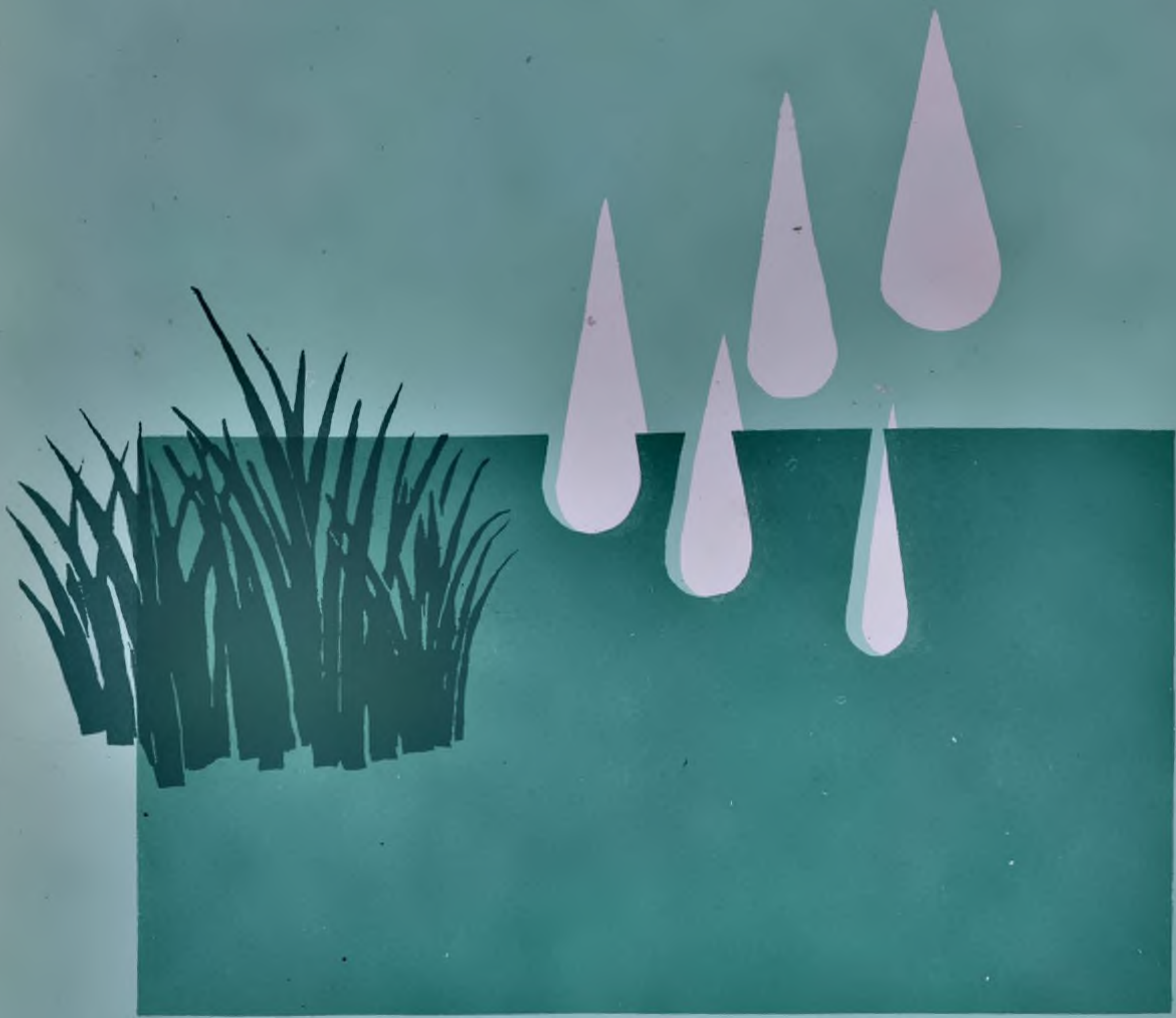


WATER AND IRRIGATION IN IRAN

Water and Irrigation in Iran

by Eng. Manuchehr Vahidi

Plan Organization

Published by
Bureau of Information and Reports

February 1968

The importance of water in the preservation and evolution of the life of man and other animals, as well as in the growth of plants, is so great that, with the exception of air, no other element or factor plays such a vital and basic role in our existence.

This publication examines the natural and geographical state of Iran and problems connected with water and irrigation, and gives an account of the ways our water resources will in future be utilized, while the measures taken in dam construction will be described in greater detail in a future publication.

It is hoped that the present volume will prove useful and that readers will gain from it a clearer idea of an important section of the development activities carried out under the Third Plan.

To all my colleagues who have helped in the compilation of this publication I express my sincere thanks.

Bureau of Information and Reports.

TABLE OF CONTENTS

Page

Introduction 5

Natural and Geographic Features of Iran 7

A Balance sheet of Iran Water Resources 10

Problems of Water and Irrigation 19

How Iran's Water Resources are Utilized 22

An Economic Study 44

Future Development Potential of Water Resources and Recommendations 75

Text prepared by: .... Eng Manuchehr Vahidi
with the assistance of
Eng. Heshmatollah Aladdin

Editorial Supervision: .... Ghodsi Nazemi

Translation by: .... Roger Cooper

Design by: .... Mohammad Zaman Zamani

Supervision of Printing: .... Gholam Ali Latifi

INTRODUCTION

Water is an essential need for the economic growth and development of every country. It is not only necessary for agricultural development but is an important factor for the continued creation and development of industry and urbanization.

In Iran, because of insufficient rainfall and other unfavourable natural factors, water, which constitutes a basic element of economic growth, tends to have a limiting effect on both the industrial and agricultural sectors of the country's economy.

The need to make the most effective use of water resources was a matter of great interest to our ancestors and as such was endowed with extraordinary value. Scientific and technical progress, far from diminishing the importance of this vital substance, actually led to it acquiring new value with the rapid increase of population and of urbanization and industrialization. The stage has been reached today where water is, after air, the most important factor in life and civilization on this planet: the utilization of water resources for elements of life, municipal water supply, industry, navigation, hydro-electric power, fish-breeding and recreation makes it one of the most essential

Water is supplied by nature almost everywhere but there are many disparities between supply & demand, the supply varying in quality, quantity, timing & mode of occurence from place to place from the 2nd World War onwards, from which time economic development became the chief goal of the various communities of mankind, water came to be recognized as one of the principal factors affecting this development, and huge efforts have been started throughout the world to bridge the gap between supply and demand by using new financial resources and technical methods.

The growing need for water, on the one hand, and its extraordinary importance in the development of economic activity, on the other, have in recent years led Iran along the same paths as other countries in the search for new water resources, and the greatest possible utilization of existing resources. Strenuous activities have been made on many fronts.

