department of HAVA. Water

measuring devices were installed on most turnouts. Even with these measuring devices and new ditchriders it has been difficult to take over complete control of the water deliveries because of the previous lax attitude exercised, but definite progress has been made.

A considerable amount of underground tile and open drains have been installed, with the result that most of the land can now be farmed.

Watermasters and ditchriders were given a training course of two hours weekly for a period of three months. They were taught how to measure water using the various structures and measuring devices, and how to compute the volume of water from the cubic feet per second flow for various lengths of time. Some of the watermasters were sent to other countries for in-service practical training and this has greatly strengthened the organization.

## Proposed Method of Operating the Irrigation System

The system used in Darweshan, Block 2E-2, was for a comparatively small area, so communications were not as important. Communications would be of greater importance in the operation of a larger system and it is proposed that radio should be the media for this purpose. Each ditchrider would operate from a pickup truck equipped with a radio. He could be in constant communication with other ditchriders and the main office. He would be responsible for all water deliveries in an area of approximately 10,000 acres.

The experience gained in Darweshan has proven that the system is workable. A complete record of all water deliveries was obtained indicating the turnon and turnoff date and time of day; the cubic feet per second delivered; the total amount of water delivered through each turnout; the number of acres irrigated, along with the acre-feet per acre for each month, and the total acre-feet per acre for the year.

In the very small sample area of Darweshan one ditchrider could easily handle the ditchrider duties and program the schedule of all deliveries. In a larger area, it is proposed that the scheduling, water accounting and overall control of the water be handled from a central water dispatching office. With this sytem, the complete overall control of the water will be in the hands of one person who can see the entire picture. He can make decisions for changes necessary before minor troubles develop into major difficulties.

Each water user will be provided with a set of rules and regulations to govern the delivery of irrigation water. These rules will be revised from time to time to include changes appropriate to fit existing conditions. A proposed set of regulations for controlling the delivery of irrigation water is presented later in this paper.

Under the dispatcher's system, the ditchrider will collect all water orders either verbally or from the water order forms deposited in locked boxes located throughout the system. The procedure will be as follows:

**Water Order and Delivery Record Card.** The ordering, distribution and recording of water will be facilitated by completion of the water order and delivery card as shown in Figure 1. The card will normally follow a series of ten steps in performing its function:

(1) When the order is given verbally, the water user, mirohb or ditchrider, will complete the following blanks:

Water User_____

Serial No._____

Canal_____ Lateral_____

Turnout_____Gate size_____

Water Order Place on_____, 13___

To begin_____, 13___, to irrigate_____
(hectares)

(2) The ditchrider will collect the order cards from the collection boxes each day, or complete the required information for the water user or mirohb and then complete the following:

Taken by _____ on_____
(ditchrider) (hour and day)

(3) The card will be turned over to the watermaster at the end of the ditchrider's daily run.

(4) The watermaster will place the orders with the dispatcher and complete the following when the dispatcher has scheduled the delivery and determined the order of rotation:

Placed on schedule by _____
(dispatcher)

Head No.____for____cms____hrs. in Head No._____

Scheduled from_____Scheduled to_____

(5) The watermaster will return the card to the ditchrider.

(6) The ditchrider records his measurements and observations on the following:

| Date | Ditch-rider | Shift | Time | $H_1$ | $H_2$ | Total | Gate Open-ing | Cms |
|---|---|---|---|---|---|---|---|---|
| | | I | | | | | | |
| | | II | | | | | | |
| | | III | | | | | | |

(7) The ditchrider will return the card to the watermaster at either the completion of the delivery or at the end of the water delivery week (midnight, Thursday).

(8) The watermaster will complete the following:

Computations

| From (Hr. & Day) | To (Hr. & Day) | Hours | CMS | H.M. |
|---|---|---|---|---|

(9) The watermaster will turn the card over to the Water Accounting office on his next scheduled visit.

(10) The deliveries will be recorded in the permanent file. The card will be filed in the Water Accounting office and kept as a reference for two years and then destroyed.

**Dispatching office.** To maintain overall control of the water in the central office, a water dispatching and accounting office is needed. The dispatcher will schedule water deliveries based on orders brought to the office daily by the watermaster. The dispatching office will also determine flows at control points on the canal as changes in delivery are made. The clerks in the Water Account office will maintain records of water delivered to each water user.

The ditchrider's beat will be increased to include all laterals and canals. The ditchrider will be the go-between for the water users, or mirohb, and the watermaster. Twenty-four hours per day surveillance can be maintained with the use of three shifts and ditchriders using suitable means of transportation. On most structures this constant surveillance eliminates the need for other watchmen.

**Ditchrider's beat.** The ditchrider should establish a regular beat so as to arrive at the same place at about the same time each day. He should visit each operating turnout each shift to check deliveries, to receive water orders, and to observe the distribution of water where changes have been made. Each ditchrider should furnish the watermaster a list showing the sequence of stops made on the beat.

The ditchrider, under the direction of the dispatcher, is responsible for balancing flows at the control points and at the canal headgates. A sample canal operations comparison sheet is given in Figure 2. In the example the diversion at the headgate would be reduced by 15 cubic feet per second. The canal can be adjusted by relaying the information up the canal from one beat to another.

**Ditchrider's handling of water orders.** A water request card is required for each delivery order or change of delivery order. The water orders should be collected each day by the ditchrider from the farmers.

**Ditchriders responsibility for delivering water.** The ditchrider must measure and deliver water accurately in the amount ordered by the farmer or mirohb and scheduled by the dispatcher. Deliveries

should be checked and corrected continuously. Corrections should be shown on the water order cards. The exact turnon and turnoff time will be observed and recorded by the ditchrider. The ditchrider will relay the estimated time of delivery to the farmer or mirohib verbally when possible, and by use of the schedule board at all times.

**Watermaster.** The watermaster is responsible for the management of all water within his designated area. This includes the main canal, laterals and drains. He must know each ditch and drain in his area, their condition, their capacity and the amount of land they serve.

Near the end of the regular shift each day, the watermaster should collect the water order cards from the ditchriders. He should also receive a verbal report of conditions on each beat. In addition, he should maintain a close personal surveillance of the canals and drains, noting moss growth, silting, erosion, structure deterioration, etc.

Each morning the watermaster should report to the central office. He should check the water orders placed the previous day, and pickup the water schedule which has been prepared from these orders. The schedule should be turned over to the ditchriders when he meets them later in the day. While at the central office he should report on the canal condition to the chief of the Irrigation Operations division. He should also learn what maintenance work is presently scheduled for his area.

**Dispatching and water accounting.** The dispatching and water account offices are separate but their functions are closely related. The dispatcher receives the water order from the watermaster, makes delivery schedules, and maintains a record of required flows at check points in the system. The water accountant records all deliveries, maintaining individual records on each water user, and a tabulation of total volume deliveries.

The dispatcher must tabulate water orders, estimate carriage losses and compute flows at the control points to maintain a constant check on the canal.

The water accounting office will maintain a complete uptodate record of deliveries to each water user. The irrigation water ledger sheet, shown in Figure 3, may be used to keep both a current tabulation and a permanent record. This information could be used to assess water charges based on a volume of delivery.

All water in the irrigation system will be controlled by the ditchriders. The services of ditchriders will be required 24 hours each day, seven days each week, or a total of 168 manhours each ditchrider-beat each week. If this load is divided between two men, each would have to work 12 hours a day every day. Three men would work eight hours daily every day. This is too continuous, so it was decided to break it into a 40-hour week as indicated on the following work schedules, Figures 4, 5 and 6.

With these schedules, it would take four men for each beat and one extra man to work an eight-hour shift one day a week in each of three beats. The "extra" or "X" man would be available to work two shifts, one on Sunday and one on Tuesday, at other assignments. This schedule is arranged so each ditchrider would have to work five eight-hour shifts each week. He would have two consecutive days off each week, and once each four weeks he would be off for four consecutive days. Each ditchrider would take his regular turn at each shift: No. 1, graveyard shift, from midnight to 8 a.m.; No. 2, day shift, from 8 a.m. to 4 p.m.; and the No. 3, swing shift, from 4 p.m. to midnight. The man who works the "X" shift on beat No. 1 Saturday, works the "X" shift on beat No. 2 Mondays, and the "X" shift on beat No. 3 Wednesdays — always the day shift. He should be the best ditchrider, one that is being groomed for promotion to watermaster or dispatcher. He will be available two shifts each week for practical in-service training in either of these positions.

The ditchrider will operate from a pickup truck and the truck will be run continuously, being transferred from one rider to the next as the shifts change.

With this type of coverage, it is believed that all water can be turned on and off and all water being delivered can be checked and measured twice each shift. The main supply canal and all laterals can be checked at inline measuring devices to assure adequate water supply for all deliveries.

**Irrigation schedule.** The entire area to be irrigated is divided into head areas, or the area that

one stream of water can irrigate if rotated in the area for one week. For instance, a stream of water amounting to 10 cubic feet per second will deliver roughly 20 acre-feet each 24 hours and, if this amount of water is applied three inches deep, 80 acres per day can be irrigated, or 560 acres each week. In this case a head area would be 560 acres, and the entire irrigated area would be divided into 560-acre areas, so arranged that one head of water could be moved around in the area with the least interruption of the normal flows in the system. The head areas for part of the proposed Shamalan project are shown on the map presented in the technical paper about Shamalan project plans.

Head area No. 1 is located in the lowest 560-acre reach of the system; head area No. 2 would be the next 560-acre area upstream, and so on upstream back to the heading. All orders for water are scheduled as the orders are received in their respective head areas on the irrigation schedule sheet, Figure 7. As the orders are received, the number of hours required for each delivery are marked, indicating the hours for each run and the length of time each head is scheduled in advance. At the top of the sheet, the date for each day is inserted and the name of each ditchrider is indicated for each shift to be worked. As each water order comes into the dispatcher's office, he can tell at a glance approximately when the water can be delivered, and as the delivery progresses the schedule can be adjusted to reflect actual conditions.

## Proposed Regulations for the Helmand Arghandab Valley Authority

**Water orders.** All orders for water shall be placed with the ditchrider or deposited in the collection box located in the area. It is requested that wherever possible, all orders be placed not later than noon on Wednesday for the week beginning the following Friday at midnight. The placing of the order at this time will greatly facilitate the scheduling of water in advance, however, if the water order cannot be placed prior to noon on Wednesday for the following week, water orders will be accepted and scheduled, but the water user making the request will have to take his turn after others are through with the water.

The following information is required for each order:

(1) Name of the water user.

(2) Serial number of owner or user.

(3) Canal system, lateral and turnout.

(4) Size of irrigation head in cubic feet per second.

(5) Number of jiribs to be irrigated.

(6) Estimated hours of the run.

**Water schedule and notice to water user.** Upon receipt of water orders, the schedule of deliveries and the order of rotation will be established by the dispatcher. Any time a water user contacts a ditchrider, the ditchrider shall contact the dispatcher and advise the water user as to the estimated time of his turnon. The ditchrider shall also maintain a schedule board at a central location in each ditchrider's beat. The schedule board will indicate the rotation of each head of water in the beat and show the estimated turnon and turnoff time to each water user.

**Water measurements.** The exact turnon and turnoff time will be observed by the ditchrider and transmitted to the dispatcher who shall record it and shall keep an accurate record of all observations taken during the irrigation run to each water user. These records will be received and recorded by the dispatcher and will become the official record and basis for all water charges. Actual elapsed time and the average of all water measurements will be used in determining the quantity of water delivered. Allowance for carriage losses will be made whenever measurements for farm deliveries are made in the lateral system above the farmer's turnout.

**Figure 1**

Front of Card

Water Order and Delivery Record

Water User _____

Serial No. _____

Canal _____ Lateral _____

Turnout _____ Gate Size _____

Water order placed on _____ , 19 _____

To begin _____ , 19 ___ to Irr. _____ He.

Taken by _____ on _____
(ditchrider) (hr. & day)

Placed on schedule by _____
(dispatcher)

for _____ cms. _____ hrs.

in Head No. _____

Scheduled from _____

Scheduled to _____

Computations

| From (Hr. & Day) | To (Hr. & Day) | Hrs. | CMS | H.M. |
|---|---|---|---|---|
| | | | | |
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**Figure 1: Continued**

Back of Card

Shift I - Midnight to 8 a.m.
Shift II - 8 a.m. to 4 p.m.
Shift III - 5 p.m. to midnight

| Date | Ditch-rider | Shift | Time | $H_1$ | $H_2$ | Total H | Gate Opening | C.M.S. | Time | $H_1$ | $H_2$ | Total | Gate Opening | C.M.S. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fri. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |
| Sat. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |
| Sun. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |
| Mon. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |
| Tues. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |
| Wed. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |
| Thurs. | I | | | | | | | | | | | | | |
| | II | | | | | | | | | | | | | |
| | III | | | | | | | | | | | | | |

**Figure 2: Canal Operations Comparison Sheet**

SAMPLE

Date May 27, 1969

Mohammed Khan Ditchrider Shamalan Canal

| Location Km. | Staff Height | Time of Clock | Cubic Feet per Second | | | | | Algebraic | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Water Order | Carr. Loss | Water Req.d | Cum. Total | Actual Measure | Diff. | Sum |
| | | | 10.0 | 0 | 10.0 | | | | |
| 65+767 | 0.32 | 5:30PM | | | | 10.0 | 12.2 | +2.2 | |
| | | | 90.6 | 16.0 | 106.6 | | | | +2.2 |
| 555+878 | 0.38 | 6:10PM | | | | 116.6 | 115.3 | 1.3 | |
| | | | 61.2 | 7.0 | 68.2 | | | | +0.9 |
| 49+180 | 0.42 | 6:25PM | | | | 184.8 | 187.2 | +2.4 | |
| | | | 147.7 | 11.0 | 158.7 | | | | +3.3 |
| 40+315 | 0.51 | 7:00PM | | | | 343.5 | 341.8 | 1.7 | |
| | | | 169.3 | 21.0 | 190.3 | | | | +1.6 |
| 22+580 | 0.70 | 7:30PM | | | | 533.8 | 536.2 | +2.4 | |
| | | | 49.2 | 10.0 | 59.2 | | | | +4.0 |
| 13+366 | 0.78 | 7:55PM | | | | 593.0 | 596.0 | +3.0 | |
| | | | 39.0 | 18.0 | 57.0 | | | | +7.0 |
| 0+200 | 0.90 | 8:25PM | | | | 650.0 | 658.0 | +8.0 | |
| | | | | | | | | | +15.0 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 3

Irrigable Area

Turnout No. _____ _____ Acres

Turnout No. _____ _____ Acres

HAVA IRRIGATION
WATER LEDGER SHEET

_____ Area

Serial No.

Water User _____

Address _____

Land Description

| No. | | | | | Hours Run | C.F.S. | Acre Feet Used | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Hour | Date | Hour | | | This Run | Previous Runs | To Date | Previous Balance | Unused Balance |
| Allotment | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
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| | | | | | | | | | | | |

**Figure 4**

SHIFT OPERATION

FOR Ditchrider Beat No. 1

FIRST WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUES. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 1 | 1 | 1 | 4 | 4 | 4 | 4 |
| Daylight | 4 | X | 2 | 2 | 2 | 2 | 2 |
| Swing | 3 | 3 | 3 | 3 | 3 | 1 | 1 |
| Off | 2 | 2-4 | 4 | 1 | 1 | 3 | 3 |

SECOND WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUES. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 4 | 4 | 4 | 2 | 2 | 2 | 2 |
| Daylight | 2 | X | 3 | 3 | 3 | 3 | 3 |
| Swing | 1 | 1 | 1 | 1 | 1 | 4 | 4 |
| Off | 3 | 3-2 | 2 | 4 | 4 | 1 | 1 |

THIRD WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUES. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| Daylight | 3 | X | 1 | 1 | 1 | 1 | 1 |
| Swing | 4 | 4 | 4 | 4 | 4 | 2 | 2 |
| Off | 1 | 1-3 | 3 | 2 | 2 | 4 | 4 |

FOURTH WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUES. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 3 | 3 | 3 | 1 | 1 | 1 | 1 |
| Daylight | 1 | X | 4 | 4 | 4 | 4 | 4 |
| Swing | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| Off | 4 | 1-4 | 1 | 3 | 3 | 2 | 2 |

No. 1 Rasshid
No. 2 Hashim
No. 3 Halim
No. 4 Asad
X Rabir

First Week from Aug. 7, 1970 to Aug. 13, 1970
Second Week from Aug. 14, 1970 to Aug. 20, 1970
Third Week from Aug. 21, 1970 to Aug. 27, 1970
Fourth Week from Aug. 28, 1970 to Sept. 3, 1970

Figure 5

SHIFT OPERATION

FOR Ditchrider Beat No. 2

FIRST WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Daylight | 2 | 2 | 2 | X | 3 | 3 | 3 |
| Swing | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| Off | 4 | 4 | 3 | 3-2 | 2 | 1 | 1 |

SECOND WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| Daylight | 3 | 3 | 3 | X | 4 | 4 | 4 |
| Swing | 4 | 4 | 1 | 1 | 1 | 1 | 1 |
| Off | 1 | 1 | 4 | 4-3 | 3 | 2 | 2 |

THIRD WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 3 | 3 | 3 | 3 | 3 | 4 | 4 |
| Daylight | 4 | 4 | 4 | X | 1 | 1 | 1 |
| Swing | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Off | 2 | 2 | 1 | 4-1 | 4 | 3 | 3 |

FOURTH WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 4 | 4 | 4 | 4 | 4 | 1 | 1 |
| Daylight | 1 | 1 | 1 | X | 2 | 2 | 2 |
| Swing | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| Off | 3 | 3 | 2 | 2-1 | 1 | 4 | 4 |

No. 1 Audin
No. 2 Akbar
No. 3 Rahman
No. 4 Shifiq
X Kabir

First Week from Aug. 7, 1970 to Aug. 13, 1970
Second Week from Aug. 14, 1970 to Aug. 20, 1970
Third Week from Aug. 21, 1970 to Aug. 27, 1970
Fourth Week from Aug. 28, 1970 to Sept. 3, 1970

**Figure 6**

SHIFT OPERATION

FOR Ditchrider Beat No. 3

FIRST WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 4 | 4 | 4 | 4 | 1 | 1 | 1 |
| Daylight | 3 | 3 | 3 | 3 | 3 | X | 4 |
| Swing | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| Off | 2 | 2 | 1 | 1 | 4 | 3-4 | 3 |

SECOND WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Daylight | 4 | 4 | 4 | 4 | 4 | X | 1 |
| Swing | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| Off | 3 | 3 | 2 | 2 | 1 | 1-4 | 4 |

THIRD WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| Daylight | 1 | 1 | 1 | 1 | 1 | X | 2 |
| Swing | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| Off | 4 | 4 | 3 | 3 | 2 | 1-2 | 1 |

FOURTH WEEK

DAY OF THE WEEK

| SHIFT | FRI. | SAT. | SUN. | MON. | TUE. | WED. | THUR. |
|---|---|---|---|---|---|---|---|
| Graveyard | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| Daylight | 2 | 2 | 2 | 2 | 2 | X | 3 |
| Swing | 4 | 4 | 1 | 1 | 1 | 1 | 1 |
| Off | 1 | 1 | 4 | 4 | 3 | 2-3 | 2 |

No. 1 Wakil
No. 2 Khliq
No. 3 Dawood
No. 4 Nabi
X Kabir

First Week from Aug. 7, 1970 to Aug. 13, 1970
Second Week from Aug. 14, 1970 to Aug. 20, 1970
Third Week from Aug. 21, 1970 to Aug. 27, 1970
Fourth Week from Aug. 28, 1970 to Sept. 3, 1970

# HAVA IRRIGATION SCHEDULE
## SHAMALAN AREA

| DAY OF WEEK | FRIDAY | | | SATURDAY | | | SUNDAY | | | MONDAY | | | TUESDAY | | | WEDNESDAY | | | THURSDAY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | AUGUST 7, 1970 | | | AUGUST 8, 1970 | | | AUGUST 9, 1970 | | | AUGUST 10, 1970 | | | AUGUST 11, 1970 | | | AUGUST 12, 1970 | | | AUGUST 13, 1970 | | |
| SHIFT | GRAVEYARD | DAY | SWING | GRAVEYARD | DAY | SWING | GRAVEYARD | DAY | SWING | GRAVEYARD | DAY | SWING | GRAVEYARD | DAY | SWING | GRAVEYARD | DAY | SWING | GRAVEYARD | DAY | SWING |
| DITCHRIDER ON DUTY | RASHID | ASAD | HALIM | RASHID | KABIR | HALIM | RASHID | HASHIM | HALIM | ASAD | HASHIM | HALIM | ASAD | HASHIM | HALIM | ASAD | HASHIM | RASHID | ASAD | HASHIM | RASHID |
| IRRIGATION FOREMAN | | | | | | | | | | | | | | | | | | | | | |
| HEAD NO. 1 | ASAD 27-10 | SHAFOOR 27-0.6 | | NAB 27-10 | AKBAR 27-0.9 | FAZEL 27-6 | BIN 27-0.6 | MEZA 27-10 | MOHD 27-0.9 | JAN 27-6 | MEZA 27-0.5 | ZIA 27-0 | | | | | | | | | |
| HEAD NO. 2 | HASHIM 25-2 | ASAD 24-2-0.6 | | MOHD ALI 24-2-1.4 | RASHID 24-2-1.8 | | HAZIB 25-2 | NAJIBULLAH 24-2-0.6 | ZARI 24-2-1.4 | BARAT 24-2-1.8 | KHAN 25-2 | | POLAD 24-2-0.6 | | | | | | | | |
| HEAD NO. 3 | HALIM 9-2-1.0 | KHALID 9-2-1.4 | RAHMAN 9-2-1.8 | SHAFIQ 9-2-0.7 | ESSA 9-2-0.6 | HAZRATY 9-2-1.4 | SHAH 9-2-1.8 | | SUBHAN 9-2-0.7 | SAFFOR 9-2-0.6 | DEWAN 9-2-1.4 | JAFER 9-2-1.8 | | JABAR 9-2-0.7 | RAHMAN 9-2-0.6 | | | | | | |
| HEAD NO. 4 | FAZLULLAH 9-4-1 | KATAWAZY 9-4-2.8 | HUSSEIN 9-4-2.6 | SOBOOR 9-4-1.0 | ZAWEL 9-4-2.6 | FAZL 9-4-2.1 | SHAZAR 9-4-3.5 | | ANWAR 9-4-2.3 | BAZ 9-4-1.0 | KHALIL 9-4-2.6 | SAGAT 9-4-1 | | NAZIR 9-4-3.2 | MAROOD 9-4-2.8 | SATAR 9-4-1.0 | | | | | |
| HEAD NO. 5 | BALIAN 9-4-2.3 | ATIF 9-4-1 | YAZEG 9-4-2.8 | ANWERY 9-4-1.6 | DAYYOOR 9-4-0.4 | YASIN 9-4-2.3 | FATAH 9-4-1.2 | | ZAIDI 9-4-0.8 | ZAHIR 9-4-1.6 | SHAREF 9-4-0.4 | KARIM 9-4-2.3 | | KABIR 9-4-1.2 | DOST MOHD 9-4-0.8 | | | | | | |
| HEAD NO. 6 | EHAN 7-2-3.1 | ZIA 7-2-2.3 | AHMED 7-2-1.2 | RAHIM 7-2-2.6 | MOSAFI 7-2-1 | OMER 7-2-1.5 | NIAZ 7-2-2.3 | HAMID 7-2-1.2 | SALIM 7-2-2.8 | SAFIQULLAH 7-2-3.1 | MAHMATULLAH 7-2-3.3 | MATIULLAH 7-2-2.3 | RAHMATULLAH 7-2-1.2 | | SAYED 7-2-2.8 | SUBLAN 7-2-3 | | | | | |
| HEAD NO. 7 | AMIR 12-2-2.0 | FAZEL 12-2-0.8 | HASHIM 12-2-1.0 | WAZIR 12-2-1.4 | HAZRAT 12-2-2.1 | SHAHBEGA 12-2-2.0 | SHOKAR 12-2-0.8 | FIZAR MIR 12-2-1.0 | SABLAN ALI 12-2-1.4 | SHAHWAR 12-2-2.1 | | BAKI 12-2-2.0 | ALI JABAR 12-2-0.8 | | ALI MOHD 12-2-1.0 | SAYED KHAN 12-2-1.4 | | | | | |
| HEAD NO. 8 | HAZIM 14-0-3.8 | HASHEM 14-0-3.1 | RAHIM 14-0-2.8 | NOOR ALI 14-0-2.0 | GAZIM 14-0-3.8 | | BUL 14-0-3.1 | MOHD HUSSEIN 14-0-2.8 | TOOR JAN 14-0-2.0 | HASSAN 14-0-3.8 | WAHAB 14-0-3.1 | | TORI 14-0-2.8 | | BAZ MOHD 14-0-2.0 | | | | | | |
| HEAD NO. 9 | ATIF 14-0-1 | ZIA 14-0-1.4 | ENGLEY 14-0-0.8 | HAFIZULLAH 14-0-1.1 | AYUB 14-0-1.3 | AYUB KHAN 14-0-2 | YAHYA 14-0-0.8 | SARJAN 14-0-1.1 | ALASAD 14-0-3.3 | LALOON 14-0-1.8 | LAL 14-0-0.6 | JUMA KHAN 14-0-1.1 | | NAJEEB 14-0-1.8 | JAN ALI 14-0-1.3 | | | | | | |
| HEAD NO. 10 | RAFIQ 8.8-4.1 | KARIM 8.8-2.2 | AZIZ 8.8-3.3 | SAYYOOR 8.8-2.0 | GHULAM 8.8-4.1 | ABDUL BARI 8.8-3.2 | ABDUL AZIZ 8.8-3.4 | SAPAR 8.8-2.9 | SHER ALI 8.8-4 | BELAL 8.8-3.2 | MOOSA 8.8-1.4 | HAJI 8.8-2.9 | POLAD 8.8-2 | SAIF DAD 8.8-4 | SAIF DAD 8.8-3.2 | | | | | | |
| HEAD NO. 11 | ZIA 8.8-4 | ANWAR 8.8-2 | SAFI 8.8-1.0 | ZIYA 8.8-2.6 | GHOZA 8.8-1.6 | HAMID 8.8-1.4 | ABDUL 8.8-2 | LATIF 8.8-1.0 | MOHD MOOSA 8.8-0.6 | KARIM 8.8-1.6 | OBAIDULLAH 8.8-1.4 | ASAM KHAN 8.8-1.4 | | HABIBULLAH 8.8-1.6 | NAZAR JAN 8.8-1.0 | | | | | | |
| HEAD NO. 12 | | | | | | | | | | | | | | | | | | | | | |
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## AFGHANISTAN

# RECONSTRUCTION AND IMPROVEMENT OF IRRIGATION SYSTEMS OF AFGHANISTAN

Most irrigation systems in Afghanistan are privately owned. Only a small number belong to the government. In some areas of irrigation land development, such as the Helmand and Nangarhar valleys, Parwan project, etc., the allocation and distribution of water are controlled by government bodies.

In these areas during the last few years a start has been made to introduce new methods of irrigation, preparation of fields and cropping practices on farms. Because only about five percent of the irrigated lands in Afghanistan are government owned, the main agricultural production is from privately owned, traditionally irrigated lands. Thus, at the present stage of national development the further increase of agricultural production is geared to the improvement of irrigation practices on farms. The average size of a farm in Afghanistan is less than one hectare. Under such conditions it is rather difficult to carry out recommendations on irrigation practices given by the fifth, sixth and seventh seminars of NESA countries. These recommendations include widespread use of sprinkler irrigation, formation of irrigation associations or cooperatives, adoption of new irrigation and water techniques, etc.

Before these things can be fully realized, it would be necessary to provide modern irrigation facilities, which would require rehabilitation and rearrangement of existing irrigation systems, because only reconstructed irrigation systems on farms can open the way for a comprehensive scientific approach to modern methods of irrigation and farming. Such reconstruction may take many years, because many difficulties connected with historically formed systems of land-tenure and water use will need to be overcome. However, we are of the opinion that the work should begin with implementation of the initial measures of a recommended stage development. The following is a preliminary outline of a plan for reconstruction of irrigation systems:

The plan should undertake to establish on irrigated farms the material basis and space-organization conditions for the widespread mechanization of agricultural operations, farm land reclamation on irrigated lands, improvement of irrigation methods, land use efficiency, productivity of labor, and economic use of irrigation water.

Measures for reconstruction of irrigation and drainage systems should be taken separately for each area, and the following points should be considered:

(1) Organization of irrigated plots, proper locations of irrigation and drainage networks; reduc-

tion of the number of water distributing points on inter-farm irrigation networks; improvement of cultivated lands; equipping irrigation and drainage networks with hydraulic structures; introducing new irrigation techniques, increasing the efficiency of irrigation networks by controlling infiltration; afforestation development; estimating costs of reconstruction, and determining of primary stages of work.

To complete the plan it will be necessary to have the following data: a 1:10,000 land use map showing the boundaries which are to be revised; 1:10,000 topographic maps with 0.5 to 1 metre contour intervals; 1:10,000 soil maps showing the characteristics of soil and land reclamation conditions; 1:50,000 hydro-geological and land reclamation maps; cropping patterns, both present and projected; crop water requirements.

Plans for rehabilitation of irrigation and drainage networks are worked out in the following succession: Reconnaissance surveys, preparation of one or several alternatives for rehabilitation of irrigation and drainage networks, reviewing and choosing of the final alternative of a project for the area development and plan for rehabilitation in order to assure the most efficient land use; elaborating the adopted version of the plan, completing necessary designs and details.

A prospective plan for rehabilitation should be designed for a period of 20 to 25 years and should be more comprehensive than the plans prepared heretofore. The plan should provide for straightening and for parallel location of main irrigation canals and water collectors. Provision should also be made for right-angled shape of farm plots to simplify irrigation and easy operation of machinery.

The above mentioned improvements may be carried out in two steps: (1) The point where water is taken from the main canal (water distribution unit on main canal), should be transferred upstream or downstream in order to obtain proper command in the main and secondary canals; (2) Eliminating of superfluous canals, and straightening of other canals.

It will be more economical to have only one water intake per farm. The number of intakes should be reduced to a minimum. Some reduction in turnouts may be achieved by redistribution of land ownerships with due regard to the command of inter-farm canals and reconstruction of irrigation ditches.

To ensure proper irrigation, leaching, seed covering, mechanized harvesting of crops and all other operations, land leveling and adjusting should be done in a manner to achieve regular shape of irrigated plots, straight alignment of irrigation canals, drainage network and water collectors. Provision should also be made in the overall land leveling plan for the construction of adequate roads for all types of farm operations.

In the plan for farmland grading an attempt should be made to maintain existing field surfaces and to minimize, if possible, amounts of cuts and fills.

The design discharges for the canals and outlets should be calculated and determined in accordance with the following water use at farms: Farms served by a constant supply of water of one canal are considered as a water-consuming unit; within the unit the capacity of the system should be enough to irrigate the entire unit during the peak water demands.

The design discharge for an area can be calculated by considering the size of the area, water requirements and other practical matters.

In designing the schemes for rehabilitation, provision is made to complete the inter-farm irrigation drainage system with all necessary engineering structures including construction of permanent outlets on the secondary canals. Since water distribution at the farms is based on water circulation within the water consuming units, as a rule, all water outlets should be coupled with permanent or temporary partition structures. Aquaducts and culverts should be envisaged not only at the places of intersection of existing canals but should also be planned for easier water distribution, independent water delivery to every single farm, and to improved conditions of command.

Additional water drops should be applied for erosion control and for converting irregular streams into controlled ones and increasing efficiency of land use by utilizing waste lands along the banks.

For increasing efficiency of land use and for erosion control purposes in steep and hilly terrain, provision for construction of terraces should be considered.

Under some conditions retaining walls should be constructed, especially if new canals are in steep slopes.

All water outlets at the farm level should be provided with water measuring facilities.

If possible farm roads, when they cross irrigation systems, should be combined with hydro-technical structures.

New irrigation techniques (sprinkler irrigation, automatic or improved strip and furrow irrigation) may be introduced.

Introduction of new irrigation techniques will require design experience, changes in structure, machinery and other equipment, and certain routines in operating the new systems.

These prerequisites for introduction of new irrigation techniques will not appear immediately. That is why, in designing schemes for rehabilitation, the stage for introduction of new techniques of irrigation should be developed in all 28 provinces of Afghanistan on a limited area of 20 to 30 hectares (a water consumption unit).

Implementation of the rehabilitation scheme will take 15 to 20 years to change traditional practices of farming. A number of projects which do not require abandonment of land, not shutting water off for a long time, during construction, can be constructed in the summer time or even all year round. As a rule, works connected with leveling of fields and improvement of shapes of irrigation plots ought to be done in stages during non-cropping periods. Priority should be given to the projects where construction work does not disturb farming, for example, in construction of collectors, construction on preserved section of irrigation networks, etc.

During the first years of rehabilitation (1970-1975) it may be necessary to choose projects which offer maximum results with minimum efforts. For the farms, where land-reclamation works are difficult, priority should be given to the development of collector-drainage systems and leveling of the surface of saline fields. On other farms application of some other reclamation works at the first stage may be found most efficient.

## CONCLUSION

While implementing five-year plans in irrigation land development Afghanistan has attained a certain success. The Ministry of Agriculture and Irrigation has created a number of experimental farms and scientific-research stations. New progressive methods of irrigated farming are being tested on some of these farms and stations. However, the efficiency of irrigation systems does not exceed 0.45 i.e. more than half of the irrigation water has not been used by agriculture. Water seepage from canals causes soil salinity problems and deteriorates the land quality. Crop yields are decreasing. All these necessitate intensification of plans for rehabilitation of irrigation systems.

Taking into consideration economic and technical difficulties it would be advisable to program these works into three periods.

(1) **Initial**. This period (10 to 15 years) includes works for the construction and rehabilitation of inter-farm irrigation networks and establishment of experimental farms for introduction of new irrigation methods.

(2) **Transitional**. During this period (also 10 to 15 years) the works of the initial period are to be continued and all necessary hydro-technical facilities on inter-farm canals should be constructed. After straightening, canals are to be lined and land leveling should be carried out as required.

(3) **General perspective**. During this period complete reconstruction of old irrigating systems should be finished.

Effective use of water, introduction of advanced agro-technics on rehabilitated farms will increase crop yields and profit from agricultural products on a national scale. Under conditions of rapid increase of population these measures will contribute to the solution of food shortage problems in Afghanistan.

## INDIA

# PLANNING AND DESIGNING FOR OPTIMUM ON-FARM WATER USE

by

**A. P. Joseph[1] P. C. Gupta[2] and R. T. Gandhi[3]**


## SUMMARY

Planning and designing, both for the installation of irrigation systems as well as management of water application on the farm, are necessary for achieving economic returns with optimum on-farm water use. The farm irrigation system must be designed to meet the irrigation requirements of the different crops proposed to be grown in rotation. It should be designed to meet the peak consumptive use of the crops and should be capable of delivering the water at a rate the application methods may demand. It is necessary in planning to have a thorough understanding of the field irrigation requirements of the crops as well as conveyance losses since the cropping patterns have to be tailored to suit the quantum of water available. The irrigator must be familiar with the basic principles of irrigated agriculture, and he should be associated in all aspects of the planning to get the maximum benefit from the system.

The important elements to be considered in planning are the soil, crops, farm conveyance and distribution system, land shaping and leveling, methods of water application, and effective drainage of excess water. While an adequate water supply and facilities for its distribution are essential, optimum use of irrigation water requires good management. Conditions on the irrigated fields are not static and hence the management has to be flexible and adjusted to the needs of farm land and changes in the cropping as desired by the irrigator to get the maximum from this water. The irrigator must schedule operations such that irrigation water may be applied to all parts of the field as it is needed. He must be as aware of the



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magnitude of the losses as he is of field irrigation requirements. Only by keeping the two in balance can he attain the highest efficiency in water use.

## INTRODUCTION

Irrigation is the planned way of partially overcoming deficiencies in the natural pattern of precipitation. Crop growth depends primarily on the supply of much needed moisture in the soil for the physiological function and at critical stages of plant growth. To ensure adequate supply of water for maintaining optimum soil moisture on the farms it is necessary to plan and design both the irrigation system and water application facilities on the farms by taking all relevant points into consideration.

Such planning leads to what is commonly known as conservation irrigation — the use of irrigated soils and irrigation water in a way that ensures high production without waste of water or deterioration in soil productivity. Conservation irrigation water management means controlling or regulating water application in a way that ensures high crop yields without wasting water, soil or plant nutrients.

Proper planning of the farm irrigation system is the principal factor in achieving economic returns from irrigation. It envisages laying out complete systems of delivery and distribution of water to make the water available in adequate amounts to all parts of the farm. A farm irrigation system must meet the irrigation requirement of the different crops grown in rotation on the farm. For this purpose it must be designed to meet the peak consumptive use requirements of the crops and should be capable of delivering the water at a rate the irrigation method may demand. It must fit into the situation with respect to soils, crops, climate, water supply and related aspects.

## PRIMARY CONSIDERATIONS

The primary considerations in planning an efficient irrigation system for optimum water use are:

(1) An understanding of the field requirements, both by the planner of the system and the user. This would include understanding the suitability and capacity of the soil to respond to irrigation, methods to use adequate water when it is needed, and other management practices such as preparatory cultivation, use of fertilizers, pesticides, provision for drainage, and the like.

(2) The planner must take into consideration the quantum of water available, the crops which the user prefers, methods of irrigation to be adopted, and pattern or layout which will minimize water losses through conveyance and over-watering. The user has to be guided in carrying the water as efficiently as possible, shaping the land to evenly spread it, and disposing of excess water without causing soil erosion.

(3) The user must be familiar with the basic principles of irrigated agriculture: capacity of soil to hold and release water, when and how to irrigate, adjustment of stream size, time of water application, and other aspects.

(4) The planner and user must work in unison so that the user gets the maximum benefit from the improved system of irrigation.

## PLANNING CRITERIA

The major factors to be considered in planning and designing for efficient on-farm water use are:

(1) Soils: Intake rate, water-holding capacity, depth of irrigation and the like.

(2) Crops: Consumptive use of water, peak consumptive use, critical periods of growth, and moisture extracting depth.

(3) Distribution system: water conveyance, division and distribution.

(4) Land shaping and land leveling.

(5) Methods of water application.

(6) Drainage: Surface and sub-surface.

## SOILS

The soils have to be classified according to their suitability for irrigation. A soil survey, therefore, is essential. Emphasis has to be given to the intake characteristics of soils, water-holding capacity, permeability, depth, salt content and physical changes that

may occur when brought under intensive irrigation. Other aspects also have to be considered, such as depth to the water table, presence of hardpan, or any other restrictive layer which may affect proper drainage. If the land has to be extensively shaped or leveled, particular attention has to be paid to the depth and the nature of the soil, as exposing of poor, infertile sub-soil may badly affect the economics of the operation.

An inadequate soil survey has stood in the way of efficient use of the irrigation potential in our country. Soils which are heavy and comparatively impermeable, with no provision made for drainage, have developed waterlogging and salinity. This is true even in some projects where, although soil surveys were completed prior to construction of the project, the dangers pointed out by them were ignored by the irrigation authorities. However, in the new projects that are being taken up, necessary provision is made for adequate soil survey and land classification of the soils of the commanded areas before designing distribution and drainage systems. Necessary technical guides for this purpose have already been prepared and distributed among the states. New projects are approved only when the soil survey is included as an integral part of the project. The existing projects are reviewed and remedial measures suggested for reclamation of the affected areas.

## CROPS

The nature of the crops, duration, growth habits, rooting system and critical stages of growth have to be taken into consideration when fixing the size of the turnouts and the size of the irrigable area. The knowledge of consumptive use of water, particularly peak consumptive use, is essential if the system is to work efficiently. While calculating the gross field irrigation requirement, it is also necessary to bear in mind the losses that occur in conveyance in water courses and field channels, through deep percolation in the field, as well as contribution of rainfall. All these points have to be taken into account while allocating the quantum of water in relation to the area to be irrigated.

There is insufficient knowledge of soil-water-plant relationship under the various climatic conditions in the country, and a great deal of study on soil conditions and water management problems have to be carried out before recommendations can be given to the farmer with regard to the cropping patterns and irrigation practices which are best suited to specific areas. With introduction of the high-yielding varieties program in the country, the importance of precision in water application has come into focus. The farmer requires uptodate scientific information on periodical requirements of irrigation as well as field drainage readily accessible to him.

A well chalked out research program to collect information on the cropping pattern and water requirements has, therefore, been launched. Pilot projects are being set up to develop and demonstrate water management techniques to the farmers. Where shortage of water is felt, crops requiring less water are being recommended for rotation with paddy and other crops with high irrigation requirements.

## DISTRIBUTION SYSTEM

Proper planning and designing of farm distribution systems are vital for achieving high efficiency in water use. Numerous factors must be considered to design adequate water conveyance and distribution systems. The annual, monthly and weekly farm delivery requirements (usually expressed in acre feet/acre) must be calculated. The demand varies with crops, climate and soil. Distribution system losses as well as field losses must be taken into account while designing the capacity of the system.

With the capacity requirements established, the field distribution system including conveyance channels and control structures can be designed for the peak demand in accordance with the fundamentals of hydraulics, field mechanics, soil mechanics and structural engineering.

India's present system of field distribution of water in the irrigation projects is not satisfactory. Water distribution within the command of the turnouts is left to the farmers' management among themselves. This usually results in water flowing from one field to the next lower down, with consequent waterlogging of some fields and inadequate irrigation of others. With such poor distribution the yield per unit of water used is unsatisfactory. Improved methods of water distribution, such as rotation irrigation as has been successfully used in Taiwan and the Philippines — as also in some old irrigation systems in India — are being more widely introduced.