In this publication, the main object of which is to highlight some of the existing wastages of water and the efforts being made to rectify them, attempts have been made:

a) to prepare an estimate of the nation's water resources, in spite of the lack of adequate statistical sources in this field, by using the most up-to-date information and in accordance with modern international standards;

b) to study the social and economic effects of the measures taken in this field and the possibilities of developing the nation's water resources in the future.

It is hoped that the present work, which consists of a collection of unpublished reports and research-work made by experts in this and related fields, will meet the needs of the growing number of interested parties.

NATURAL AND GEOGRAPHIC FEATURES OF IRAN

Iran lies in the southern part of northern temperate zone between 35 and 40 degrees of latitude north, and because of its geographic position on the earth's surface and the special nature of its topography it is classified as an arid or semi-arid region.

The mean annual precipitation in Iran is only about 25-30 centimetres, the equivalent of only one third of the world mean of 86 centimetres.

To illustrate Iran's degree of aridity and the insignificance of her rainfall a comparison is made in Table 1 of the mean annual precipitation of Iran with that of the whole surface of the world, the land surface, the continents and certain selected Asian countries.

TABLE No. 1

	AREA	MEAN ANNUAL PRECIPITATION in cms.
1	Whole World	86
2	The Land Surface of the World	66
3	South America	135
4	Africa	71
5	Asia	64.5
6	Europe	62
7	North America	60
8	Australia	46
9	Malaya	254
10	East Pakistan	193
11	Japan	160
12	Afghanistan	58
13	Iran	28

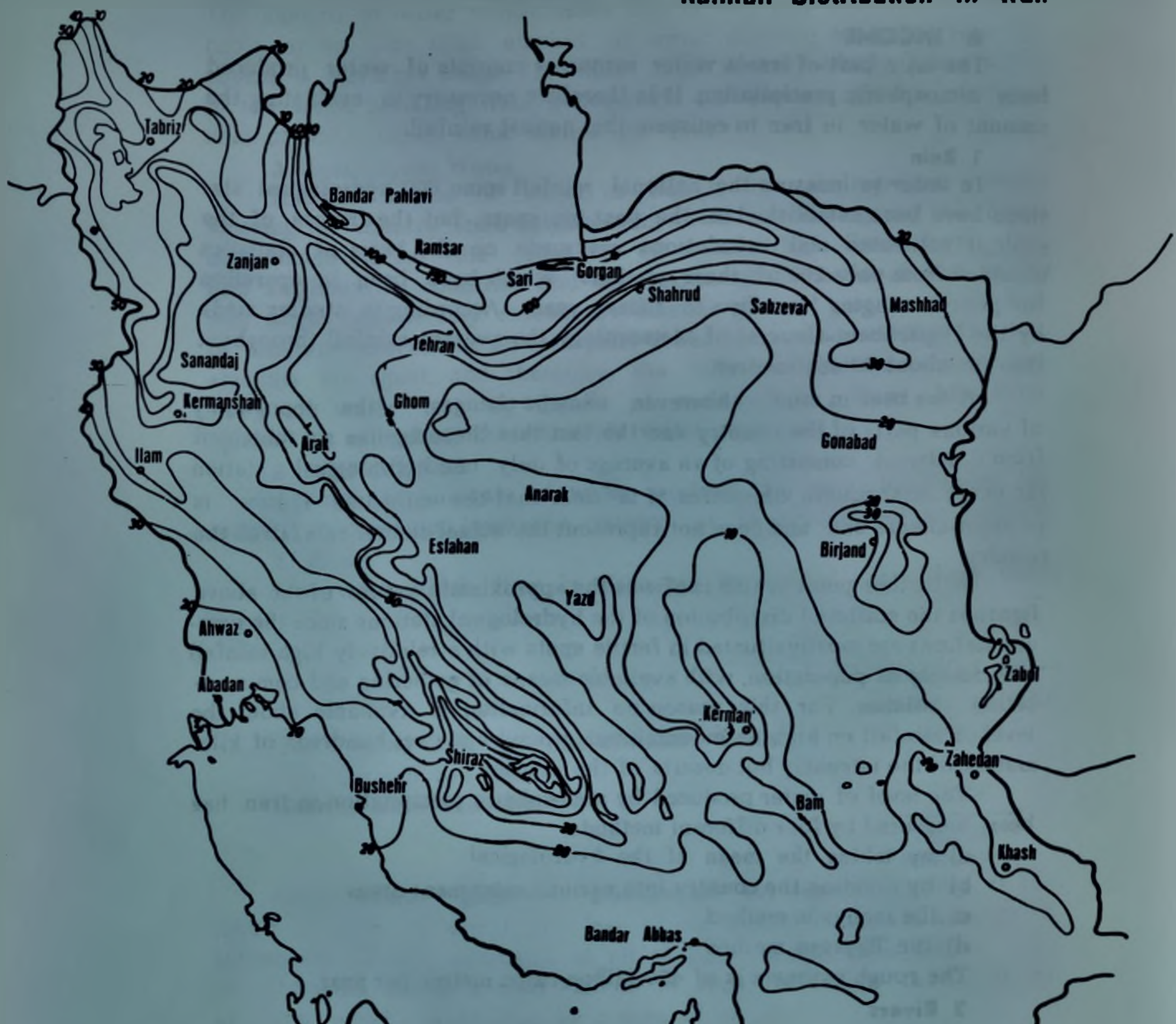
The factors causing the lack of rainfall in Iran are the country's latitude, the distance from the sea, and the topography, which are all unfavourable to high rainfall.

In the northern hemisphere between latitude 30 and latitude 60 which is the position of most of Iran, the prevailing winds blow in a west-east and north-south direction. These winds bring the water vapour of the Mediterranean and Atlantic Ocean from the west and that of the Caspian Sea from the north towards Iran, but the presence of the Alborz mountain range in the north and the Zagros range in the west prevents this vapour from reaching the central plateau on which most of Iran's plains are situated.

When the clouds reach the Alborz range in the north and the Zagros range in the west rain is formed. It runs down the sides of these two ranges giving rise to flash floods and perennial water-courses, most of which flow into the Caspian Sea or towards the western frontiers of the country without being properly utilized.

As a result, and as can be observed in Fig. 1, which shows the distribution of rainfall in Iran, the rainfall in the north and west of the country is relatively heavy, while in the remaining regions, which form the major part of the country's land surface and consist of huge fertile plains, it is a mere 4 _ 20 centimetres.

Fig. No. 1
Rainfall Distribution in Iran



NOTE : Figures on map indicate annual precipitation in centimetres.

BALANCE SHEET OF IRAN'S WATER RESOURCES

A INCOME

The main part of Iran's water resources consists of water produced from atmospheric precipitation. It is therefore necessary in evaluating the amount of water in Iran to estimate the annual rainfall.

1 Rain

In order to measure the national rainfall some 600 hydrological stations have been established in the past ten years, but the criteria of the rainfall estimates and calculations are made on the basis of statistics obtained from only 200 of these stations, which have been in operation for periods ranging from five to fifteen years. According to studies made by the Department-General of Meteorology the average rainfall throughout Iran is about 30 centimetres.