Rotation schedules, on which water is distributed in some of the projects, need improvement. Considering the crop, the soil and the climate, the rotation interval should be such that the crops are not put to moisture stress. Farmers must also get water on time and in adequate amounts.

For proper distribution of water at the field level, there is need for properly designed channels for water conveyance as well as structures for its division and distribution. Where these are not properly planned and constructed, a substantial quantity of water is lost. To reduce transit losses, channels must have control structures and lining. Underground pipelines may be installed where the situation demands.

In most of the irrigation projects, the water conveyance beyond the turnouts fixed in the public canals are not satisfactory. Usually, crude channels are dug by the farmers along the field boundaries. The resulting circuitous channels lose head rapidly, lose command and cause wastage of the precious water. Besides wastage of the resource, these poor channels contribute to creation of waterlogging and salinity.

The construction and maintenance of field distribution channels are now given high priority. Legislative measures have been taken to make properly planned and constructed field channels and water courses compulsory. Lining of the channels to reduce the seepage losses is encouraged, and necessary governmental assistance is given in their design and installation.

## LAND SHAPING AND LEVELING

For proper management of water on the farms, besides having properly laid out farm water distribution systems, there is need for proper shaping and leveling of the farm lands for uniform water application and preventing water stagnation. Generally, the shaping is done to provide uniform grades or to reduce the grades in the direction of irrigation or at right angles to it. Land shaping and grading are also needed to provide good surface drainage. If designed in accordance with infiltration rates, soil, size of the irrigation stream available, the crops to be grown and the erosion hazard from rainfall, a good irrigation grade permits uniform distribution of water and results in efficient irrigation. Land grading should also suit the method of irrigation adopted. Selection of the type of leveling and the layout of the various fields should always take into consideration all the crops to be grown in rotation.

Surveying and mapping are needed to develop a good plan for land preparation. Soil surveys should also be made before leveling is done. A topographic survey map should usually form the basis for preparation of the plan and the layout. Besides showing the shape and the size of the field, the map should show surface topography, proposed surface elevations and irrigation layout as well as drainage facilities wherever they exist or are proposed. In planning a field to be leveled, it is helpful to square up the layout with location of the existing drainage ditches, farm road, field boundaries, etc. After the design is complete, estimates can be prepared for the earthwork involved and its cost. It is important that the details are discussed with the farmer to apprise him of the arrangements, including the cost of the leveling job.

Land leveling is done most effectively with tractor-drawn or motor-propelled equipment. Different types of equipment are used under different situations. Mainly land leveling is done by scrapers, usually a carryall type. For lighter soils or small farms bullock-drawn implements are also being used effectively. The leveling jobs are finished with levelers or floats or land planes.

Leveling makes possible a more even distribution of irrigation water through its better control and management. The result is water saved, labor saved, more uniform stands, and increased crop yields of better quality.

Lack of land leveling has been one of the important factors in poor performance of irrigated agriculture in the past. Necessary financial assistance is given to the farmers to meet the cost of land development for irrigation. Technical assistance is also given through governmental agencies.

## METHODS OF WATER APPLICATION

Planning of water application methods is very important to achieve high efficiency in water use. A good method of water application with a suitable stream of water would enable the irrigator to have complete control over water and would facilitate its

uniform application in all parts of the farm, and also provide effective drainage of the excess. When water is applied without proper planning and without the adoption of suitable methods, not only uneven distribution of water occurs but wastage of the resource and inefficiency result.

The method of irrigation to be adopted in a particular situation depends on the topography, soil conditions, crops to be grown, and its cost. Each method has certain limitations. Several methods of application can be used on some soils and only one method on others. If more than one method is suitable, it is necessary to study and evaluate each method as to efficiency in water application and arrangement of irrigation units and other necessary facilities. The method that best suits the fields and crops and is acceptable to the farmer can be adopted.

In India several methods of water application are practiced by the farmers. One of the common methods used is that of check basin. For paddy irrigation, however, the traditional method of wild flooding is still in vogue in most of the areas. All these methods need improvement for obtaining high efficiency of water application.

Such methods as border strip and furrows are getting popular. Sprinkler method of water application has recently been introduced at several places. Demonstrations of improved methods have been organized under the intensive agricultural program as well as in the Pilot Water Management projects set up on a regional basis. Farmers are gradually improving in water application methods.

## DRAINAGE

For optimum water use, provision of adequate drainage facilities is as important as irrigation itself. Drainage is necessary not only in the high rainfall areas but also in other areas, in that rainfall occurs in a concentrated manner, causing water stagnation. Such crops as cotton, maize, jowar (sorghum) and bajra are very sensitive to water stagnation. Even paddy cultivation needs drainage. Drainage in the sub-soil can prevent concentration of toxic substances. With effective drainage most crops show significant increases in yield.

Drainage is vital for saline soils to leach away the salts. Irrigation without adequate drainage thus often becomes a detriment rather than an aid for increasing production, especially for obtaining sustained increases in yield.

The planning and design for efficient water use should, therefore, provide facilities of adequate capacity to remove excess water from the irrigated land promptly and safely. Excess of water may be caused from irrigation, surface runoff from rainfall or excess percolation of irrigation water or rainfall water. It may also include leakage or seepage from parts of the conveyance system. It is necessary to plan and install the drainage system simultaneously with planning and installing the water distribution system.

## MANAGEMENT OF WATER APPLICATION

While an adequate water supply and facilities for its distribution are essential, optimum use of irrigation water also requires good management. The irrigator or the farmer plays a key role in making optimum use of the water resources developed for irrigation. Irrigation water management is defined by U.S. Soil Conservation Services as the "use and management of irrigation water where the quantity of water used for each irrigation is determined by the water-holding capacity of the soil and need of the crop where the water is applied at the rate and in such a manner that the crop can use it efficiently and significant erosion does not occur."

To optimize production, irrigation water has to be applied before the plants deplete the moisture in the soil to the wilting point. At each irrigation, sufficient water needs to be applied to replenish the soil moisture and provide the leaching requirements in the root zone of the particular crop. The irrigation interval and the amount should be worked out to meet these requirements. A longer interval than the optimum may reduce the yield. An excess application causes wastage of water as well as loss of nutrients through deep percolation.

Conditions on an irrigated field never remain static. As the crop roots develop, the amount of soil water that can be stored increases. The soil intake characteristics and susceptibility to erosion change with tillage practices, climatic conditions, and crop influences. Thus, the irrigator is faced with an ever changing set of conditions requiring adjustments in his irrigation techniques. He must keep abreast of

these needs and must continually evaluate his irrigation operation and plan for the changed conditions so that he may make the best use of his water.

The irrigator can detect erosive streams by simple observations, but he must rely on moisture meters, soil examinations, or time estimates to evaluate the amount of water remaining in the soil. He must be able to measure the amount of water applied and compare this with the volume needed to fill the root zone. He also needs to estimate how uniformly the water is being applied over the field and how much is being lost as surface runoff and by deep percolation.

Techniques for estimating surface waste and deep percolation vary with different methods of irrigation. With sprinklers, for example, it is quite simple for the irrigator to know how much water has been applied, for the system delivers a predetermined amount each hour. With sub-irrigation systems, the water conditions can be observed by the depth to the water table as measured in a shallow well. With surface methods, an experienced irrigator can judge the uniformity of his application by noting the times of advance and recession of the irrigation water over the border, furrow, or field.

Level borders or basins must be filled quickly with the correct volume of water to make the desired application. With graded borders, the irrigator must have his stream large enough to spread across the border strip and should have the correct volume applied by the time the water has approached the lower end of the border. If the water does not get there soon enough, he should increase the size of his stream or shorten his length of border and irrigate for a shorter period of time.

The irrigator can best judge the uniformity of application in furrows or corragations by observing the time water is running in the upper and lower ends of the furrow. Irrigation should be continued until adequate water is applied at the lower end. If the furrow length and stream size are in proper proportion, the upper end will not have received an excessive application.

The irrigator can compensate somewhat for distortion of the sprinkler pattern by wind. In severe instances, irrigations may be scheduled during the time of day when the normal wind velocity is lowest.

With all systems the irrigator must schedule his operations so that irrigation water will be applied to all parts of the field as it is needed. He must be equally aware of the magnitude of the deep percolation losses as he is of the water lost in surface runoff. Only by keeping the two at a minimum can he attain the highest overall farm irrigation efficiency.

# IRAN

## PRINCIPLES AND PROCEDURES OF WATER RESOURCES INVESTIGATION IN THE SOUTH COAST OF IRAN

by

Farhad Esfandiari*

### ABSTRACT

This paper discusses the water resources investigation being conducted on the northern coast of the Persian Gulf (northeast of Bandar-Abass) by the Iranian Ministry of Water and Power. An attempt is made to show how preliminary water resources evaluation can be obtained with a limited amount of initial information and in a short period of time.

The project area covers some 700 square kilometers, and receives runoff from the southern slope of the Zagross mountains in four separate drainage systems. This investigation has been in progress for about 18 months.

Preliminary results of this study are presented, and to compute a comprehensive water balance the programs for the additional necessary work are shown. Descriptions of the use of aerial photographs, field geology, geophysics, water points inventory, meteorologic data, surface flow measurements, geochemistry, water quality variations and underground water flow are also presented.

A preliminary water balance is made for the area. Also included are sample maps showing geology, resistivity variations, rainfall, water points, and water levels.

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### INTRODUCTION

Water resources in many areas of Iran have been studied. Through these investigations various development projects such as dam construction, irrigation networks, reclamation programs, etc., have been implemented. One of these investigation projects is in the Takht basin, located on the south coast of Iran, about 60 kilometers northeast of Bandar-Abass (see map No. 1). The investigation is by the Ministry of Water and Power.

The project area, covering about 700 square kilometers, has been under study since January, 1969, and is scheduled for completion in June, 1971. This means that at the time of preparation of this paper the investigation is not completed. Therefore, it is not possible to draw final conclusions. However, in principle an attempt is made to show which kind of study is necessary in evaluating water resources in an area, and how satisfactory preliminary results can be obtained with limited information.

Adverse geological conditions along the Persian Gulf and Oman Sea, particularly in the project area, have created serious salinity problems resulting in excessive salt contamination of much of the available water supply. Therefore, an attempt is made to show how to prevent contamination.

The investigation is being made by a team of hydro-geologists, engineers and technicians of the Ministry of Water and Power. Investigation methods comprise: Preparation of base maps from aerial photographs, inventory of water points, geological survey, hydrological and meteorological data collection, geochemical sampling and analysis, surveying of observation wells and recording of water levels, and periodic measurements of discharges of wells, rivers, and springs.

From the information obtained it is expected that an approximate evaluation of the water balance can be made.

## GEOGRAPHY

The town of Bandar-Abass is situated at 56° - 17'E, 27° 11'N on the northern shore of the Strait of Hormuz connecting the Oman Sea to the Persian Gulf. The project area (so-called Takht basin) is a composite synclinal valley located 60 kilometers northeast of Bandar-Abass, along the southern foothills of the Zagross mountain chain, on the gently sloping alluvial plain. The area of the basin is about 700 square kilometers. The elevation of the valley above sea level is 60 to 70 meters in the north and about 30 meters in the south. The basin is bounded on the north by the mountain ridges of Niam and Kush-Kuh, on the east by the northern part of the anti-clinal ridge of Shamil, on the south by the Jamough ridge, and on the west by the eastern slopes of the Sarkhun and Shur ridges.

The project area can be divided into four sections with separate catchment areas.

Most of the streams reaching the basin, and in particular the Garu river, spread out on the surface. The waters of the Garu and Jamough rivers merge and flow through a breach in the Jamugh ridge. The eastern section of the basin is drained by a number of small streams.

## CLIMATE

The project area is in one of the hottest parts of Iran. The average temperature for the period of record, January 1957, through October, 1967, is 28° C (82°F). The highest recorded daily temperature of 45.4°C (113°F) occurred in August, 1957, while the lowest daily temperature of 4.8°C (40°F) occurred in January, 1964. Freezing temperatures have never been recorded at the project area.

The average annual precipitation at the project area is about 145 millimeters.

The relative humidity is comparatively high during the entire year, ranging from about 60 to 80 per cent.

## PRINCIPAL SUBJECTS OF INVESTIGATION AND PROCEDURES

### *Geological Survey*

The geological survey comprises interpretation of aerial photographs of the project area at a scale of 1:20,000, supplemented by field checks.

Out-crops in the northern part of the basin (Kush and Niam mountains) are comprised of the following formations: Jurasic (massive bedded dark limestone), cretaceous (blue marls, conglomerates, marly and sandy limestone, graded [illegible] limestone), eocene (limestone and marly limestone), oligo-miocene (so-called Asmari limestone), neogene (so-called Fars group) which is divided into three separate formations and which may reach a thickness of several thousand meters. They are composed of silty limestone, some interbedded gypsum, sandstone, marls, and silts with intercalated evaporites, and pliocene (so-called Bakhtiari conglomerate). The basin itself is filled with alluvial material. In the northern fringes this fill consists mostly of pebbles and sand, and lies in alluvial fans. In the central and southern part of the basin, it consists of fine sand, silt, marly clay, etc. Most of the soils in the central and southern parts are saline.

### *Water Points Inventory*

An inventory has been made of all wells, including technical specifications, date of completion, and discharge measurements.

This inventory will furnish a quantitative value for one of the most important factors in the output side of the hydrologic balance, i.e., the bulk rate of groundwater extraction for agricultural and domestic uses.

There are about 400 wells in the project area. As this number is very great and production rates vary, there is no practical way to measure the extraction directly. Thus the ultimate figure for bulk extraction can only be approximated.

### *Geophysical Survey*

Electro-resistivity surveying by the Schlumberger method has been used in the project area. In total 150 electric soundings with electrode distance (AB) of 2,000 meters, have been made. A resistivity map was prepared for AB 400 meters. Further, a transverse resistivity map, a contour map of the top of the bedrock (miocene), and several geo-electric cross-sections were prepared.

The purpose of this survey is to assess subsurface conditions of the alluvium, such as the total thickness, saturated and unsaturated zones, and approximate groundwater quality.

### *Hydro-geology*

At higher elevations in the Zagross mountains, where there is adequate rainfall, surface streams with substantial flows exist and are sources of portable water. However, as these surface or groundwater flows move toward the coast, they can be contaminated by two major stratigraphic units. These two major units are the miocene (Fars series) and the cambrian (Hormuz series).

The Fars series is divided into three separate formations composed of silty marls, limestone, some interbedded gypsum, sandstone, marls, and silts with intercalated evaporites. Fars formations are encountered throughout the entire coastal area, and are responsible for several localized salinity problems.

The Hormuz series, less prevalent than the Fars series, represents an almost unique geological feature composed of varigated sandstones and shales, rock salt, laterites and gypsum arranged in a random, disorderly stratigraphical manner. This series presents a serious salinity problem since it can appear in diapiric structure (salt plugs) which are found in the anticlines and long faults.

It is particularly in the project area, where both Fars series and Hormuz series are present, that unusually severe salinity problems can be experienced.

These problems arise since the Fars series generally underlies the water-bearing Bakhtiari conglomerate and recent alluvium in the project area. Hence, the probability of precipitation eventually coming in contact with the Fars series is extremely high.

This exposure results in both surface waters and groundwaters that are high in chlorides and sulphates, making them generally unfit for domestic and/or agricultural use. Similarly, water flowing over or coming in contact with the Hormuz series will also become very salty.

By comparison, where precipitation falls directly on or runoff occurs from non-salinizing geological formations such as exposed eocene, cretaceous or Asmari limestone into the synclinal area of Bakhtiari conglomerate or alluvium without coming into contact with the Fars or Hormuz series, water of good quality usually exists. Due to the relatively high porosity, hydraulic conductivity, and transmissivity of both the Bakhtiari conglomerate and recent alluvium, the natural recharge and storage of groundwater is good. As might be expected, the quality of water deteriorates down gradient or in proximity to the coastline.

This brief, general summary of geology and stratigraphy throughout the area represents a controlling factor for investigating potential means of water resources development.

The Takht basin contains a phreatic aquifer in Bakhtiari conglomerate and in alluvial fill. Investigation of a number of shallow wells showed that the water level is usually at a depth of less than 20 meters. From the geo-hydrological point of view, the Takht basin is divided into four sections, each with its own catchment area.

Investigations in the Takht valley show that the bedrock slopes toward the mountains, opposite to the

ground surface slope, so that the groundwater reservoir is deepest in the upper areas of the valley. This fact, plus information on groundwater flow lines, suggests that groundwater, now being salinized as it reaches salt formations in the lower reaches of the valley, could be extracted by deep wells before it contacts the salt formations and becomes unusable. Additional investigations are planned to study this possibility.

### *Hydrology*

Only one known stream with water of acceptable quality exists, and that is the Shamil river. Because of the low flows, the potential of this surface water source is extremely limited.

There are four other known surface waters which suffer from excessive salt contamination, making these waters unfit for human consumption. These streams are: Garu, Iamugh, Jalbi, and Shur rivers.

### *Geochemistry*

The study of geochemistry is a very important tool in the evaluation of water resources in semi-arid countries like Iran, as water quality is often a critical factor in the agricultural potential of the basin, and will be an important consideration in the establishment of development and management schemes.

The project area's 400 wells are sampled and analyzed seasonally. With these data the following maps and graphs were prepared: electro-conductivity, chlorine concentration, sodium adsorbtion ratio (SAR), water type total dissolved solids (TDS), and about 18 schoeller diagrams.

The electro-conductivity ranges from 1,000 microomhos per centimeter in the north up to 10,000 micromhos per centimeter in the extreme southeast of the project area. Similarly, the chlorine concentration ranges from 100 mg/lit. in the north up to 3,000 mg/lit. in the extreme southeast of the project area. The total dissolved solids content ranges from 500 mg/lit. in the north up to 4,000 mg/lit. in the extreme southeast. SAR ranges from seven in the north to 50 in the extreme southeast of the project area. Therefore, water quality in the lower part of the basin is generally poor as a result of contamination by saline formation and a high evaporation rate.

### *Groundwater Level Data And Isopiezometric Maps*

Water level gauge data are collected monthly in about 170 observation wells. Isopiezometric maps are being prepared for spring (maximum) and autumn (minimum), 1969. A seasonal water-level difference map will also be drawn, in order to assess the seasonal change in storage. Lastly, an equal- depth map of the groundwater table will be prepared.

The assessment of real water levels for these maps necessitates a highly pragmatic approach, since many of the hand-dug observation wells do not yield useful data at the time required, as a result of the drying up of these wells during summer and autumn, or the effects of neighboring pumping wells.

## FURTHER STUDIES REQUIRED

Further studies necessary to complete a water balance are as follows.

(1) In light of the above surveys, about six exploration boreholes should be drilled which can serve as production boreholes at a later stage. The exact location should be decided on the basis of the results of the geophysical survey.

(2) In order to investigate such aquifer characteristics as transmissivity and specific yield, a pumping test program should be executed.

(3) A soil study and land classification should be conducted throughout the project area.

## ESTIMATED WATER BALANCE

In calculating the water balance, many assumptions have to be made, such as assessment of the rate of deep percolation from irrigation, infiltration of domestic waters and of precipitation, total extraction rate, regional specific yield and transmissivity.

The usual procedure for assessment of the water balance is to calculate a preliminary balance for the period of an irrigation season, so that a basin-wide change in storage can be compared with total production records and other output and input data to obtain an approximate figure for regional storage capacity. For this calculation a period with an

optimal amount of data is selected in order to verify the diverse assumptions made, and to correct these where necessary. Furthermore, it is expected that this preliminary balance computation will expose whatever weak points there are in the assembled data, so that additional data collection can be effected where necessary, before the project is scheduled for completion. After this, an attempt will be made to obtain a more definite water balance, valid at least for the time of data collection.

Preliminary estimates show that the amount of water pumped from the Takht basin at present is about 10 million cubic meters per year. Safe yield calculations show that at least three million cubic meters per year more than present use can be extracted from the Takht basin.

## CONCLUSIONS AND RECOMMENDATIONS

Hydro-geologic studies of the project area suggest measures that can be taken to increase safe yield of good quality water from the Takht basin. These measures would include mainly:

(1) Modernizing traditional irrigation systems to salvage water now wasted and increase agricultural production and income.

(2) Substituting strategically placed deep wells for the hand-dug wells that now merely skim the surface of the groundwater reservoirs.

(3) There are a number of intermittent streams, such as the Garu and Jamugh rivers, that essentially dry up during the summer months and are not potential sources of increased surface water supply. Although the flowing stream is normally small the beds of these rivers are large, indicating that large volumes flow periodically. It is believed that measures can be taken at reasonable cost to divert at least a portion of these flows to upper areas of the valleys to accomplish significant recharge of the underground aquifers.

(4) Interception and diversion of fresh ground or surface waters high in their respective basins for use prior to contamination, isolation of fresh waters to keep them from becoming saline, and recharging fresh water into conglomerate or alluvium along the mountain fronts for subsequent groundwater withdrawal.

(5) A pilot project to study and modernize traditional irrigation systems could be highly profitable in the project area and the information gained could be valuable in other areas of Iran.

## ACKNOWLEDGMENT

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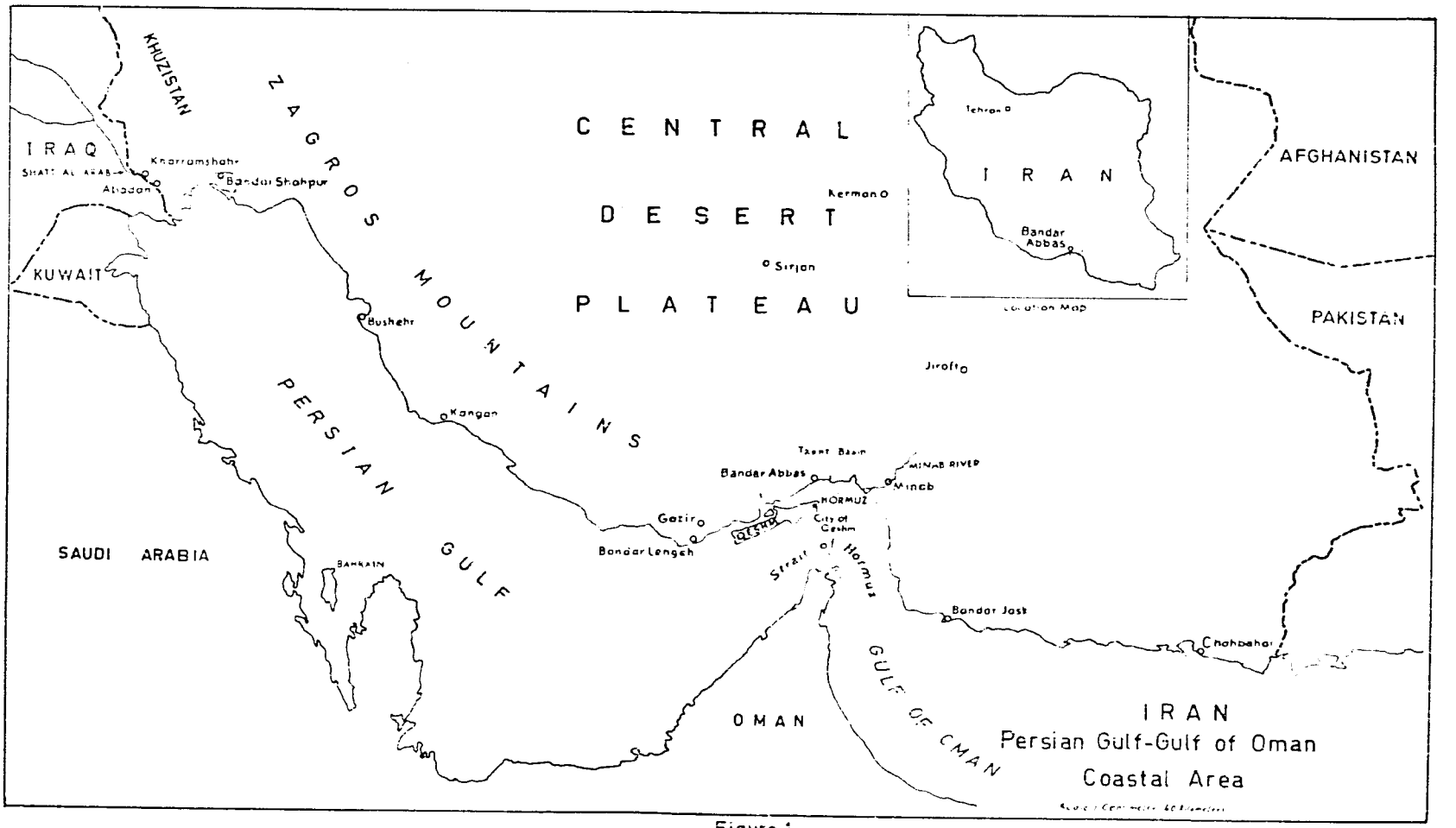
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Abadan
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ZAGROS MOUNTAINS
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Jiroft
Bushehr
Kangan
KUWAIT
PERSIAN GULF
SAUDI ARABIA
BAHRAIN
Bandar Abbas
Tahert Basin
MINAB RIVER
Minab
HORMUZ
City of Qeshm
Gatir
Bandar Lengeh
Strait of Hormuz
Bandar Jask
Chabbahar
GULF OF OMAN
OMAN
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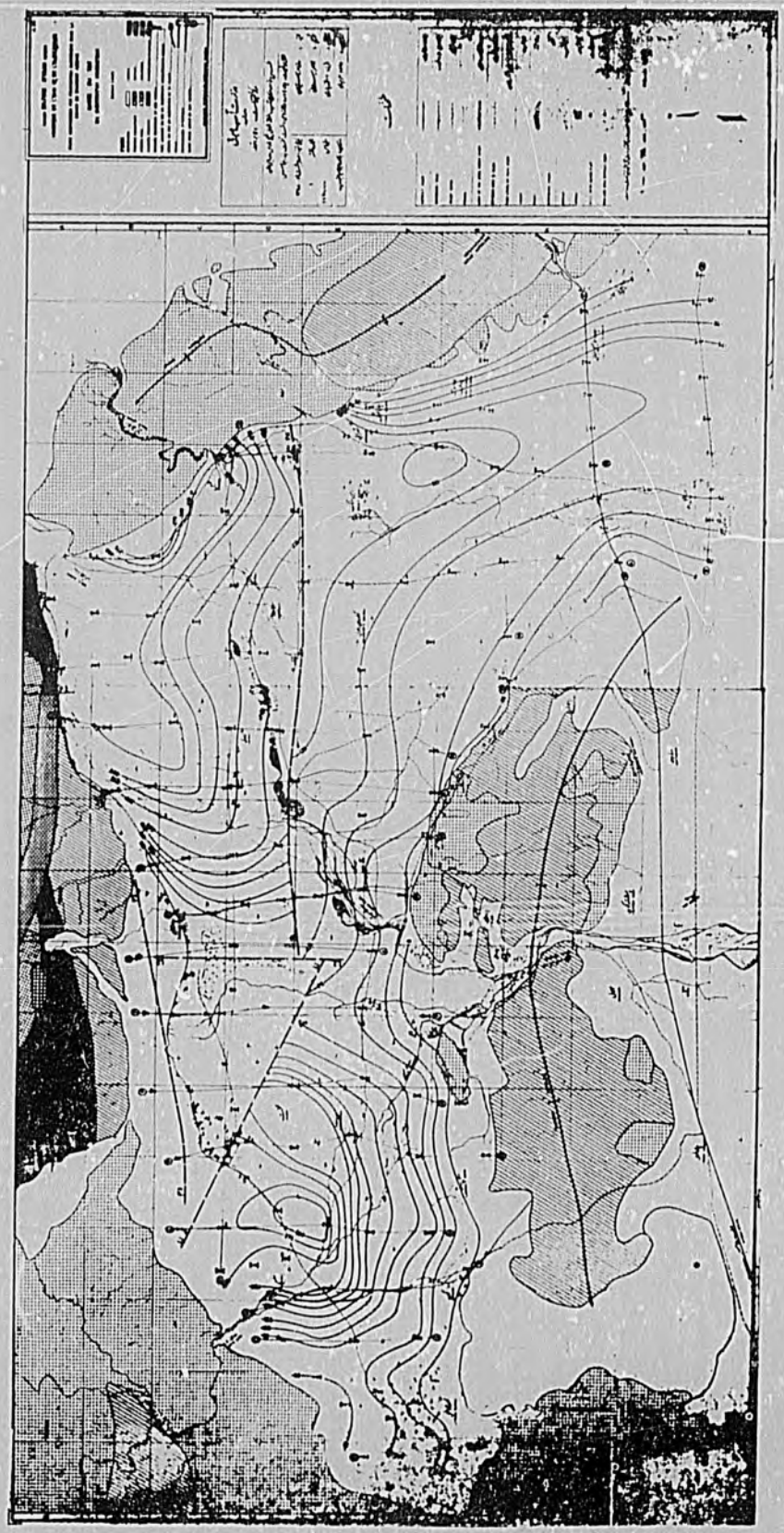
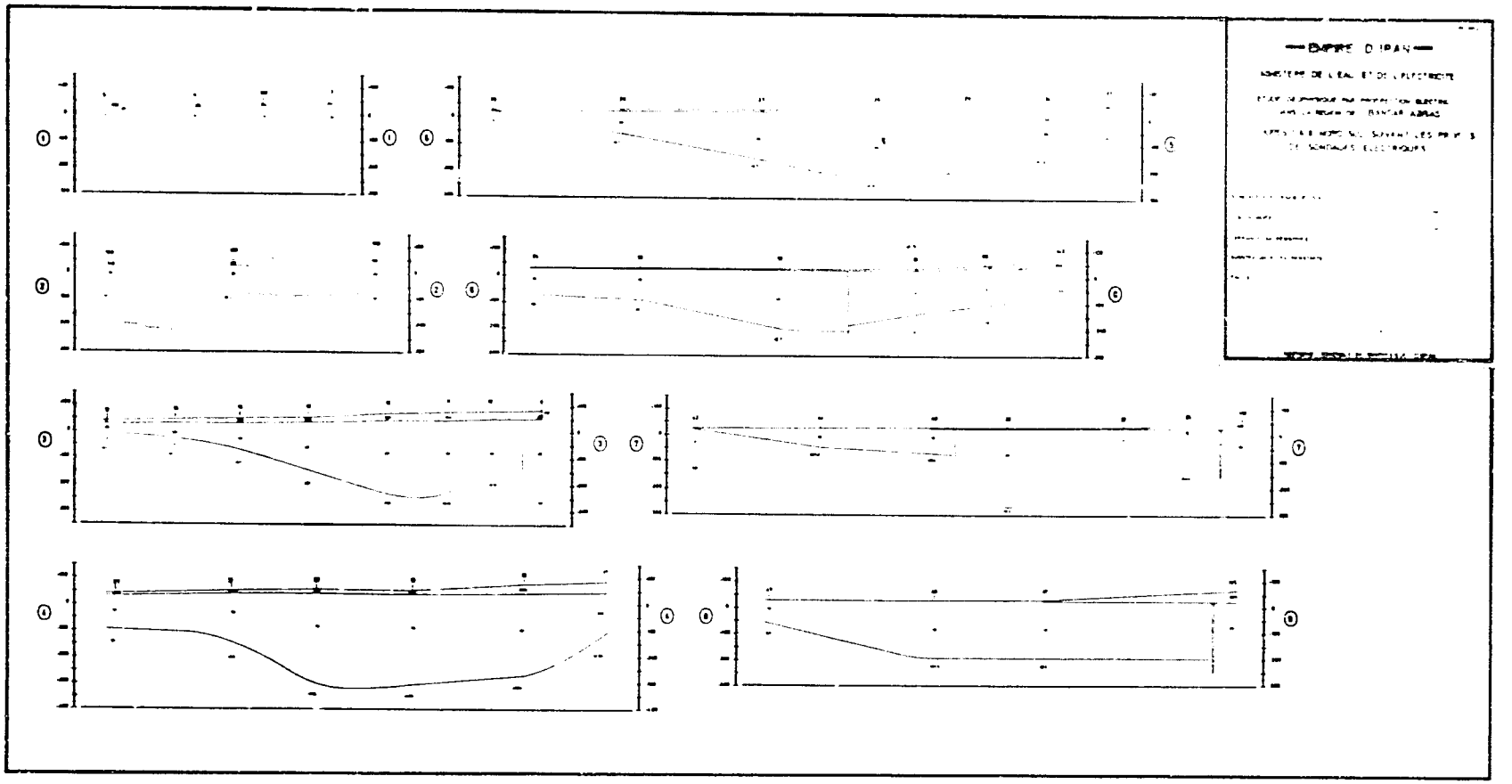
Bandar Abbas
Location Map
IRAN
Persian Gulf-Gulf of Oman
Coastal Area

Figure 1

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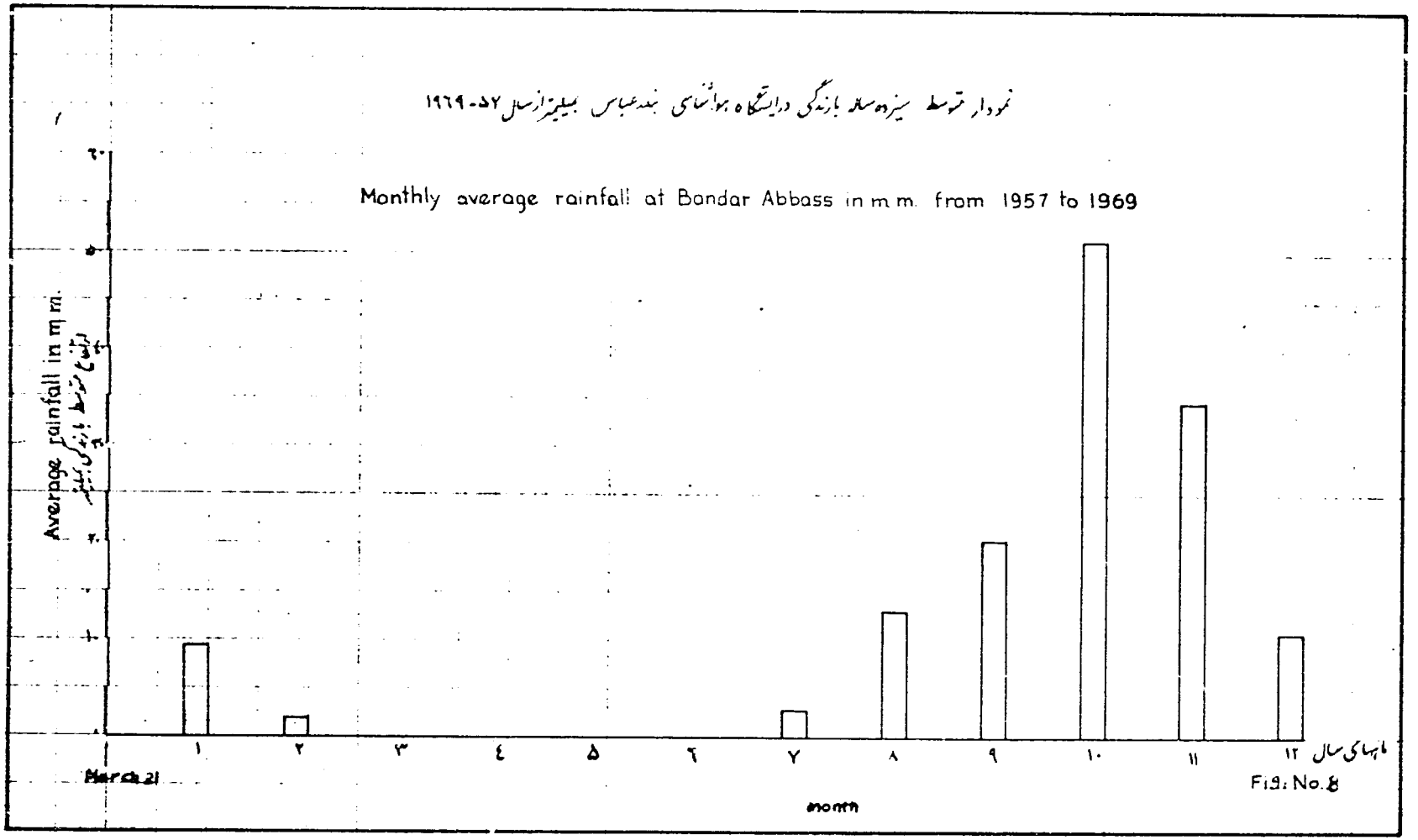
نمودار متوسط سیزده سال بارندگی در ایستگاه هواشناسی بندرعباس بمیلیمتر از سال ۵۷-۱۹۶۹
Monthly average rainfall at Bandar Abbass in m.m. from 1957 to 1969
Average rainfall in m.m.
ارتفاع متوسط بارندگی بمیلیمتر
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ماههای سال
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Fig. No. 8

## UAR

# ECONOMICAL USE OF NILE WATER

by

**Abd El-latif M. Rashwan***

The Nile river is one of the largest and most important rivers in the world. The earliest civilizations flourished along its banks. Its waters created from the dead lands a source of vegetation which the inhabitants could depend on, especially in Egypt and northern Sudan.

The Nile river attracts adventurers because some remote sources of the river have not yet been discovered. It also attracts archaeologists who are interested in reading the history of Egypt on the pyramids, temples, and tombs which were erected by the ancient Egyptians about 7,000 years ago.

The Nile river spreads its influence over the northeastern part of Africa and affects all of Egypt, Sudan, and Uganda, one-third of Athubian country, and some parts of Kenya, Tanzania, Rowandi, Borandi, and the Congo.

The Nile's very existence is dependent on the sun: Atlantic Ocean water is converted to vapor by the sun aided by the rotation of the earth and the difference in atmospheric pressure across Africa for 2,200 miles until it reaches the Athubian mountains and falls in heavy rains on the high mountains. It gathers in small valleys which feed the sources of Nile Sobat, the Blue Nile, and the branches of Atbara Nile, and then to the main Nile and on down to the Mediterranean. This cycle is repeated again and again.

From the equatorial source of the Nile to its end in the Mediterranean, it runs a distance of 6,700 kilometers, extending between latitude 4 South and latitude 31 North, through extensive lands of various countries with temperatures varying from moderate on the equatorial ridge and Athupia to hot in the Sudan and cooler in Egypt.

Agriculture in Egypt and Sudan forms a great part of the economy of these countries. And the Nile

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*Sub General Inspector of Egyptian Irrigation in Sudan.

river is the only source of irrigation water. The Nile is characterized by its wide variation in water yield from month to month, season to season, and year to year. It falls in the low season to such an extent that the discharge is not enough for the agricultural requirements, and rises in the flood season to such a dangerous stage that it destroys life on its banks and overflows to the sea.

The Nile collects its water from three basins:

(1) The basin of the rivers which emerge from the Ethiopian mountains.

(2) The equatorial lakes plateau basin which comprises some of the lands of Tanzania, Uganda, Congo, Rowandi, and Burendi.

(3) The Bahr El-Ghazal basin in southwestern Sudan.

These basins differ greatly in both their total annual contributions and their seasonal contributions to the Nile. The Ethiopian plateau, which contributes about 90 per cent of the flood waters of the Nile, diminishes to only 28 per cent of the water supply during the low period, while the remaining 72 per cent is brought by the equatorial plateau.

In total annual yield the Ethiopian plateau supplies the river with 84 per cent of its waters and the equatorial plateau with the remaining 16 per cent. Most, if not all, of the water of the Bahr El-Ghazal basin is lost in the swamps, and the river does not benefit from it.

Other than the great difference in the contribution of the various sources, the Nile yield is characterized by its wide variations. In the low period of a dry year, the discharge at Aswan drops to a minimum of 25 m $m^3$/day and rises in the flood period of a wet year to a maximum of 1,250 m $m^3$/day. Moreover, the six months of the low period brings only one-fifth of the total annual yield in an average year, the remaining four-fifths coming during the six months of flood water.

The average annual flow of the Nile river during this century has been about 84 billion $m^3$ at Aswan. There is a great difference in the yield between one year and the next as it rises to 150 billion $m^3$ in a wet year and drops to only 40 billion $m^3$ in a dry year.

The above facts indicate that the river is most unstable and that its yield differs from day to day, month to month, season to season, and year to year.

This phenomenon has made the Nile a subject for research in which engineering science has developed advanced methods and techniques in river control. This has made it possible to avoid the damage caused by either a flood or a very low yield. Many barrages and dams have been built across the river to raise the water level and control the usage of abundant waters. This network of canals was planned to carry water to all cultivatable areas.

Until 1959 Egypt and Sudan used only 52 billion $m^3$ from the average annual yield of 84 billion $m^3$, and the remaining 32 billion $m^3$ passed down to the sea. The two countries had to do something to make use of it and to prevent the flow of water to the sea. The over-year storage system was found to be the only solution to this difficulty. Accordingly, large dams capable of storing the excess waters in high years for use in poor years were needed, thus making it possible to have a fixed annual flow during all times and consequently satisfy the demands for increasing cultivated areas.

The two countries agreed to build the High dam, which is now in its final stages of construction, to achieve this over-year storage. Although construction of the High dam makes it possible to control the Nile water, still more efforts must be made before we can fully use the Nile.

The economic benefits of the High dam include:

(1) Expanding the cultivated area by 1.3 million acres of newly reclaimed lands.

(2) Converting 700,000 acres from the basin irrigation system to perennial irrigation, thus raising productivity.

(3) Ensuring water requirements for irrigation of present and newly reclaimed lands.

(4) Protecting the country against high floods.

(5) Improving productivity of the cultivated land through improved drainage by lowering the level of subterranean water.

(6) Expanding the cultivation of rice for export.

(7) Improving navigation conditions on the Nile through the whole year.

(8) Generating an electric power of 10 billion KW/h annually; i.e., five times the power generated from the electric power station of the Aswan reservoir. This power will be used for industrial and agricultural development. The electricity generated from the electric power station will also be transmitted to consumption centers throughout the republic.

It is anticipated that the High dam can satisfy all these needs if the water yield of the Nile during the ensuing years is adequate. But if the water yield is low a deficit is anticipated in the annual requirements. The 1959 agreement emphasized that the committee is obliged to make the necessary preparations to face such a situation.

To prevent this it was necessary to seek other storage projects outside the UAR, either on the main Nile or in the equatorial and Ethiopian reaches, to help in the formation of another water balance to compensate for the deficit in High dam storage or to store waters exceeding the capacity of the High dam in some high flood years.

Consequently, much planning is essential because there is a great need for the implementation of a series of large projects on the upper Nile reaches to control and increase its yield. This is because the flow into the Nile channel is not all that the Nile sources supply. This may be explained by the fact that many of the swamps which engulf the equatorial lake basin absorb considerable amounts of water and prevent it from flowing down to the lakes that supply the Nile. Lake Victoria is a good example, since the amount of water coming out of Lake Victoria to the Nile is only eight per cent of the rain waters that fall in its basin; the remaining 92 per cent is lost in evaporation, seepage, and absorption by the swamps. Also, after the southern boundaries of the Sudan, the Nile is surrounded by numerous swamps, some of which are connected with Bahr El-Gebal, Bahr El-Zeraf and Bahr El-Ghazal. The other swamps are connected with River Sobat and its tributaries and with the White Nile basin.

Along these swamps, the river flows inside a flat channel having very few banks and carrying a limited flow which, if it exceeds the capacity of the channel, results in overflowing the banks, thus dissipating most of it in the swamps; thus most of the water is lost without finding its way northward. The total amount lost annually is estimated at 36 billion $m^3$.

The losses of the Nile in the swamps of the southern Sudan are as follows:

(1) Almost all the flow of Bahr El-Ghazal is lost.

(2) On the average, half of the flow of Bahr El-Gebal and Bahr El-Zeraf is lost.

(3) Approximately one-third of the yield of the Sobat river and its tributaries and the Khors adjacent to its basin is lost.

By continuous hard work much of the Nile water has been put to use. The High dam was constructed mainly to make use of 32 billion $m^3$ of water which is lost yearly to the sea.

Consequently it becomes necessary to study and execute large irrigation projects in the upper Nile reaches for the benefit of both Egypt and Sudan, thus improving the productivity of the recently cultivated land and expanding the cultivated land to parallel the increase in the number of inhabitants. The ratio of persons to the cultivated area in Egypt has increased as follows in the past four decades:

.39 acres per person, 1927
.31 acres per person, 1947
.26 acres per person, 1957
.22 acres per person, 1967

The number of inhabitants in Egypt is expected to reach 36 million by 1975. Accordingly, the land acreage per person will decline further. This continued decrease in the individual share of the cultivated area makes it essential to put forth the best efforts to implement large irrigation projects to reclaim all lands and make them fit for cultivation. The agreement between Egypt and Sudan indicates the importance of this situation and encourages the efforts to construct projects to control the Nile and increase its yield. This agreement ensures the rights of each country along the Nile river.

When these projects are ready, they will be approved by the two countries and work agreed upon will commence. The regions included in the agreement are:

(1) Bahr El-Gebal and Bahr El-Zeraf swamp region.

(2) Bahr El-Ghazal swamp region.

(3) Sobat river swamp region.

(4) Swamps near the White Nile.

## Bahr El-Gebal and Bahr El-Zeraf Swamp Region

The total yield of Bahr El-Gebal at Mongalla is 28 billion $m^3$ per year while the amount reaching Malakal through both Bahr El-Gebal and Bahr El-Zeraf does not exceed 14 billion $m^3$. That means that about one-half of the river yield is lost through these swamps. Research has proved that the river channel is limited to a certain discharge not exceeding 30 million $m^3$/day, so any discharge less than that will pass with reasonable loss. If the discharge exceeds this amount, the excess will spread all over the swamps and be lost. To spare these losses, two projects have been discussed:

(1) Increasing the capacity of natural channels and embanking them from both sides to avoid the seepage of river water through the swamps and transferring it to the White Nile with the least amount of loss.

(2) Passing a part of the river discharge through the natural channels within its actual capacity or, after some remodeling and digging, constructing new channels to convey the rest of the discharge to the White Nile.

The research closed with acceptance of the second solution because of its economic and technological advantages.

This project will be constructed in two stages:

First stage: Increase the natural channel efficiency and construct new channels to pass some of the discharge. The water benefit expected from this stage is 3.5 billion $m^3$ per year at Aswan.

Second stage: This joins the first stage projects with the storage in the equatorial lakes as follows:

(1) Use Lake Victoria as a main reservoir.

(2) Erect a regulator at the exit of Lake Kioga.

(3) Erect a dam at Lake Albert and use the lake as a supplementary reservoir.

These storage structures will keep a constant discharge equal to the mean yield of the river so it can reach the White Nile with reasonable losses.

By installation of these two stages, the water benefit expected at Aswan will reach seven billion $m^3$ per year.

## Bahr El-Ghazal Swamp Region

This basin lies to the west of Bahr El-Gebal basin and extends to the southern borders between Sudan and Congo. Its area exceeds one-half million acres and the total rainfall on the gross area exceeds 500 billion $m^3$ yearly. This huge amount of water is lost and none of it reaches the White Nile.

Before it enters the swamp region, the yields of Bahr El-Ghazal tributaries are estimated at 14 billion $m^3$ yearly, but not more than one-half billion $m^3$ reaches the White Nile. To make use of this large amount of water lost, the following projects have been discussed:

(1) Construction of a canal to collect the northern tributaries of Bahr El-Ghazal to carry their yields to the White Nile.

(2) Construction of another canal to collect the southern tributaries and carry their yields east to Bahr El-Gebal.

(3) Investigation of the possibilities of storage in the upper stages of these tributaries to control their yields to an extent that can be carried by the new channels. The water benefit from these projects is estimated at seven billion $m^3$ per year as computed at Aswan.

## River Sobat Swamp Region and Maschar Swamps in the White Nile Basin

The Sobat river has two main tributaries, the Baro river and the Pibor river. The Sobat basin includes a part of the Ethiopian plateau and almost all the plain to the east of Bahr El-Gebel and the Zaraf, an area of about 18,7,000 km$^2$.

The Baro river is considered the main tributary of the Sobat river. Its tributaries descend from the Ethiopian plateau and its water flows through the mountains down to Gambaila, a town near the border between Ethiopia and Sudan.

The Baro river loses about 4 billion m$^3$ of its annual yield along its length, which is about 200 kilometers from Gambela to its outlet in the Sobat river. It loses 1.5 billion m$^3$ in the fast 100 kilometers and 2.5 billion m$^3$ in the second 100 kilometers.

There is no easy way to stop these losses except by controlling the river yield in its upper stage by construction of a year storage dam to receive the constant discharges near the mean yield to be supported by the banks of the Baro river.

If this solution is not accepted by all states or if it is difficult to find a better place for storage, the only solution is to make banks for the lower Baro river to the inlet of Khor Maschar, and also coordinate the effort to avoid these losses with research in the Maschar swamp region where most of these losses take place.

These swamps lie between the Baro river, the Sobat river, the edges of the eastern mountains, and the White Nile. These swamps are produced by water from the following sources:

(1) The overflow of the Sobat and Baro rivers, with an estimated annual loss of three billion m$^3$.

(2) The water of the plains that descends from the Ethiopian mountains, with an estimated loss of 1.8 billion m$^3$ yearly.

(3) The rainfall over the basin area, which is estimated at 15 billion m$^3$ per year.

All these waters are lost in Maschar swamp with the exception of a small amount going to the White Nile through Khor Adar.

To stop the loss and make use of the water of these swamps, it was decided to drain it into a main channel that begins from Khor Maschar inlet and ends at the White Nile at the outlet of Khor Adar. It can be noted in the cross-section of this channel that it will be capable of carrying all waters coming from all the above sources. Some secondary channels must be made to carry the overflow of the Ethiopian mountains to the main channel.

This main channel will carry all the waters lost to the White Nile, with an estimation of about four billion m$^3$ yearly computed at Aswan.

## Improving the Capacity of the White Nile and the Main Nile

The excesses mentioned before which will be available after the construction of the proposed projects will gather in the White Nile and then be carried by the main Nile. Therefore it is essential to examine the White Nile's capability to carry these excesses safely to the main Nile.

Much research and many cross-sections were made to examine the capability of the Nile in all its reaches to carry all the possible excesses and decide on the best method for widening and deepening the Nile if needed. Several borings were made in the Nile bed and by the end of this research the final project will be prepared for approval.

The same research is to be done in the main Nile to ensure that it can carry all these excesses; otherwise, it must be widened and deepened.

It can be said that according to the research done these projects will increase the yield of the Nile by 18 billion m$^3$ yearly as computed at Aswan. This yield will be divided equally between Egypt and Sudan. This gain will be expected not at once but within several years as decided in the following program shown in Table 1:

The total expected benefit is 18 billion m$^3$. The estimated cost of these projects is about 60 million pounds.

It is clear that to reach this extent in controlling the Nile and making full use of its yield it is necessary to reach a technical union between all the countries lying along the Nile so that each country recognizes the rights of the others.

It is not realistic for any country having headwaters of the Nile to believe that the Nile is hers alone. Rather, she must accept the opposite view and agree that further use of the Nile water must be agreed upon by all concerned countries. This rule must not reduce the autonomy of any country but improve the good relationship between countries and harmonize with international law. This principle is not new: in Nile history there is more than one example to prove that cooperation between adjacent countries lying along the Nile is necessary and respectable.

For example, the agreement signed between Ethiopia and the United Kingdom representing Sudan in 1902, concerning the boundaries along the Nile, said, "The King of Ethiopia promises not to give orders or permit any orders relative to the Blue Nile or Lake Tana which may cause any stoppage or obstruction of the flow of its waters to the Nile unless the two governments agree previously."

Another example is the Nile water agreement between Egypt and the United Kingdom representing Sudan, Uganda, Kenya, and Tanzania which said that, "No water project or power generator is to be erected on the Nile, its tributaries, or on the lakes, that may lessen Egypt's share of the Nile water or change the time of its arrival or decrease its level by any means that affects Egypt."

A third example concerns the Nile tributaries in Congo which forbids any work without the agreement of all countries concerned.

All these examples assure us that all nations on one river are obliged to keep the rights of each other in mind and that any work done on the river must be agreed to by all concerned.

The agreement between Egypt and Sudan signed in 1959 ensures the rights of possession of both countries at the time of signature. It was declared that Egypt's share was 48 billion $m^3$ and that Sudan's share was four billion $m^3$, and it was pointed out that the amount of water lost from the Nile, both in the sea and in the swamps, would be shared proportionally. Both countries were instructed to research and erect projects to save the losses for the benefit of each other in the proportion mentioned in the agreement.

The agreement did not deny other countries rights to the Nile waters and declared that the two countries were ready and willing to discuss the rights of the other countries.

That 1959 agreement specifically deals with the following:

(1) Compiling the laws of both countries concerning the Nile and combining their efforts at controlling the river.

(2) Uniting the two countries in all matters to be discussed between them and any other country along the Nile.

The Nile committee representing both Egyptians and Sudanese was formed as a result of this agreement. The committee has included representatives from East African states of Tanzania, Kenya, and Uganda to discuss their claims to the Nile waters, to create a technical union between the five states for the sake of all, to stop all the yield losses inside these countries, and to share the gain between them.

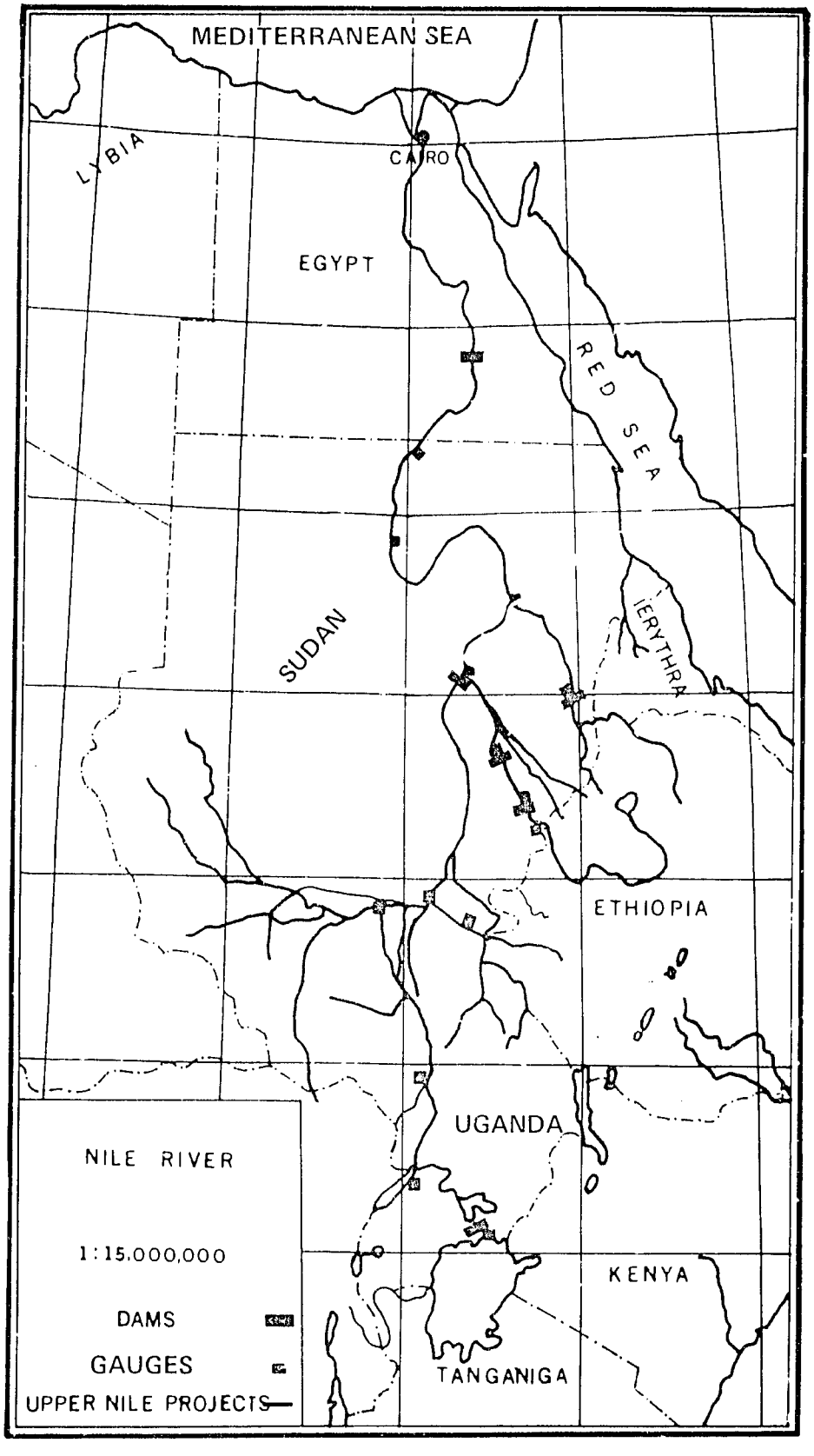
The union between the five states has already resulted in some research being done with the aid of the United Nations to study the water balance and projects making full use of the Nile water.

To complete the union between the equatorial states on one side and Egypt and Sudan on the other side, the committee asked Congo, Ruanda, and Borandi to share in the research being done on the plateau.

The Ethiopian plateau is left, and it is not reasonable that Ethiopia should stay apart from the Nile countries, especially since a great percentage of the Nile yield comes from them. Egyptian officials were recently in contact with Ethiopia in regard to Nile affairs. Discussions concerning the dam to be erected on Lake Tana exit was stopped when the over-year storage in the High dam advanced the year storage in Tana dam.

**Table 1**

| NAME OF PROJECT | Date and amount (in billion $M^3$) expected for utilization and benefit | | | |
|---|---|---|---|---|
| | 1978 | 1980 | 1985 | 1990 |
| 1 First stage of the project to lessen losses in Gebal and Zeraf rivers. | 4 | | | |
| 2 Second stage of the project to lessen losses in Gebal and Zeraf rivers | -- | -- | 3 | -- |
| 3 First stage of the project to lessen losses in the Maschar swamps | -- | 2.5 | -- | - |
| 4 Second stage of the project to lessen losses in the Maschar swamps | - | -- | 1.5 | |
| 5 First stage of the project to lessen losses in Bahr El-Ghazal swamps | | | 3 | - |
| 6 Second stage of the project to lessen losses in Bahr El-Ghazal swamps | | | | 4 |
| Total: 18 billion $M^3$. | 4 | 2.5 | 7.5 | 4 |


MEDITERRANEAN SEA
LYBIA
CAIRO
EGYPT
RED SEA
SUDAN
ERYTHRA
ETHIOPIA
UGANDA
KENYA
TANGANIGA
NILE RIVER
1:15.000,000
DAMS
GAUGES
UPPER NILE PROJECTS

## UAR

# IRRIGATION AND DRAINAGE IN FAYOUM AS A UNIQUE SYSTEM IN THE UAR

by

**Abd El-latif Mohamed Rashwan**

## DESCRIPTION

Fayoum region, sometimes called an oasis, is a depression in the western desert about 100 kilometers southeast of Cairo. It is separated from the Nile by a narrow strip of desert; however, the Nile water reaches the region by Bahr Josef, the main branch of the Ibrahimia canal. Fayoum differs from other oases in two ways:

(1) Its water source depends on surface Nile water as well as artesian water.

(2) The soil is conveyed there, as all Nile valley soils are, and is not a local soil.

The Fayoum region has two main features:

(1) A great part of it lies below sea level. The lowest part of it is that occupied by Lake Karoum which is about 45 meters below sea level.

(2) The slope of the ground does not occur in any other parts of the UAR.

The surface of Fayoum has three main slopes (see Figure 1):

(1) The first begins from Lahoun barrage (elevation 26 meters above sea level) and ends at Fayoum (elevation 24 meters above sea level).

(2) The second is from Fayoum to Sanhour (10 meters below sea level).

(3) The third begins at Sanhour and ends at the south shore of Lake Karoum (45 meters below sea level).

The Fayoum region resembles a leaf in which Bahr Josef is the stem and the secondary canals are the veins. Fayoum can be divided into the following physiographic sections:

(1) The valley of Bahr Josef

(2) The delta

(3) The plain shore of Lake Karoum

(4) The depression of Tamia-Roda northeast of Fayoum

(5) The depression of Kalansheh-Tatoon

(6) The basin of Gharah Sultany which is a small depression surrounded by high contours through the big depression but not related to its inclination.

(7) Lake Karoum which engages the north-western parts of Fayoum, the lowest section of which is about 45 meters below sea level with a water depth of about 6 meters. The lake has no exit but receives all the drainage water.

Each section has its own features, inclinations, and soil types. Fayoum has green vegetation, gardens in the east, an attractive blue lake in the north and the brown desert surrounding it.

This lake is the remaining part of a lake that covered all Fayoum in ancient times. Fayoum was not connected with the Nile until the Paleolithic time when the Nile river swept its left bank and forced its way to the depression.

The lake varied from level to level in the past until the year 2,000 BC when one of the ancient Egyptian kings cleared the canal connecting the depression with the Nile and the lake level rose nearly to the level of the Nile.

One of the kings of the twelfth family constructed a dam with vents on the depression head to regulate the entrance and exit of the water and to convert the depression to a big reservoir in order to provide the country with water when the Nile was at its low stages. This reservoir was known in history as "Lake Moris Reservoir" and was perhaps the first of its kind in the world.

The famous story of the Prophet Joseph and the dream of the king of lower Egypt is well known, and the battles over the Fayoum dam between lower and upper Egyptian kings was the main reason for the crisis which occurred at that time.

When the Nile was well controlled by the erection of dams, barrages, and regulators, the area of the lake decreased gradually and reclamation of the uncovered lands took place by the ancient Greeks and Romans. In Islamic times the lake descended to its present level of 45 meters below sea level.

## IRRIGATION SYSTEM IN FAYOUM

Perennial irrigation has been known in Fayoum for 700 years, while it was not known in the rest of Egypt before 1832 when it was first used in lower Egypt. The main source of irrigation water in Fayoum is Bahr Josef, which has two main branches (see Figure 2).

(1) Bahr Hassan Wassef, which feeds about 30 per cent of the province.

(2) Lower Bahr Josef, which feeds the rest of the province.

From the point of view of irrigation, Fayoum can be divided into regions as follows:

(1) The valley of Bahr Josef which is irrigated directly from it.

(2) The delta of Bahr Josef (17,000 acres) which is irrigated from a Makasem group of regulators.

(3) The northern east depression (64,000 acres) which is irrigated by Bahr Wahby and its branches.

(4) The southern and western parts of the province (109,400 acres) which are irrigated from Bahr Hassan Wassef and its two main branches - Bahr el-Gharak and Bahr El-Nazla.

Nearly all the area of Fayoum is irrigated by gravity except some 6,000 acres which are irrigated by lifting pumps and/or water wheels.

Because of the large inclination of Fayoum, where the ground level varies from an elevation of 23 meters above sea level near the city of Fayoum to an elevation of 45 meters below sea level within 20 kilometers of the lake, a special distribution system of irrigation water is followed which is unlike any

other in Egypt. This distribution is made by weirs with main and subsidiary canals and vents which have the following capabilities:

(1) Decrease water velocity through canals to prevent degradation.

(2) Assure a just distribution of water, because if an increased number of weirs were erected at short distances of not more than two or three kilometers, it would be easy to control the water by keeping the depth of water uniform over all weirs.

All vents in Fayoum are free overfall weirs which vary in width according to the area served, and their sill level is the same as the sill level of the control weir on the downstream canal.

Whenever the head of water over all sills is the same and all weirs are free overfall, the distribution will be exact and just between all the holders.

This system is very sensitive and the vents are measured to the nearest millimeter. The discharge would be greatly affected if the head varied only as much as one or two centimeters, while the pipe vents could vary within one inch in width and the head could vary within 10 centimeters without any great effect in the discharge. For example, if the head on the pipe vent decreased from 50 to 25 and to 6.5 centimeters, the discharge would decrease to 70 percent and to 35 percent, while in the weir vents if the head decreased with the same ratio, the discharge would decrease to 32 percent and to four percent.

In addition, the water in Fayoum is divided between holders by hours and minutes, while the matter is different outside of Fayoum.

This system of distribution is called "Mitarfa," which means that the rotation period is divided in the area served by each vent and the time of every feddan is known up to the nearest minute. The rotation period is distributed partially between holders according to their holdings. For this reason the rotation followed in Fayoum is seven days high and seven days low during the year. Each holder has complete information about his defined time in a certain day of the week and must take all the water of the vent in his definite time, whether by day or by night. The duty must be the same during the whole rotation so that everyone gets the same share.

If some land remained unirrigated, there would be no solution except to install a temporary pipe to compensate for the retardation. These pipes could not be widely used because they would spoil the sensitive system of irrigation, due to the following reasons:

(1) The difference in the geological form, inclination, and levels of lands.

(2) Different crops which may need more water than others.

(3) Some unreclaimed lands on the vent which need more water for washing.

(4) The different suitable times for cultivating and curing several crops.

Although the irrigation in Fayoum is very systematic and exact it creates the following problems:

(1) Difficulty in distribution of long reaches of canals because the inclination varies from that designed and the backwater curve upstream from the weirs has a great effect on the discharge of vents according to the distance between them. If the water level decreases a few centimeters upstream from the weir, it decreases more farther away from it.

This problem is solved by not exceeding the water inclination more than five centimeters per kilo and by preventing erection of vents downstream from the control weirs. The vents must be remodeled on the basis of one meter width for every 2,000 or 3,000 acres, for prevention of any wider remodeling as long as the width is narrow and the head is great so the discharge effect will be small.

For example, if the water duty is 20 meters per acre per day and the head is increased by five centimeters, the discharge increases by 16 per cent if remodeling 3,000 acres, 21 per cent if remodeling 2,000 acres, and 31 per cent if remodeling 1,000 acres.

(2) The great difference in land level even in places where there are small areas on the sides of some canals of higher levels. It is not right to raise the flood level for the sake of these small areas and spoil the majority of the surrounding lower areas if it is

necessary to use free overfall vents for these high lands. Generally the flood level is not raised for the sake of these high lands, nor are the sills of the weirs and submergency obliged, because it is a source of trouble for holders and engineers due to the fact that the vents in this case will not have full discharge, thus indicating the need to compensate these vents by recalculating the discharge by the following equation of submerged weirs:

$$Q = \frac{2}{3} c\, b \sqrt{2g}\, h^{3/2} + c\, A \sqrt{2gh'}$$

where h' is the submergency depth.

(3) The effect of wide weirs on smaller ones due to the greater velocity of water towards the wide one. This problem is solved by curving the entrance of the smaller ones.

(4) Drainage through canals is sometimes obligatory and cannot be avoided because of the difference of levels. For that reason the water rises at the end of some canals more than at the beginning.

(5) Many illegal trials are made by holders to get more water than their share especially in regions where rice and other crops are grown which need an excess amount of water. They use pipes or syphons so that they can steal water without being detected. One trick they may use is to swim beside the control weirs or stand or sit on them to raise upstream water without being observed.

(6) An excess number of small holdings necessary to lengthen the period of irrigation and slow the submergency of the soil with water does not fulfill the suitable humidity of the soil, which affects greatly the amount of crops. For example, if the area served is 200 acres and the rotation is seven days, the share of each acre would be:

$$\frac{7 \times 24 \times 60}{200} = 50 \text{ minutes}$$

If the area served is 20 acres, each acre would have about eight hours and 24 minutes. That indicates that the nearer the land to the vent the longer it would be submerged and vice versa. For that reason the area served by any vent must not be less than 50 acres with a time of three hours and 20 minutes. A solution to this problem would be to gather the small holdings which are less than 50 acres and connect them to the larger ones in the same vent.

From ancient times Fayoum used water falls for power. This power was used in turning water wheels, water mills, and generating electricity.

## FAYOUM DRAINAGE PROBLEM AND THE WADY EL-RAYAN PROJECT

The Fayoum ground slopes from 26 meters above sea level near Bahr Josef to 45 meters below sea level near Lake Karoum and has an inclination of three meters per kilo.

Although the irrigation water comes to Fayoum through the Ibrahimia canal and Bahr Josef from the Nile, as in all the UAR cultivated areas, yet the drainage water does not flow to the Nile nor to the Mediterranean, as it does in other provinces. It flows to a closed lake 200 kilometers from the sea.

For this reason it is essential to make a balance between the amount of drainage water entering the lake and the amount of evaporation from its surface; otherwise the level of the lake may rise and affect the surrounding lands adversely.

The majority of the Fayoum lands are drained by two main drains, the Bats drain in the east and the Wady drain in the west, and some other small drains that are connected directly to the lake.

At 44.30 meters below sea level the area of the lake reaches 55,000 acres or 231 square kilometers. The annual mean evaporation from its surface is 400 million $m^3$. The drainage water is estimated to be one-fifth of the irrigation water. This must not exceed two billion $m^3$ per year and the water duty must not exceed $\frac{2{,}000{,}000{,}000}{360{,}000} = 6{,}100\ m^3$ per year.

(Area served in Fayoum is 36,000 acres).

This area is far less than the normal duty. The lake level has risen to 43.63 during the last three years due to the increase in rice cultivation as well as other crops which need excess water. This has resulted in improved drains and the spreading of field tile drainage in a large area of the province.

This rising of the lake has greatly affected the lands near the lake. For this reason reclamation of new lands stopped.

Summary of the effects of this rising is as follows:

(1) It was essential to minimize the drainage water passing to the lake to make a balance between it and that evaporating from the lake surface so that no rising or falling in the lake level would occur.

(2) To minimize the drainage water it was necessary to control the irrigation water so it would not exceed a limit that would keep the lake level constant. The limitation of irrigation water entering Fayoum through Bahr Josef indicates the following

(a) A lower duty of irrigation water would not exceed 6,100 $m^3$ per acre per year although it was 6,900 in other provinces of the UAR.

(b) The water duty given is insufficient to protect the cultivated area from deteriorating because of the increase in the percentage of salt.

(c) About 32,000 acres were destroyed and could produce nothing because of the shortage of irrigation water.

(d) Stopping of all reclamation works in a gross area of 40,000 acres proved to be valuable to the cultivated area. There is also another 29,000 acres from the third and fourth class; i.e., this special position causes a loss of about 100,000 productive acres.

(e) Stopping all efforts to produce any further crops like rice that need excess water.

(f) Retarding the land submergency and cultivation of maize, which greatly affects the production.

(g) Closed drainage through the lake increases the salt percentage, thus affecting fish production.

(h) The worst effect of this position on Fayoum is that it does not benefit from the High dam, which spreads its benefits all over the rest of the UAR.

As a result of all these facts the government of the UAR tried to find a solution to this problem and discussed many projects to get rid of the excess drainage water in Fayoum. The following data is pertinent:

(1) The recent area served 360,000 acres, of which 32,000 acres were uncultivated.

(2) The area subject to reclamation is 40,000 acres.

(3) The area from the third to fourth degree is 28,000 acres. The total area to be served in the future is 360,000 + 40,000 + 28,000 = 428,000 acres.

(4) The present mean duty is 6,100 $m^3$ per acre per year.

(5) The proposed duty is 6,900 $m^3$ per acre per year.

(6) The mean annual discharge of irrigation water in Fayoum is two million $m^3$ per year.

(7) The mean annual drainage through the lake is 400 million $m^3$ per year; i.e., the drainage water = one-fifth of the irrigation water.

(8) In the future the drainage water after reclamation of the whole area will be

$$\frac{6900 \times 428{,}000}{5} = 590 \text{ million } m^3 \text{ per year}$$

If we add 100 million $m^3$ per year for washing and reclamation needs the drainage water would be 690 million $m^3$ per year.

(9) The excess drainage water that is needed to get rid of it from the area of Lake Karoum is

$690 - 400 = 290$ million $m^3$ per year

Projects discussed as a possible solution included the following:

(1) Making a protection bank around the lake so that the lake can be raised without any damage to the surrounding areas. It was found that this project

would temporarily solve the problem but would not permanently solve it.

(2) Mixing the irrigation water with a certain percentage of drainage water. This project was not accepted because a great deal of the Fayoum land has a certain amount of salt, the water table is high, and the mixing of irrigation and drainage water would increase the alkalinity of the soil, necessitating the expensive addition of gypsum.

(3) Finding another depression near Fayoum called Wady El-Rayan to get rid of the excess. This project would keep the lake level at a constant -44.30 meters below sea level, within a variation of five to 10 centimeters, by getting rid of the excess water by draining it to Wady El-Rayan depressions. It was found that this project was the best one. The Swedish VBB advisor offered to complete the project, which can be described as follows:

The project began with an open channel providing water from the Sadi drain upstream. The hydroelectric power plant is at Moktalat nine kilometers from the border of the western desert 500 meters to the east of Bahr el-Banat where the tunnel began with a diameter of three meters and eight kilometers in length. The bed slope of the tunnel is 14 meters below sea level and ends at the beginning of the depression at 10 meters below sea level. Cost estimate of the project is 3.14 million Egyptian pounds, and will be constructed by Egypt.

## SUMMARY DESCRIPTION OF THE PROJECT

The Wady El-Rayan depression lies to the southwest of Fayoum about 40 kilometers from the town of Fayoum. The lower point in the depression is 63 meters below sea level. Its lower leg is 10 meters below the lowest point in Lake Karoum.

At 10 meters below sea level, the area of the depression of Wady El-Rayan reaches to 222 million $m^2$; i.e., about 55,000 acres equal to the Lake Karoum area. Its contents are 3,400 million $m^3$, while the volume of Lake Karoum is 981 million $m^3$.

This project will drain the excess drainage water of Lake Karoum (capacity 290 million $m^3$ per year) through an open channel beginning at the upstream drain El Wady, with the hydroelectric power station at Mouktalat at a level of one meter above sea level and with a length of five kilometers, until it reaches the border of the desert 800 meters east of Bahr El-Banat where the tunnel began, with a diameter of three meters within a rocky region, with a base level of 14 meters below sea level. The project also includes digging the outlet with a length of one kilometer and exploring two plateaus which lie between the two depressions of Wady El Rayan, with a length of 1.5 kilometers.

The work in this project can be summarized as follows:

(1) Digging the open channel at the inlet and outlet: Amount of excavation in soft soil, 20,000 $m^3$, amount of excavation in rock soil, 35,000 $m^3$.

(2) Exploring the two plateaus between the two depressions: Amount of excavation of soft soil, 1,000 $m^3$; amount of excavation in rock soil, 18,000 $m^3$.

(3) Digging the tunnel with a length of 7.75 kilometers. The excavation amount is 75,000 $m^3$. The tunnel lies at a depth of several meters from the ground surface and varies from 15 to 45 meters. To facilitate the digging of this long tunnel, five vertical wells four by five meters were made along the axis of the tunnel and reach to the bottom. There are 10 regions of work besides the entrance and exit.

(4) Strengthening the weak points through the tunnel and lining some parts of it. The amount of concrete work for lining only 50 per cent of the total length is 6,300 $m^3$ and the grouting of 25 per cent of the total length is 47,500 $m^2$.

(5) Construction at the entrance and exit includes concrete structures and gates.

## BENEFITS OF THE PROJECT

(1) Improving the state of irrigation and drainage in Fayoum, by giving sufficient irrigation water without fear, which will lead to more income.

(2) Increasing the cultivated area from 360,000 acres to 400,000 acres.

(3) Reclamation of 32,000 acres, increasing the cultivated area by use of excess irrigation water.

(4) Increasing the reclaimed area by 28,000 acres from the third and fourth degrees.

(5) Increasing the rice area from 20,000 to 40,000 acres.

(6) Increasing the sanar area from 3,000 acres to 10,000 acres.

(7) Making use of the New lake to encourage tourists.

(8) Stopping the rising level of Lake Karoum.

(9) The total reclaimed area will rise to 100,000 acres, the income of which will cover the project expenses in one year.

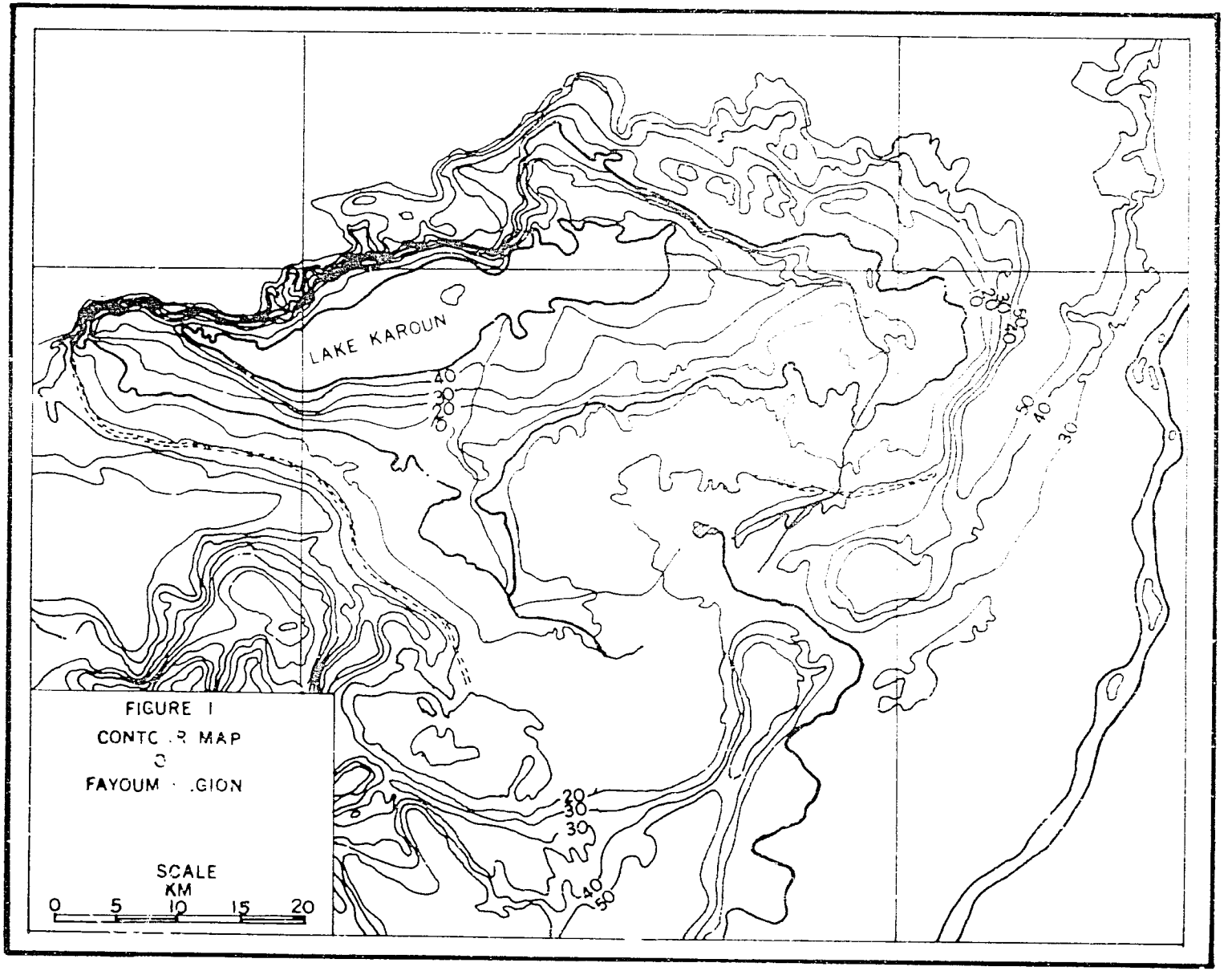



FIGURE 1
CONTC .R MAP
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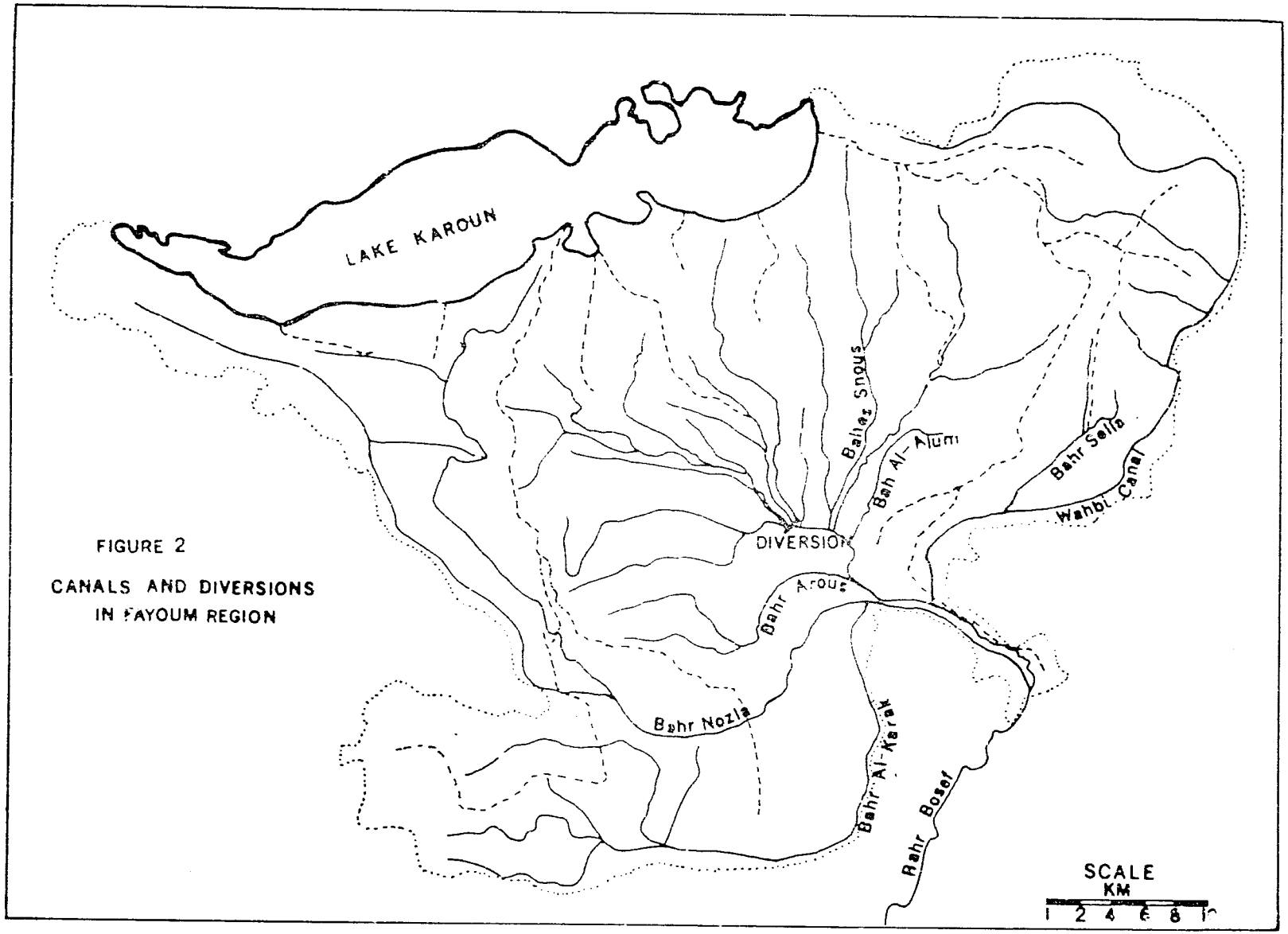


FIGURE 2

CANALS AND DIVERSIONS IN FAYOUM REGION

# CHAPTER VIII

# Irrigation Practices Research And Soil Salinity

## HELMAND VALLEY SHAMALAN LAND DEVELOPMENT PROJECT PLANS

by

A. T. Assifi*

## ABSTRACT

The Helmand Valley Shamalan project area is presently served by a main irrigation canal, which has replaced individual farmers' numerous old river diversions, creating a steady water supply to the heads of the old ditches, and major outlet drains to prevent rapid waterlogging of the lands.