If we bear in mind, however, climatic changes, the topography of various parts of the country and the fact that these figures are obtained from a network consisting of an average of only one hydrological station for every 8000 square kilometres, it is clear that the estimated figure is an approximate one and does not represent the actual annual rainfall of the country.

A further point which confirms the approximate nature of the above figure is the scattered distribution of the hydrological stations since the present stations are mostly situated in fertile spots with a relatively high rainfall and density of population, with available means of gathering and communicating statistics. For this reason no information is available about the level of rainfall on high or mountainous ground and over hundreds of kilometres of the intensely hot deserts of the interior.

The level of water produced by atmospheric precipitation in Iran. has been measured by four different methods.

a) by taking the mean of the hydrological

b) by dividing the country into various catchment areas.

c) the isohyetic method.

d) the Thyssen method.

The rough estimate is of 450 billion cubic metres per year.

2 Rivers

Another source of water in Iran is from rivers which rise in other countries and flow into Iran. These rivers fall into two categories. The first category is of rivers which rise in the USSR or Turkey. They include the Aras and the Atrak rivers. The amount of water which enters Iran in this way is about 3.9 billion cubic metres. The second category is of rivers which rise in Afghanistan. They include the Hirmand and Harirud rivers. The amount of water which enters Iran in this way is about 3.6 billion cubic metres. The total amount of water accruing to Iran from this source is therefore about 7.5 billion cubic metres, which when added to the water resulting from atmospheric precipitation gives a combined total of 457.5 billion cubic metres per year.

3 Underground Water

Another source of water in Iran is from underground streams entering the country from neighbouring countries. But against this quantity should be set the quantity of water which flows from Iran into neighbouring countries and seas. Although the amount lost in this way might considerably exceed the amount gained, because of the lack of accurate information on this point it has been assumed that the two amounts are equal, and therefore the difference between water gained and water lost by means of underground flow has been ignored in estimating the country's water resources

B OUTGOINGS

Against the amounts of water received the amounts leaving the country or consumed inside the country can be summarized as follows:

1 Rivers

The rivers which flow in Iran can be divided into three main basins.

	Millions of cubic metres per year
The Persian Gulf and Sea of Oman Basin	57751
The Caspian Sea Basin	16627
Central lakes and swamps	6450
	80828

Since several gauging stations are not situated exactly at the mouth or point of exit from Iran of the rivers a certain amount of subsequent offtake, estimated in all at 2.83 billion cubic metres, may be subtracted, giving a total amount of about 78 billion cubic metres of water which leaves Iran by means of rivers.

2 Consumption

The water consumed for various agricultural, urban, industrial and animal husbandry purposes in fact constitutes the useful annual consumption.

Table No. 2 shows the consumptive use of water and the area under cultivation of various crops.

As will be noted, the amount of water used in the more than 3,068,070 hectares of irrigated land is about 29 billion cubic metres, an average of 9450 cubic metres per hectare. It is necessary to add in this connection that this figure only indicates evapotranspiration and field evaporation loss. The following amounts of water are at present obtained from each of the given resources:

	in billions of cubic metres per year
Rivers	16
Ghanats	9
Deep and shallow wells	4
	29

According to calculations carried out for the roughly 1,800,000 hectares irrigated by rivers some 1600 cubic metres water per second are withdrawn from the rivers. The annual consumption of water per hectare including wastage is therefore about 27,000 cubic metres. As we have already seen, the consumptive use is 9450 cubic metres per hectare, the co efficient of efficient use of surface waters for the whole country is about 35 per cent. Thus, in order to obtain the 16 billion cubic metres required for useful consumption it is necessary to withdraw about 45 billion cubic metres from the rivers, of which seven billion cubic metres drains back into the rivers, consequently reducing net withdrawal from rivers for purposes of irrigation to 38 billion cubic metres.

Regarding ghanats, although water losses in ghanats are considerably smaller than in the case of surface water, the wastage of ghanat water in certain months of the year is such that the co-efficient of efficient utilization of ghanat water has been estimated at about 60 per cent. It therefore follows that the total amount of ghanat water consumed in a year is about 15 billion cubic metres.

Studies carried out indicate that the amount of wastage of water from deep and shallow wells, which occurs only in the fields and in irrigation networks is limited and has been estimated at 20 per cent. Thus the total offtake from deep, medium-depth and shallow

Table No. 2

Estimate of the Total Annual Amount of Water Required for Irrigated Cultivation in Iran

Crop	Area of Irrigated Cultivation (in thousands of hectares)	Percentage of Total Area of Irrigated Cultivation	Average Amount of Water Required for Crop during Cultivation (in cubic metres per hectare)	Total Amount of Water Required (in millions of cubic metres)	Area of Non-irrigated Cultivation (in thousands of hectares)	Percentage of Total Area of Nonirrigated Cultivation
Wheat	1414	46.1	4649	8033	2598	66.5
Barley	314	10.2			879	22.5
Cotton	260	8.4	8191	2130	100	2.6
Rice	347	11.4	34685	12037	3	—
Sugar Beet	82.5	2.6	8216	678	—	—
Sugar Cane	435	0.2	60000	261	—	—
Potatoes & other vegetables	111	3.6	7607	844	99	2.5
Fruit	280	9.6	11110	3110	80	2.1
Tea	—	—	—	—	26	0.7
Tobacco	10	0.3	5550	55	10	0.3
Oil Seeds	25	0.8	4942	123	1.2	—
Grasses (alfalfa lucerne, French grass)	110.22	3.6	11000	1212	24.18	0 6
Cereals not otherwise included	110	3.6	4364	480	90	2.2
Total	3068.07	100	9440	28963	3910.38	100

wells is estimated at about 5 billion cubic metres. In short, to obtain the 29 billion cubic metres required for irrigation in Iran the quantities of water withdrawn from surface or underground resources are as follows:-

		in billion of cubic metres per year
Rivers	38+7	45
Ghanats		15
Wells		5
	Total	65

Table No. 3 shows in summary form the amount of consumptive use of water in the various types of cultivation and in forest regions and pastures in the whole country, and as will be observed the total amount of water required annually for the more than 20 million hectares of cultivated land, including irrigated and non-irrigated land, forests and pastures, is about 78 billion cubic metres.

Table No. 3
Estimate of Total Annual Amount of Water Actually Used in Cultivation, including Evaporation

Type of Cultivation	Area of Cultivation (in hectares)	Total Amount of Water Used for Each Type of Cultivation (in millions of cubic metres per year)
1 Irrigated Cultivation	3,068,070	28.96
2 Dry Farming	3,910,380	7.84
3 Forest Regions	6,600,000	21.00
4 Pastures	6,740,675	20.10
Totals	20,319,125	77.90

Forest regions and pastures other than first and second class land have been ignored in this table.