The lack of adequate controlled irrigation water delivery to the farms, availability of irrigation water to all the lands, a required drainage system, necessary land development measures, and the problems of soils and soil fertility, land ownership, legal titles, fragmentation and dissipation of ownership lots — all of these problems have impeded full land and agricultural development and possible higher crop yields and returns.

Investigations and economic studies show the feasibility of land development project completion. Plans have been worked out for land development, farm delivery, irrigation distribution, drainage, roadways and drinking water systems. Necessary measures have either been taken or are contemplated for the remedy of ownership problems, soils amelioration and efficient project construction, operation and maintenance.

*Chief Engineer, President of Technical & Engineering Department, Helmand-Arghandab Valley Authority

## PROJECT AREA DESCRIPTION

### *Location*

Helmand valley. The Helmand valley includes over 260,000 square kilometers in southwest Afghanistan, between 29° to 33° North Latitude and 61° to 69° East Longitude (see map no. 1).

Shamalan. The Shamalan unit is located on the west side of the Helmand river between 31° 6' 35" to 31° 38' 54" North Latitude and 64° 8' 26" to 64° 21' 42" East Longitude. The unit extends to the north and south of the confluence of the Helmand and Arghandab rivers, and is about 64 kilometers in length and one to seven kilometers in width, comprising a gross area of 259 square kilometers.

## *History*

The earliest irrigation and agriculture of the Helmand valley and Chakhansur Siestan area began prior to written history. Although archaeological research has given indication of this, only a fraction of this vast area has been examined. Some archaeological studies have revealed the earliest phases of the bronze age, and ruins have been found dating back to about 3,000 BC. Qala Bist is mentioned in ancient history, along with the earliest cities of Nineveh and Ur.

Ruins of old cities and villages are scattered all along the Helmand river and its tributaries reflecting a period which apparently had more prosperous and extensive irrigated agriculture than now. Remains of large canals and irrigation ditches indicate that irrigated farming in the Helmand valley supported large populations for centuries. The recent history of this area dates back some 60 years, with reclamation of the lands and recreation of productive agriculture. Soon after the turn of the twentieth century, repair and rehabilitation work was started on some old irrigation systems such as the Seraj canal (old Choghra canal) which heads on the east bank of the Helmand river at Sangin and irrigates the valley and bench lands downstream as far as the Arghandab river. In the late 1930's work was started to improve and rehabilitate the old Deh Adam Khan and the old Boghra canals, which had functioned more than 200 years, serving the lands west of the Helmand river above and below Girishk.

By 1946 about 26 kilometers of this canal had been dug by hand, and afterward by the employment of Morrison-Knudsen Afghanistan contractors and the use of heavy machinery. The concept of the rehabilitation and realignment of the Boghra canal evolved into a regional development activity.

By 1949 the proposed development plan had expanded, and units and facilities were added until irrigation development embraced both Helmand valley, from Kajakai to a point about 45 kilometers below Darweshan, and the Arghandab valley in the vicinity of Kandahar. Two major dams were constructed, the Kajakai on the Helmand and the Arghandab on the Arghandab river. The Boghra canal was extended from the diversion works above Girishk to a point southwest of Marja, the Shamalan canal was constructed to branch from Boghra about 31 kilometers below the diversion dam and extend along the right bank of the valley alluvial lands nearly to Darweshan.

By 1954 the main Shamalan canal had been completed, with a 750-cubic feet per second capacity and 66 kilometers in length with necessary check drop, turnout, siphon and cross drainage structures. By 1956 eight main outlet drains with a total length of 118 kilometers had been completed.

## *Climate*

The climate of the Helmand river valley is similar to that of the deserts of southwestern United States and is comparable to continental desert climates in similar latitudes and situations in other countries.

**Temperature.** Summarized temperature data from Lashkar Gah weather station for the period 1955 to 1965 are given in Table 1.

**Precipitation.** The average annual precipitation is 135 millimeters (5.3 inches) of which 121.1 millimeters (4.77 inches), approximately 90 percent, occurs during the period of November through April, the three months of highest precipitation being December (22.4 percent), January (24.6 percent), and March (18.4 percent), accounting for about 65.4 percent of the total annual precipitation. The period May through October is extremely dry, with a yearly average total precipitation of 14.3 millimeters (0.56 inches). See Table 2.

**Evaporation.** Evaporation in the central Helmand valley is very high and greatly exceeds precipitation. The weighted average for a period of approximately nine years of pan evaporation is given in Table 3.

The adverse climate phenomenon of the Helmand region is the sand and dust storms, which are most common in spring and fall. Occasionally these storms, generated by high winds in the central parts of the basin, may reach velocities as high as 100 kilometers per hour. The fine particles picked up by these storms may eventually reach heights of about 3,000 meters above the surrounding terrain. Sometimes these storms last for several days.

## Table 1: Temperature Data - 1955-1965

| | Annual | July Averages | January Averages |
|---|---|---|---|
| Average Maximum: | 28.9°C. (84.0°F.) | 41.7°C. (107.1°F.) | 14.2°C. (57.6°F.) |
| Average Minimum: | 16.7°C. (62.1°F.) | 14.2°C. (57.6°F.) | 1.9°C. (35.4°F.) |
| Hottest during record period: | | | |
| Maximum: | 46.3°C. (115.3°F.) | July, 1958 | |
| Minimum: | 16.7°C. ( 62.1°F.) | July, 1958 | |
| Coldest during record period: | | | |
| Maximum: | 24.8°C. (76.6°F.) | January, 1960 | |
| Minimum: | -11.6°C. (11.1°F.) | December, 1964 | |

## Table 2: Average Precipitation Distribution

| Month | Millimeters | Inches | Annual Distribution |
|---|---|---|---|
| November | 9.1 | 0.36 | 6.8% |
| December | 30.3 | 1.19 | 22.4 |
| January | 33.3 | 1.31 | 24.6 |
| February | 7.3 | 0.29 | 5.4 |
| March | 25.0 | 0.98 | 18.4 |
| April | 16.2 | 0.64 | 11.9 |
| | 121.2 | 4.77 | 89.5% |
| May-October | 14.3 | 0.56 | 10.5% |
| Total | 135.4 | 5.33 | 100 % |

## Table 3: Weighted Evaporation: (Chah-i-Anjir - Lashkar Gah)

| | Pan Evaporation | | Free Water Surface (0.75) | |
|---|---|---|---|---|
| | Millimeters | Inches | Millimeters | Inches |
| October | 201 | 7.91 | 151 | 5.93 |
| November | 130 | 5.12 | 98 | 3.84 |
| December | 83 | 3.27 | 62 | 2.45 |
| January | 81 | 3.19 | 61 | 2.39 |
| February | 106 | 4.17 | 80 | 3.13 |
| March | 164 | 6.46 | 123 | 4.84 |
| April | 250 | 9.84 | 188 | 7.38 |
| May | 345 | 13.58 | 259 | 10.19 |
| June | 438 | 17.24 | 328 | 12.93 |
| July | 416 | 16.38 | 312 | 12.25 |
| August | 270 | 14.57 | 278 | 10.93 |
| September | 268 | 10.55 | 201 | 7.91 |
| Total | 2,852 | 112.28 | 2,141 | 84.20 |

## *Physiography and Geology*

The topography of Afghanistan is influenced by the central divide of Kohi Baba Parapamisus and Hindu Kush ranges. Spreading in the southern exposure of these mountains are the Helmand river basin and a few smaller watersheds. The lower extremity of the basin, ending in the Chakhansur-Seistan, sinks. Approximately one-half of the watershed areas lie above 1,000 meters altitude. The principal mountain ranges rise to over 7,000 meters in the east and from 3,000 to 4,000 meters in the west. The foothills follow a westerly course and great outwash fans and plateaus extend in a southwesterly direction from the foothills. These vast outwashes are predominantly desert, with occasional flats and swales covered with more heavily vegetated silts of varying depths. The topography of these desert plains is gently rolling to hilly and broken near stream courses, with occasional isolated uplifts of basalts, limestone, granites and schists breaking the vast sweep of the desert plains. The main rivers in this area are the Helmand, Arghandab, Farah Rud, Khash Rud, Musa Qala, Tarnak, Arghastan and Dori.

The Shamalan unit is located on the first and second terrace levels bordering the Helmand river, varying from one to four meters (three to 13 feet) above the normal river surface. It is bounded on the east by the Helmand river and on the west by a third, higher, older terrace, probably of the tertiary geologic period. Altitudes within the unit vary from 789 meters (2,588 feet) above mean sea level at the northern end to 708 meters (2,323 feet) at the southern extremity, with an approximate mean average gradient of 1.3 meters per kilometer (6.9 feet per mile). East-west gradient within the terrace levels is nearly flat for most of the area.

## *Soils*

The soils of most of the potentially arable lands have developed from alluvial and aeolian materials. The original bedrock sources are the uplifts of the Hindu Kush range and its westward extensions. Extreme tilting, folding and warping are evidence of great pressures exerted during the uplift. Glacial and post-glacial movement of materials from these uplifts covers a large area to the south and southwest of the mountains and foothills.

The soils of the Shamalan unit are derived largely from alluvial materials of the quaternary geologic period, with areas of aeolian deposits occuring in a narrow strip along the western edge of the unit. These aeolian materials originate from the vast desert to the west of the unit known as the Dasht-i-Margo.

The alluvial sediments from which the bulk of the soils in the unit are derived consist largely of medium textured materials, varying from moderately fine to moderately sandy in texture. These materials generally range from approximately two to four meters (six to 13 feet) in depth, below which they grade into sands and gravelly sands. All the unit's lands are underlain by gravel at various depths ranging from at or near the surface to depths exceeding five meters (16 feet). Occasional gravel bars are found on the land surface. On the basis of explorations conducted to date the gravelly substrata appear to be open and nonconsolidated. The unit soils are predominantly very light brown to light greyish-brown in color and are very low in organic matter, typical of soils developing under very arid conditions with sparse vegetation. They show little effect of weathering due to prevailing climatic conditions.

**Typical profiles.** The profiles of the alluvial soils of the second terrace level, which comprises the great majority of the project lands, typically have relatively uniform medium textured soils consisting largely of loams and silt loams.

A typical profile for these soils has from 30 to 40 centimeters (12 to 16 inches) of light greyish-brown friable calcareous loam. This is underlain by a layer of light yellowish-brown loam, or slightly sticky silt loam to light silty clay loam, which may have some visible disseminated lime and lime splotches, extending to from 90 to 180 centimeters (36 to 72 inches) depth. This in turn is frequently underlain by a layer of light brown slightly compacted loam approximately 30 centimeters (12 inches) in thickness. Below this third level the soil becomes increasingly sandy with depth varying from sandy loam to loamy sand and is grey in color. The sandy layer normally continues to the underlying gravel.

### *Irrigation Water*

Surface water flows of the Helmand river constitute the principal dependable water resource of

the Shamalan unit. This water supply is of excellent quality, with ample storage provided at the Kajakai reservoir (presently 1,354,200 acre feet). The project water requirements are diverted from the Helmand river by the Boghra canal diversion works about nine kilometers to the north of Girishk via Boghra canal (2,700 cubic feet per second capacity) into the Shamalan canal (750 cubic feet per second capacity). The quality of the water of Helmand river is good to excellent for irrigation, municipal and industrial use. Analysis of the water from the river and from the Boghra and Shamalan canals, which take water directly from the river, shows that total dissolved solids vary from a minimum of about 190 parts per million to a maximum of about 260 parts per million. Sodium constitutes about 10 percent of the total cations. Parts of the drains within the Shamalan unit and the Nadi-Ali wasteway, which may be considered in the project plan for integration with the irrigation system of the unit, have salt concentrations ranging from approximately 1,000 to 1,500 parts per million. They do, however, have favorable calcium-sodium relationships (see Table 4), and when mixed with adequate quantities of river water can be safely used for irrigation.

### *Present Land Use*

The Shamalan unit is one of the older farmed areas in the valley and is also one of the better areas to consider for agricultural irrigation development. There are some 200 villages, of which about 23 villages are of larger size. The population of these villages is estimated to total approximately 24,000. Statistics and census are incomplete and it is possible that the area population may be larger. The villages, which vary in size from a few families to relatively larger communities, are typical mud-hut construction. The villages are usually temporary and are frequently relocated and the site of the old village is used for farming.

## PROJECT NEEDS

Afghanistan, like many other countries of the world, is in great need of increased agricultural production. In the past decade or so, considerable advances have been achieved in higher socio-political, agricultural, industrial and economic standards of the country. The Afghan government has made a concentrated effort to re-establish a greater population in the sparsely populated areas of the country. The Helmand valley has received special attention through intensified activities of the government in this area, notably in the construction of storage dams, diversion dams, main canals, outlet drains, roads, land development, population centers, industrial activities, etc.

The need for yet higher and more intensive agricultural production and the favorable physical potential of the Shamalan unit with respect to lands, water and climate argue well for a priority of land development in the Shamalan. However, the area requires additional physical facilities before the base for successful development is complete.

The reasons for the present lower returns in the area are: Inadequate distribution of irrigation water, irrigation of unsuitable lands, waterlogging, salinity, incomplete or poor land preparation, and poor farming and irrigation practices. Physical inputs in the form of improved seeds, livestock, fertilizers, insecticides and machinery are not adequately available, agricultural credit at low interest rates has not been fully established, and much work needs to be done in the way of social reform to change traditional attitudes of the people away from mere subsistence.

Many problems must be solved and needs fulfilled if the Shamalan unit is to achieve successful development. The problems and needs of the Shamalan area may be considered to fall into three principal categories:

(1) Project development completion.
(2) Agricultural development extension.
(3) Institutional establishments.

This paper will mainly discuss the first category.

### *Irrigation*

The Shamalan canal was constructed to intercept the intakes of all the old canals which fan out from the right bank of the river into the various land tracts lying between it and the west scarp. Prior to the construction of the Shamalan canal, large tracts of land, particularly between station 30 on the canal and the village of Shamalan, were cultivated only occasionally or were prepared for cultivation but left idle or abandoned because of the lack of dependable water supplies, and only one-fourth of the total irrigable lands were utilized. Many of the canal

**Table 4: Boghra Canal Water Quality**

(Average Composition)

| | | |
|---|---|---|
| EC x $10^6$ | = | 336 |
| Total dissolved solids ppm | = | 215 1/ |
| Percent Na | = | 15 |
| Percent Ca+Mg | = | 85 |
| Boron ppm | = | 0.21 |
| Na | = | 0.50 Milli equivalents/liter |
| Ca+Mg | = | 3.02 Milli equivalents/liter |
| $SO_4$ | = | 0.24 Milli equivalents/liter |
| Anions Cl | = | 0.50 Milli equivalents/liter |
| Anions $CO_3$ | = | 0.34 Milli equivalents/liter |
| Anions $HCO_3$ | = | 2.61 Milli equivalents/liter |
| Sodium Absorption ratio (SAR) | = | 0.44 2/ 2.6 3/ |
| Exch. Sodium at Equil. | = | Neg. 2/ 2.4 3/ |
| Irrigation Water Class | = | $C_2 - S_1$ 4/ |

1/ Calculated by use of conversion factor conductivity to parts per million + 0.64 x ECx$10^6$ for irrigation waters in the range of 100 to 700 micromhos/cm (Source - USDA Handbook 60).

2/ Based on actual chemical analysis of water.

3/ Assuming all $CO_3$ and $HCO_3$ reacts with Ca and Mg., and are precipitated out as $CaCO_3$ and $MgCO_3$.

4/ USDA Handbook 60 "Diagram for the Classification of Irrigation Waters."

intakes would wash out during a high flood period and could not be restored in time to finish the winter crop. In other cases, the canals were so located that they only obtained water during a normal or high flow of the river. When the river level dropped in the summer months, the people were unable to get water for summer crops. Very few summer crops were produced, except adjacent to the small villages until the Shamalan canal was installed. Necessary turnout structures were provided from the Shamalan canal into people's old irrigation ditches, except for areas that belonged to no one and were considered government property; no lateral and irrigation distribution system was constructed.

The dependability of the Shamalan canal turnouts that have replaced the old dilapidated diversion works has resulted in some increase in the lands under cultivation and in acreage being double cropped.

The report on "Soil and Water Resources of S.W. Afghanistan 1959" gives the Shamalan irrigable cultivated area as 31,647 acres. A HAVA Extension and O&M survey gives the total Shamalan irrigated area as 32,528 acres for the year 1969-1970.

The extent of summer crop acreage has changed from about 10,000 acres in 1955 to almost 17,627 acres in 1969.

The immediate impact of the Shamalan canal in the area can be seen from the previous figures but still, at present, of 43,820.6 total irrigable acres only 32,528 acres are irrigated, leaving about 26 percent unused project lands, and of the acres irrigated, 45 percent is still left fallow or idle part of the year.

One of the many reasons for the inefficient land use, low yields and high costs is the inadequacy of the present irrigation system.

While the Shamalan canal has mainly replaced old diversion works of the people, giving a stable and dependable source of water, the old irrigation ditches

that were serving the area are still almost the same as before. This has critically limited availability of irrigation water to the project lands that were not developed by the government. These irrigation ditches (juis) are long, winding, narrow, sluggish, with weak banks and no control and distribution turnouts into the farm ditches. There are big trees on the banks of the ditches with no roads on the sides. Farmers in the upper sections usually cut the banks at will to get water for their farms. Quite often they check or dam up the ditch to deliver water to higher lands, thus reducing the capacity of the ditch and restricting the flow of the irrigation water to the lower areas. Many people have built their homes, yards and orchards right along the bank of these ditches and without access roads the patroling of the ditches by the "mirabs" becomes almost impossible.

The longer winding and sluggish sections cause excessive seepage and loss of water to the land, limit the capacity and make the operation, maintenance, cleaning and desilting jobs difficult, more costly and time-consuming. Also, evaporation and evapotranspiration losses are quite high for these ditches.

Because of the lack of a controlled lateral and farm irrigation distribution system, the application of water to the farm suffers the same or similar inefficiencies. There are many of these ditches, and the following are given as examples:

| | | |
|---|---|---|
| The Ainak ditch: | Capacity | 40 cubic feet per second |
| | Length | 21 kilometers |
| | Area presently irrigated | 2500 acres |
| | Area irrigable | 3190 acres |
| The Khusrabad ditch: | Capacity | 40 cubic feet per second |
| | Length | 20 kilometers |
| | Area presently irrigated | 4820 acres |
| | Area irrigable | 7580 acres |

With the present system crops are usually irrigated according to the amount of water available and the distance from the head of the ditch, but only occasionally by the crop requirements. Irrigation water is distributed by means of small, low head ditches, often several kilometers in length, to small farm basins. The basins are seldom more than half an acre in size. A sample survey shows average sizes of 20 multiplied by nine meters surrounded by 0.30 meter high border ridges and about 20 percent of the total area being lost under the border ridges.

The problem is evidently due to uneven ground surface and insufficient land leveling, done by the use of hand labor and animal power within small basins. Irrigation of these small basins is done by turning in small streams of water for long periods of time and by filling them from two to six inches at each irrigation, and then directing the water to the next basin, resulting in over-irrigation of the first basins and loss of water due to deep percolation into the ground, and sometimes under-irrigation of the last basins.

Irrigation of these small basins is very time-consuming and labor-demanding. The labor development and operation costs of the farmer-developed smaller basins are twice and three times more than the equipment-developed larger basins.

### *Drainage*

Most of the valley lands along the Helmand river which are now suitable or have been suitable for irrigation, have been irrigated at one time or another for many centuries. Where good drainage and an adequate water supply are available, lands have remained under cultivation. Where poor drainage, poor irrigation practices or a combination of these factors have occurred, and high water tables, salinization and excessive exchangeable sodium levels have developed, large areas have been abandoned.

A majority of soils in the Shamalan unit are affected by drainage problems of varying degrees which inhibit crop growth and contribute to salinization of the soils. The only sizable contiguous block of land within the unit not affected at present by high water table conditions is the area comprising approximately the southern one-third of the South Shamalan division, where irrigation water is perennially in short supply. The major contributing factor to existing problems is the lack of an effective drainage system and natural topographic and ground conditions.

There are no natural drainage-ways within the unit and the existing constructed drains are not adequate to control the water table at safe levels from the standpoint of depth, location, spacing and channel clearance. The current existing drains are of inadequate depth and have poor maintenance characteristics. Considering all of these factors the existing drains do have considerable flow, indicating favorable sub-surface drainage characteristics.

Other important factors which are contributing to the widespread drainage problems are irrigation system losses, poor distribution and lack of effective and adequate water distribution controls.

### *Soils*

**Fertility and organic matter.** The Shamalan unit lands are among the oldest irrigated lands in the Helmand river valley. They have been farmed for many centuries and, with minor exceptions, without use of fertilizers of any kind and with little or no organic residues being returned or green manure applied to the land. The only exceptions of note are small areas located near villages which have received rather heavy applications of animal and human manures. The result is that a great majority of the soils are seriously depleted in fertility and nearly all have very low organic matter levels. Low organic matter levels have affected soils adversely in many ways, causing poor soil structure and tilth, low water holding capacity, poor soil-air relationships, reduced biological activity, and making fertility maintenance more difficult.

**Salinity and alkalinity.** Salinity and exchangeable sodium constitute moderate to severe problems on the majority of Shamalan unit lands. Concentrations of both occur in sporadic and highly variable patterns with conditions ranging from soils which are unaffected, or only slightly affected, to those classed as totally unsuitable for irrigation agriculture, due to high levels of soluble salts exchangeable sodium, or a combination of both. Moderately high to high concentrations of boron are also found, but these are consistently associated with very high salt concentrations and exchangeable sodium concentrations. Only a few scattered profiles were found where boron was present in damaging quantities where the soils were otherwise arable. In the Shamalan unit approximately 82 percent of the irrigated lands are affected by salt and/or exchangeable sodium. Of the total irrigated area approximately 30 percent is affected to a moderate degree by salt concentrations; approximately 10 percent is affected by moderate concentrations of salt and exchangeable sodium; approximately 17 percent is affected by combinations of relatively high salinity and exchangeable sodium, but can be reclaimed by moderate applications of gypsum and by leaching, assuming adequate drainage; and approximately 25 percent of these lands have such high concentrations of salts and/or exchangeable sodium that reclamation is not considered feasible. In the majority of the affected lands, salt and exchangeable sodium excesses are associated with seasonal or constant high water table conditions. But there are sizable areas of saline and/or sodic soils where water table is not a problem.

**Land Classification.** Detailed land classification has been made in the Shamalan area to determine the extent and character of the lands and to classify them according to their degrees of suitability for irrigation farming. The field classification is based on the physical factors, soils, topography and drainage, involving the determination of arable and non-arable lands on the basis of present conditions. A summarized acreage of present and future land classes is given in Table 5.

### *Roads*

There are quite a number of project roads constructed within the Helmand Valley project area. The Shamalan unit is accessible through the main canal and drain bank roads, and a fair road exists on the desert floor parallel to the western border of the project. But there is complete lack of on-farm roads and of farm-to-secondary roads. The average farmer has access to these existing secondary roads only on foot or by draft animals. The shortage of necessary roads has impeded the marketability of the produce and the desirable rapid agricultural economic growth of the area.

### *Agriculture*

Agricultural problems and needs are the outgrowth of centuries of farming with methods which tend to impoverish lands and depress yields. Many agricultural problems can be traced to physical causes; others have an institutional or social base. A

## Table 5: Results of Land Classification
## Present Conditions

| | Land Classes and Subclasses | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2sa | 2sk | 2sd | 2st | 2sv | Total Class 2 | 3sa | 3sk | 3sd | 3st | 3sv | Total Class 3 | Total Arable | Irrigated Class 6 | Nonirrig Class 6 | Total Classified |
| | NORTH SHAMALAN DIVISION | | | | | | | | | | | | | | | | |
| Hectares | 97.1 | 642.4 | | 54.9 | | 0.5 | 697.8 | 322.3 | 0.6 | 30.4 | 11.7 | 1 | 366.3 | 1,161.2 | 277.9 | 623.2 | 2,062.3 |
| Acres | 239.9 | 1,587.4 | | 135.6 | | 1.3 | 1,724.3 | 796.5 | 1.4 | 75.1 | 29.0 | 3.2 | 905.2 | 2,869.4 | 686.4 | 1,539.8 | 5,095.9 |
| | WEST SHAMALAN DIVISION | | | | | | | | | | | | | | | | |
| Hectares | 1,213.6 | 2,297.0 | 34.8 | 100.3 | 7.4 | | 2,439.5 | 1,031.4 | 36.3 | 657.5 | 8.8 | | 1,734.0 | 5,387.1 | 1,032.8 | 2,141.7 | 8,561.6 |
| Acres | 2,998.8 | 5,675.9 | 85.9 | 247.8 | 18.2 | | 6,027.8 | 2,548.6 | 89.7 | 1,624.7 | 21.8 | | 4,284.8 | 13,311.5 | 2,551.9 | 5,292.3 | 21,155.7 |
| | EAST SHAMALAN DIVISION | | | | | | | | | | | | | | | | |
| Hectares | 1,219.1 | 1,223.7 | 40.0 | 232.7 | 9.3 | 59.8 | 1,565.5 | 886.7 | 61.6 | 276.6 | 86.4 | 33.2 | 1,344.5 | 4,129.1 | 1,301.7 | 1,739.1 | 7,170.0 |
| Acres | 3,012.3 | 3,023.7 | 98.9 | 575.1 | 22.9 | 147.8 | 3,868.4 | 2,191.0 | 152.2 | 683.6 | 213.5 | 82.2 | 3,322.5 | 10,203.1 | 3,216.6 | 4,297.4 | 17,717.1 |
| | SOUTH SHAMALAN DIVISION | | | | | | | | | | | | | | | | |
| Hectares | 217.3 | 1,338.2 | 28.4 | 108.4 | | 2.6 | 1,477.6 | 776.9 | 13.4 | 15.1 | 10.8 | 53.9 | 864.1 | 2,559.0 | 1,884.8 | 3,636.7 | 8,080.6 |
| Acres | 537.0 | 3,306.8 | 70.2 | 267.7 | 0.1 | 6.4 | 3,651.2 | 1,904.9 | 33.1 | 37.4 | 26.7 | 133.1 | 2,135.2 | 6,323.4 | 4,657.4 | 8,986.3 | 19,967.1 |
| | TOTALS SHAMALAN UNIT | | | | | | | | | | | | | | | | |
| Hectares | 2,747.1 | 5,501.3 | 103.2 | 496.3 | 16.7 | 62.9 | 6,180.4 | 3,011.3 | 111.9 | 979.6 | 117.7 | 88.4 | 4,308.9 | 13,236.4 | 4,497.2 | 8,140.7 | 25,874.5 |
| Acres | 6,788.0 | 13,593.9 | 255.1 | 1,226.2 | 41.1 | 155.5 | 15,271.8 | 7,441.0 | 276.5 | 2,420.8 | 291.0 | 218.5 | 10,647.8 | 32,707.6 | 11,112.7 | 20,115.8 | 63,936.0 |

host of physical factors contribute to poor farm returns. These include inadequate land preparation; poor seed and inefficient seeding; inferior crop and livestock varieties; lack of soil-building rotations (although some alfalfa is grown, none is ever plowed under as green manure), the lack of fertilizer and pest and disease control agents and necessary farm machinery. The Shamalan unit is one of the older farmed areas in the valley. The principal crops presently grown in this area are wheat, cotton, corn, mung beans, with minor amounts of barley, alfalfa, fruits, vegetables, grapes and other horticultural crops. Wheat is the basic crop, occupying about one-half of the cropped land. Small numbers of livestock are kept, principally for draft purposes. Sheep and goats are purchased from Nomads in the fall and are fattened for winter meat. Small numbers of poultry are kept for eggs and meat. Farming methods and practices in the valley are for the most part of a low standard and crop yields are for the most part quite low. The "1968 Shamalan Feasibility Report" gives the average yields and farm income for the present conditions (see Table 6).

The 1969-1970 average yield of wheat, as reported by HAVA Extension, is 1,900 kilograms per hectare; 1,673 pounds/acre or 28.2 bushel/acre. Part of the increased production is due to the use of improved seed, application of fertilizer and better land preparation. The potential soil, water and climatic conditions of this area are favorable to irrigation agriculture. The long growing season plus relatively mild winters give rise to a wide range of crop adaptability and to potentially favorable yields. In addition to the present popular crops, sugar beets, grain sorghums and soybeans have been grown successfully on an experimental basis. Alfalfa pasture grass and the commonly grown clovers continue to produce through the winter months, although production during the coldest weather is limited. The hardier vegetables are also grown throughout the winter months.

### *Land Ownership*

Land ownership in the Shamalan area is badly fragmented. Ownership of parcels of land as small as a fraction of an acre is common. One person may own as many as 20 or more lots scattered at different locations and of various shapes and sizes. Some of these lots may be jointly owned by as many as six persons. The reasons for these conditions are the sub-division of the land through inheritance and the incapability of the legal mechanism to determine each owner's share and issue deeds and titles.

Under the conditions of ownership the legal sale and purchase of land property has not been possible, thus inhibiting the free economic processes for the full utilization of the economic potential of the land resources. Also, farming of scattered, fragmented parcels of land becomes too difficult and inefficient which, in turn, reduces agricultural production and owners' incentives for land improvement and the achievement of higher production.

A sample area of a cadastral survey map is shown as map No. 2, and information picked at random from this and other maps is shown in Table 7. The distribution of sizes of the ownership lots as registered in the old tax books and as presently surveyed by the cadastral for some sample areas is shown in Figure 1.

## PROJECT PLANS

### *Feasibility*

The physical potential of the Shamalan unit with respect to lands, water and climate is favorable for increased agricultural production. However, many physical, social and institutional weaknesses must be corrected before production can advance significantly over present levels. Irrigation deficiencies must be removed, drainage problems remedied, land properly prepared, the road network enlarged, a system of domestic wells or some other source of drinking water installed, soil amendments applied where needed, and the necessary amounts of fertilizer applied.

After installation, the project works must be properly operated and maintained. This will prepare the base for a sound agriculture, and must be followed by improved farming practices. Farm credit, improved seed and stock, fertilizer, insect and disease control agents, and machinery must be introduced and successfully used to create the returns of which the project will be capable. At the same time, pertinent measures should be applied to alleviate and remedy the land ownership problems of fragmentation, deeds and titles to the land, and to make possible the maintenance of adequate farm sizes. And finally, charges should be made against water and land to cover operation and maintenance and a portion of capital expenditure costs.

## Table 6: Present Conditions, Shamalan Unit

### Units in Metric System & U.S. Dollars

| | Land Use | Hectares | Yield Kg Hectare | Total, Kg | Price $/Kg | Per Ha | Per Composite Ha | Total | Gross Costs $ | Net Income $ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Single Crop** | | | | | | | | | | |
| Wheat | 47.0 | 5,972 | 1,215 | 7,255,980 | 0.060 | 73.35 | 34.47 | 438,047 | | |
| Barley | 2.2 | 279 | 1,287 | 359,073 | 0.026 | 33.15 | 0.73 | 9,248 | | |
| Cotton: Seed Cotton | 27.4 | 3,482 | 662 | 2,305,084 | 0.157 | 103.50 | 28.36 | 360,380 | | |
| Lint | | | (231) | (804,342) | (0.392) | (90.82) | (24.88) | (316,220) | | |
| Seed | | | (431) | (1,500,742) | (0.029) | (12.68) | (2.48) | (44,160) | | |
| Alfalfa, Hay | 4.6 | 584 | 4,364 | 3,132,576 | 0.001 | | | [1] | | |
| Orchard | 2.2 | 280 | 8,079 | 2,262,120 | 0.026 | 213.19 | 4.70 | 59,694 | | |
| Garden | 1.5 | 191 | 6,432 | 1,228,512 | 0.009 | 56.54 | 0.85 | 10,799 | | |
| Vineyard | 3.2 | 407 | 2,975 | 1,210,825 | 0.024 | 72.01 | 2.30 | 29,307 | | |
| Clover | 0.7 | 89 | 1,502 | 133,678 | 0.003 | | | [1] | | |
| Tobacco | 0.2 | 25 | 1,147 | 28,675 | 0.121 | 141.80 | 0.28 | 3,545 | | |
| Drugs | 4,164 plants | Ha52,910 Plants | 0.0102/Plant | 5,378 | 7.242 | | 0.31 | 3,889 | | |
| Subtotal, Single Crop | 89.0 | 11,309 | | | | | 72.00 | 914,909 | | |
| **Double Crop** | | | | | | | | | | |
| Corn | 12.8 | 1,626 | 622 | 1,011,372 | 0.039 | 24.47 | 3.13 | 39,788 | | |
| Carrots | 1.8 | 228 | 3,707 | 845,196 | 0.007 | 24.56 | 0.44 | 5,599 | | |
| Mung Beans | 9.2 | 1,169 | 318 | 371,742 | 0.046 | 14.69 | 1.35 | 17,169 | | |
| Sesame | 0.1 | 13 | 342 | 4,446 | 0.117 | 38.54 | 0.04 | 501 | | |
| Subtotal, Double Crop | (23.9) | (3,036) | | | | | 4.96 | 63,057 | | |
| Crop Residue | | | | | | | | [1] | | |
| Idle and Farmstead | 11.0 | 1,398 | | | | | | | | |
| Subtotal, Crops | 100.0 | 12,707 | | | | | 76.96 | 977,966 | | |
| **Livestock and Products** | | | No Hectare | Number | | | | | | |
| Oxen | | | 0.27 hd | 3,454 hd | 6.35 | 1.73 | 1.73 | 21,933 | | |
| Milk Cows | | | 0.30 hd | 3,768 hd | 2.89 hd | 0.86 | 0.86 | 10,890 | | |
| Other Cattle | | | 0.29 hd | 3,768 hd | 2.31 hd | 0.68 | 0.68 | 8,704 | | |
| Donkeys & Horses | | | 0.19 hd | 2,512 hd | 0.26 hd | 0.05 | 0.05 | 653 | | |
| Sheep and Goats | | | 0.26 hd | 3,454 hd | 10.72 hd | 2.92 | 2.92 | 37,027 | | |
| Milk | | | 111.05 kg | 1,411,112 kg | 0.03 kg | 3.42 | 3.42 | 43,519 | | |
| Eggs | | | 36.57 eggs | 464,700 eggs | 0.013 egg | 0.48 | 0.48 | 6,041 | | |
| Subtotal, Livestock Products | | | | | | | 13.05 | 165,730 | | |
| Fuel Income | | | | | | | 7.41 | 94,197 | | |
| Total Income | | | | | | | 97.42 | 1,237,893 | 564,868 | 673,025 |
| Average per Hectare | | | | | | | | 97.42 | 44.45 | 52.97 |
| Grazing Income Nonarable Land | | | | | | | | | | 24,671 |
| Grazing Income per Hectare [2] | | | | | | | | | | 1.94 |
| Grand Total Income | | | | | | | | | | 697,696 |
| Grand Total Income per Hectare | | | | | | | | | | 54.91 |

1 Fed to livestock

2 Per hectare of nonarable land (12,638 hectares)

## Table 7: Land Ownership Sample Information

| | | | | | |
|---|---|---|---|---|---|
| **Khosrabad, Khalach Area** | | | | | |
| 2179 | M. Aziz | – | 2.378 | 13 | 34.253 |
| 1962 | Khudaidad | – | 7.509 | 4 | 14.326 |
| 2094 | A. Nabi | – | 3.734 | 14 | 28.826 |
| 2095 | M. Karim | – | 14.414 | 9 | 49.274 |
| 1958 | A. Ali | 4 | 13.613 | 1 | 3.403 |
| 2061 | Shir M. | 2 | 12.370 | 9 | 21.163 |
| 1915 | A. Hag | – | 9.460 | 1 | 9.460 |
| 1834 | Jan Aga | 5 | 4.111 | 21 | 36.333 |
| 1858 | Adam Khan | 2 | 13.550 | 1 | 6.775 |
| **Ainak, Sayed Abad Area** | | | | | |
| 189 | Government | – | 283.090 | | |
| 247 | M. Karim | 2 | 29.410 | 5 | 26.527 |
| 244 | M. Karim | – | 1.510 | 1 | 1.510 |
| 236 | Mohaiuddin | – | 47.680 | 1 | 47.680 |
| 224 | Khudaidad | – | 0.670 | 2 | 22.670 |
| 215 | Amir Jan | – | 16.770 | 2 | 19.570 |

## Table 8: Shamalan Unit – Benefit-Cost Ratio

| | Dollars |
|---|---|
| Capital Costs | |
| Distribution system | 5,116,000 |
| Drainage system | 1,562,000 |
| Land development | 1,962,000 |
| Roads | 392,000 |
| Domestic water system | 287,000 |
| Soil amendments | 540,000 |
| Resettlement costs | 191,000 |
| Interest during construction | 528,000 |
| Total | 10,578,000 |
| Average Annual Benefits | |
| Total | 2.505,000 |
| Primary only | |
| Annual Project Costs | |
| Capital costs | 451,000 |
| O & M costs (increase over present) | 20,000 |
| Total | 471,000 |
| Benefit-Cost Ratio | |
| Total | $5.32 to $1.00 |
| Primary | $1.79 to $1.00 |

If the Shamalan unit plan is implemented as recommended within the framework of guiding legislation, then the project will be financially feasible.

The Shamalan Unit Feasibility Report, prepared by the U.S. Bureau of Reclamation for the Helmand Arghandab Valley Authority and AID in 1968, gives the benefit cost ratio as shown in Table 8.

In this report it has also been worked out that the economic feasibility of the project will depend largely upon successful operation of the farm units, and that there is a direct relationship between farm size and successful farm operation. It is recommended that the farm size be not less than nine irrigable hectares (22.2 acres), plus additional non-arable land for grazing. It has been recommended that this size be a long-term goal, and should be achieved as individual farmers become more efficient, release their share-croppers, replace their oxen with machinery, and gradually expand their holdings. Farm units of inadequate size will only perpetuate subsistence agriculture by denying the farmer the base and business volume upon which to build a commercial unit.

### *Irrigation Plans*

In the Helmand valley's Shamalan unit, agriculture is critically dependent on irrigation. In Section I, "Project Area General Description" and Section II, "Project Needs," the importance of irrigation in the scope of past and present conditions has been fully demonstrated. Project irrigation plans have been worked out to completely remedy the problems and shortcomings of irrigation and to make necessary quantities of irrigation water available when needed to all the lands and farms under the system consistently and indiscriminately.

**Irrigation and farm delivery requirements.** The primary problem in the Shamalan unit is one of distribution and to provide ample canal and lateral capacity to fully meet farm delivery requirements on time throughout the periods of maximum demand.

Estimates of monthly farm delivery requirements were arrived at by the HAVA and Bureau of Reclamation engineering teams through a review of consumptive use studies made by International Engineering Company, Inc., "Soil and Water Resources of Afghanistan," review of data furnished by the director of the Bolan Experimental farm on frequency and amount of irrigation application for various crops; and by observations of irrigation throughout the project. Consideration was also given to the leaching requirement, irrigation efficiency and pre-irrigation to condition land for seedbed preparation.

**Distribution system requirements.** It is assumed that in the early years of the project operation the proper irrigation efficiency will not be attained. Until irrigators can be trained in proper irrigation management, the traditional ways of operation will result in excessive losses through deep percolation and surface waste.

Lateral design capacities and canal diversion requirement are based upon the adoption of the maximum monthly consumptive use (in July) shown in Table 9, as 0.420 feet per acre and applying percentages of loss by deep percolation, farm waste, lateral and canal losses.

Water Requirements Acre-Feet Per Acre

| | |
|---|---|
| Maximum weighted consumptive requirement | 0.420 |
| Deep percolation loss: 25 percent | 0.141 |
| Weighted net input | 0.561 |
| Farm irrigation waste: 15 percent | 0.099 |
| Weighted farm delivery requirement | 0.660 |
| Lateral losses: 10 percent | 0.074 |
| Lateral diversion requirement | 0.734 |
| Supply canal losses: 20 percent | 0.184 |
| Supply canal diversion requirement | 0.918 |

In the early years of a project it is assumed that irrigation of class 6W lands will be continued, at least until such time as a reform toward establishment of water charges is effected and the farmers realize that continued irrigation of these lands is no longer economical. Land classification surveys have determined that there are 11,113 acres of class 6W land.

Using the proposed farm layouts, (see map No. 5), Table 10 indicates the deductions for the various rights-of-way, and it is assumed that only 60 percent of the farmstead will be irrigated. This will leave a balance of 173.29 hectares (428.04 acres) irrigable out of each two square kilometers, or 86.64 percent of the land.

The following is a tabulation of the entire Shamalan area by land classification:

**Shamalan Lands**

| | |
|---|---|
| Class 1 | 6,788.0 acres |
| Class 2 | 15,271.8 acres |
| Class 3 | 10,647.8 acres |
| Class 6W | 11,113.0 acres |
| Total | 43,820.6 acres |

Using the above acreage figures and the estimated water requirements, the following computations give an indication of the minimum water requirements:

43,820.6 acres x 86.64 percent = 37,966 acres
37,966 acres x 0.918 = 34,853 acre-feet July
34,853 acre-feet ÷ 31 = 1,124 acre-feet daily July
1,124 acre-feet ÷ 1.98347 = 566 cubic feet per second = 80 percent peak requirements
566 ÷ 80 x 100 = 708 cubic feet per second designed capacity

From the previous paragraph on Distribution System Requirements one notes that under maximum use the weighted farm delivery requirement per acre for the month of July is 0.660 acre per feet. Based on this estimate and the further assumption that the land will require an average of one irrigation each ten days, Table 11 indicates the water requirement for 1,000 acres in acre feet and canal capacity in cubic feet per second.