The amount consumed in towns varies according to the degree of importance of the towns, so that the annual per capita consumption of water is 60 cubic metres in Tehran, while in third class towns the comparable figure is 10 cubic metres. For this reason it is extremely difficult to determine an exact figure for urban consumption. From available figures, however, it can be estimated that the average annual per capita consumption of water is 18 cubic metres, which gives a total figure of consumption for the entire population of the country of 450 million cubic metres. The consumption of water by domestic livestock of all kinds, totalling 50 million in all, is estimated at about 100 million cubic metres.

Although the consumption of water for industrial purposes in Iran is at present very small, it is expected that since heavy industry (such as the steel, petrochemical and aluminium industries) will get underway in the next few years, the quantity of water required for this purpose will also increase. At present the water required for the steel industry, which is at the initial stages of its development, is about three cubic metres per second and allowing for losses an annual consumption of about 200 million cubic metres is envisaged for this industry. It is planned to obtain this quantity of water from the reservoir of the Shah Abbas the Great dam, which is to be built on the Zayendeh Rud river.

If it is supposed that the water consumed in industry and for other urban purposes and the offtake from rivers by farmers for various non-agricultural purposes is about 450 million cubic metres, then the total consumption for all urban, industrial and livestock purposes is about one billion cubic metres per year.

3 Infiltration

A further quantity of water obtained from atmospheric precipitation permeates down to the existing underground water resources. Since, however, there is always a kind of equilibrium between the input and offtake of underground water resources and also since the utilization of underground water resources to an extent greater than the safe yield is not permitted, infiltrated water can therefore be divided into two categories.

The first category consists of water which is taken from ghanats, wells and a few rivers fed from underground resources, and utilized. Since this quantity has already been provided for in the calculations of outgoings of water under the heading "water consumed" there is no need to consider it again here. The second category consists of water which when it percolates to groundwater, without being utilized in any way, into swamps and lakes where it evaporates. This water is considered in the estimates of total evaporation in the country.

Based on the above calculations we can draw up the following balance sheet of Iran's estimated water resources:

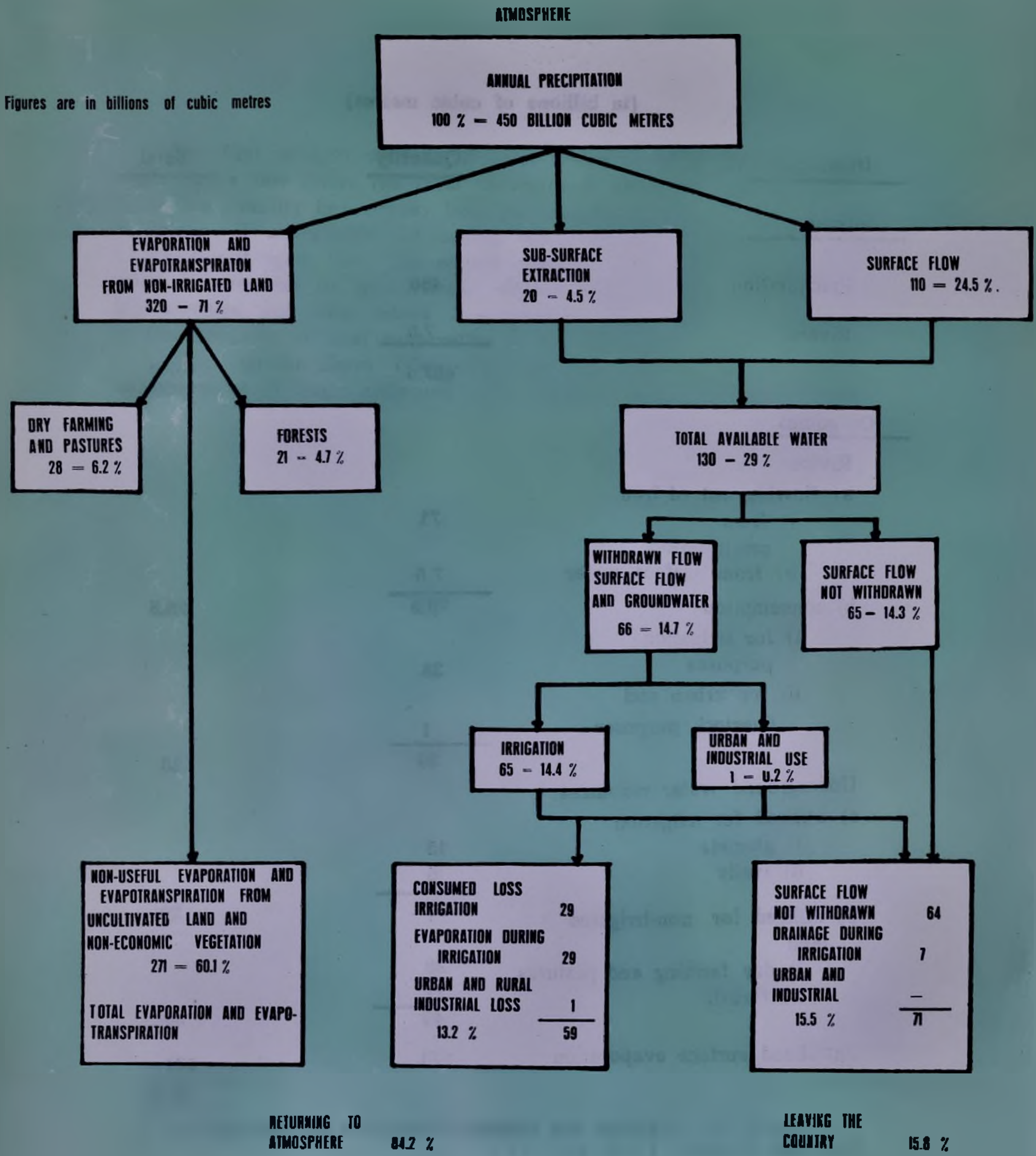
(in billions of cubic metres)

Item	Quantity	Total
Income		
Precipitation	450	
Rivers	7.5	
	457.5	457.5
Outgoings		
Rivers:		
a) flowing out of Iran		
i) from precipitation	71	
ii) from surface water	7.5	
	78.5	78.5
b) consumption		
i) for irrigation purposes	38	
ii) for urban and livestock purposes	1	
	39	38
Underground water resources:		
a) utilized for irrigation		
i) ghanats	15	
ii) wells	5	
	20	20
b) utilized for non-irrigated land		
i) dry farming and pastures	28	
ii) forests	21	
	49	49
Unutilized surface evaporation	271	271
		457.5

Figure No. 2 shows the average distribution of precipitation in Iran and its cycle. (See page 18)

FIG. NO 2

Water Balance and Water Cycle of Iran



Note : The above figure only covers water produced from atmospheric precipitation, the 7.5 billion cubic metres received from rivers flowing into Iran being equated with the amount leaving the country as surface flow.

PROBLEMS OF WATER AND IRRIGATION

As has already been indicated, the amount of water produced by atmospheric precipitation each year in Iran is about 450 billion cubic metres, the equivalent of 28 centimetres of rain over the entire surface of the country.

From the point of view of irrigation, geographic and seasonal distribution of precipitation are both of great importance. One third of the entire rainfall in Iran occurs in the Caspian Sea drainage area which represents one tenth of the land surface of the country, while another third occurs in the central plateau, the area of which is more than one half of the country's land surface.

Another aspect of the rainfall distribution in Iran is that only 4 per cent of the area of the country receives more than 50 centimetres of rain per year and this represents 27 per cent of the entire rainfall, whereas the remaining 73 per cent of rainfall occurs in 96 per cent of the country, in other words the averege rainfall in 96 per cent of the area of the country does not exceed 20 centimetres.

It should therefore be noted that the local distribution of this slight rainfall is by no means uniform throughout the country: the major part of it occurs on the northern slopes of the Alborz mountain range and in the west of the country and because of the mountainous nature of these regions a large amount of the rainfall turns into surface torrents and flows out of the country.

A further adverse factor is that on the plains, because of the scattered nature of the rainall and the high temperatures, before the rain can form a surface flow or link up with surface or underground water resources it re-evaporates and returns to the atmosphere. As a result, it is primarily the rainfall on high ground which feeds the surface and underground water resources.

As regards seasonal distribution, although most plants have their maximum period of growth in summer, most of the country's rainfall occurs at the end of winter and the beginning of spring, whereas in the summer months when the need for water is at its greatest the amount of rainfall reaches its minimum level, and the water-level of the rivers also drops.

Another unfavourable factor which has an adverse effect on irrigation in Iran is the high rate of evaporation. As a result of the abundant sunshine in Iran the rate of evaporation (including evapotranspiration of plants) is exceptionally high. In Tehran, for example, where the mean annual rainfall is 22 centimetres, the rate of potential evaporation is about 300 centimetres, in other words the rate of potential evaporation is almost 13 times that of actual rainfall. In the central desert region, the rate of potential evaporation is as much as 62 times that of actual rainfall. These high rates of evaporation, which occur mostly in the hot months of the year, both intensify the need of plants for water and at the same time result in an increase in the wastage of water.

One final factor which must be taken into consideration in any study of the state of irrigation in Iran is the quality of the water and soil. Unfortunately as a result of the large extent of evaporate geological formations containing lime and salt a considerable number of the rivers in Iran are brackish. The use of water from these rivers for irrigation purposes and the prolonged cultivation of land without restoring its fertility by means of fertilizers has led to large areas of level land on the central plains and plateaus becoming brackish and eroded.

These four principal factors: the unfavourable geographic distribution of rainfall, the unfavourable seasonal distribution of rainfall, the high rate of evaporation, and the erosion and development into brackish land of low-lying downstream land, have caused numerous difficulties in irrigation and agriculture in Iran.

Inasmuch as these natural factors have from the earliest times led to a connection between the nature of agriculture in Iran and the amount of rainfall and the possibilities of utilizing rivers for irrigation purposes and since except for the Caspian Sea littoral most parts of Iran receive their rainfall at the end of winter or beginning of spring, agriculture in Iran has mostly been limited on the central plains to winter crops which have their greatest need for water in winter or early spring and in the foothill areas to dry farming. The two principal crops involved in this type of farming are wheat and barley. Of the four million hectares that are estimated to form the dry farmland of Iran, 3.5 million are under these two crops. Since they both tend to require most water towards the end of the spring when there is rarely any rainfall it follows that as a result of the inefficient methods of irrigation the yield per hectare is extremely low. In Iran the average yield for non-irrigated wheat is 482 kilogrammes per hectare, and that of non-irrigated barley 508 kilogrammes.

For this reason Iranian farmers long sought to make the maximum utilization of underground and surface water resources by digging wells and ghanats, and building dams and canals. As evidence of their struggle against the shortage of water we can still see signs of their activities, in various parts of the country such as numerous reservoir and diversion dams like the Shah Abbas dam near Saveh and the Amir dam near Birjand, the Golestan, Akhlemad and Torogh dams near Mashhad, the Abbasi and Shish Taraz dams near Kashmarv, the Foriman dam near Torbat Jam the Band-e Amir, Feizabad and Tilkan dams near Shiraz, and the Band-e Bahman dam at Kavar; large-scale canals such as the Shahpour canal downstream of Dezful and the Darius canal in Fars, which was used to irrigate land in Khuzestan as well as around Persepolis, the Nader canal at Moghan, and the Gargar canal in Khuzestan; and various constructions to stabilize river beds or raise the water level.

The digging of ghanats goes back at least 2500 years in Iran, and was especially practised on elevated and sloping plains on the central plateau and in the dry, unfertile desert regions where rivers did not give sufficient year-round water. These ghanats used to number more than 40,000 separate networks and serve more than 30,000 villages or farms. Studies*carried out in 1963, which were based on statistics available on ghanats up to the year 1961, showed that there were about 20,000 ghanats in use, with an estimated annual output of about 16 billion cubic metres. At the time these ghanats supplied about one third of the water required for irrigation in Iran, although in recent years, because of the increase in the numbers of deep wells and the drop in the water-table resulting from prolonged periods of drought, the use of ghanats has somewhat declined. Some ghanats now have a lower output, others have gone completely dry. For these reasons at present the total annual output from ghanats, including both consumption and waste, is estimated at 15 billion cubic metres, of which only 9 millon is usefully consumed.

---

* Source "The Ghanats of Iran" by Eng. Manuchehr Vahidi, published 1963.

HOW IRAN'S WATER RESOURCES ARE UTILIZED

The hydrological nature of water creates four major problems affecting the balance between the supply and demand of water. These are:

a) **Differences of Time**

By this is meant the fact that the time when water is usually available and the time when it is actually needed do not co-incide with each other, as for example the fact that rain usually falls in winter and spring whereas plants require water for their growth and fruition in summer.

b) **Differences of Quality**

By this is meant that the quality of water available in its natural state does not conform to the quality of water required. Sea-water cannot be used in its natural state, for example.

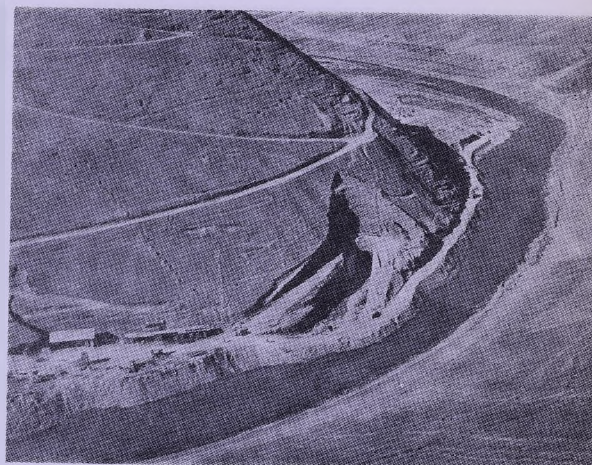
c) **Differences of Quantity**

By this is meant that at a given time and place there is no balance between the amount of water available and that required. For example, at the end of winter when the need for water is at its minimum the amount of water in the rivers is at its maximum.

d) **Differences of Place**

By this is meant that the place where water is available is not the same as that where it is used. For example, water from rivers or lakes which is needed for urban or agricultural purposes may have to be conveyed to where it is needed.