## *North and West Shamalan Area*

Table 12 is a tabulation of the acres in these two areas, and the deductions shown are for areas that will not be irrigated from the supply canal which will take off from the Shamalan canal at station 10+800. For the purpose of this paper these are the only acreages covered.

Based on the above acreage, the supply canal taking off from the Shamalan canal at station 10+800 should have a capacity estimated as follows:

18,112 acres ÷ 1,000 acres x 17.1 cubic feet per second per 1,000 acres = 310 cubic feet per second.

MKA's engineering studies indicate that each foot of soil has a moisture-holding capacity of 1.7 inches of water in the four-foot deep effective root zone of the plants. It is assumed that the plants will take 40 percent of their moisture from the top foot of soil, 30 percent from the second foot, 20 percent from the third foot and only 10 percent from the fourth foot.

Table 13 indicates the condition of the soil and the amount of water needed for an irrigation.

Consumptive use factors for the month of July, using Blaney-Criddle methods of computation, indicate a requirement of 8.23 inches of water for cotton, the highest water user, or roughly three three-inch applications of irrigation water for plant use.

If the irrigation water is applied three inches deep each 10 days, it would require .250 acre-feet per acre each 10-day irrigation cycle. If it is delivered at the rate of 10 cubic feet per second x 1.98347 acre-feet ÷ .250 acre-feet = 79.33 acres irrigated each day with each 10 cubic feet per second head of irrigation water or 790 acres irrigated each 10-day cycle. The 18,112 acres should be divided roughly into 22.9 head acres, or say into 24.

The 310 cubic feet per second canal capacity for 24 head areas would indicate 12.9, say roughly 14 cubic feet per second of canal capacity for each head area.

Considering the above basic information, the head areas were delineated. Consideration was given to layout areas that could be irrigated most easily by one 14 cubic feet per second head of water being moved about in the area with the least amount of interruption of the regular flow in the main supply canal. The head areas in the lower end of the system were kept smaller than average to provide extra capacity where the canal and lateral size were a limiting factor. It was also considered necessary to deliver water to the class 6W lands so these acres are included.

Table 14 indicates the acreage actually measured and the land classification of the acreage included in each head area. It is seen that the gross irrigable acreage is 17,239, and when this is reduced to 86.64 percent due to exclusions for rights-of-way, we have 14,935 acres to irrigate with 24 heads of water, or an average of 622 acres per head area to be irrigated by each 14 cubic feet per second head of irrigation water, or one cubic feet per second per 44.4 acres.

## Table 9: Shamalan Unit Crop Consumptive Use[1]

| Crop | | *Jan. | *Feb. | *Mar. | *Apr. | May | June | July | Aug. | Sept. | Oct. | *Nov. | *Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Effective Precip. = 80% average | | 1.05 | 1.23 | 2.80 | 0.51 | | | | | | | 0.29 | 0.95 | |
| Wheat | 28.0 | 0.28 | 1.23 | 2.80 | 3.63 | 5.54 | - | – | – | – | 4.08[2] | 2.11 | 0.43 | 20.10 |
| Cotton | 21.9 | – | – | – | 3.53[2] | 3.27 | 4.32 | 5.94 | 5.20 | 4.28 | 1.84 | – | – | 28.38 |
| Alfalfa | 23.9 | 0.79 | 2.20 | 3.07 | 4.54 | 6.54 | 7.56 | 8.10 | 315[3] | 5.14 | 4.34 | 2.60 | 0.97 | 49.00 |
| Orchard | 3.0 | – | – | 0.29 | 2.77 | 4.90 | 5.18 | 5.40 | 4.72 | 3.74 | 2.04 | 0.76 | – | 29.80 |
| Vineyard | 3.3 | – | – | 0.29 | 0.70 | 3.87 | 4.43 | 4.97 | 3.68 | 1.28 | 1.02 | 0.23 | – | 20.47 |
| Garden | 2.8 | 0.53 | 1.93 | 1.90 | 3.03 | 4.63 | 4.32 | 4.32 | 4.72 | 3.75 | 3.06 | 1.81 | 0.70 | 34.70 |
| Corn | 14.3 | – | – | – | – | 1.50[2] | 4.32 | 4.86 | 6.72 | 4.92 | 3.57 | – | – | 25.89 |
| Carrots | 2.7 | – | – | – | – | – | – | – | – | 4.55 | 3.57 | 2.55 | 1.53 | 12.20 |
| Mung Beans | 9.8 | – | – | – | – | – | 2.16 | 5.40 | 4.72 | 3.74 | – | – | – | 16.02 |
| Sunflower | 2.3 | – | – | – | – | – | 5.40 | 5.83 | 5.15 | 4.28 | – | – | – | 20.66 |
| Wt. Total (inches) | | 0.31 | 1.04 | 1.86 | 3.41 | 5.00 | 4.13 | 5.04 | 3.83 | 3.72 | 3.78 | 1.57 | 0.45 | 34.14 |
| Wt. Total (feet) | | 0.026 | 0.087 | 0.155 | 0.284 | 0.417 | 0.344 | 0.420 | 0.319 | 0.310 | 0.315 | 0.131 | 0.038 | 2.846 |
| Percentage of land irrigated during month | | 68.0 | 68.0 | 71.0 | 92.9 | 107.2 | 81.3 | 81.3 | 81.3 | 84.0 | 109.0 | 73.7 | 70.7 | |

[1] Monthly consumptive use from International Engineering Company (MKA) Report, 1959, based on Blaney-Criddle method.
[2] Includes irrigation for land preparation for seeding.
[3] Alfalfa dormant during most of August.
* Crop consumptive use less effective precipitation.

**Table 10: Shamalan Farm Units**

| | Area Acres | Area Hectares | Percentage |
|---|---|---|---|
| Gross Area | 494 | 200 | 100 |
| Deductions for | | | |
| Main Roads | 14.72 | 5.96 | 2.98 |
| Entrance Roads | 1.53 | .62 | .31 |
| Drains | 9.78 | 3.96 | 1.98 |
| 40 percent Farmsteads | 9.48 | 3.84 | 1.98 |
| Laterals | 4.89 | 1.98 | .99 |
| Farm Ditches | 25.56 | 10.35 | 5.18 |
| Total Deductions | 65.96 | 26.71 | 13.36 |
| Farm Land | 428.04 | 173.29 | 86.64 |

**Table 11: Water Requirements 1,000 Acres**

| Description | Acre-Ft. | CFS |
|---|---|---|
| Maximum monthly farm use | | |
| 0.660 acre-ft. x 1,000 acres | 660 | |
| 660 acre-ft. : 31 days : 1.98347 | | 10.7 |
| Maximum 10 day delivery, 20% peaking | | |
| 660 acre-ft. : 31 days x 10 days x 120% | 256 | |
| 256 acre-ft. : 10 days : 1.98347 | | 12.9 |
| Lateral loss @ 10 percent | 26 | |
| Lateral delivery in peak 10 days | 282 | |
| 282 acre-ft. : 10 days : 1.98347 | | 14.2 |
| Canal loss @ 20 percent | 56 | |
| Peak 10 days diversion from Shamalan | 338 | |
| 355 acre-ft. : 10 : 1.98347 | | 17.1 |

**Table 12**

| | Class 1 | Class 2 | Class 3 | Class 6W | Total |
|---|---|---|---|---|---|
| North Shamalan | 239.90 | 1,724.30 | 905.20 | 686.70 | |
| Deductions | 143.02 | 257.77 | 211.09 | 24.82 | |
| Remaining Acres | 96.86 | 1,466.53 | 694.11 | 661.88 | 2,919.38 |
| West Shamalan | 2,998.80 | 6,027.80 | 4,284.80 | 2,551.90 | |
| Deductions | 0.00 | 166.04 | 175.43 | 329.49 | |
| Remaining Acres | 2,998.00 | 5,861.76 | 4,109.37 | 2,222.41 | 15,192.34 |
| Total area to be irrigated | | | | | 18,111.72 |

**Table 13**

| Effective Root Zone Depth of Soil (Feet) | | Available Moisture Holding Capacity | Soil Moisture Remaining Before Irrigation (Percent) | (Inches) | Moisture Used by Plants (Inches) | Rate of Use (Percent) |
|---|---|---|---|---|---|---|
| From 0 | To 1 | 1.7 inch | 30 | 0.50 | 1.20 | 40 |
| 1 | 2 | 1.7 inch | 47 | 0.80 | .90 | 30 |
| 2 | 3 | 1.7 inch | 65 | 1.10 | .60 | 20 |
| 3 | 4 | 1.7 inch | 82 | 1.40 | .30 | 10 |
| | | 6.8 inch | 56 | 3.80 | 3.00 | 100 |

Table 15 indicates the number of farms, gross acreage, net acreage and the number of days required to apply three inches of water to each head area. It is assumed that due to the farm operation, it will seldom be necessary to irrigate more than 80 percent of each farm. An estimate is also included to show the time required to irrigate 80 percent of each head area, and this should be a close estimate of actual conditions. Parts of the land will not be irrigated each time because areas will be plowed, harvesting will be carried on, and there will be other farm operations that would interfere with irrigation.

Another safety factor would be that the irrigation canals and laterals can often be operated in excess of actual designed capacity. Head area number 15 extends over a large segment of the main supply canal and this will provide excess capacity from head area seven to 15 inclusive. In other words, there is sufficient designed capacity to move one extra head of water about in this reach.

Table 16 indicates the hydraulic properties designed into the proposed canal. In the upper sections of the canal where the freeboard is from 1.9 to 2.6 feet the canal capacities are shown for conditions when the freeboard is encroached on to the extent of one foot. This would indicate additional capacity of from 27 to 46 percent of the designed capacity.

### *Drainage Plans*

The present outlet drains in the Shamalan unit constructed mostly prior to 1960 were built in topographic lows that meander along the river valley and conform to the existing old irr system. They serve as combination of outlet and relief drains, giving fairly adequate drainage protection to most lands adjacent to the Shamalan canal, but providing little relief to lands more distance from the Shamalan canal.

The general direction of groundwater movement is along the river valley, not toward the river. Over large areas under present conditions the groundwater has to travel more than 10 kilometers before reaching an effective drain or the river.

Although the existing outlet drains are effective to some extent in collecting and disposing of groundwater, much more drainage protection could have been realized if the drains had been constructed diagonally toward the river with sufficient grade to maintain velocity of flow. Drains in this alignment could cross or intercept the general groundwater slope (about one meter per kilometer) and be fully effective. The proposed drainage plans are aligned in this direction.

Since the lands classified as irrigable in the Shamalan unit project area have good to excellent drainage characteristics, and an excellent drainage aquifer underlies practically all of the project area extending from the top of the groundwater table down to eight to 12 meters (26 to 39 feet) below the ground surface.

Over practically all of the project area the drainage aquifer is comprised of two parts. The upper part is a stratum of loam to loamy sand material two to four meters (6.6 to 13 feet) thick encountered two to four meters below the ground surface. The lower part is a stratum of unconsolidated rounded and sub-rounded gravelly material usually with a loamy sand or sandy matrix. This part of the drainage aquifer is six to eight meters (20 to 26 feet) thick and generally overlies a sandstone stratum encountered 10

## Table 14: North and West Division Head Area

| Head Area No. | Land Classification Class 1 Acre | Class 2 Acre | Class 3 Acre | Subtotal Acre | Class 6W Acre | Subtotal Acre | Class 6 Acre | Total Acre |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 48 | 48 | 254 | 302 | 150 | 452 |
| 2 | 0 | 3 | 123 | 126 | 148 | 274 | 197 | 471 |
| 3 | 11 | 96 | 342 | 449 | 111 | 560 | 325 | 885 |
| 4 | 0 | 241 | 350 | 591 | 65 | 656 | 132 | 788 |
| 5 | 0 | 2 | 450 | 452 | 220 | 672 | 198 | 870 |
| 6 | 63 | 479 | 257 | 799 | 34 | 833 | 12 | 845 |
| 7 | 0 | 123 | 426 | 549 | 197 | 746 | 136 | 882 |
| 8 | 325 | 441 | 101 | 867 | 14 | 881 | 38 | 919 |
| 9 | 0 | 552 | 163 | 715 | 104 | 819 | 37 | 856 |
| 10 | 119 | 665 | 57 | 841 | 10 | 851 | 18 | 869 |
| 11 | 365 | 397 | 72 | 834 | 3 | 837 | 20 | 857 |
| 12 | 207 | 508 | 117 | 832 | 21 | 853 | 43 | 896 |
| 13 | 432 | 363 | 47 | 833 | 1 | 834 | 62 | 896 |
| 14 | 336 | 612 | 32 | 980 | 51 | 1,031 | 80 | 1,111 |
| 15 | 143 | 169 | 214 | 526 | 17 | 543 | 218 | 761 |
| 16 | 177 | 348 | 209 | 734 | 116 | 850 | 112 | 962 |
| 17 | 0 | 29 | 123 | 152 | 519 | 671 | 129 | 800 |
| 18 | 468 | 242 | 65 | 775 | 48 | 823 | 112 | 935 |
| 19 | 29 | 248 | 342 | 619 | 98 | 717 | 82 | 799 |
| 20 | 87 | 229 | 268 | 584 | 204 | 788 | 26 | 814 |
| 21 | 58 | 423 | 170 | 651 | 59 | 710 | 38 | 748 |
| 22 | 56 | 446 | 172 | 674 | 96 | 770 | 47 | 817 |
| 23 | 136 | 473 | 151 | 760 | 26 | 786 | 72 | 858 |
| 24 | 0 | 127 | 189 | 316 | 116 | 432 | 55 | 487 |
| Totals | 3,003 | 7,216 | 4,488 | 14,707 | 2,532 | 17,239 | 2,339 | 19,578 |

Table 15: Shamalan Unit
Head Areas

| Head Area No. | Number of Farms | Acres in Farm Gross | Acres in Farm Net* | Days to Apply 3" Irrigation | 80% of Net Acreage | Days to Apply 3" Irrigation |
|---|---|---|---|---|---|---|
| 1 | 13 | 302 | 261 | 3.28 | 209 | 2.63 |
| 2 | 16 | 274 | 237 | 2.99 | 190 | 2.40 |
| 3 | 28 | 560 | 485 | 6.11 | 388 | 4.89 |
| 4 | 29 | 656 | 568 | 7.16 | 454 | 5.72 |
| 5 | 29 | 672 | 582 | 7.34 | 466 | 5.87 |
| 6 | 29 | 833 | 722 | 9.10 | 578 | 7.29 |
| 7 | 28 | 746 | 646 | 8.14 | 517 | 6.52 |
| 8 | 29 | 881 | 763 | 9.62 | 610 | 7.69 |
| 9 | 28 | 819 | 710 | 8.95 | 568 | 7.16 |
| 10 | 28 | 851 | 737 | 9.29 | 590 | 7.44 |
| 11 | 28 | 837 | 725 | 9.14 | 580 | 7.31 |
| 12 | 29 | 853 | 739 | 9.31 | 591 | 7.45 |
| 13 | 28 | 834 | 722 | 9.10 | 578 | 7.29 |
| 14 | 34 | 1,031 | 893 | 11.25 | 715 | 9.01 |
| 15 | 25 | 543 | 470 | 5.92 | 376 | 4.74 |
| 16 | 27 | 850 | 736 | 9.28 | 589 | 7.42 |
| 17 | 1 | 671 | 581 | 7.32 | 464 | 5.85 |
| 18 | 26 | 823 | 713 | 8.99 | 570 | 7.18 |
| 19 | 25 | 717 | 621 | 7.83 | 497 | 6.26 |
| 20 | 25 | 788 | 682 | 8.60 | 546 | 6.88 |
| 21 | 30 | 710 | 615 | 7.75 | 492 | 6.20 |
| 22 | 23 | 770 | 667 | 8.41 | 534 | 6.73 |
| 23 | 26 | 786 | 681 | 8.58 | 545 | 6.87 |
| 24 | 16 | 432 | 374 | 4.71 | 299 | 3.77 |
| | | | | 188.17 | | 150.57 |
| | | | Average | 7.84 | | 6.27 |

*Net acreage is 86.64 percent of gross.

## Table 16: Proposed Hydraulic Properties

| Section From | Section To | Q | A | V | B | d | r | s | B/d | Fb. | d+l | V | Q | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 521 | 522 | 336 | 127.5 | 2.64 | 18 | 5.0 | 3.62 | .00029 | 3.60 | 2.6 | 6.00 | 2.64 | 428 | 27% |
| 522 | 523 | 336 | 127.5 | 2.64 | 18 | 5.0 | 3.62 | .00029 | 3.60 | 2.6 | 6.00 | 2.64 | 428 | 27% |
| 523 | 529.5 | 308 | 117.5 | 2.62 | 16 | 5.0 | 3.45 | .00030 | 3.20 | 2.5 | 6.00 | 2.62 | 393 | 27% |
| 529.5 | 532 | 294 | 117.5 | 2.50 | 16 | 5.0 | 3.45 | .00027 | 3.20 | 2.5 | 6.00 | 2.50 | 375 | 27% |
| 532 | 534.5 | 266 | 105.34 | 2.53 | 16 | 4.6 | 3.23 | .00031 | 3.48 | 2.4 | 5.60 | 2.53 | 346 | 30% |
| 534.5 | 538.5 | 238 | 91.14 | 2.48 | 14 | 4.6 | 3.14 | .00031 | 3.04 | 2.4 | 5.60 | 2.48 | 311 | 30% |
| 538.5 | 542 | 224 | 87.94 | 2.56 | 14 | 4.3 | 2.98 | .00035 | 3.26 | 2.4 | 5.30 | 2.56 | 298 | 33% |
| 542 | 543.5 | 210 | 82.62 | 2.54 | 14 | 4.1 | 2.87 | .000364 | 3.42 | 2.4 | 5.10 | 2.54 | 280 | 33% |
| 543.5 | 544 | 196 | 77.42 | 2.53 | 14 | 3.9 | 2.76 | .000380 | 3.59 | 2.3 | 4.90 | 2.53 | 265 | 35% |
| 544 | 545 | 168 | 67.26 | 2.51 | 12 | 3.8 | 2.62 | .0004 | 3.16 | 2.2 | 4.80 | 2.51 | 231 | 37% |
| 545 | 545.5 | 140 | 55.94 | 2.50 | 12 | 3.3 | 2.34 | .00046 | 3.64 | 2.1 | 4.30 | 2.50 | 198 | 41% |
| 545.5 | 546.5 | 112 | 43.50 | 2.57 | 10 | 3.0 | 2.09 | .000565 | 3.33 | 1.9 | 4.00 | 2.57 | 164 | 46% |
| 546.5 | 549 | 70 | 27.84 | 2.51 | 8 | 2.4 | 1.67 | .0009 | 3.33 | 1.7 | | | | |
| 549 | 554 | 42 | 16.82 | 2.52 | 6 | 1.9 | 1.31 | .00125 | 3.16 | 1.5 | | | | |
| 554 | 556 | 28 | 10.88 | 2.57 | 5 | 1.5 | 1.05 | .00175 | 3.33 | 1.4 | | | | |
| 556 | 557 | 14 | 5.76 | 2.54 | 4 | 1.2 | 0.79 | .002506 | 3.33 | 1.1 | | | | |

to 12 meters (33 to 39 feet) below the ground surface. In a few places it overlies a stratum of conglomerate material eight to 10 meters (26 to 33 feet) below the ground surface. Deep exploration holes have shown the sandstone stratum to be more than 30 meters (98 feet) thick. Both sandstone and conglomerate strata constitute effective horizontal drainage barriers.

Permeability rates in the upper part of the drainage aquifer range from two to 10 meters per day (3.3 to 16.4 inches per hour), increasing with depth. The lower part of the acquifer has permeability rates in the order of 10 to 50 meters and higher per day (16 to 82 inches per hour). There is little indication of vertical drainage barriers within the drainage aquifer, and shallow horizontal drainage barriers above the gravelly stratum apparently do not affect extensive areas of irrigable lands. Over practically all of the project area there should be no critical resistance to movement of groundwater downward and toward existing and proposed drains.

Effective open drains can easily be constructed to depths of two to four meters (7 to 13 feet) in stable material, with the bottom of the drains being in and over strata that offer non-critical resistance to movement of groundwater upward into drains.

On irrigable lands, the soil surface infiltration rates are low to moderate. With reasonably good irrigation water management, leaching can be accomplished without excessive additions to the groundwater table. Because of good to excellent quality of irrigation water supply, the leaching requirement is only about 10 to 15 percent of the irrigation input.

The Shamalan unit project area has a relatively uniform and gentle slope down the valley, with few excessive irregularities to cause accumulation of surface and groundwater. Most project lands are situated relatively high above outlets to the river, and the general slope of the land permits orderly layout and construction of adequate distribution and drainage systems with gravity flow. Due to low rainfall intensities and gentle slope of the lands, surface drainage and protection of project works from storm runoff is not a significant problem. Since permeability rates generally increase with depth over the project area, deep percolation losses from irrigation, and low to moderate seepage losses from the canals, laterals, and farm ditches, are largely influenced by infiltration rates into and through the upper soil zone. Topography, irrigation practices, and distribution system operation and maintenance also affect deep percolation and seepage losses.

Field infiltration tests conducted over the area to determine moisture penetration rates into and through the upper soil zones gave rates ranging from 0.2 to 4.0 centimeters (.08 to 1.57 inches) per hour, averaging approximately 1.0 cm/m. (0.39 inches per hour). Laboratory permeability rates have averaged two-thirds the field rates. Observations of farm irrigation have showed that infiltration rates and lateral movement of moisture are low to moderate. Over large areas of the project, irrigation water will have to be ponded to ensure sufficient infiltration to saturate the crop root zone and accomplish leaching.

**Lateral Drainage.** The principal factors affecting spacing, location and cost of lateral drains have been considered as depth of drain, depth of drainage barrier, permeability of various strata down to the drainage barrier, and groundwater additions. Since consideration has been given to open lateral drains, the spacing of these drains is in turn influenced by the general layout and farm unit boundaries and sub-lateral canals. Considering the characteristics of the drainage aquifer and other factors, it has been determined that lateral drains dug 2.5 meters (eight feet) deep and spaced 500 to 1,500 meters (1,640 to 4,920 feet) apart will provide adequate drainage protection by keeping the water table more than 1.5 meters (five feet) below the ground surface. Where existing and proposed outlet drains provide adequate drainage relief there will be no requirement for lateral drains. The water from the lateral drains will be discharged by gravity into the river through the present main outlet drain system.

### *Potential Soil Conditions*

Because of the prevailing favorable drainability characteristics of the project lands, and since the project plan of development provides for construction and maintenance of the necessary drainage facilities and provision of ample quantities of good quality irrigation water, no significant additional salinity or alkalinity problems are anticipated following project development. Furthermore, it is anticipated that most of the lands classed as arable now affected by salinity and alkalinity can be effectively and economically reclaimed to Class 1, or near Class

1, productivity levels. Where soluble salt excesses constitute the only inhibiting factor, lands classed as arable can be reclaimed by leaching. The great majority of the lands placed in Class 2 because of moderate exchangeable sodium concentrates can be reclaimed by use of green manures, crop residues, animal manures, and leaching. The more severely affected sodic soils that were included in the arable lands as sub-class 5sa, measuring about 7,140 acres, will, in addition to these treatment measures, require moderate applications of gypsum to achieve full reclamation within a reasonable leagth of time. Gypsum is available locally in ample quantities to meet project needs in the form of "gotch" averaging 60 to 70 percent gypsum content. The gypsum requirement varies from four to 20 tons per acre of equivalent pure gypsum, depending on the sodic affectation of a particular area. In areas under sub-class 5sa, four to six tons per acre are required in light to medium texture areas, and six to 10 tons in medium to fine textured areas. Heavily affected subclass 6sa will require 15 to 20 tons per acre.

It is also hoped that by use of the results of research conducted for several years, the deficiencies in the levels of soil fertility and absorbed phosphates, ranging up to 400 to 500 pounds per acre, and low levels of iron and zinc, could be overcome as part of the project development or subsequently through agricultural credit programs.

## *General Project Layout*

The narrower strip of North Shamalan lands follows a north-south direction, and the widerspread West Shamalan lands are oriented in a northwesterly direction. Ground surface and underground water slopes are parallel to the river valley course but not toward it.

Drainage requirements are not as heavy in the narrow north section as in the wider west section area. In the West Shamalan area the best drainage system alignment that will cut the underground water movement and have favorable channel slopes is in a north-south direction. Furthermore, the lateral drainage requirement of the area averages about 1,000 meters spacing, and is a controlling factor influencing the irrigation lateral spacing. Therefore, the kilometer lateral drainage and irrigation system spacing in the north-south direction meets drainage and irrigation requirements, it has favorable drainage and irrigation channel flow characteristics and fits in with our present horizontal control, kilometer square grid system. This layout has the added advantage of lending itself to suitable farm orientation and the ease of farm and land ownership boundary descriptions (see map No. 3).

With this plan of the general layout the lateral drainage discharge will be carried to the river through the present main collector drains. The irrigation water requirement will be brought in through a feeder branch canal following the contour of the escarp to the west of the project lands. This position of the branch canal will minimize project construction and operation and maintenance costs.

Necessary roads for access into the farmland and operation and maintenance of the system are planned on the side of the lateral canal following a north-south direction and on the main branch canal. Also an east-west lateral road system is provided at two-kilometer intervals. A main project access road is planned at the top of the escarp to the west of the project lands.

## *Project Farm Layout*

A typical two-by-one kilometer farm layout can be seen on map No. 3. This type of a farm layout is not only compatable with the requirements of the general layout but also with farm unit sizes considered to be economically feasible in the long run. Economic studies have indicated that an economic farm unit should consist of around 24 acres of irrigable land.

The lateral irrigation ditch will deliver water through farm turnouts and farm ditches to each farm unit independently. Water will be delivered to the field or borders by small turnouts from the farm ditches. Four farmsteads are positioned back to back to economize in the costs of entrance roads and domestic wells, or some other means of clean drinking water supply, and future power supply. Thus, one domestic well will serve four rather than only one, farmstead. Presently the people are drinking irrigation ditch water. Each farmstead is adjacent to the farm land, making farm management and operation more efficient and reducing costs of production. This will simplify commutation and transport problems to and from the village and the farm.

The roads on the side of the irrigation laterals and the two-kilometer interval east-west roads will provide enough coverage so that no place in the farm is more than 500 meters away from a main road.

This typical layout, or another variation of it, could be adapted to larger or smaller farm units.

The layout will also facilitate land descriptions. Each kilometer would be designated by the number of the coordinates of the northeast corner of the kilometer. Thus a square kilometer where the coordinates of the northeast corner are West 31 and South 45 would be noted as kilometer 31-45. A farm unit would consist of one-half of a quarter kilometer square, so the land description for a farm could be written as the east one-half of the northeast one-quarter of kilometer 31-45.

A typical kilometer intersection is shown as map No. 4.

### *Land Ownership*

The project development plans as outlined in the previous pages offers a unique opportunity to remedy some of the critical land ownership problems and difficulties, namely: fragmentation, unsettled joint ownership and odd sizes and shapes of land parcels. It is planned that a specially appointed high power committee will review each owner's latest ownership tax forms and on the basis of the latest cadastral survey (1968) performed in Shamalan, arrive at the total consolidated area of land ownership. A specially appointed mobile court will be made available to work in coordination with the special committee to make final settlements of joint ownerships and possible disputes among claimants, and award the seal of approval for the ownership deeds and titles to the final consolidated areas.

The principle of economic farm sizes has been accepted and it is planned that ways and measures of preventing further fragmentation of farm sizes should be sought and adopted.

The acquisition of deeds and titles by the owners will free the economic processes of sale and purchase of the land, and with the added incentives for higher agricultural production and farm income, it is hoped that more economic farm unit sizes will prevail.

The processes of higher economic returns from the land may further be enhanced by the establishment of credit cooperatives and other institutional facilities.

## WORK PLANS

Following investigative and feasibility studies in the Shamalan unit and the approval of the Land Development project completion in the area, detailed work plans, programs and schedules are being prepared to implement the project. The project development is planned to start first in the West Shamalan area for the first two years, after which the land betterment program of the North, South and East Shamalan areas will be accomplished during the third through the fifth years of the project.

Most of the lands in the Shamalan project are owned by the people of this area, hence the efficient development and success of the project would greatly depend on the full understanding and cooperation of the people — the owners and farmers whose lands are to be improved. Necessary plans have been developed to publicize the project and negotiations are currently underway to get the development work started as soon as possible.

Detailed topographic and engineering surveys have been conducted in the project area. The cadastral ownership surveys have been completed for most of the project. A census of people, livestock and property has also been started. The engineering designs, plans and specifications for the first several kilometers of the main branch canal have been completed and necessary work is underway to finish designs of the first section of the canal and some land development, lateral irrigation and drainage facilities. It is planned that after completion of the first section of the branch canal, the development of the land, irrigation, drainage and land leveling, if necessary, of the project area be continued in such a way that small units of land will be thoroughly completed and be ready for recultivation in less than about six months time. To accomplish this the construction units will be laid out according to the general layout plans in small sections to make possible complete unit development in a period of three to four months, after which the farmers will occupy their land and start cultivation.

Necessary plans have been prepared to help farmers resettle on their land and start farming their consolidated property.

Present plans call for compensation to the farmers on the loss of crops and other property that may be unavoidable due to special project construction conditions. Special care will be taken to avoid damage to permanent buildings and villages and established orchards in the area; however, these are not very extensive or large in number.

Special consideration will be given to farmers whose lands are under construction for food, health and sanitation programs, transportation, housing, employment and government land lease opportunities. People whose lands are under construction will be exempted from operation and maintenance and land taxes for that year.

Necessary legislation and amendments to existing laws have been proposed and are now under consideration by the parliament to make possible the consolidation of fragmented land holdings, project period tax exemptions, compensation for loss of crops and property during project development construction, project development cost repayments and project operation and maintenance charges.

In preparation of all the above mentioned plans and measures, one of the most important factors considered has been the farmer and his land. All efforts have been directed toward creating the necessary infrastructure and the means to help him produce the maximum returns and benefits from his land and property leading to the achievement of a higher standard of living for the nation as a whole.

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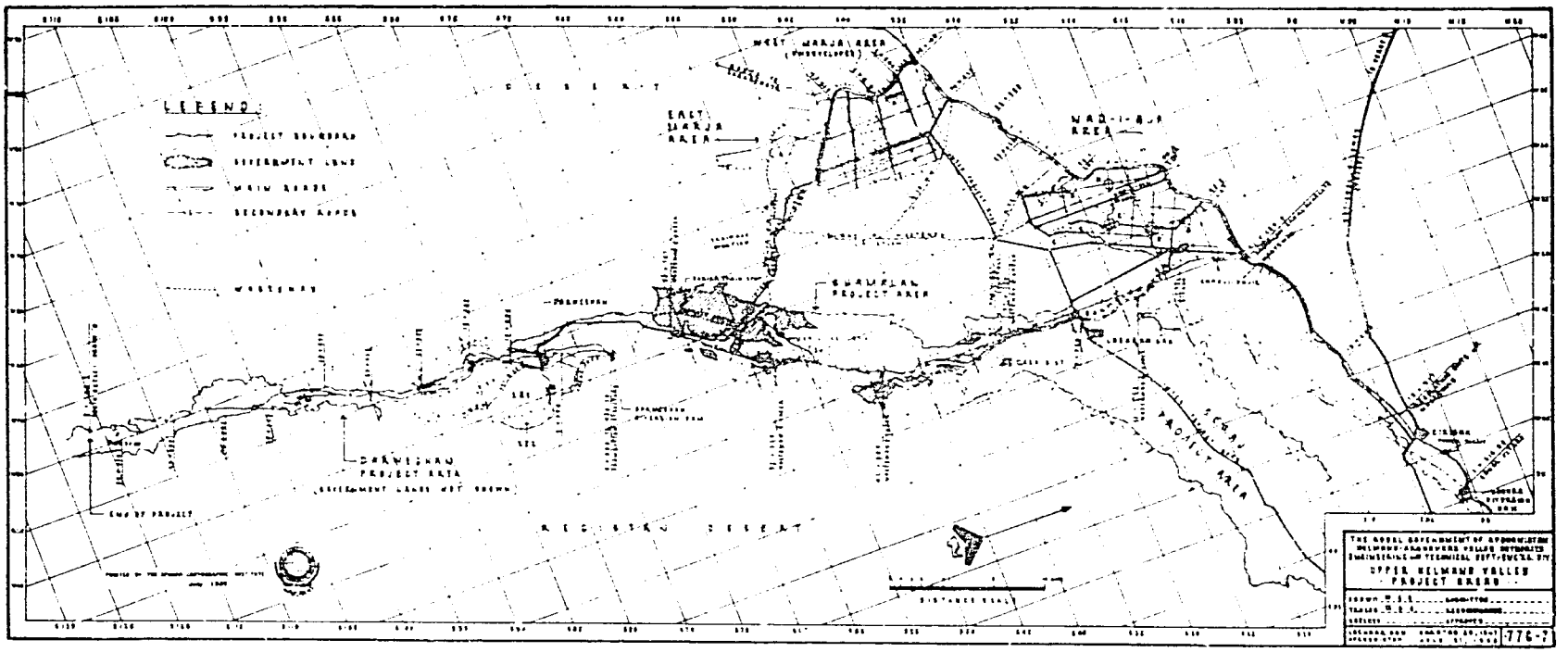
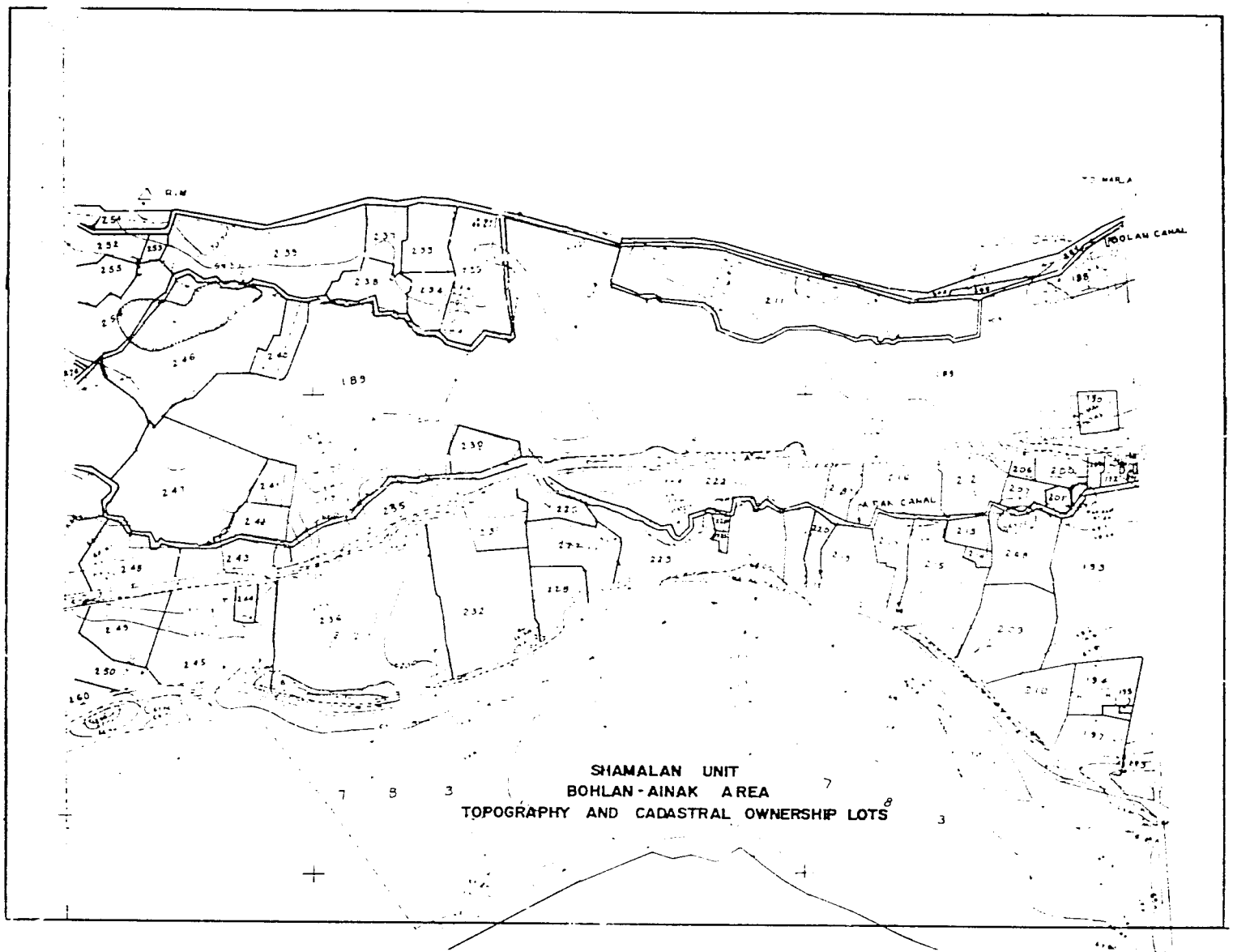
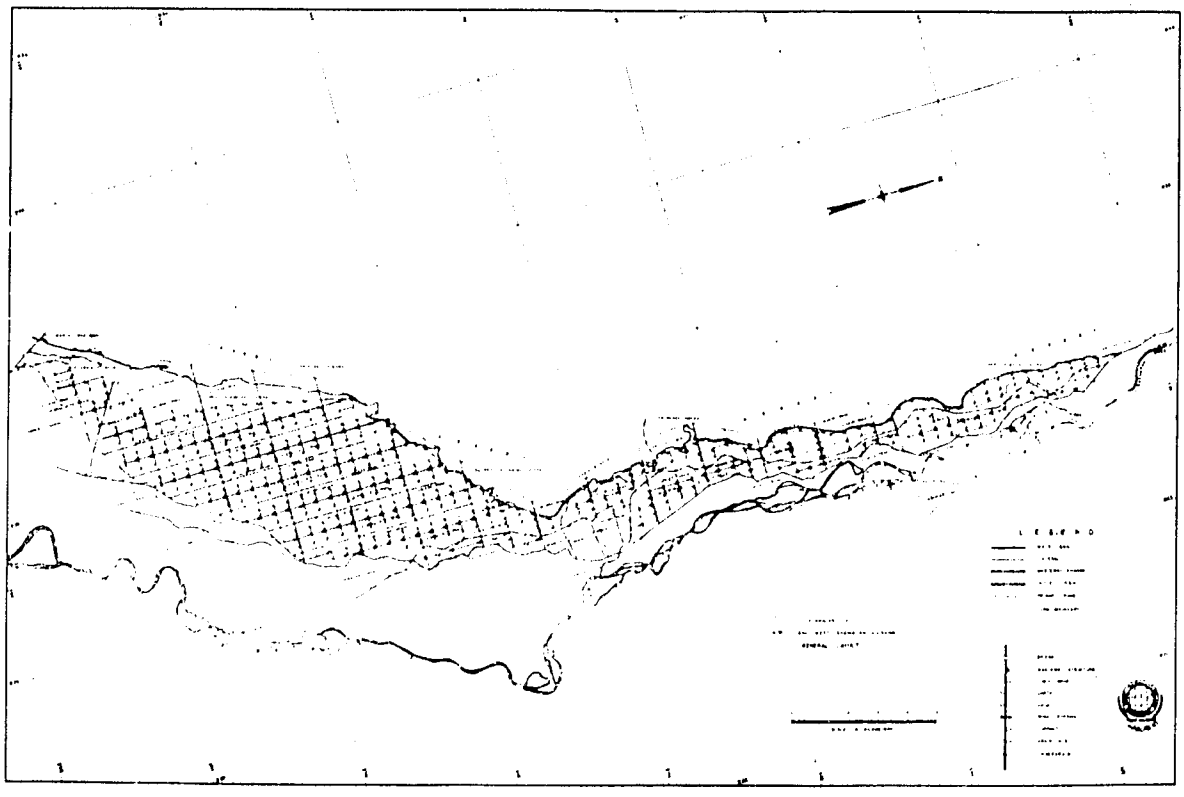
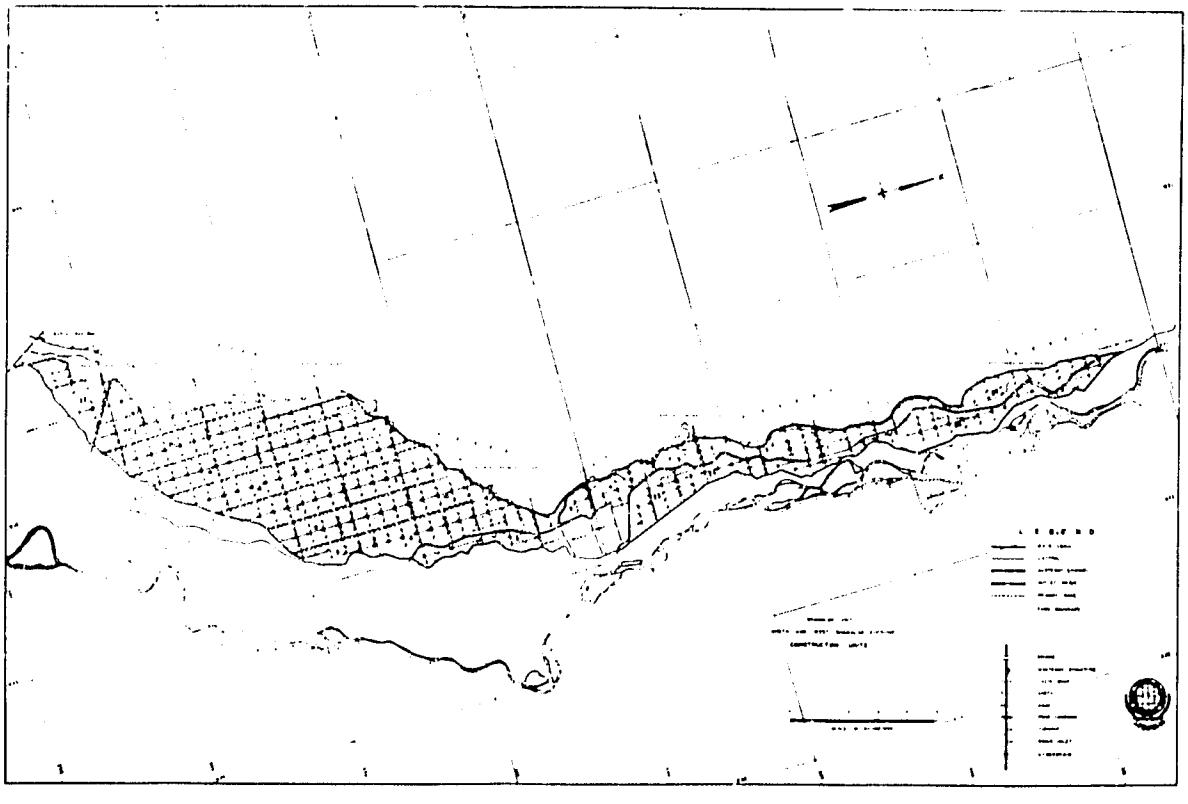
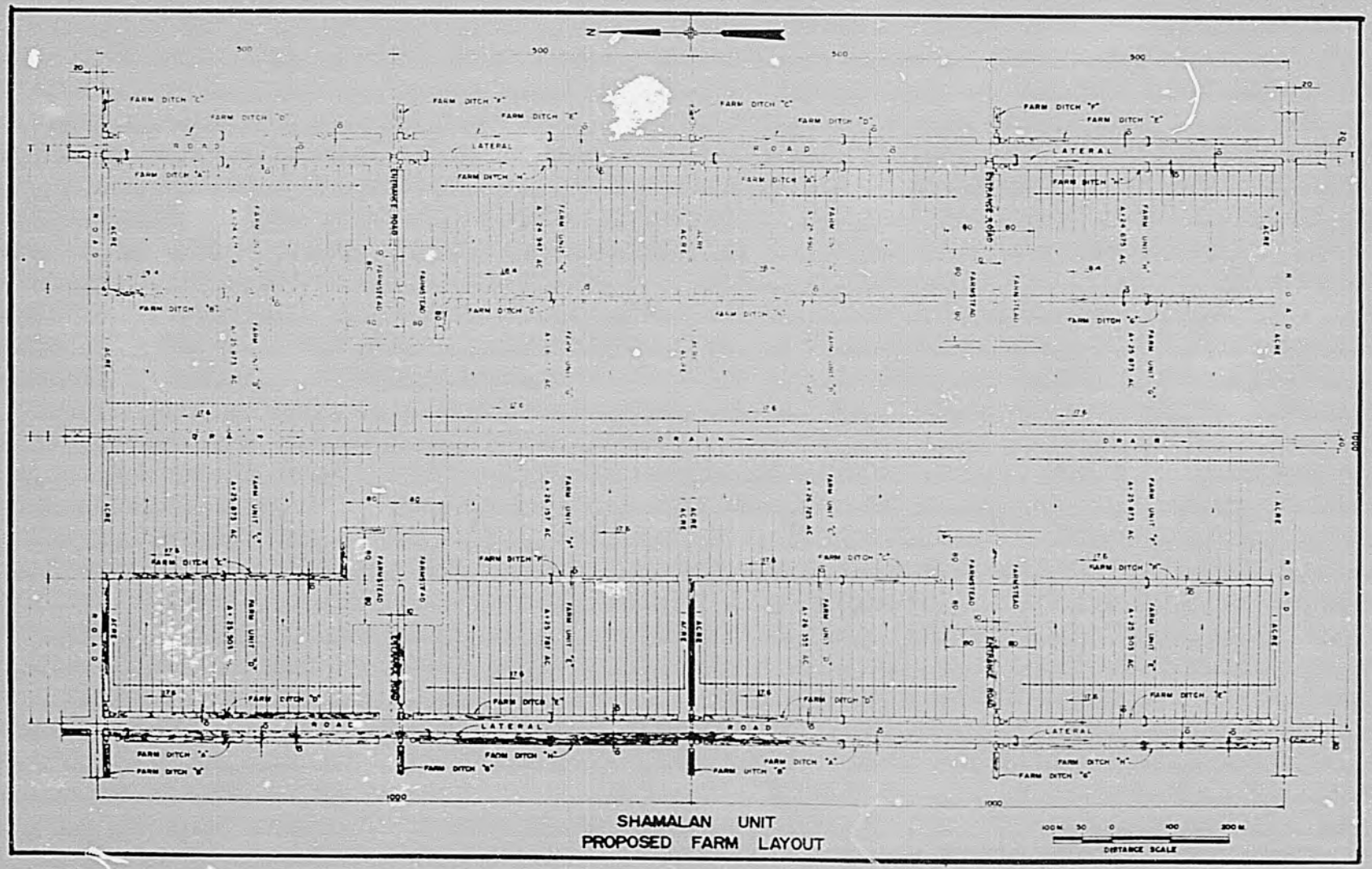

LEGEND
UPPER HELMAND VALLEY
PROJECT AREAS
776-7



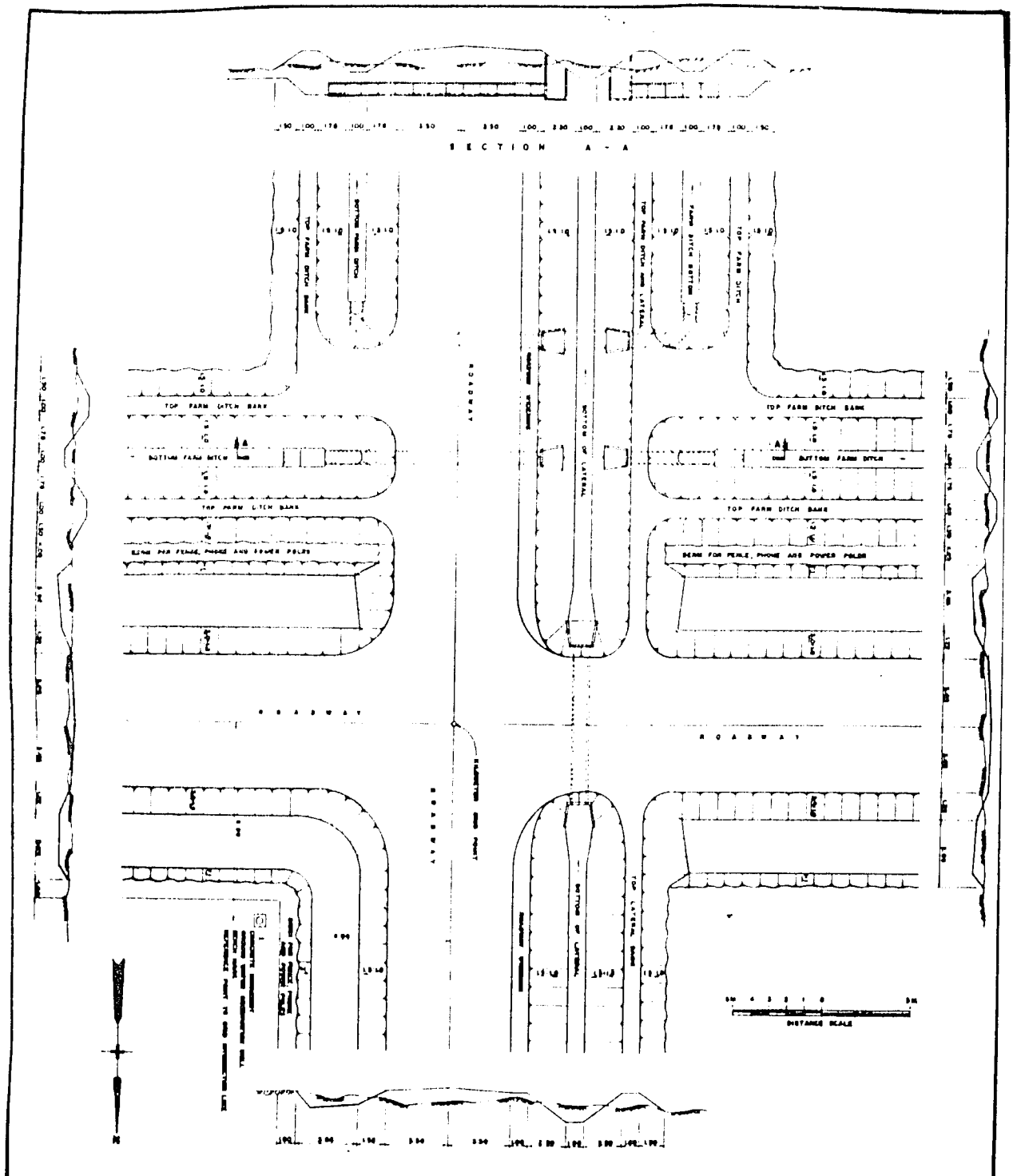

SHAMALAN UNIT
BOHLAN - AINAK AREA
TOPOGRAPHY AND CADASTRAL OWNERSHIP LOTS








SHAMALAN UNIT
PROPOSED FARM LAYOUT




SHAMALAN UNIT

TYPICAL KILOMETER INTERSECTION

## AFGHANISTAN

# CONTRIBUTION OF $CaCo_3$ IN SOME IRRIGATION WATERS TO SOIL DETERIORATION

by

**M. Z. Salem, PhD***

## ABSTRACT

Some irrigation waters used in Afghanistan tend to precipitate $CaCO_3$ in the soil. This precipitation has modified soil physical, chemical, and mineralogical properties which contribute to soil deterioration. Evidences are presented to illustrate such modifications.

## INTRODUCTION

Various amounts of calcium carbonate precipitates in the soil from waters containing appreciable concentrations of $HCO_3$ and Ca ions according to the equation:

$$2HCO_3 + Ca \longrightarrow CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

The precipitation is a direct function of the actual pH of the water (Bower et al., 1965), $Pco_2$ and the rate of evapotranspiration for a given soil province. Langlier (1936) has devised a water saturation index that indicates precipitation (+value) or dissolution (-value) of calcium carbonate as the water passes through the soil or a calcareous medium:

$$\text{Saturation index} = pHa - pHc$$

where pHa is the actual measured pH and pHc is the calculated pH that the water may have when it is in equilibrium with calcium carbonate. The pHc values can be calculated by Langlier's equation:

$$pHc = (pK_2 - pKc) + pCa + pAlk$$

where $pK_2$ and pKc are the negative log of the second dissociation constant for $H_2CO_3$ and the solubility constant of $CaCO_3$, respectively; pCa and pAlk are the negative log of the molal concentration of Ca and equivalent concentration of titratable base ($CO_3$ + $HCO_3$), respectively.

Water hardness for domestic uses is a well known problem in arid regions and where water passes through limestone, dolomite, or other calcareous rock beds. Mistakenly, in irrigation agriculture water hardness has not been considered a problem. The purpose of this paper is to show the importance of water hardness as it modifies soil chemical,

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physical, and mineralogical properties which lead to soil deterioration.

## METHODS

Soil samples were collected from various parts of Afghanistan (Figure 1) of which undisturbed clods (natural peds) were examined under a binocular microscope and pedological features were described, using Brewer's terms (1964). Following the method described by Buol and Eadness (1961), undisturbed soil cores and whole features were used for thin section preparation. After identification of pedo features, high speed Ektochrome and black and white films were employed to prepare photomicrographs through a petrographic microscope. Calcium carbonate was determined by Leo's gasometric method (1963); iron and silicon by methods of Jackson (1956); aluminum by ferron procedure of Ramwater and Thatcher (1960); and gypsum by the acetone precipitation method of the U.S. Salinity Laboratory Staff (1954). Saturation indices for irrigation waters collected in the Kabul basin were calculated from data of Bower, et al. (1965). Particle size distribution was determined by decantation and centrifugation methods of Jackson (1956).

## RESULTS AND DISCUSSION

Table 1 shows the saturation indices of irrigation waters from rivers, karazes (ganat), and wells in the Kabul basin. They are all positive and thus precipitate $CaCO_3$ to the soil. Most irrigation waters in Afghanistan fall into this category. When waters reach soil depths (especially where roots are dense) they are concentrated with respect to their solutes as the plants withdraw water and thus $CaCO_3$ precipitation is further enhanced. Precipitation of $CaCO_3$ in the soil contributes to the formation of pedological features such as tubules, tubes, nodules, calcans, etc. All of these features have been seen and described for some soils of Afghanistan (see Salem, 1969). Table 2 shows the composition of some pedo-features and their host horizons. In the development and evolution of these features, $CaCO_3$ has had a major role. This is evidenced by the higher $CaCO_3$ contents of the feature than their host horizons. In most soils, other pedo-cements such as gypsum, silica, iron, and aluminum have a secondary role in the formation of the features.

The loci of precipitation in a soil are voids (pore spaces) in their surfaces. In the soils studied, as a general rule, root channels were very important for $CaCO_3$ precipitation because the features observed either were formed in the channels (Figure 2) or were closely related to some water conducting voids, Figure 3. Figure 4 is a pedotube photograph which has formed around an alfalfa tap root in the formation of which $CaCO_3$ has had a leading role (Salem, 1969).

Diffused precipitation of $CaCO_3$ in soil plasma occludes fine clay particles or coats their reactive surfaces and hence reduces cation exchange capacity, a very important soil chemical property. In a recent study, Salem (1969) removed carbonates of silt fraction of some Afghan soils from which were released significant amounts of clay which were mineralogically similar to the clay fraction of the same soils. It is therefore concluded that precipitation of $CaCO_3$ also affects soil particle size distribution by increasing the size of the smaller particles. Calcium carbonate precipitation decreases the release of plant nutrients due to weathering in the soil, either by protecting the surfaces of easily weatherable minerals or through its effect on soil pH.

When solid $CaCO_3$ is in equilibrium with soil solution, it stabilizes its pH at a value of about eight. At this pH, availabilities of P, Fe, Mn, B, Cu, and Zn are at their minimum.

Permeability of soil to air and water is decreased by $CaCO_3$ precipitation on the walls of conducting channels which are constricted (Figure 2) and eventually plugged, Figures 5A and 5B. It is possible, however, that soil permeability is enhanced by the development of large pedotubes (Figure 4) around plant tap roots. After the roots decompose, these tubes may serve as large conducting channels for a few growing seasons, depending on the degree of their development. Calcium carbonate accumulation in the soil is a major contributor to the caliche (petrocalcic horizon) development which often is a serious permeability and drainage problem leading to the evolution of saline and sodic soils.

In view of the above discussion it seems highly advantageous that control of $CaCO_3$ precipitation from irrigation waters should be included in the general soil and water management schemes. It appears logical that leaching requirements for salinity

control should contain a factor for the control of $CaCO_3$ precipitation. To avoid soil drying (loss of water from the soil through evapotranspiration) which results in precipitation of $CaCO_3$, frequent irrigation may be practiced. Another possibility to improve deteriorated permeability is to rotate crops with large penetrating tap roots such as alfalfa, clover, cotton, etc. These roots may form temporary conducting channels which can facilitate infiltration.

## SUMMARY

Irrigation water samples were analyzed and tested for their tendency to precipitate $CaCO_3$ in the soil. Soil samples were pedographically described, using undisturbed peds and thin sections. It is concluded that $CaCO_3$ precipitation from waters (in the soil) affects soil chemical, physical and mineralogical properties leading to soil deterioration. It is recommended that $CaCO_3$ precipitation from irrigation waters should be regulated through soil and water management schemes.

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**Table 1: Calculation of pHc and Saturation Index of Irrigation Waters Used in the Kabul Basin**

| Source of Irrigation Water | Total Cations, meq/l | $p(k_2-kc)$ | pCa | pAlk | pHa | pHc | (Sat. Index) pHa-pHc |
|---|---|---|---|---|---|---|---|
| Lalandar River | 5.5 | 2.23 | 2.56 | 2.24 | 8.30 | 7.03 | +1.27 |
| Chamchamast River | 12.3 | 2.28 | 2.20 | 1.88 | 8.10 | 6.36 | +1.74 |
| Jui Shir Canal | 13.1 | 2.29 | 2.17 | 1.85 | 7.80 | 6.31 | +1.49 |
| Gozargah River | 13.6 | 2.30 | 2.18 | 1.84 | 7.80 | 6.32 | +1.48 |
| Chamchamast River | | | | | | | |
| Nov. 18, 1963 | 6.3 | 2.23 | 2.50 | 2.19 | 8.30 | 7.92 | +0.38 |
| Nov. 25, 1963 | 5.75 | 2.23 | 2.55 | 2.23 | 8.20 | 7.01 | +1.19 |
| Dec. 5, 1963 | 5.4 | 2.21 | 2.56 | 2.25 | 8.40 | 7.93 | +0.47 |
| Dec. 11, 1963 | 5.2 | 2.22 | 2.59 | 2.27 | 8.10 | 7.08 | +1.02 |
| Dec. 17, 1963 | 5.3 | 2.22 | 2.57 | 2.26 | 8.30 | 7.05 | +1.25 |
| Dec. 23, 1963 | 5.15 | 2.22 | 2.59 | 2.27 | 8.50 | 7.08 | +1.42 |
| Najarkhana well | 7.9 | 2.24 | 2.40 | 2.10 | 7.20 | 6.74 | +0.46 |
| Ali Abad well | 15.3 | 2.23 | 2.11 | 1.80 | 7.50 | 6.24 | +1.26 |
| Faculty of Agr. well | 16.5 | 2.25 | 2.08 | 1.77 | 7.30 | 6.15 | +1.25 |
| Jamal Mayna well | 6.0 | 2.23 | 2.52 | 2.72 | 7.70 | 6.97 | +0.73 |
| Ali Abad well | 8.0 | 2.25 | 2.40 | 2.10 | 7.40 | 6.75 | +0.75 |
| Ministry of Agr. well | 8.0 | 2.25 | 2.40 | 2.10 | 7.60 | 6.75 | +0.85 |
| Ali Abad karaze (qanat) | 7.0 | 2.28 | 2.45 | 2.13 | 7.50 | 6.86 | +0.64 |
| Dehbori karaze | 7.0 | 2.28 | 2.45 | 2.13 | 7.50 | 6.86 | +0.64 |
| S. Jamaludin karaze | 8.0 | 2.25 | 2.40 | 2.10 | 7.70 | 6.75 | +0.95 |
| Ali Abad karaze | 15.5 | 2.32 | 2.08 | 1.78 | 7.50 | 6.18 | +1.32 |
| Hypothetical well | 50.0 | 2.42 | 1.60 | 1.30 | 8.50 | 5.37 | +3.23 |
| Hyp. snow water | 0.1 | 2.08 | 4.30 | 4.00 | 7.20 | 10.38 | - 3.18 |
| Water + $CaCO_3$ | 0.28 | 2.09 | 3.90 | 3.50 | 8.80 | 9.49 | - 0.69 |

**Table 2: Composition of Some Pedological Features and Their Host Horizons in Soils of Afghanistan**

| Horizon and Feature | Particle Size Distribution (mm) >2 Gravel | 2-0.05 Sand | 0.05-0.002 Silt | < 0.002 Clay | Cementing Agent $CaCO_3$ | $Fe_2O_3$ | $Al_2O_3$ | $SiO_2$ | Gypsum |
|---|---|---|---|---|---|---|---|---|---|
| Kabul loam (Desert soil) | | | | | | | | | |
| B32 | 26.4 | 18.4 | 45.0 | 9.2 | 13.3 | 0.52 | 0.50 | 0.58 | 0.0 |
| Nodule | trace | 16.0 | 28.0 | 1.0 | 54.4 | 0.53 | 0.54 | 0.48 | 0.0 |
| IIIC3 | 16.9 | 47.4 | 28.9 | 6.0 | 10.5 | 0.49 | 0.47 | 0.58 | 0.0 |
| Tubule | tr | 34.0 | 19.6 | 4.0 | 40.0 | 2.29 | 0.59 | 0.75 | 0.0 |
| Nadi Ali sil (Desert soil) | | | | | | | | | |
| IIB21 | 28.8 | 39.3 | 15.1 | 15.2 | 18.9 | 0.72 | 0.52 | 0.82 | 0.0 |
| Nodule | tr | 35.6 | 12.6 | 9.0 | 40.6 | 0.76 | 0.64 | 0.82 | 0.0 |
| IIIB3 | 8.8 | 62.2 | 12.2 | 15.1 | 8.4 | 0.64 | 0.54 | 0.69 | 2.8 |
| IVCcam (caliche) | tr | 6.7 | 2.6 | 4.4 | 84.8 | 0.34 | 0.52 | 0.69 | 0.0 |
| Bost gsl (Desert soil) | | | | | | | | | |
| IIC1 | 1.9 | 51.4 | 28.7 | 15.7 | 27.0 | 0.19 | 0.52 | 0.30 | 4.5 |
| Nodule | tr | 2.4 | 3.4 | 1.0 | 0.0 | 0.0 | 0.23 | 0.41 | 92.6 |
| IIC4 | 35.8 | 36.9 | 12.3 | 10.0 | 28.6 | 0.44 | 0.47 | 0.41 | 1.7 |
| Nodule | tr | 34.0 | 13.4 | 0.5 | 0.0 | 0.0 | 0.52 | 0.58 | 51.0 |
| Pozay Aishan sil (Humic gley) | | | | | | | | | |
| B3 | 2.6 | 39.2 | 44.2 | 12.4 | 8.5 | 0.75 | 0.52 | 0.48 | 0.0 |
| Tube | tr | 28.7 | 23.9 | 3.5 | 42.6 | 1.32 | - | - | 0.0 |
| Clg | 1.8 | 30.6 | 57.9 | 8.8 | 18.0 | 3.26 | 0.59 | 1.37 | 0.0 |
| Tube | tr | 20.2 | 30.8 | 25.0 | 22.5 | 1.51 | - | - | 0.0 |

Fig. 1

SOILS AND PHYSIOGRAPHY OF AFGHANISTAN

Generalized map, provisional

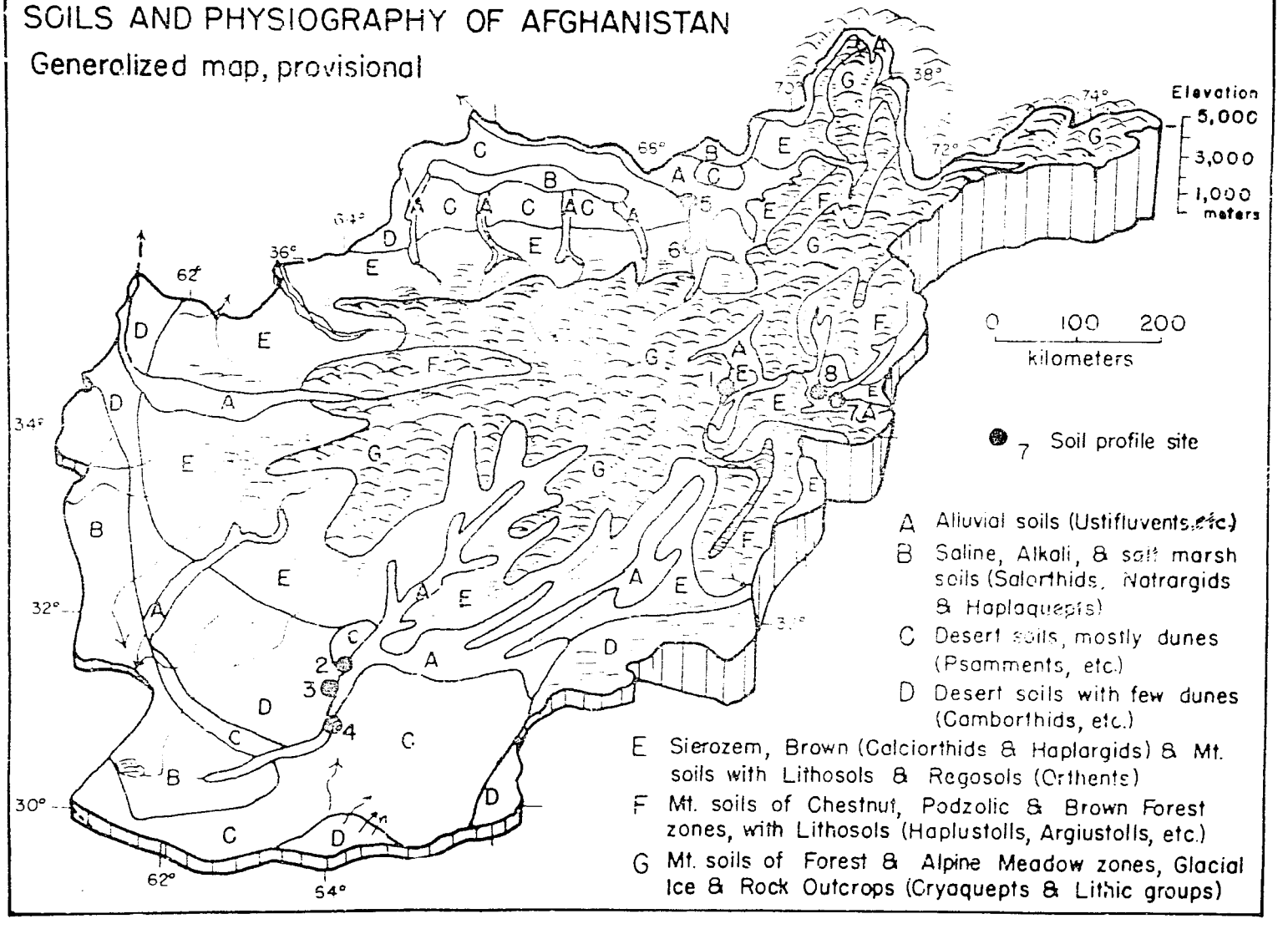


Fig. 2. Photomicrograph showing (arrows) cross section of channels where $CaCO_3$ has precipitated. Kabul pedon, IIC2 horizon.

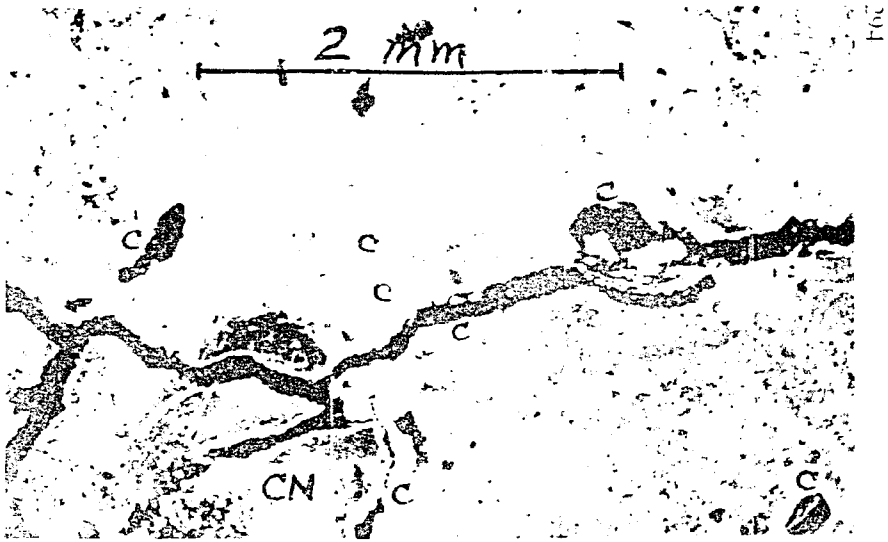



Fig. 3. Photomicrograph showing relation of a calcareous nodule (CN) and calcans (C)--$CaCO_3$ coatings--to a water conducting channel in the B3t horizon of Alchin pedon.

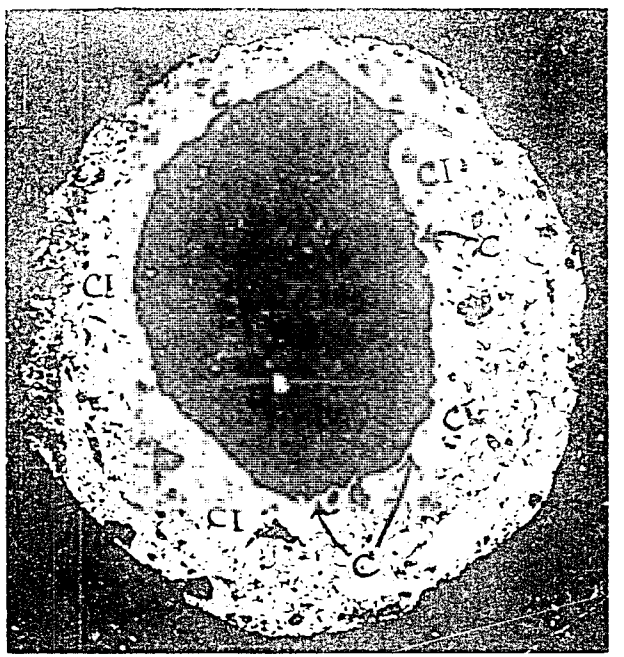
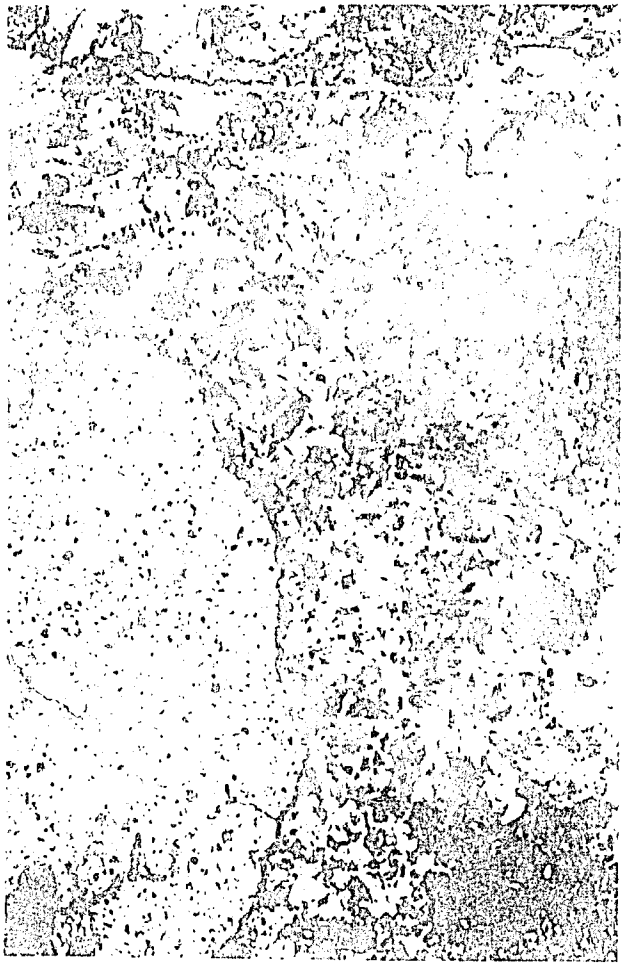



Fig. 4. Cross section of a pedotube showing the $CaCO_3$ impregnated (CI) and calcan (C) portions of its rigid wall. Negative print, 4X, Kabul pedon.

A

Thin section of large channels, up to 2 cm, lower left hand corner and 0.6 cm upper right hand corner. Nadi Ali, IIB3, 4X.



B

Of a channel 2 mm in diameter only 0.15 mm opening or lumen (L) is left. $CaCO_3$ precipitation has practically plugged the channel

Fig. 5. Photomicrographs showing channels which are "choked" by $CaCO_3$ precipitation and only a small lumen (L) has survived in each case.

# INDIA

## SYSTEMS ANALYSIS APPROACH TO OPTIMUM USE OF IRRIGATION WATER

by

**N. D. Rege***

India has developed and is further developing water potential to meet the ever increasing demand for use in irrigated agriculture, industry, human consumption and so on. As the pressure increases on water availability for different purposes it becomes imperative to make the best use of irrigation water through efficient water management.

### PROBLEMS IN IRRIGATED AGRICULTURE

In planning for irrigated agriculture, one is confronted with a number of intricate and interdependent questions. Some of these are:

(1) Whether intensive or extensive irrigation is more desirable.

(2) Whether emphasis should be on protective or productive irrigation.

(3) How will the soils respond to different doses of water and time of application?

(4) How best to save the water which otherwise goes to waste through seepage, deep percolation, etc.?

(5) Will it be economical to line the distributory system, and if so, what type of lining?

(6) Given certain irrigation facilities in different areas, what changes in irrigation intensities are desirable, keeping in view the costs and benefits?

(7) To what extent is "timely irrigation" possible under the present system of water distribution and, if necessary, how to improve it?

(8) What water control measures are necessary for improving water management of individual farms?

(9) What are nutrient requirements for the area and whether through manipulation of crop pattern and water application and increased/decreased dose of water/nutrient one can get the same yield?

In addition to numerous questions, including those noted above, the soil and water management (irrigated agriculture) program involves a number of side issues equally important in successful implementation of the program. These pertain to a variety of policy decisions — legal or otherwise — to be taken at different levels of authority — local, state and national levels. Similarly, there may be some other

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possibilities, such as availability of groundwater and its use in combination with surface water, which involve a number of policy decisions.

With the introduction of high yielding varieties to meet an ever growing demand for food, additional burden has been placed on the decision-making agencies — scientists and administrators. To achieve high yields it is necessary to make the best of the available resources such as water, soil, fertilizers, labor and the like, and to modify the present system of meeting these requirements. It is well known that in this new strategy, the emphasis is on adequate and timely supply of inputs. It is, therefore, important that in arriving at a decision, all the important possibilities and combinations be taken into account while making an effort to increase the yields.

To optimize the benefits of irrigation water one has to take into consideration all the ingredients necessary in increasing the yields of crops, then individual performance and interactions and then collective contribution toward achieving the goal. This means that a thorough and detailed study has to be undertaken to evaluate the role of each parameter singly and in combination through systematic analysis. There are a number of ways one can do this. Some are extremely complex, some time-consuming, and some relatively simple but quite accurate. One such method is the application of the principle of systems analysis through construction of a mathematical model and to establish its utility and practicability in agricultural program planning.

Systems analysis with computer is, therefore, no more and no less than an attempt to eliminate less important or less useful possibilities or alternatives more quickly and efficiently than can be achieved through human judgment.

Realizing the complexity of the generalized problem of the optimization of soil and water management (irrigated agriculture) in India, an attempt has been made by the joint Indian-American team in 1969 to analyze this problem in a comprehensive manner. This study was made primarily to illustrate the potentiality of using the modern techniques of optimization for more effective use of irrigation for agricultural development.

The team, during the discussion, identified six major problems facing soil and water management programs in India. These are:

(1) The optimum timing and the amount of water for individual crops.

(2) The optimum distribution of a given volume of water among crops and as between different stages of growth of individual crops.

(3) The effect on output of departing from the optimum solution for areas irrigated under items 1 and 2.

(4) The "break even" point for use of high yielding varieties under irrigated and non-irrigated conditions (when the change from local to high yielding varieties is justified).

(5) Allocation and scheduling of water with varying degrees of assurance.

(6) The question of the relative intensiveness of irrigation water use.

To study these problems in depth, it was observed, would need a considerable amount of accurate and reliable data on soils, crops, water availability and the like. After taking into consideration the data made available for a number of districts, it was decided that the study be confined to three districts: Ferozepur (Punjab), Cuttack (Orissa) and Coimbatore (Tamil Nadu). The crops studied were cotton, jowar, wheat, sugarcane, rice, maize and others. However, it was discovered that enough relevant data for even these crops did not exist. The joint study team, therefore, concluded that it was not possible to utilize the systems analysis method for any practical purpose at the present stage of our knowledge regarding crop-soil-water-fertilizer interactions.

The joint team realized that the non-availability of certain critical data has made it difficult to conduct the study as contemplated. The team emphasized that:

"The utility of any systems analysis is directly related to the reliability of the data on which it is based. In a study of the kind we are attempting, the data required in the relationship between yields and the various inputs, such as water, fertilizer, cultural practices, which are responsible for production, not only must the response to each input be determined

and reduced in the form of mathematical equations, but the interaction between the various inputs has also to be similarly determined and expressed in mathematical forms, so that these in turn may be translated into 'computer language'. The advantage of the systems analysis approach lies in the speed with which the computer can calculate the combined result of the various equations which represent any given set of circumstances governing production. The accuracy of the data and the validity of the equations used to convert them into computer language will, therefore, be the measure of the success achieved in the use of the model. Since data on the relationships of water and other inputs on yield is extremely meagre — whether in India or in any other country — the team realizes that what can be required at present is only a start in building the model which will serve as a reliable guide for maximizing overall production in due course. It is also realized that before that 'final' step can be reached, a great deal of research and experimental work will have to be done to establish the relationships on which sufficient information is not yet available. This suggests the desirability of giving a new direction and purpose to our research programs, with the object of ultimately fashioning a planning tool which can be of inestimable value in quickly — indeed, almost instantaneously — indicating possible alternative policy decisions in a given set of circumstances to soil types, water and fertilizer availability and feasible crop patterns, etc. In this context, the dangers of expecting too much from the model at this stage are apparent. The team would not like to see the future and long-range possibility of the systems analysis approach jeopardized by any immediate disappointment over its present limited application. We would, therefore, recommend that the model be tried out firstly only in situations of varying water inputs and that it then be progressively developed to cope with other inputs and situations as more and better data become available with respect to each of the major crops of India."

## CONCLUSIONS AND RECOMMENDATIONS

The main difficulty experienced while developing the model, and testing it for its usefulness, is the inadequate information on the relationship between the timings of irrigation and the corresponding crop yields. However, there was fairly good agreement between the hypothetical relationship developed based on qualitative aspects of physiological effects of soil moisture stress, and the relationship based on limited experimental data on wheat and jowar. If this model is to serve a useful purpose for other crops then it is very necessary that much more research be undertaken to study the inter-relationship between different inputs.

Some of the important suggestions made by the team are as follows:

(1) Intensive research should be conducted to study the interaction between soil types, crops, amount of water and timing of water application, rooting characteristics with relation to stage of growth, interaction between moisture and fertilizer, etc.

(2) Since the production function must be related to water available for crop use, it is necessary to have careful water measurements to permit a reasonable estimate of that portion of the water diverted into a supply stream which ultimately reaches the root zone for use by the crop. This includes evaluation of climatological factors such as evapotranspiration and effective rainfall for the lands served by the supply systems.

(3) Additional data and interpretation will have to be gathered for specific localities, concerning total and effective rainfall, reliability of water supply, present and potential yields, fertilizer practices, pest and disease control.

(4) Field tests using the model in specific areas should be conducted when the above steps are sufficiently advanced. These tests should be able to evaluate the ability of the model to predict yields obtainable from: (a) model recommendations only; (b) model recommendations amended by judgment, and (c) the customary or existing practices in the district.

(5) On the basis of sensitivity trials and field tests of the model conducted by soil scientists, agronomists, economists and irrigation engineers, a manual should be prepared which describes precisely the kinds of data and the forms in which these are to be used in the analysis of a number of specific problems facing soil and water management in India.

The manual should contain sufficient details to allow those engaged in the tasks of data collection and proceedings, including new research, to proceed without the necessity of all becoming experts in systems analysis in addition to being proficient in agricultural research or in operations and maintenance of irrigation projects.

# IRAN

## ESTIMATE OF WATER CONSUMPTION OF AGRICULTURAL CROPS THROUGHOUT IRAN

by

A. H. Sohai *

### INTRODUCTION

The correct and proper use of water resources is considered to be one of the most important problems in Iran, and the conditions involved in agricultural activities and the method of irrigation are discussed for the following reasons.

(1) Rapid population growth requires an increased farming area, changes in the system of farming, the side effect of the law of nationalization of water resources, and the methods of correct use of water.

(2) Proper implementation of the nationalization of water resources.

(3) Iran with a semi-arid climate and a scarcity of water is involved with a basic hindrance and difficulty and thus the crops are mostly produced by irrigation.

(4) Providing and using underground and surface water involve a rather high expenditure.

(5) Often, due to lack of proper irrigation practices, a considerable amount of required water is wasted.

In response to this utmost need and urgency which may be vital to the future of farming and irrigation in the country, the Agricultural Engineering department of the Ministry of Agriculture, with the cooperation of Rural Development department of the Agricultural College of Tehran University have taken some steps to overcome this very important problem. Thus, the water consumption for crops throughout Iran is estimated and computed.

### PROCEDURE

The Blaney-Criddle formula is used to study the water requirements of crops. Blaney and Criddle have taken the two following factors into consideration in their formula:

(1) Mean monthly temperature in the considered month.

(2) Monthly percentage of annual daytime hours.

*Ministry of Agriculture, Agricultural Engineering Department, Irrigation and Drainage Division.

The above mentioned formula in the English system may be written as:

$$U = KF = Kf = K\frac{t.p.}{100}$$

in which U = Consumptive use in inches

K = An empirical seasonal coefficient

$F = f = \frac{t.p}{100}$ Sum of the monthly factors (f) for the season i.e. sum of the products of mean monthly temperature t in F and (p) i.e., monthly percentage of annual daytime hours

K is a coefficient which depends upon the quality of the crop and the different stages of its growth. In the metric system it is:

$$U = KP\frac{(45.7t + 813)}{1000}$$

in which t is mean temperature in C and U in Cm.

The coefficient proposed varies with the different stages in the growth of crops, including the peak months. Use of the formula is very simple and practical.

The formula of Blaney and Criddle is considered as the most convenient formula for calculating the water consumption of crops in Iran. This formula has been found to be satisfactory for computing the seasonal water requirements of crops in the western part of the USA where the climate and the geographical conditions are very similar to Iran's. This formula has mostly been used by the Soil Conservation Service of the USDA, and it has been shown that the formula can successfully be used in most arid zones of the world.