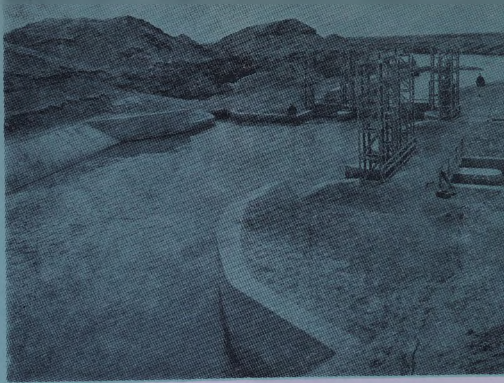
It should be borne in mind, of course, that at any given time and place the amount of water for which a demand exists is fairly fixed and defined, or at least only undergoes slight variations. In most cases therefore, in order to bring about a balance between supply and demand the natural supply of water has to be brought under control. For example the amount of water required by the city of Tehran in July or the amount required for cultivation of a given area and crop is fixed, and to supply these fixed amounts it is first of all necessary to control the amount of water naturally available. To achieve this aim, to regulate the available water and to co-ordinate it with the demand, the following methods can be used.

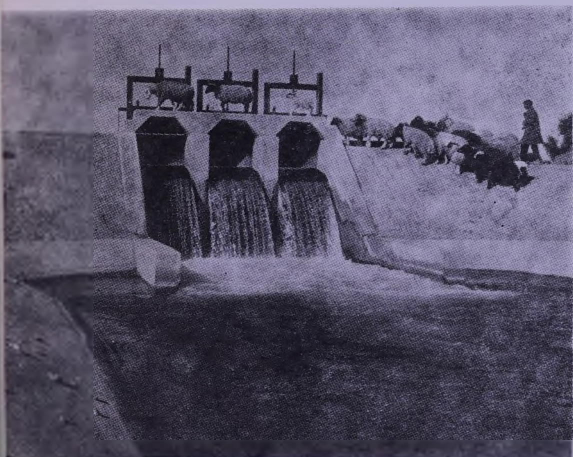


Precipitation is the chief source of Iran's water supplies

The Zayandeh Rud river, Esfahan province

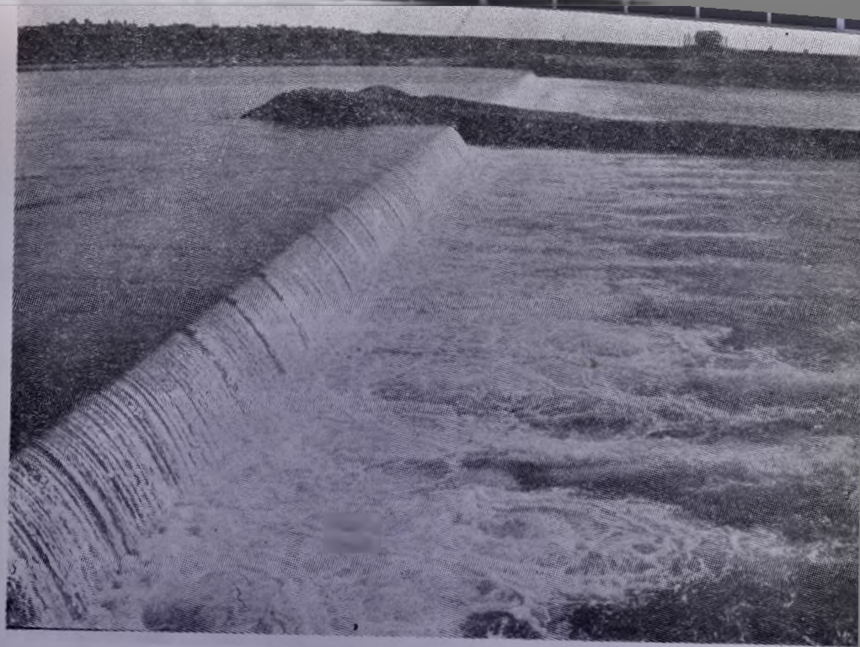
Another view of the Dasht Moghan irrigation network





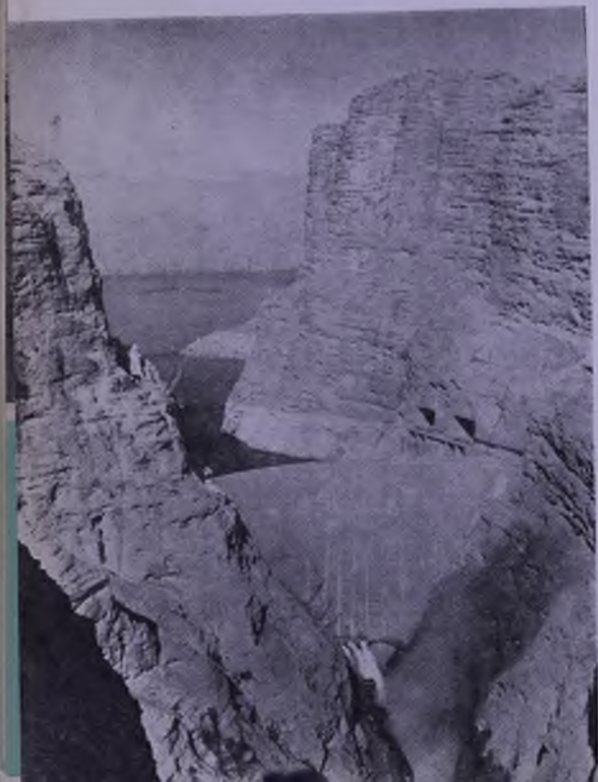
Regulating reservoir of the Dasht Moghan irrigation network

View of the irrigation network of the Mohammad Reza Shah Pahlavi dam, Khuzestan province



Some of the installations of the Dasht Moghan irrigation network, East Azarbaijan

Extraction of groundwater



Mohammad Reza Shah Pahlavi dam,
on the Dez river, Khuzestan province

A) Desalination of Salt-water

The distribution of water in nature is such that the oceans form 97 per cent of all the water and only 3% is found on the land surface. Only 35 per cent of this latter amount is in fact capable of being utilized for reasons of quantity or quality. In other words only 0.1 per cent of all the earth's water resources can be utilized, i. e. the water of the oceans is 970 times greater than what can be utilized on the land surface. It follows that there are tremendous possibilities for using this mighty untapped resource. In Iran, which has access to the open sea as well as the inland Caspian Sea, there is scope to desalinate sea water, especially in the southern regions of the country. With existing methods, and considering the annual income per hectare irrigated desalination of sea water for purely agricultural purposes is simply not economically viable. For drinking too, other than in exceptional or unavoidable cases, it is not a practical proposition.

In recent years attempts have been made to use intermediate energy for power generation in the process of desalination and to reduce the unit cost per cubic metre produced by increasing the capacity of the desalination plants. The cost of producing one cubic metre of water by conventional means, however, is still in the region of 10 - 20 Rials, which is very high in comparison with other methods. The cost of a cubic metre of ghanat water, for example, is 0.35 Rials, and the comparable figure for deep wells is between 0.4 and 0.8 Rials and for reservoir dams it is between 0.6 and 1.0 Rials. As a result of the progress which is being made in this field, however, the cost per cubic metre of desalinated sea-water will be reduced and at the same time as a result of the limitations of existing surface and groundwater resources and the gradual rise in the price of agricultural products the marginal cost of a cubic metre of water produced from existing resources will also rise. This will probably mean that at some future date the only unlimited source of water which can be utilized will be sea-water and this method will become practical and economically viable. For the country's development agency has not ignored the importance of this matter and intends to set up fully-equipped research centres on the southern coast of Iran to investigate the various methods of desalination. For this purpose a desalination project was approved by Plan Organization under the Third Plan (1962 - 1968) and the Faculty of Engineering of Tehran University was given the task of carrying out the preliminary research in this subject.

Tehran University, utilizing the credits approved for this project, has completed the first stages of this work, and now intends to make use of two desalination units bought years ago. Another plan is to take advantage of the abundant sunshine in the country to set up various evaporation plants and to build an experimental plant which would utilize solar energy to desalinate the water. Steps in this direction have already been taken.

B Direct Utilization of Precipitation

In places where the amount of rainfall is sufiicient and the cultivation of crops is possible without irrigation, atmospheric precipitation is utilized directly for dry farming. At present almost four million hectares of land are under such cultivation. This land accounts for 7.84 billion cubic metres of rainwater a year. Of the total 2,600,000 hectares (66.6 per cent) is given over to wheat and 900,000 hectares (22.5 per cent) to barley.

Other methods are also used for the direct utilization of rainfall, such as gathering the water in reservoirs and so on, but such utilization was mostly restricted in former days to ensuring a supply of summer drinking water in places where rivers run dry or become brackish in summer. Such methods are gradually being abandoned.

C Utilization of Surface Waters

A brief examination of the balance sheet of the country's water resources reveals the fact that of the 457.5 billion cubic metres which enters the country each year 117.5 billion metres takes the form of surface flow and the remainder returns to the atmosphere by means of evaporation or evapotranspiration. Of this amount 39 billion cubic metres are utilized for irrigation, urban consumption, etc. and the balance of about 78.5 billion cubic metres leaves the country without being utilized. It may therefore be noted that in Iran vast opportunities exist for the harnessing of surface water resources.

Most of the rivers of Iran are fed by rain and a small number also by melting snow. For this reason they are mostly full of water and subject to flash floods in winter and early spring and become dry or very low in water in summer, which is the season when summer crops and industrial cash crops such as cotton, sugar beet, sugar-cane and oil-seeds tend to have their greatest need for water. In order to utilize the spring surplus waters in summer or in other words to make the natural supply of water, which is at the end of winter and the beginning of spring, conform to the demand of various cash crops whose need for water reaches its peak in summer, two procedures are possible.

1. Surface Storage

In recent years the following surface reservoirs (dams) have been constructed and are now in use:-

a) The Shah Esmail dam (Golpayegan)
b) The Amir Kabir dam (Karaj)
c) The Empress Farah dam (Sefid Rud)
d) The Shahnaz dam (on the Yalfan river near Hamadan)
e) The Mohammad Reza Shah dam (Dez)
f) The Farahnaz dam (Latiyan)

and the following dams are at present under construction:

a) The Washmgir dam (at Sangarsavar, near Gorgan)
b) The Shah Abbas the Great dam (Zayendeh Rud)
c) The Aras dam
d) The Shahpour I dam (Mahabad)
e) The Cyrus the Great dam (Zarineh rud)

Five more dams are either at the feasibility preliminary planning stage:

a) The Jiroft dam (Halilrud)
b) The Taleghan dam (Shahrud)
c) The Reza Shah the Great dam (Karun)
d) The Nader Shah dam (Marun)
e) The Minab dam

The specifications of each of these Dams is given in Table 4, and its location is shown in Figure 3.

The dams already constructed or under construction harness a total of 9.5 billion cubic metres of floodwater and generate 800 megawatts of power. The water they contain, in addition to meeting the needs of Tehran and Hamadan, irrigates 800,000 hectares of land.

If the above figures are added to those for the dams on which construction will begin during the Fourth Plan the total volume of dam storage capacity will amount to 15 billion cubic metres, and the capacity for controlling flood water will be 27 billion cubic metres (Table 4, column 7). The latter figure is almost equal to the amount of water at present used for irrigation purposes, which is estimated at 29 billion cubic metres. The total storage capacity of dams constructed, under construction or at the planning stage will ultimately enable more than one million hectares of virgin land or farmland which was hitherto inadequately irrigated to receive the benefits of complete and regular irrigation and at the same time will generate 1400 megawatts of power, which apart from operating deep well pumps will serve the needs of new industries such as the steel, petrochemical and aluminium industries.

Finally these dams will also supply the water requirements of various towns and of the steel and other industries.

The cost of constructing the above dams excluding their associated irrigation networks and power generation facilities will amount to 40 billion Rials ($533 million). Including the irrigation networks the total cost will be more than 100 billion Rials ($ 1333 million).

2. Underground storage

Since the surface storage of spring floodwaters in the case of all rivers, especially small ones because of their scattered nature and small volume of water, is either not feasible or uneconomic, the waste of such floodwaters can be prevented by storing them in underground reservoirs and used later at a more favourable or necessary season.

In this respect comprehensive studies for the utilization of seasonal floodwaters in alluvial plains where such procedures are feasible have taken place, and the plains of Ghazvin, Varamin and Garmsar may be mentioned.

For this purpose seasonal rivers flowing in flood channels can be broken up in times of spate by means of small dams and penetration wells drilled in alluvial formations and stored in the ground. The water of these underground reservoirs can be utilized later on since the velocity of underground flow is very slight.