This report includes a summary of a part of the irrigation research which has been done by the irrigation and drainage research section of the Agricultural Engineering Department on water requirements of crops in different parts of the country.

The amount of water needed (evapotranspiration) for the different crops in every region is computed. The climatic condition and the efficiency of irrigation say, 50 percent to 60 percent – are considered.

Considering the principle of farming while planting, growing and harvesting, the first stages of irrigation and the different intervals and the quantity of water in each irrigation are shown in Figures 1 and 2. These figures show a recommended plan of irrigation for different crops in every region in future years, together with the completion and performance of the irrigation tests. The suggested figures periodically will be corrected and adjusted in enforcing the relevant laws in using water.

## *Explanation of Figures*

Considering the best planting and irrigation, the starting and the end of cropping are shown in dotted lines and are scaled to 1,500 cubic meters per hectare. In the later irrigations a rate of 1,000 cubic meters per hectare is shown with full lines in the chart. The number and intervals of irrigation are also indicated, and finally the total consumptive use of water for each crop per hectare is shown in the chart.

The following points have been considered in our studies:

(1) The period of the growth of crops and thus the period of their water consumption during the time of the year when there is no frost. The water consumption for grains only have been computed for the months of Bahman and Esphand (February and March) and accordingly in Dey (December) also. In most areas in Iran in the said months, especially in the months of Dey and Bahman, frost prevails. As a result, the calculation shows that during the above mentioned months precipitation completely takes care of the water consumption of the crops. For example, the water consumption of grains during the months of Dey and Bahman in the Karaj area is 1.27-2.81 cm which is provided by the seasonal precipitation.

(2) The range of need of water for the crops is calculated on an average basis. So if there is some considerable difference in temperature or in the rate

of precipitation, undoubtly the proper adjustments must be made. For example, if in any year the climatic condition is advanced or retarded, the water consumption of the crop will start earlier or later than usual, and thus it will affect the amount of need. Therefore, the side effects must be considered. Or if in any year the precipitation is less than average, irrigation must be more frequent. Contrarily, during the growth of crops when there is a considerable amount of rain the water consumption will be less.

(3) When in a month the amount of water, either through precipitation or by irrigation, is more than the crop requirement, part of the water will be stored in the soil and that water consumption will be decreased in the coming months.

(4) At the time of sowing and germination, the water consumption is more than it appears. To maintain the germination of the seeds, a thorough irrigation must be done and this means the quantity of water used is more than will be the next irrigations, rating 1,500 cubic meters per hectare (15 centimeters depth) of additional water. Obviously, during spring planting, part of this water is stored in the soil and to a certain extent will be used during the growth of the seed. The net quantity of this part is considered to be 250 $m^3$/hectare. This is equivalant to an efficiency of 50 percent with an application of 500 $m^3$/hectare or five centimeters of depth.

The coefficient K, as mentioned earlier, depends upon the quality and stages of growth of the crop and varies from 0 to 1.3. The temperature and physiological condition of the crop affect this coefficient.

As a rule, the average value of this coefficient differs in different plants. The variation of K in relation to the relative percentage of the crop generally is formed in a parabolic shape. The attached graphic indicates the said variations. (see Figure 1.) It is difficult to determine the coefficience of K. Yet, the coefficient K is the key to the proper use of the Blaney and Criddle formula. To obtain the coefficient K, we have compared the geographical and climatic condition of Iran with some western states of the USA which are very similar and have computed the K. The climatical condition of 77 regions in the states of Utah, California, Arizona, Nebraska and Texas have been used as a means of comparison. The date of planting and harvesting of different crops and the period of their growth have been indicated through the research and studies of each region. Further, the experiments of Utah State relevant to the said activities have been followed.

Figure 1. Variation of the Empirical Coefficient K in Relation to the Stages of Growth of Various Crops

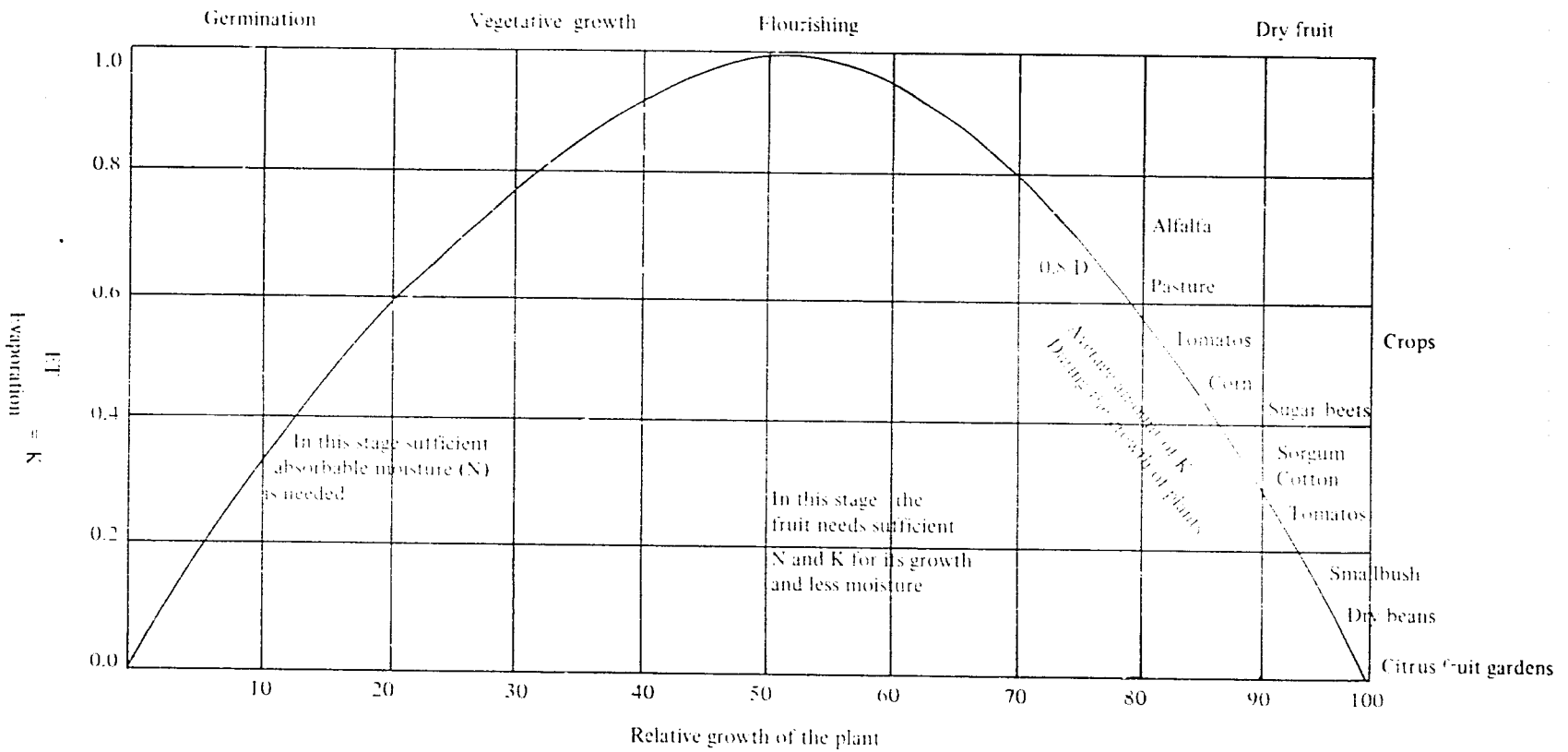
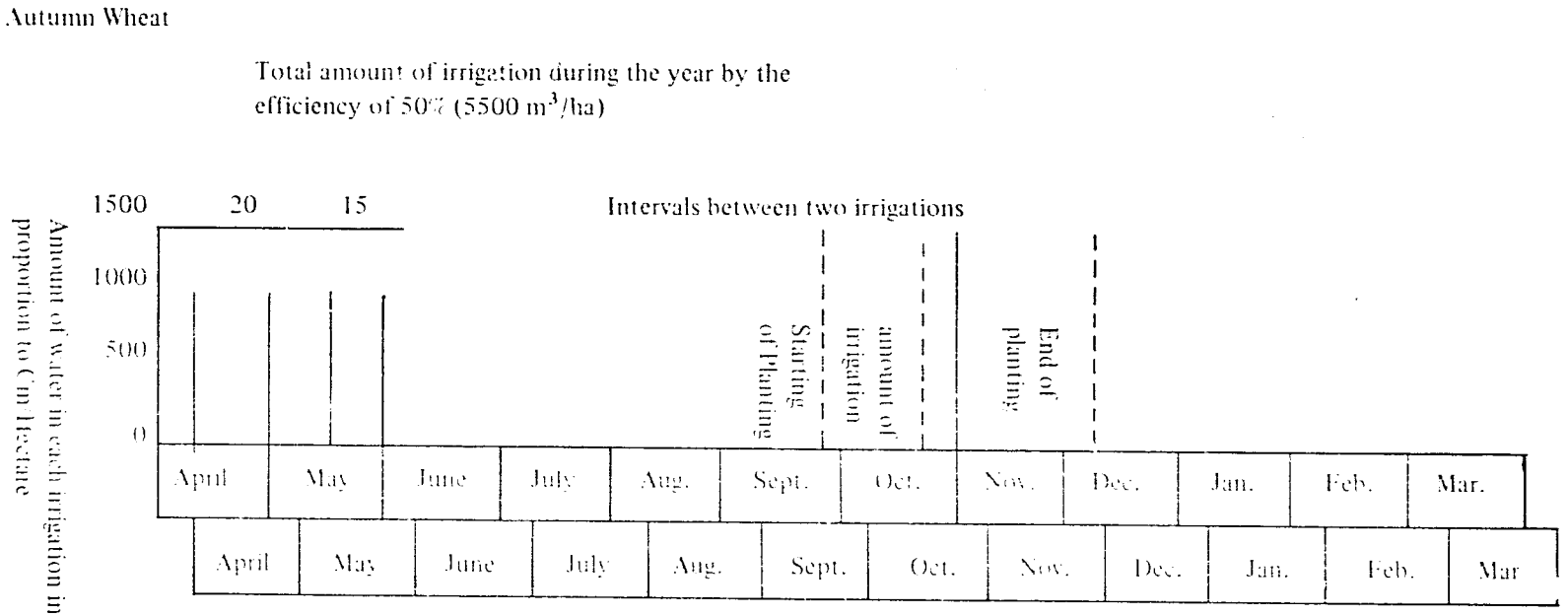


Figure 2. The Number, Intervals and Amount of Water in Each Irrigation for Autumn Wheat in Arak



## PAKISTAN

# WATER QUALITY IN RELATION TO ON-FARM WATER MANAGEMENT IN WEST PAKISTAN

by

**Ch. Mohammad Hussain**

## INTRODUCTION

The importance of irrigated agriculture is recognized all over the world. Of 3.4 billion acres of cultivated land about 800 million acres of irrigated area are enough to feed the population of the world. Nearly two-thirds of the world's population is living in diet-deficient countries. These countries depend heavily upon irrigated lands for food production. Of the total area of arable land of the world, less than half is in these countries, but they do contain about three-fourths of the total irrigated area. On this earth, and more particularly in arid and semi-arid zones, every country has the objective of attaining maximum benefits from its water resources and consequently is developing numerous irrigation systems. A permanent irrigated agriculture can be maintained if the mistakes of the past are avoided.

## FACTS BEARING ON THE PROBLEM

In its Indus basin, West Pakistan has the largest contiguous irrigation system in the world, with annual total river diversions of 103 million acre feet irrigating an area of 30 million acres. But this area gradually fell into the grip of salinity and waterlogging. Seriously affected was the productivity of deep fertile alluvial soils of the Indus plains in about 46 percent of 37.7 million acres within the command of canal irrigation. Unscientific land and water use ruined the physical value of the soils. The malady of waterlogging and salinity started appearing immediately after the introduction of irrigation in upper reaches of the canals. The water table was 40 to 100 feet deep from the ground surface at the commencement of canal irrigation in 1892. Later it came close to the surface, and now it is ranging in depth from five to 10 feet from the soil surface in 60 to 65 percent of the canal irrigated areas. Drainage was not given due attention as a part of irrigation. Seepage losses from the irrigation system caused an annual rise of the water table to the order of one to 1.7 feet. Inadequate irrigation application, short of consumptive use and leaching requirements, caused an upward movement of salts.

This all happened with what is considered to be an excellent quality of irrigation water. This indicates again that the superior quality of water alone will not

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maintain permanent irrigation agriculture, unless drainage, soil management and irrigation requirements are adequately met.

## WATER QUALITY STANDARDS

Water quality is an important factor in the maintenance of proper soil moisture level for optimum growth of the crops. The high concentration of salts on the surface or in the root zone is to be brought to the normal permissible limits by the adjustment of surface irrigation applications and with the help of chemical and biological treatments.

Under all conditions, for successful growth of crops, the root zone is to be kept in fit condition to supply ample moisture and air needed for the development of roots and plant growth. To do this, it is essential to have intimate knowledge of the chemistry of the water to be used for irrigation, physico-chemical characteristics of the soil on which irrigation is to be applied, the physiology of the plants to be grown, and the meteorological conditions of the region.

In the evaluation of water quality, the chemistry of water received due attention in this part of the country. As a result of experience and experimental work, the Irrigation department as far back as 1935 laid down permissible limits of salinity and alkali of irrigation water. The suitable limit for salt concentration in irrigation water was fixed at 1,170 parts per million. Similarly a salt index was established, indicating the suitability or non-suitability of water from the point of view of the alkalinity hazard. The salt index was expressed as below:

$$(\text{Total Na} - 24.5) - (\text{Total Ca-Ca in } CaCO_3^*)\ 4.85$$

| | | |
|---|---|---|
| -- ve salt index | Good Water | * All values are expressed in ppht. |
| + ve salt index | Bad Water | |

Interpretations of salt index are limited up to 1,200 parts per million of dissolved solids. Magnesium is added to calcium for calculating the salt index.

Until 1947 there was not much use made of groundwater in this part of the province. After Pakistan came into being, serious attention was paid to the use of groundwater resources, as the available surface water supply of 142 million acre feet was way short of the 400 million acre feet required to bring under irrigation the entire cultivable area of 73 million acres in the Indus plains. The balance needed therefore, must be met with the groundwater reservoir, which is of the capacity of two billion acre feet when calculated to the depth of 450 feet. Presently the water quality classification as adopted in the USA is widely used in Pakistan. The permissible limits for the water fit for irrigation are given as below:

(1) Salt concentration = EC 1,500 micromhos or 1,000 parts per million

(2) Sodium absorption ratio (SAR) $= 10 = \dfrac{Na}{\sqrt{\dfrac{(Ca+Mg)}{2}}}$ This indicates the effect of relative cation concentration on sodium accumulated in the soil

(3) Residual sodium carbonate = 2.5 me/l. $(CO_3+HCO_3)-(Ca+Mg)$ All values are expressed in milli-equivalents per litre. RSC indicates the potential sodium hazard in the soil

(4) Boron = 1 part per million

The limits prescribed above are quite appropriate under the existing cropping pattern, favorable soil permeability and drainage conditions for favorable salt balance in arid and semi-arid conditions. When the salt balance is adverse the input of the salt exceeds the output. This condition must be avoided in sustained irrigated agriculture.

There can, however, be modification in the permissible limits prescribed above, provided good management and favorable drainage conditions are created and adequate leaching requirements are ensured by making available sufficient water supply for irrigation.

### *Scope for Modifications in the Limits of Residual Sodium Carbonate*

The extent to which exchangeable sodium accumulates in soils irrigated with high carbonate water depends upon the SAR of the water and the fraction of applied carbonate that precipitates as $CaCO_3$. To isolate the effects of RSC and SAR, waters of low salt content with varying RSC and low SAR values well within the permissible limits were passed through soil columns of 16 inches in four sets. The interval between each irrigation was five days. The application was made in four-inch installments and the total depth of application was 50, 70, 90, and 120 inches in each case. There were two replications of each set. The results of 50 and 70-inch irrigation have already been reported, in the seminar in 1968. Now the results of all irrigation, viz. 50, 70, 90 and 120 inches, are herein discussed:

The results of water quality analysis and the soil analysis before and after the treatment of each set are given in Table 1.

The data given in Table 1 clearly indicate that so long as the EC and the SAR of the irrigation water are within the permissible limits, the RSC, even up to 4.2 me/l, do not show any alkalinity hazards in the soil. In the evaluation of the quality of water with respect to the presence of RSC, the salt content and SAR of the water should be simultaneously considered. If the salt content and SAR are well within the prescribed permissible limits there is ample room for raising the RSC limits to the extent even up to four me/l for medium textured non-saline and non-alkali soils with good permeability and adequate drainage.

The above observations are supported by the data on the use of groundwater, with RSC 2.7 me/l, EC 650 micromhos and SAR 3.72 for a period of over 25 years. Chemical analysis of the water used for irrigation is shown in Table 2.

The water table in the tanks under observation was kept at 10.5 feet and after a period of 15 years the water level was raised to five, seven and nine feet, where it has been maintained for the last 10 years. The total amount of water applied so far works out to 80 acre feet including rainfall.

The results of the surface soil of the Lysimeters are given in Table 3.

From the above results it is inferred that the RSC of 2.7 me/l has not produced any effect to increase the SAR of the soil beyond the permissible limit of 10 even under the high water table conditions.

### *Scope for Use of Waters of High Salt Concentration*

The analysis of the saturated extract of the normal good soil indicates an EC of less than four mmhos, exchangeable sodium less than two to three me/100 gm of soil and pH of saturated paste about eight. To maintain a favorable salt balance there are limitations on the use of groundwaters. Herein attempts have been made to indicate up to what salt content the irrigation waters can be used safely for raising various crops. On the basis of the U.S. Salinity Laboratory salt tolerance data, the EC value to be used in calculating the leaching requirements for some lands as adopted by Maasland and Chaudhry (1966) is reproduced in Table 4.

Based upon the permissible salt concentrations of leachate, the content of irrigation water at 10 percent and 20 percent leaching would be as shown in columns 4 and 5 of Table 4.

When leaching requirements are limited to 10 percent the salt content of the applied irrigation water may be about 1,000 parts per million for barley, cotton, wheat, sugar beets, rye-grass and sorghum, and not to exceed 500 to 600 parts per million for rice, sugar cane, corn, cabbage, soybeans, tomatoes and alfalfa.

If the leaching requirement is limited to 20 percent, the salt content of the irrigation water must be approximately 2,300 parts per million for barley, 2,000 parts per million for sugar beets, cotton and wheat, 1,500 parts per million for rye-grass and sorghum, and 1,000 parts per million for soybeans, rice, sugar cane, corn, cabbage and alfalfa.

At present, as already expressed, we are applying less irrigation. But with the increased water supply for the groundwater source and with 150 percent intensity of cropping as aimed at in our SCARPS it will be possible to meet with the full consumptive use requirements and the leaching requirements to the extent of about 10 percent. As

**Table 1: Showing Results of Quality Analysis in Water Used for Irrigation and of the Soil Before and After Treatment**

| Depth of Irrigation | Milliequivalents per litre Ca+Mg | Na | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | Total Cations Anions. | Electrical Conductivity. Millimhos | pH | Res $CO_3$ Me/l | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | SET NO. I | | | | | | |
| | | | | | Water Quality (A) (Control Canal Water) | | | | | | |
| | 2.2 | 0.8 | | 0.7 | 0.3 | 2.0 | 3.0 | 250 Micromhos | 8.1 | - | 0.76 |
| | | | | | Original Soil | | | | | | |
| | 6.25 | 9.25 | - | 6.32 | 5.9 | 3.28 | 15.5 | 1.55 Millimhos | 8.1 | 0.07 | 5.25 |
| | | | | | Treated Soil | | | | | | |
| | | | | | | | | Millimhos | | | |
| 50" | 3.37 | 3.17 | - | 3.37 | 1.31 | 1.86 | 6.55 | 0.65 | - | 0.5 | 2.49 |
| 70" | 2.69 | 3.01 | - | 2.75 | 1.5 | 1.45 | 5.7 | 0.57 | - | 0.06 | 2.59 |
| 90" | 2.94 | 3.56 | - | 2.81 | 1.5 | 2.19 | 6.5 | 0.65 | - | - | 2.93 |
| 120" | 5.6 | 1.85 | - | 5.00 | 1.75 | 0.7 | 7.5 | 0.75 | - | - | 1.09 |
| | | | | | SET NO. II | | | | | | |
| | | | | | Water quality (B) (Containing no Residual Carbonate) | | | | | | |
| | 4.6 | 8.4 | | 3.7 | 2.5 | 6.8 | 13.0 | 1230 Micromhos | 8.5 | - | 5.46 |
| | | | | | Original soil | | | | | | |
| | | | | | | | | Millimhos | | | |
| | 6.25 | 9.25 | | 6.32 | 5.9 | 3.28 | 15.5 | 1.55 | 8.1 | 0.07 | 5.25 |
| | | | | | Treated soil | | | | | | |
| 50" | 4.0 | 5.62 | | 3.25 | 3.06 | 3.31 | 9.62 | 0.96 | - | - | 4.02 |
| 70" | 4.87 | 9.62 | | 4.12 | 4.75 | 5.62 | 14.5 | 1.45 | - | - | 6.15 |
| 90" | 4.0 | 10.2 | | 4.0 | 4.0 | 6.2 | 14.2 | 1.42 | - | - | 7.2 |
| 120" | 5.25 | 5.2 | | 4.9 | 2.6 | 2.9 | 10.4 | 1.04 | - | - | 3.19 |
| | | | | | SET NO. III | | | | | | |
| | | | | | Water Quality (C) (Containing Medium Residual Carbonate) | | | | | | |
| | 2.6 | 6.1 | 0.7 | 3.8 | 1.2 | 3.0 | 8.7 | 770 Micromhos | 8.6 | 1.9 | 5.3 |
| | | | | | Original Soil | | | | | | |
| | | | | | | | | Millimhos | | | |
| | 6.25 | 9.25 | - | 6.32 | 5.9 | 3.28 | 15.5 | 1.55 | 8.1 | 0.07 | 5.25 |
| | | | | | Treated Soil | | | | | | |
| 50" | 2.87 | 7.12 | - | 5.0 | 3.37 | 1.62 | 10.0 | 1.00 | - | 2.12 | 5.87 |
| 70" | 2.62 | 8.32 | - | 4.0 | 2.25 | 4.45 | 10.94 | 1.08 | | 1.37 | 7.21 |
| 90" | 3.9 | 7.9 | - | 5.25 | 3.0 | 3.5 | 11.8 | 1.18 | - | 1.4 | 5.4 |
| 120" | 5.0 | 6.9 | - | 5.6 | 2.75 | 4.3 | 11.9 | 1.19 | - | 0.6 | 4.4 |
| | | | | | SET NO. IV | | | | | | |
| | | | | | Water Quality (D) (Containing High Residual Carbonate) | | | | | | |
| | 2.0 | 8.9 | 0.7 | 5.5 | 1.2 | 3.5 | 10.9 | 1000 Micromhos | 8.8 | 4.2 | 9.07 |
| | | | | | Original Soil | | | | | | |
| | | | | | | | | Millimhos | | | |
| | 6.25 | 9.25 | | 6.32 | 5.9 | 3.28 | 15.5 | 1.55 | 8.1 | 0.07 | 5.25 |
| | | | | | Treated Soil | | | | | | |
| 50" | 2.5 | 7.87 | | 3.87 | 2.87 | 3.62 | 10.37 | 1.04 | - | 1.37 | 7.36 |
| 70" | 2.25 | 10.12 | | 5.0 | 2.5 | 4.81 | 12.37 | 1.24 | - | 2.75 | 9.51 |
| 90" | 3.19 | 11.19 | | 5.25 | 3.9 | 5.2 | 14.35 | 1.44 | - | 2.06 | 8.76 |
| 120" | 3.9 | 7.1 | - | 5.9 | 2.4 | 2.7 | 11.0 | 1.1 | - | 2.0 | 5.5 |

**Table 2**

| Milliequivalents per litre | | | | | | | | EC x $10^6$ at 25°C | RSC | SAR |
|---|---|---|---|---|---|---|---|---|---|---|
| Ca | Mg | Na | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | Total Cations Anions | | | |
| 1.70 | 2.50 | 5.40 | – | 6.90 | 1.9 | 0.70 | 9.60 | 650 | 2.70 | 3.72 |

**Table 3**

| Depth Water Table | Milliequivalents per litre | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | Total Cations Anions | EC x $10^3$ | pH | SAR |
| 5 feet | 3.0 | 2.5 | 18.00 | – | 5.5 | 5.5 | 12.5 | 22.9 | 2.4 | 8.3 | 10.85 |
| 7 feet | 1.20 | 5.3 | 12.00 | – | 3.5 | 2.5 | 12.5 | 16.4 | 1.9 | 8.0 | 6.66 |
| 9 feet | 1.5 | 6.1 | 6.15 | – | 5.0 | 2.5 | 5.65 | 14.0 | 1.4 | 8.15 | 3.28 |

such, theoretically, under no circumstances should we exceed the limit of 1,000 parts per million of the salt concentration of our irrigation waters. But in actual practice the irrigation field efficiency in case of a one-acre plot is about 55 percent and in a one-eighth-acre plot it is 70 percent. This would mean that about 45 percent of water is wasted or passed through the root zone in case of one-acre plots, and about 30 percent in case of one-eighth acre plots. The penetration in a one-acre plot, however, is not uniform throughout the field; the far ends receive but a shallow irrigation application, hardly sufficient to wet the soil to a proper depth for the root zone. This results in salinization (in slick spots) and unnecessary wastage of water in other areas. From this it can be inferred that at 70 percent irrigation efficiency under ideal field conditions approximately 20 percent leaching requirements are automatically met from the irrigation water applied irrespective of the consumptive use requirement of crops. From this it appears that the permissible limit of the salt concentration of irrigation water can be raised without any danger of salinity, to the extent as given in column 5 of Table 4, provided that the SAR and the RSC responsible for alkalinity remain well within the permissible limits. More data, however, are needed in this regard. Intensive research work thus is in progress at the Directorate of Land Reclamation, in the laboratory and field stations.

### *Field Observations on Poor Quality Water Use*

To study the effects of some of the relatively poor quality waters which may be taken as marginal from the quality rating considerations a few tubewells were selected in the central region of West Pakistan. The soil and water analyses of the tubewells and of the area being irrigated by these particular tubewells are given in Appendix 4.

The results of group I tubewells indicate that waters of EC 4,500 to 5,200, RSC 3.9 to 5.5 and SAR 20.44 to 24.91 have seriously affected the soils and increased the salinity to the maximum value of 7.2 millimhos/cm and SAR to 23.01 despite the adequate drainability of the soil. In case of group II tubewells, the water quality of EC 1,100, RSC six and SAR 11 have likewise greatly increased the SAR of the soil, particularly which carried low delta crops. The results indicate that EC of the treated soil vary between 1.27 to five millimhos/cm and SAR 10.7 to 49.8 despite the fact that the soil was of coarse texture.

The group III tubewells having water quality as EC 3,200 to 4,100 micromhos/cm, RSC 15.10 to 16.34 and SAR 33 to 51 had by far the most pronounced effect on the alkalinity hazard of the

**Table 4: Permissible salt concentrations of leachate expressed as electrical conductivity (Ecd), for calculating the leaching requirements for various crops**

| Crop | Permissible ECd mmhos/cm | Permissible ECd parts per million | Possible salt concentration (ppm) of irrigation water with leaching requirements of: 10 percent | 20 percent |
|---|---|---|---|---|
| Columns: 1 | 2 | 3 | 4 | 5 |
| Barley (grain | 18 | 11,520 | 1,152 | 2,304 |
| Barley (hay) | 13.5 | 8,640 | 864 | 1,728 |
| Sugar beet | 16 | 10,240 | 1,024 | 2,048 |
| Cotton | 16 | 10,240 | 1,024 | 2,048 |
| Wheat | 14 | 8,960 | 896 | 1,792 |
| Sorghum | 12 | 7,680 | 768 | 1,536 |
| Sunflower | 12 | 7,680 | 768 | 1,536 |
| Ryegrass | 13 | 8,320 | 832 | 1,664 |
| Sesbania | 9 | 5,760 | 576 | 1,152 |
| Soybean | 9 | 5,760 | 576 | 1,152 |
| Alfalfa | 8 | 5,120 | 512 | 1,024 |
| Tomato | 8 | 5,120 | 512 | 1,024 |
| Sugar cane | 8.5 | 5,440 | 544 | 1,088 |
| Rice | 8 | 5,120 | 512 | 1,024 |
| Corn | 7 | 4,480 | 448 | 896 |
| Cabbage | 7 | 4,480 | 448 | 896 |
| Potato | 6 | 3,840 | 384 | 768 |
| Sweet Potato | 6 | 3,840 | 384 | 768 |

parts per million is equal to 640 x mmhos/cm.

soil. The SAR of the treated soil went as high as 82.4 and the EC to nine millimhos/cm.

Alkaline conditions marked by poor tilth and low permeability were created in the soil receiving irrigation from these tubewells, thus greatly impairing the productive capacity of the soil. Cotton was almost eliminated from the cropping pattern. Maize and tobacco were seriously affected. Only rice and sugar cane could grow, but these did not give any economic return either. All this resulted in a few years of irrigation application in conjunction with the river water of excellent quality. The indiscriminate use of such waters without caring for the limitations for the use of such waters resulted in the closure of about 41 tubewells in SCARP I and 24 tubewells in SCARP II.

### *Water Quality Standards in the Development of Planning Projects*

As explained in the foregoing paragraphs, it is possible to increase the salinity level of the irrigation water from EC 1,500 to 2,000 under the existing irrigation practices provided that a leaching allowance of about 20 percent is made. But the application of this is limited because many of the fields in which the irrigation water is applied are not properly leveled. The penetration of water in such fields is not uniform throughout and far ends do not even get wet to root zone depth. For meeting the leaching and drainage requirements, proper layout and level of the fields is a prerequisite. Under the prevailing condition, it has been considered advisable to use water with:

EC = 1500 micromhos or 1,000 ppm

RSC = 2.5 me/l. Its limit can be increased even to 4 me/l provided the EC of water is less than 750 micromhos.

SAR = 10.

When the water of higher EC up to 2,000 is to be used, the SAR limit should not be more than seven and RSC not more than 1.25 me/l. Under present land management conditions the variation in the level of SAR and RSC should be adjusted on the basis of salt concentration of the irrigation water as indicated below:

The limit of critical values as prescribed above would eliminate most of the sodium hazards potentially present in the above different groups of waters. In case it is intended to use water of inferior quality, the judicious use of gypsum will be constantly required or else the quality of water should be improved by mixing it with a suitable proportion of good quality river water.

Table 5 shows the area underlain by deep groundwaters of various quality classes in West Pakistan.

**Table 5**

| Salinity (ppm) | Area (M. Acres) | Percentage |
|---|---|---|
| 1,000 | 14.22 | 48% |
| 1,000 - 2,000 | 3.46 | 12% |
| 2,000 - 3,000 | 1.09 | 4% |
| Above 3,000 | 10.59 | 36% |
| Total | 29.36 | 100% |

Water quality of 1,000 to 3,000 parts per million of total salt is now being used on an area of 4.55 million acres (16 percent of the total 29.36 million acres of the culturable commanded area) by mixing it with river water which lowers the ultimate tubewell quality to the permissible limits.

Thus, based on the consideration of total dissolved solids and statistical analysis of the SAR and RSC distribution in the natural groundwaters, the following mixing ratios are adopted for overall irrigation planning:

**Table 6**

| Groundwater Salinity (ppm) | Mixing Ratio |
|---|---|
| Up to 1,000 | No mixing is required with canal supply |
| 1,000 - 2,000 | 1 surface and 1 groundwater |
| 2,000 - 3,000 | 2.5 surface and 1 groundwater |
| Above 3,000 | No use of groundwater |

## *Controlled Use of Inferior Quality of Water*

The operation of Salinity Control and Reclamation Project II (Chaj Doab) is under the Irrigation department. Efforts have been made to make scientific land and water use by bringing into maximum use the inferior quality of groundwater. Of 1,026 tubewells commissioned, the quality of water of 133 tubewells is such that it remains unusable even after mixing with the available canal water supply. To find the best use of these tubewells, the following alternatives have been given due attention in the monitoring program:

(1) Reducing the discharge of the tubewell so that after mixing with the available canal supply it becomes suitable for irrigation.

(2) Reducing the working hours of the tubewell so as to decrease the quantum of water ultimately pumped and used in conjunction with canal water supply.

(3) Needed increase in canal supply when the use of tubewell water is totally eliminated and the pumped water is merely drained off or put in some irrigation channel carrying bigger discharge.

(4) Elimination of the hazardous effects by use of amendments.

The actual program for putting all these alternatives into practice has been worked out for all 133 tubewells of poor quality. A specimen of 10 tubewells is shown in Appendix II. Since the flow of the canal supply is a continuous process and with restricted working hours of the tubewells, there was a problem of equitable distribution of mixed water supply. For that purpose a formula was developed and used for equitable distribution of supply, as shown in Appendix III.

All the tubewells which show less than 12 working hours for proportionate mixing have been kept under watch. About 24 tubewells, where effects on soil and crops were more severe, have been totally closed.

### *Method for the Use of Amendments*

There are certain tubewells where canal water is not available or it is not in sufficient quantity for proportionate mixing. In such cases the use of gypsum is suggested for improving water quality, in respect to SAR and RSC. Gypsum may be used either on the soil or mixed with the water. Field application of gypsum should be preceded by leaching for maximum exchangeable sodium replacement.

In case it is intended to mix gypsum in irrigation water, care should be taken that not only proper mixing is done but also that exact requirements are met. It has been calculated that in order to reduce one me/l of sodium carbonate, 0.4 ton of gypsum is required in once acre per foot of irrigation water. In other words, 0.2 ton of gypsum per cusec is required to reduce one me/l of sodium carbonate.

When the intention is to reduce the SAR level to the desired permissible limits the gypsum requirements are worked out for the relations between SAR and calcium plus magnesium and sodium contents. A chart showing the need of calcium at various SAR values and sodium content of water is reproduced in Table 7.

For illustration, if it is intended to bring the water of 16 SAR to a 10 SAR limit, it is necessary to maintain the level of Ca+Mg as 7.2 meq/l. The analysis of the water with 16 SAR indicates the presence of Ca+Mg as 2.8 me/l. As such the additional Ca+Mg required to bring down the SAR limit from 16 to 10 would be (7.2 − 2.8) i.e. 4.4 meq/l. Since one meq. of calcium equals 2.35 pounds of gypsum per acre foot of water, it will need treatment with (2.35×4.4) = 10.28 pounds of gypsum per one Af to bring the above to the desired SAR level. In other words, 2,050 pounds of gypsum will be needed per day for a treatment of tubewell water giving a discharge of one cusec.

### *Application of Amendments Direct to Soil to Reduce the Ill Effects of Water*

Generally three types of soil amendments are used in alkali soil reclamation:

(1) Soluble calcium salts, including calcium chloride and gypsum.

(2) Acids or acid formers, including sulphur, sulphuric acid, iron sulfate, aluminium sulphate and lime sulphur.

(3) Calcium salts of low solubility, including principally ground limestone and by-product lime from sugar factories.

The relative requirements of the various amendments compared with gypsum on a chemical equivalent basis are given in Table 8.

The choice among these materials depends on availability, cost and soil conditions. Keeping these considerations in view, gypsum is the only economical material that can be used in the reclamation of sodic soils in West Pakistan.

### *Important Factors in Quality Rating*

More attention should be diverted toward the chemistry of water, which involves the determination of the individual constituents by improving the existing analytical technique. Perfected accuracy in analytical methods will give close appraisal of quality ratings. While assessing the water quality, it is necessary that a complete analysis of the water should be given due consideration. In some quarters, however, there is a tendency to project the suitability of water for irrigation, based on EC and the apparent experience gained from a minor observation of the use of such water. This opinion-forming process leads to faulty conclusions, and the utilization of such water may bring misery and devastation to the farmer. In West Pakistan we were the victims of such suggestions and were put to a great economical loss. However, the mistakes and the experience gained in such a short span have made us more cautious in the use of groundwaters. Now we are successfully operating 87,752 tubewells, of which 79,233 are privately owned and 8,519 are in the public sector. The total volume of water annually pumped was 14.4 million acre feet and 3.3 million acre feet respectively. In all

Table 7: Need of Calcium at Various SAR Values and Sodium Content of Water

SAR Level

| Na in water Meq/litre | 16 | 15 | 14 | 13 | 12 | 11 | 10 |
|---|---|---|---|---|---|---|---|
| | | | Ca+MG Needed (Meq/litre) | | | | |
| 35 | 9.6 | 10.9 | 12.5 | 14.5 | 16.8 | 20.3 | 24.5 |
| 34 | 9.1 | 10.3 | 11.8 | 13.7 | 16.1 | 19.1 | 23.1 |
| 33 | 8.5 | 9.7 | 11.1 | 12.9 | 15.1 | 18.0 | 21.8 |
| 32 | 8.0 | 9.1 | 10.5 | 12.1 | 14.2 | 16.9 | 20.5 |
| 31 | 7.5 | 8.6 | 9.8 | 11.4 | 13.3 | 15.8 | 19.3 |
| 30 | 7.0 | 8.0 | 9.2 | 10.6 | 12.5 | 14.9 | 18.0 |
| 29 | 6.6 | 7.5 | 8.6 | 10.0 | 11.7 | 13.9 | 16.8 |
| 28 | 6.1 | 7.0 | 8.0 | 9.2 | 10.9 | 12.0 | 15.7 |
| 27 | 5.7 | 6.5 | 7.5 | 8.6 | 10 1 | 12.1 | 14.6 |
| 26 | 5.3 | 6.0 | 6.9 | 8.0 | 9.5 | 11.2 | 13.5 |
| 25 | 5.0 | 5.5 | 6.4 | 7.4 | 8.7 | 10.3 | 12.5 |
| 24 | 4.5 | 5.1 | 5.9 | 6.8 | 8.0 | 9.5 | 11.5 |
| 23 | 4.1 | 4.7 | 5.4 | 6.2 | 7.3 | 8.8 | 10.6 |
| 22 | 3.8 | 4.3 | 4.9 | 5.7 | 6.7 | 8.0 | 9.7 |
| 21 | 3.4 | 3.9 | 4.5 | 5.2 | 6.1 | 7.3 | 8.8 |
| 20 | 3.0 | 3.6 | 4.1 | 4.7 | 5.6 | 6.6 | 8.0 |
| 19 | 2.8 | 3.2 | 3.7 | 4.2 | 5.0 | 6.0 | 7.2 |
| 18 | 2.5 | 2.9 | 3.3 | 3.8 | 4.5 | 5.4 | 6.5 |
| 17 | 2.3 | 2.6 | 2.9 | 3.4 | 4.0 | 4.8 | 5.8 |
| 16 | 2.0 | 2.3 | 2.6 | 3.0 | 3.6 | 4.2 | 5.1 |
| 15 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 | 3.7 | 4.5 |
| 14 | 1.5 | 1.8 | 2.0 | 2.3 | 2.7 | 3.2 | 3.9 |
| 13 | 1.3 | 1.5 | 1.7 | 2.0 | 2.4 | 2.8 | 3.4 |
| 12 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.4 | 2.9 |
| 11 | 1.0 | 1.1 | 1.2 | 1.4 | 1.7 | 2.0 | 2.4 |
| 10 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 | 1.7 | 2.0 |

Note: One meq of Ca = 233 pounds of $CaSO_4$ per one AF of water

**Table 8: Tons of Various Amendments to be Equivalent to One Ton of Gypsum**

| Amendment | Tons equivalent to one ton of gypsum |
|---|---|
| Gypsum | 1.00 |
| Sulphuric Acid | 0.57 |
| Sulphur | 0.186 |
| Lime sulphur solution 24 percent sulphur | 0.756 |
| Iron sulphate | 1.62 |
| Aluminium sulphate | 1.29 |

such areas efforts are made to use the right quality of water, either by mixing it with river water or by the use of suitable amendments or by following other biological measures.

The successful utilization of improved irrigation and cultural practices and the application of fertilizers can only be made if the soil is kept in normal condition. Even the small higher limits of salinity or alkalinity have a hazardous effects in supressing the yields.

It has been experimentally demonstrated (8) that to offset the adverse effect of 0.516 percent salinity in case of Irri-Pak rice where the water is allowed to stand constantly, it requires an application of 100 pounds of nitrogen as ammonium sulphate to get an equivalent yield from the normal soil without the application of any fertilizers. Under standing water conditions naturally the salinity in the root zone is diluted and EC is reduced to half. Even then high doses of fertilizers are needed to offset the effects of salinity hazard. As such this important factor should always be kept in view in the program of increased production.

## ACKNOWLEDGEMENT

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Nitrogen uptake by Irri-Pak Rice as affected by Salinity and various sources of Nitrogen.

## Appendix I

Group I Tubewells (Lyallpur District)

| | | | Milliequivalents per litre | | | | | | | | Parts per Million D.S. (by Evap). | Electrical Conductivity at 25°C | pH | Res $CoO_3$ me/1 | S.A.R. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ca | Mg | Na | $Co_3$ | $HCO_3$ | Cl | $So_4$ | Total cations Anions. | | | | | |
| | | | | | WATER ANALYSIS | | | | | | | micromhos | | | |
| T/well No. 1 | | | 3.2 | 4.4 | 39.9 | - | 11.5 | 30.0 | 6.0 | 47.50 | 2,880 | 4,500 | 7.30 | 3.9 | 20.44 |
| T/well No. 2 | | | 2.0 | 5.0 | 47.0 | - | 12.5 | 34.0 | 7.5 | 54.00 | 3,528 | 5,200 | 7.50 | 5.5 | 24.91 |
| Field No. | Depth | Saturation %age | | | SOIL ANALYSIS | | | | | | | millimhos | | | |
| 70/21 | 0-1' | 37 | 7.0 | 6.0 | 44.4 | | 2.25 | 42.0 | 13.15 | 57.4 | – | 7.1 | 7.6 | | 17.4 |
| | 1-2' | 26 | 7.0 | 5.0 | 48.0 | | 2.50 | 37.5 | 20.00 | 60.0 | – | 6.0 | 7.6 | | 19.6 |
| | 2-3' | 27 | 14.5 | 6.0 | 52.2 | | 2.50 | 39.5 | 30.7 | 72.7 | – | 7.5 | 7.5 | | 16.3 |
| 70/24 | 0-1' | 36 | 2.5 | 2.0 | 11.0 | | 2.50 | 8.0 | 5.0 | 15.50 | – | 1.6 | 8.2 | | 7.5 |
| | 1-2' | 25 | 1.75 | 0.25 | 23.0 | | 2.50 | 13.5 | 9.0 | 25.0 | -- | 2.6 | 8.0 | | 23.01 |
| | 2-3' | 28 | 3.0 | 2.0 | 31.0 | | 4.0 | 19.0 | 13.0 | 36.0 | – | 3.7 | 7.85 | | 11.0 |

Group II Tubewells (SCARP I No. 14 Chuharkana)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | WATER ANALYSIS | | | | | | | micromhos | | | |
| Tubewell | | | 0.42 | 1.58 | 11.00 | - | 8.00 | 1.0 | 4.0 | 13.00 | 704 | 1,100 | 7.95 | 6.0 | 11.9 |
| | | | | | SOIL ANALYSIS | | | | | | | | | | |
| Field | Depth | Texture | Ca+Mg | | | | | | | | | millimhos | | | |
| Cotton | 0-1' | Sandy Loam | 4.0 | 53.0 | 2.0 | 4.5 | 17.0 | 33.5 | 57.0 | – | 5.7 | – | | 37.1 | |
| | 1-2' | -do- | 7.0 | 70.0 | 1.0 | 3.5 | 17.5 | 55.0 | 77.0 | – | 7.7 | – | | 37.1 | |
| | 2-3' | -do- | 3.5 | 66.5 | 2.0 | 6.5 | 15.0 | 46.5 | 70.0 | – | 7.0 | – | | 49.8 | |
| Rice | 0.1' | -do- | 2.0 | 14.0 | 1.0 | 5.0 | 5.5 | 4.5 | 16.0 | – | 1.6 | – | | 14.0 | |
| | 1-2' | Loamy sand | 2.0 | 10.7 | 0.5 | 5.25 | 4.0 | 2.95 | 12.7 | -- | 1.27 | – | | 10.7 | |
| | 2-3' | -do- | 2.0 | 11.7 | 0.5 | 8.25 | 3.5 | 1.45 | 13.7 | - | 1.37 | -- | | 11.7 | |

Group III Tubewells (Shah-kot, 75 RB)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tubewell No. | | | | | WATER ANALYSIS | | | | | | | micromhos | | | |
| 203 | | | 1.21 | 3.20 | 33.67 | - | 19.96 | 8.55 | 9.57 | 38.08 | 2,500 | 3,800 | 7.4 | 15.55 | 33 |
| 203-A | | | .24 | 1.41 | 32.28 | | 16.75 | 5.32 | 11.86 | 33.93 | 2,140 | 3,200 | 8.0 | 15.10 | 35 |
| 204 | | | .24 | 1.12 | 42.43 | | 18.86 | 7.98 | 16.93 | 43.79 | 2,750 | 4,100 | 8.2 | 15.52 | 51 |
| 204-A | | | .29 | 1.12 | 34.09 | – | 17.75 | 5.70 | 12.05 | 35.50 | 2,270 | 3,400 | 8.2 | 16.34 | 41 |

(continued on next page)

## Appendix I: (continued)

Group I Tubewells (Lyallpur District)

| T/W No. | Field No. | Depth | Ca+Mg | Mg | Na | $Co_3$ | $HCO_3$ | Cl | $So_4$ | Total cations Anions. | Parts per Million D.S. (by Evap). | Electrical Conductivity at 25°C | pH | Res $CoO_3$ me/l | S.A.R. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Milliequivalents per litre | | | | | | | | | | | | |
| | | | SOIL ANALYSIS | | | | | | | | | millimhos | | | |
| 203-A | 54/16 | 0-1' | 2.0 | | 58.0 | 2.0 | 5.70 | 25.5 | 26.80 | 60.0 | | 7.0 | 8.75 | – | 58.0 |
| | | 1-2' | 16.0 | | 44.0 | | 2.30 | 7.0 | 50.7 | 60.0 | | 6.0 | 8.05 | – | 15.4 |
| | | 2-3' | 22.25 | | 35.75 | | 1.80 | 22.35 | 33.85 | 58.0 | | 5.8 | 7.95 | – | 10.7 |
| | | 3-4' | 11.0 | | 36.0 | | 2.80 | 17.90 | 26.30 | 47.0 | | 4.7 | 8.20 | – | 15.1 |
| | | 4-5' | 5.5 | | 28.5 | | 3.2 | 12.25 | 18.55 | 34.0 | | 3.4 | 8.35 | – | 17.1 |
| 203 | 34/13 | 0-1' | 1.75 | | 47.25 | 2.0 | 4.50 | 20.25 | 22.25 | 49.0 | – | 4.9 | 8.80 | – | 50.5 |
| | | 1-2' | 3.5 | | 25.50 | | 3.70 | 10.00 | 15.30 | 29.0 | – | 2.9 | 8.20 | – | 19.1 |
| 204 | 63/4 | 0-1' | 2.25 | | 87.75 | 2.60 | 7.50 | 31.75 | 48.15 | 90.00 | – | 9.0 | 9.15 | – | 82.4 |
| | | 1-2' | 2.35 | | 27.65 | – | 3.70 | 10.75 | 15.55 | 30.0 | – | 3.0 | 8.40 | – | 25.4 |
| 204-A | 82/5 | 0-1' | 2.65 | | 57.35 | 2.00 | 9.90 | 25.00 | 23.10 | 60.0 | – | 6.0 | 8.75 | – | 49.5 |
| | | 1-2' | 3.75 | | 28.25 | – | 3.50 | 11.0 | 17.50 | 32.0 | – | 3.2 | 8.05 | – | 20.6 |

## Appendix II: Quality Ratings of Tubewells of Scarp II

| Name of Unit | T/well No. | EC Micromhos /cm. | D.S. p.p.m. | SAR | RSC | Required dilution ratio of T/W & Canal water | Actual discharge available T/W (Cs) | Actual discharge available Canal (Cs) | Mixing Ratio of T/W Canal Water | Required discharge of T/W (Cs) | Needed reduc- in the dis- charge of T/W (Cs) | Required working hours of T/Well | Needed increase of Canal supply (Cs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Khadir | 4 | 1,770 | 1,133 | 21.94 | 5.7 | 1:1.28 | 4.0 | 1.98 | 1:0.49 | 1.54 | 2.46 | 9.24 | 3.16 |
| | 5 | 2,500 | 1,600 | 26.88 | 9.6 | 1:2.05 | 2.0 | 1.60 | 1:0.80 | 0.78 | 1.22 | 9.36 | 2.54 |
| | 5-A | 3,000 | 1,920 | 28.08 | 9.2 | 1:1.94 | 2.0 | 1.20 | 1:0.69 | 0.61 | 1.39 | 7.32 | 2.72 |
| | 6 | 2,400 | 1,536 | 23.08 | 9.3 | 1:1.95 | 2.0 | 0.79 | 1:0.39 | 0.44 | 1.56 | 5.28 | 2.32 |
| | 16 | 2,600 | 1,664 | 32.24 | 15.1 | 1:3.6 | 2.0 | 1.25 | 1:0.62 | 0.34 | 1.66 | 4.08 | 5.96 |
| | 24 | 1,600 | 1,024 | 16.56 | 2.3 | 1:0.69 | 5.0 | 2.83 | 1:0.56 | 4.1 | 0.90 | 19.7 | 0.65 |
| | 26 | 3,200 | 2,040 | 11.24 | – | 1:1.25 | 3.0 | 3.54 | 1:1.18 | 2.83 | 0.17 | 22.64 | 0.21 |
| | 38A | 3,100 | 1,984 | 32.76 | 11.7 | 1:2.65 | 2.0 | 3.75 | 1:1.88 | 1.41 | 0.59 | 16.92 | 1.54 |
| | 185 | 1,000 | 640 | 7.80 | 5.4 | 1:0.84 | 4.0 | 0.88 | 1:0.22 | 1.04 | 2.96 | 6.24 | 2.48 |
| | 186 | 850 | 544 | 12.30 | 6.7 | 1:1.20 | 5.0 | 1.19 | 1:0.24 | 0.99 | 4.01 | 4.75 | 4.80 |

| Salinity | EC | SAR up to | RSC up to |
|---|---|---|---|
| Low | 750 micromhos | 10 | 4 me/l |
| Medium | 750-1,500 micromhos | 7.5 | 2.5 |
| High | 1,500-2,000 micromhos | 5 | 1.25 |

## Appendix III: Guide to Work Out Modified Warabandis for the Distribution of Tubewell and Canal Supply with Different Working Hours of the Tubewells

This exercise has been conducted to work out the warabandi for a tubewell proposed to work for eight hours per day. This pertains to outlet R.D. 49443-L of Lalian Distributary, with a canal discharge of 1.74 cusecs mixed with 2.32 cusecs from the tubewell. The canal command area of this outlet is 630 acres. The relevant data used in this warabandi were obtained from the Executive engineer, Kirana division. This exercise is exclusively for the area where tubewell water is put in the outlet head. The new formula evolved for framing the modified warabandi is as follows:

FORMULA FOR CALCULATING TIME IN MINUTES PER ACRE WARI.

$$T_2 \text{ or } T_1 = \frac{\Delta}{Q1 \text{ or } Q1 + Q2} \times \frac{12 \times 60}{C.C.A.}$$

Where

$\Delta$ = Total water supply in acre feet delivered in a week from all sources viz. Tubewell & Canal.

Q1 = Discharge of the canal outlet.

Q2 = Discharge of the tubewell.

$T_1$ = Time in minutes per acre of wari (irrigation turn) of tubewell plus canal supply.

$T_2$ = Time in minutes per acre of canal supply alone.

$$T_1 = \frac{(105.56 \text{ AF}) \text{ delivered in a week from canal + Tubewell source}}{(\underset{\text{Canal}}{1.74 \text{ Cs.}} + \underset{\text{Tubewell}}{2.32 \text{ Cs.}}) = 4.06 \text{ Cs.}} \times \frac{12 \times 60}{\underset{\text{acres CCA}}{630}} = \underset{\text{per acre}}{9.9 \text{ minutes}}$$

$$T_2 = \frac{(105.56 \text{ AF}) \text{ delivered in a week both from Canal \& Tubewell sources}}{1.74 \text{ Cs. (Canal Discharge)}} \times \frac{12 \times 60}{\underset{\text{acres CCA}}{630}} = \underset{\text{per acre}}{23.1 \text{ minutes}}$$

(continued on next page)

## Appendix III: (continued)

WARABANDI OF OUTLET R.D. 49443/L OF LALIAN DISTRIBUTARY
VILLAGE: MAGNI.

Wari per acre with tubewell. = 9.9 minutes.

Wari per acre without tubewell. = 23.1 minutes

| S. No. | Name of Shareholders | Square No. | C.A. | Area irrigated With T/well | Without tubewell | With tube-well | Wari Without T/well | Total Wari* | Timing |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | H - M | | H - M | |
| 1. | Rehman etc s/o Karam Ali. | 3,4,5,6,16 20,26. | 31 | 31 | – | 5-7 | – | 5-7 | Monday 6.00 a.m. to 11.7 a.m. Monday |
| 2. | Sahlon, Mohammad etc. | 2,8,15,24, 31,32,35. | 31 | 17.5 | 13.5 | 2-53 | 5-12 | 8-5 | Monday 11.7 to 7.12 p.m. |
| 3. | Mohabti etc. | 4,5,11,17, 23,31,34. | 27 | – | 27 | – | 10-25 | 10-25 | Monday 7.12 p.m. to 5.37 a.m. Tuesday. |
| 4. | Sajjada. | 6,10,17, 25,32. | 9 | 8 | 1 | 1-19 | 0-23 | 1-42 | Tuesday 5.37 a.m. to 7.19 a.m. Tuesday. |
| 5. | Raja etc. | 24,26,31,32, 33,6,18,21,16. | 31 | 31 | – | 5-7 | – | 5-7 | Tuesday 7.19 a.m. to 12.26 Noon Tuesday. |
| 6. | Khan s/o Bakho. | 31,26,25,16, 17,32. | 14 | 9.5 | 4.5 | 1-34 | 1-44 | 3-18 | Tuesday 12.26 Noon to 3.44 p.m. Noon. |
| 7. | Ziada Jara. | 1 & 6. | 10 | – | 10 | – | 3-51 | 3-51 | Tuesday 3.44 p.m. to 7.35 p.m. Tuesday. |
| 8. | Sohna, Dara s/o Ismail | 9,7,6,3,17, 11,9,8. | 15 | – | 15 | – | 5-48 | 5-48 | Tuesday 7.35 p.m. 1.25 a.m. Wednesday |
| 9. | Sahlon, Amir etc. | 24,25,50,16, 23,34. | 44 | 32 | 12 | 5-17 | 4 37 | 9-45 | Wednesday 1.23 A.M. to 11.17 a.m. Wednesday. |
| 10. | Nabo. | 13,12,10,33, 24. | 27 | 16.5 | 10.5 | 2-43 | 4-3 | 6-46 | Wednesday 11.17 a.m. to 6.3 p.m. Wednesday. |
| 11. | Ali s/o Bakho. | 24,17,33,12, 13. | 8 | | 8 | – | 3-5 | 3-5 | Wednesday 6.3 p.m. to 9.8 p.m. Wednesday |
| 12. | Wa'i s/o Nathu. | 24,13,12,7, 23. | 16 | – | 16 | – | 6-10 | 6-10 | Wednesday 9.8 p.m. to 3.18 a.m. Thursday. |
| 13. | Manak, Lala, etc. | 17,16,23,6. | 30 | 23 | 7 | 3-48 | 2-42 | 6-30 | Thursday 3.18 a.m. to 9.48 a.m. Thursday |
| 14. | Jokra s/o Ali. | 32,25,17,40. | 19 | 10 | – | 3-8 | – | 3-8 | Thursday 9.48 a.m. to 12.56 noon Thursday. |
| 15. | Allah Ditta s/o Bahawal | 32,13,25,40. | 9 | 6.5 | 2.5 | 1-4 | 0-58 | 2-2 | Thursday 12.56 a.m. to 2.58 p.m. Thursday. |
| 16. | Raja. | 6,16,19,4, 32. | 12 | – | 12 | – | 4-37 | 4-37 | Thursday 2.58 p.m. to 7.35 p.m. Thursday. |
| 17. | Rahana. | 23,16,32,22. | 8 | – | 8 | – | 3-5 | 3-5 | Thursday 7.35 p.m. to 10.40 p.m. Thursday. |

(continued on next page)

# Appendix III: (continued)

WARABANDI OF OUTLET R.. 49443/L OF LALIAN DISTRIBUTARY
VILLAGE MAGNI.

Wari per acre with tubewell = 9.9 minutes.

Wari per acre without tubewell = 23.1 minutes

| S. No. | Name of Shareholders | Square No. | C.A. | Area irrigated With T/well | Area irrigated Without tubewell | Area irrigated With tube-well | Wari Without T/well | Total Wari* | Timing |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | H - M | | H - M | |
| 18. | Raju etc. | 16,17,9,10,32. | 21 | 2 | 19 | 0-20 | 7-20 | 7-40 | Thursday 10.40 p.m to 6.20 a.m. Friday. |
| 19. | Samail s/o Nathu. | 19,17,10,5, 23. | 30 | 30 | – | 4-57 | – | 4-57 | Friday 6.20 a.m. to 11.17 a.m. Friday. |
| 20. | Mekhan etc. | 20,16,22,23, 32,25,26. | 18 | 16.5 | 1.5 | 2-43 | 0-35 | 3-18 | Friday 11.17 a.m. to 2.35 p.m. Friday. |
| 21. | Rem Jawaya. | 17,32,21. | 14 | – | 14 | – | 5-24 | 5-24 | Friday 2.35 p.m. to 7.59 p.m. Friday. |
| 22. | Karam Ali etc. | 9 & 18. | 12 | – | 12 | – | 4-37 | 4-37 | Friday 7.59 p.m. to 0.36 a.m. Saturday. |
| 23. | Sher s/o Sardara. | 34,9,6,19. | 43 | 29 | 14 | 4-47 | 5-24 | 10-11 | Saturday 0.36 a.m. to 10.47 a.m. Saturday. |
| 24. | Babo s/o Mehdi. | 16. | 3 | 3 | – | 0-30 | – | 0-30 | Saturday 10.47 a.m to 11.17 a.m. Saturday. |
| 25. | Road. | – | – | – | – | 1-39 | – | 1-39 | Saturday 11.17 a.m. to 12.56 noon Saturday. |
| 26. | Mehar Radha. | 26,11,12,32, 25,16,17,31, 4,25,21,16,27,30. | 75 | 6.5 | 41.5 | 5-31 | 16-0 | 21-31 | Saturday 12.56 Noon to 10.27 a.m. Sunday. |
| 27. | Patti Sahawal. | 10,7,11,12, 26,41,40. | 63 | 21.5 | 41.5 | 3-33 | 16-0 | 19-33 | Sunday 10.27 a.m. to 6.00 a.m. Monday. |
| | | | 620 | 329.5 | 290.5 | 56-0 | 112-0 | | *Irrigation Turn |

# CHAPTER IX

## Field Trip

### EIGHTH NESA IRRIGATION PRACTICES SEMINAR

### Field Trip Schedule in the Helmand-Arghandab Valleys

| | |
|---|---|
| Sept. 24 | Kabul |
| | Kandahar (Manzel Bagh) |
| Sept. 25 | Kandahar (Manzel Bagh) |
| | Visit to Karz and Zakir |
| | Diversion of Zahir Shahi Canal |
| | Lunch (Manzel Bagh) |
| | Visit to Khirqa-i-Mobaraka and tombs of Ahmad-Shah Baba and Mir Waise Neeka |
| | Boghra Diversion Dam (Cold soft drinks served by Hotel and Tourist Enterprise) |
| | Lashkar Gah - Bost Hotel (Reception - Helmand Arghandab Valley Authority) |
| Sept. 26 | Lashkar Gah - Bost Hotel |
| | Visit to Research Station and Livestock Farm |
| | Marja Area |
| | Darweshan Diversion |
| | Lunch (Served by Helmand-Arghandab Construction Unit) |
| | Shamalan (Kharaba) - visit to a farm |
| | Visit to Oil Mill and Cotton Gin (Afternoon tea served by Helmand Oil Mill) |
| | Lashkar Gah - Bost Hotel (Reception - USAID) |
| Sept. 27 | Lashkar Gah - Bost Hotel |
| | Visit historic Arch of Bost |
| | Kandahar |
| | Kabul |

# Field Trip Notes

by
**Diane Rice and Mary Jean Sallee**

## SEPTEMBER 24

Delegates to the Eighth Irrigation Practices Seminar left Kabul at 12 noon for a four-day field trip to examine the irrigation works of the Kandahar and the Helmand river valley region.

The delegates traveled in two small buses along the hard-topped road to Kandahar. Mr. Mastrofini and Dr. Corey, USAID, Pakistan, were extremely interested in the extensive network of karizes that could be seen from the road. Mr. Mastrofini remarked that it was probably the largest underground irrigation system, built without steel pipes, in the world. He felt that someone should make a thorough investigation of these works, if it had not already been done. We stopped at Ghanzi, the ancient city of Mahmood the Great, Muslim scholar and conqueror. Many of the delegation visited his tomb.

The delegates arrived in Kandahar at 8 p.m. The acting governor of Kandahar greeted the delegates at the Kandahar hotel. A large and excellent dinner was served.

One Iranian delegate remarked that, "coming to this area is very interesting from an educational point of view." He indicated that he had extensively studied Iranian history and that for many centuries this area was a part of Iran.

## SEPTEMBER 25

At 8 a.m. delegates left the Kandahar hotel for the first field visit.

### Visit to Kandahar Drain Manzel Bagh Spur

The land surrounding this drain could hardly be cultivated. Water level was 30 centimeters below the surface. The drain was constructed in two years, with an approximate depth of three to four meters. We stopped to examine a crossing which combined two juis (irrigation canals). Mechanical equipment was used to build the drain, which is 4,315 kilometers long. We saw fields which were flooded to leach the salt. Kandahar drain water has 700 to 800 parts per million salt; at some times of the year it will increase to 3,000 parts per million. We stopped to examine the confluence of the Kandahar and Shorab Spur. Even to the untrained eye, the salt problem is severe. We passed several small vineyards having very poor production because of salinity. The section of the drain that was built earlier is being clogged by vegetation and needs cleaning. We stopped to look at a drain handdug by the farmers. It was crooked because of property lines. Hope was expressed that the drains can be straightened by getting farmers to cooperate. Historically the area was irrigated by the kariz system. The boron content was reported to be 12 parts per million; 88 per cent sodium in water. Mr. Ercan of Turkey remarked that the composition of the soil is very good, better than in Turkey, and that with proper irrigation the results could be good.

## GRAPE PALACE

A stop was made enroute to visit the grape drying operations. In the grape vineyards, aerated mud buildings are used for drying the grapes to make raisins. The delegates were invited to visit the largest of these buildings, called "The Grape Palace," located in the middle of a vineyard three years old. The grapes are hung on forked rods extending from one wall within the building, and it was explained that they are dried in this manner to preserve their white or light green appearance. Were they to be spread out on a flat surface and dried, as is done in other areas, the intense sun of the region would cause them to turn red. Very narrow apertures in the building permit air to circulate but do not permit sunlight to penetrate the building.

**Arghandab river outlet drain from Arghandab irrigation project:** It has a four-foot diameter pipe, built to accept 110 c.f.s., but usual rate is 50 c.f.s. Potential irrigated land is 24,000 acres. River runs only at flood stage in early spring.

**South canal extension of Zahir canal:** Diversion 60 c.f.s. passed check gate on jui turnout. Passed drop structure. Passed mother check and drop system. Some farming in this area, mainly fruit. Poor quality agricultural practices.

**Lower Shamalou:** No water, because of a water distribution problem. Planning canal and lateral system. Also has drainage problems.

**Intake to Zahir Shah canal from Arghandab river:** Not a stabilized system; some places are not receiving water, while other areas are waterlogged. Indian delegate asked who was paying for water and maintenance costs. Answer: Government. No studies have been done on increased productivity. Cropping practices have not changed. We examined an area adjacent to this canal. Still in use are six parallel juis in an area 200 meters wide. This is a part of the old irrigation system. Mr. Leatham of Turkey emphasized the waste in maintaining these old juis which run parallel with the main canal. Conversation explored the water laws of Afghanistan. When the project was planned, there was no discussion of the obligation of farmers to contribute financially to it. Lately the government has felt financial pressure and is running into the Islamic belief that water is a God-given right. Mr. Clark believes that it will be two generations before any legislation will be enacted even in a limited form.

A luncheon was held at the Manzel Bagh Hotel. The food was excellent. Mr. Treakle of USDA is extremely interested in the design of the project. He feels that there is a great potential for the whole area. At 1:30 p.m. we left to visit the Khirga-i-Morbarak Mosque which reputedly holds the cloak of the Prophet Mohammed.

We also visited the tomb of Ahmad Shah Baba on the road to Lashgar Gah. Traveling due west we could see off to the south the Registon desert. This is a loose soil desert. The possibility of irrigating the area near the hard-top road before turning off the Lash is small, but Mr. Clark suggested that tubewells possibly could be used. In this area we saw a few karizes. There is strong evidence that at some time, perhaps eons ago, a climatic change took place here. There is a lot of wood buried, suggesting that the desert was at one time covered with forests. Vegetation in this region is now very sparse. The nomadic people (Koochis) have not yet arrived from their northern pastures in great numbers for the winter. One cannot help but be impressed by the hardness of the few people who inhabit the areas which are not irrigated in the southern deserts of Afghanistan. The water which comes from wells and karizes is scarce. Agriculture is virtually impossible. Heat is intense, even in September. Yet the people survive, though one could hardly say they live.

**Boghra diversion dam and canal:** Passed small power plant which supplies electricity for Girisk, Lash and a few other towns in the HAVR. Quite a lot of bullrushes in the canal. Neither chemical nor mechanical means have been used to clear them. Local people cut some for weaving. Farming along the canal of very poor quality. Possibly saline soil. The diversion dam was briefly looked at. It was very hot and everyone was anxious for a cool drink. There were a group of Pathans fishing with shotguns — a new approach! Along the canal, traveling southwest to Lash, there are many ancient ruined structures in the area where the river banks used to be.

## SEPTEMBER 26

Stopped at Bohlan livestock farm which has 236 animals, including Brown Swiss (imported), Thorpakir, Sohiwall, native breeds, Knorry, Sistany and Kandahari. Farm started in 1955. Artificial breeding introduced in 1969. Very short stop. Stopped to look at Bohlan research farm (Payanda Mohammed hosted us.) Testing cotton, wheat and corn. No breeding program. Tested 2,000 varieties; now using 50. Maximum yielding wheat is an FAO variety. The farmers prefer white wheat. A yield of 3,000 pounds of wheat per acre is possible, using nitrogen and phosphate. All tests are conducted for four years before recommendations are made. They like Mexipak, a cream wheat. Cotton research has not been so successful. No specific recommendations have been made, although experimenting continues with Delphus and C-47, which out-produce Delphus, with a yield of 500 pounds of lint cotton per acre. Will continue experimentation for two more years before making specific recommendations to farmers. Pests: bollworm and aphids. C-47 takes only 100

days to grow. Plant it in April, attempting double cropping with wheat. Delphus takes 130 days; can't double crop with wheat. Irrigate 15 times, with a total of 84 inches. When in bloom, irrigate every week. Clay-loam soils.

**Corn** is being tested for five years. Best results have been had with Yellow Starcropper, Test J-1 and Synthetic 2, three varieties that are self-pollinating. Behind in fertilizer experimentation on corn. No recommendations been made. Double crop corn and wheat. Yield of corn is 50 bushels per acre.

Corn in this area is not a hybrid but a combination of several strains. A selection is made each year as to the best varieties to be combined for the next year's planting. Fertilizer for corn is the same as for wheat and thus corn and wheat are double cropped.

Irrigation is available for eleven months of the year, but must be done between the twentieth and thirtieth day of the planting for maximum yield. This critical period is overseen by advisors to help the individual farmers.

The experiment farm shares wheat and fertilizer with individual farmers and it has increased the nitrogen input from five to 200. It has also discovered that nitrogen and phosphorus can be added at the same time, instead of separately, with no change in yield.

**Marja:** Extensive drainage system being built to combat a serious salinity problem. Four drains 100 meters apart under construction. Comment: This was reportedly the best land they had, but the drains are 10 years late. Water level 1.5 meters after drainage; 8,000 parts per million saline content. The Helmand river drains into a lake in Iran, and a question was raised by an Iranian delegate as to pollution of the river by drainage water having a high salt content. No one in any country has the answer to such a problem. It is universal.

Extremely arid area in and around Darweshan, which is on the edge of the Sesistan desert. Food is difficult to get; rice and tea are the main staples. Water in Darweshan is safe, however, because of a deep well dug by M. & K. years ago. A vocational agriculture school formerly located in Kabul is now in Darweshan. Darweshan diversion dam visited.

Lunch was served at the Darweshan nursery, a delightful spot. Afghan rugs were spread under a cool grape arbor. A slight cooling breeze refreshed us.

**Visit to farm in Kharaba:** The farmer, Noor Mohammed, has 7.5 acres; does rotation cropping. He has two sons and one daughter. He and they are illiterate. His income is 14,000 Afs per year. This is over and above what he uses to maintain himself and family. He settled the land eight years ago. Leached the soil. Produces pomegranates, corn, carrots, wheat, grapes and cotton. When he settled the land he received one ox, 5,000 Afs for a house, plus a plan, plough and shovel. However, this is not now given to settlers. For the first three years no payment is expected; after that for 20 years there is no interest, nor is there any payment for water or for upkeep of canal. Land is divided as follows. Class 1 is 7.5 acres, class 2, 10 acres; class 3, 12.5 acres; class 4, 15 acres. The land must be occupied. If it is not, after two years it reverts back to the government.

Returned to Lash, where delegates saw an oil factory and a marble factory. That evening Mr. Barron, American head of HAVR, hosted a cocktail party.

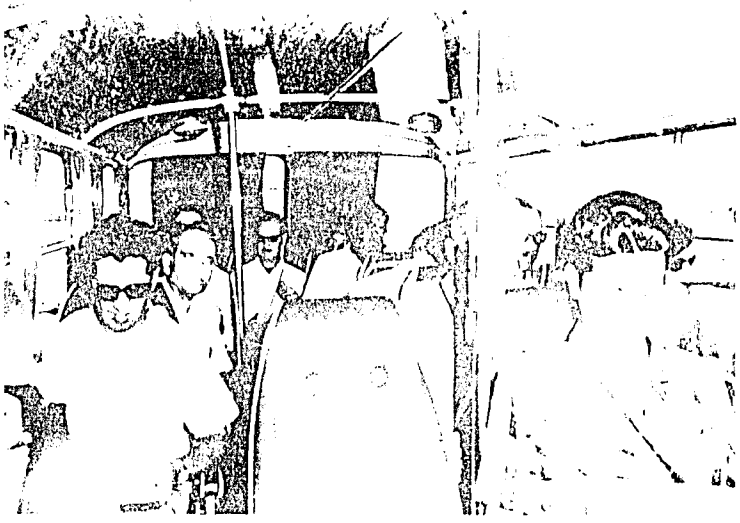
## SEPTEMBER 27

Returned to Kabul. Delegates stopped on the way for sightseeing and shopping.

Excess water is drawn off many farms by oil drum pipes which are constructed by tops and bottoms of oil drums being welded together and stretched across a ditch, with sometimes a flat mud platform constructed on top of them for the use of donkeys crossing.

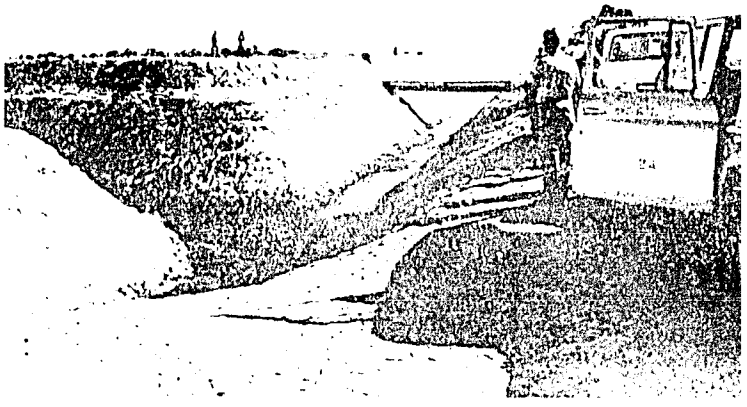
# FIELD TRIP PHOTOGRAPHS

It was a long ride

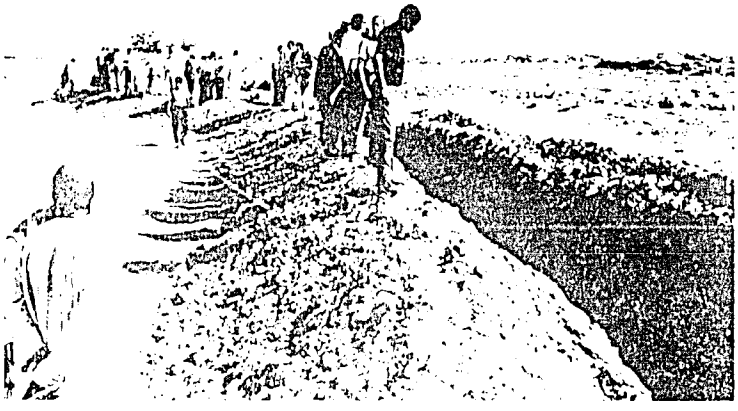


Hand dug drain near Kandahar

Kandahar — Manzel Bagh Drain. Note the suspended culvert constructed of old oil barrels for the jin crossing

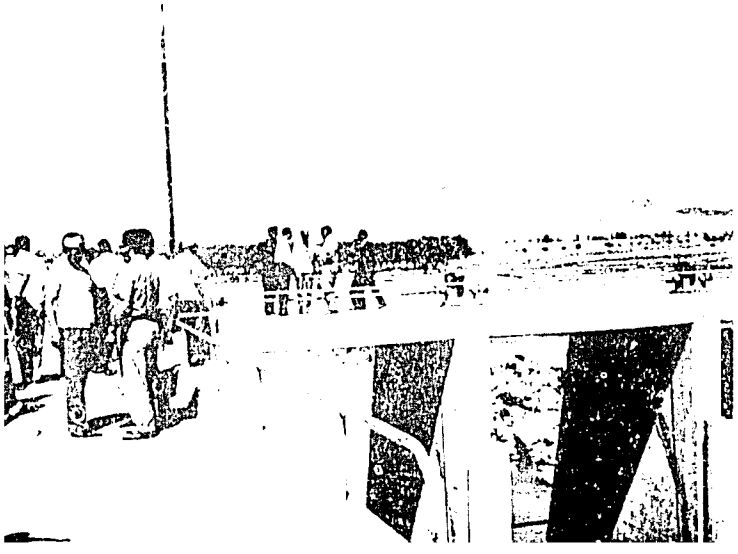


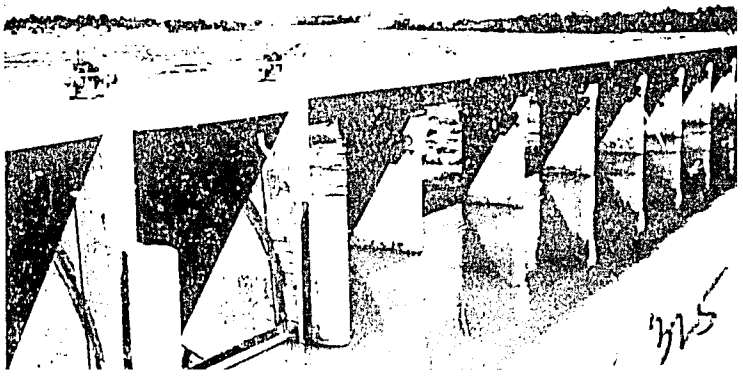
Along — e Manzel Bagh Drain



Intake to Zahir Sha Canal

Zahir Sha Diversion Dam



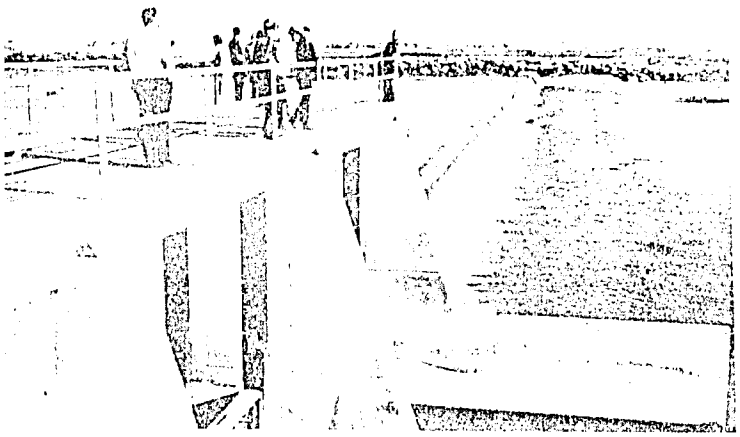


# FIELD TRIP PHOTOGRAPHS

[illegible] near Kandahar

Tomb of Ahmad Sha Baba

[illegible] Diversion Dam



The livestock farm at Lashkar Gah

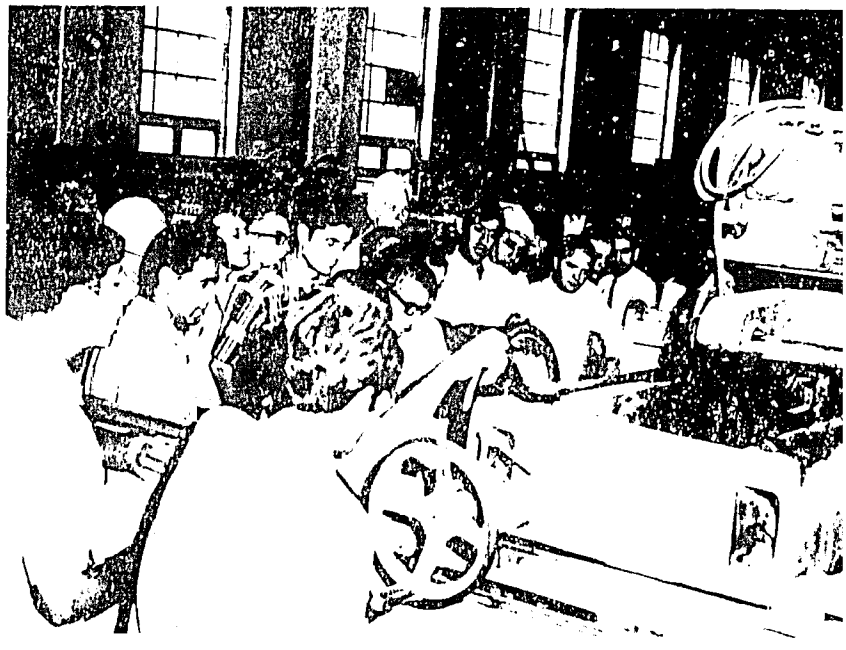
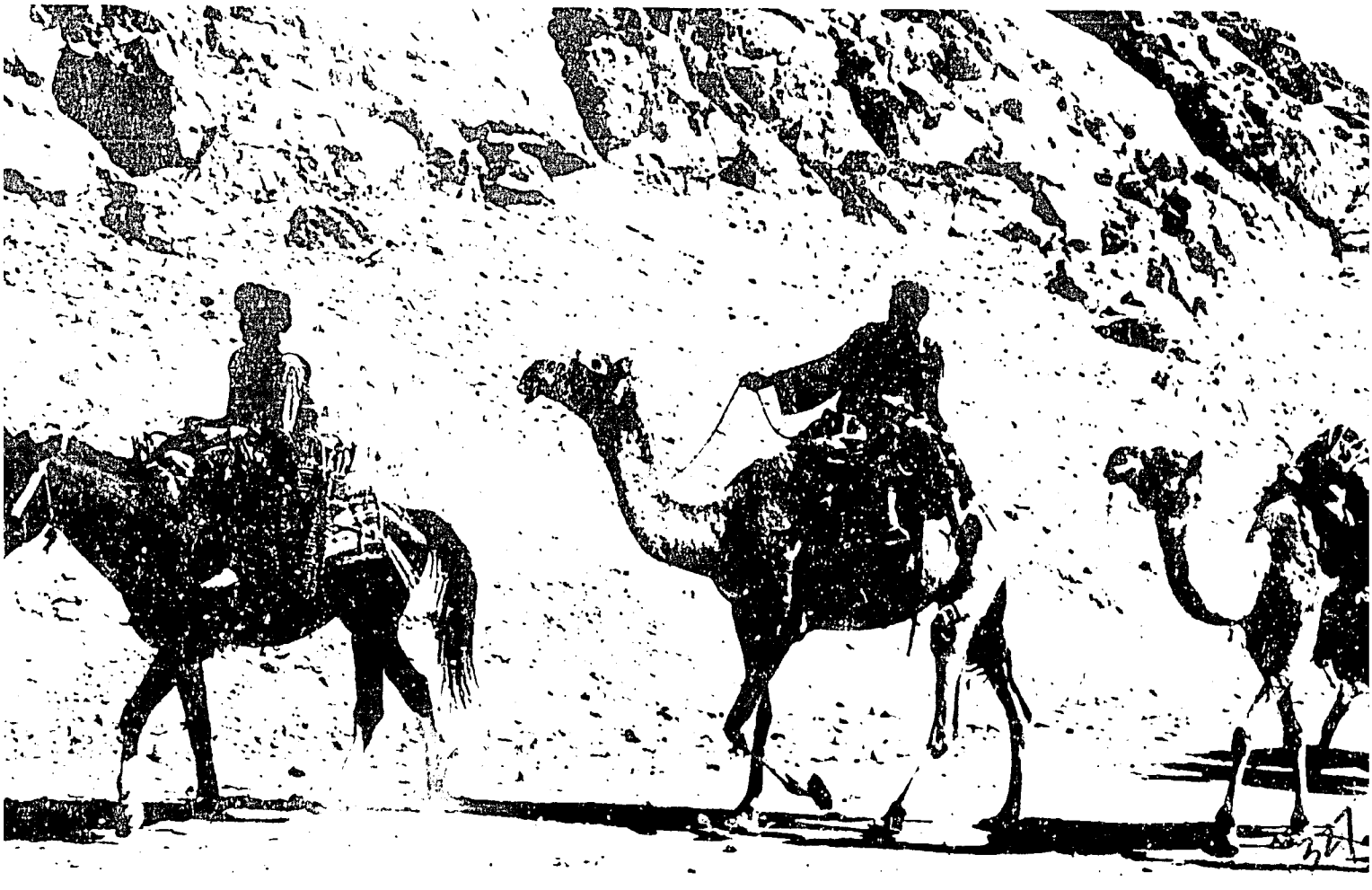
[illegible] research station in the Helmand Valley

Lunch at Darweshan

# FIELD TRIP PHOTOGRAPHS

An Afghan farmer and his corn in Shamalan

The alabaster plant at Lashkar Gah



Camels are seen everywhere