It should be mentioned that this method of storing water was commonly practised in ancient Iran, especially in south Khorasan and on the fringes of the Dasht-e Kavır and even today such facilities known as "band-sar" in Khorrasan and "ab-band" in Biabanak, are constructed

D. Utilization of Underground Water

As we have already observed, the Iranians have from time immemorial been initiators in the construction of ghanats and in utilizing underground water resources. They used the force of gravity to extract this water and brought it to their fields without the use of pumps. Underground water also flows downhill, just as perennial rivers do, until it

Figure No. 3

Dams constructed or under construction in Iran

Table No. 4

Reservoir Dams

Location				Technical Specifications				
Name of project	River	Province	Type	Height (in metres)	Capacity of reservoir (in millions of cubic metres	Annual volume of water regulated (in millions of cubic metres)	Area of land irrigated (in thousands of hectares)	Capacity of power generation (in thousands of kilowatts)
1. Dams already constructed								
Shah Esmail (Golpayegen)	Ghom	Esfahan	Rock-fill	51	28	50	5	—
Amir Kabir (Karaj)	Karaj	Central	Double arch	185	205	400	21(2)	75
Empress Farah (Sefid Rud)	Sefid Rud	Gilan	Concrete-buttressed	106	1,660	2,000	238	87
Shahnaz	Ghoreh Chai	Hamadan	Concrete-buttressed	53	8	17	—(3)	—
Mohammad Reza Shah Pahlavi (Dez)	Dez	Khuzestan	Double arch	203	3,350	6,000	125	520(4)
Farahnaz (Latiyan)	Jajeh Rud	Central	Concrete-buttressed	104	95	245	30(2)	22
				Total this section	5,546	8,712	419	704
2. Dams under construction or for which the final design has been approved								
Washmgir (Sangarsavar)	Gorgan	Mazandaran	Earth-fill	17	60	100	20	—
Shah Abbas the Great	Zayandeh Rud	Esfahan	Thick arch	95	1,450	1,500	85-100	60
Aras	Aras	W. Azarbaijan	Earth-fill	38	675	1400 (1)	70	21(1)
Shahpour I (Mahabad)	Mahabad	W. Azarbaijan	Rock-fill	48	250	195	20	5
Darius the Great (Dorudzan)	Kar	Fars	Rock-fill	60	993	526	76	20
Cyrus the Great	Zarineh Rud	W. Azarbaijan		50	610	535	95	10
				Total this section	4,038	4,256	366	116
3. Dams under study								
Taleghan (with Ghazvin project)	Shah Rud	Central	Rock-fill	68	195	450	60	20
Jiroft	Halil Rud	Kerman	Arched	120	400	325	20	35
Minab	Minab	Southern Ports and Sea of Oman	—	—	—	400	25	—
Reza Shah the Great (Karun)	Karun	Khuzestan	Rock-fill	80	2,700	12,000	132	500
Nader Shah (Karun)	Marun	Khuzestan	Arched	190	1,620	1,150	62	50
				Total this section	4,915	14,325	299	605
Grand Total					14,499	27,293	1,084	1,425

Notes:

1. Iranian share of joint project with USSR
2. Also supplies drinking water for Tehran
3. Supplies drinking water for Hamadan
4. Of this capacity only 130 is at present installed

eventually reaches low-lying land such as river beds, swamps, lakes or salt marshes, where it appears on the surface and then evaporates. As a result of this evaporation, not only is a large part of the country's water resources wasted but in addition the salts contained in the water remain behind and form salt deserts and marshes on the surface of low-lying land.

Since there is always a balance between the evaporation and replenishment of underground water resources the less the latter are utilized the more water will flow into the salt-marshes and evaporate, leading to the formation of more salt-desert. The gradual expansion of desert has ruined much potentially arable land and has increased the level of salinity in water. It is estimated that every year about five billion cubic metres of underground water are wasted in this way.

In Iran there are about 65 million hectares of alluvial plain, most of which has underground water resources. Hitherto, the utilization of these resources has been more or less limited to alluvial formations and of these mostly to existing wells and ghanats. At present the objectives of projects relating to the country's underground water consist of a speedy introductory reconnaissance of these aquifers which are to be found in alluvial formations, and also of studying the possibilities of exploiting resources located in limestone formations. The latter are mostly to be found in Zagros region and in the west of Iran, and at present the limestone aquifers in these parts are exploited by numerous natural springs, the most prolific of which is to be found near Khorramabad. This has an output of about four cubic metres per second and confirms the existence of considerable resources in this formation.

One of the great advantages of exploiting limestone formations is that since limestone aquifers are in direct connection with each other, as long as the confines of the aquifers are known water can be extracted from any convenient location thus avoiding the heavy expenditures involved in conveying water to where it is needed. In several cases, in fact, it is not even necessary to construct water-bearing tunnels as water can be drawn off from a single limestone aquifer on both sides of the mountain it is located beneath. At present the authorities concerned are engaged on gathering complete statistics on springs in the limestone regions of west Iran, and it is planned to carry out useful studies on the exploitation of these resources by means of credits allocated under the Fourth Plan.

In recent years because of continued periods of drought and the relative increase in agricultural activity and the need for more water, and especially because of the facilities made available as a result of the development of engineering techniques and equipment, farmers have been paying increasingly greater attention to the exploitation of underground resources by drilling deep wells. Every year a large number of deep and medium-depth wells are drilled. Since the utilization of these underground water reserves has been at rates greater than the safe yield the water-table has been dropping or the water has dried up completely. This has resulted in the need to take a whole range of precautionary measures designed to prevent such dangers. In some parts of the world, in California for example, where such measures have not been taken, underground water resources have been totally consumed in a period of less than 50 years. Therefore, in order to make the most complete use of these resources and to prevent the desert from advancing and also in order to give guidance to private individuals who have invested their capital in the drilling of deep wells, special projects are being undertaken to study underground water resources.

The purpose of these studies has in the first instance been to find suitable locations in Iran for drilling and to fix permissible offtakes from underground water resources. The basic study of underground water resources in various parts of the country began in 1962 with the start of the Third Plan and by the end of the Plan (March 1968) credits totalling about 500 million Rials ($ 6.6 million) will have been allocated to this study.

The study of the country's underground water resources has in general been carried out by study groups consisting of Iranian engineers and technicians. Their findings are given in 17 volume report "The Management of Groundwater" by the Ministry of Water and Power.

At the same time as the basic study of the underground water resources has been carried out on-the-job courses have been held to train personnel and produce the necessary technical staff. To date about 100 engineers, graduates and geologists have undergone such specialized training

Parallel with the above study projects related to the utilization of underground water resources have also been carried out. A good example of this is the development of the Ghazvin plain by means of deep wells.

Based on studies already completed in Ghazvin the amount of underground water in the region is estimated at 360 million cubic metres and it is known that every year part of this water flows to the desert without being utilized To prevent this, and to utilize such water, irrigation and agricultural development work have been carried out side by side in the Ghazvin region.

For this purpose, in addition to the existing private wells, which yield roughly 80 million cubic metres of water per year, it is planned to drill a further 350 wells so as to utilize the remaining 270 million cubic metres of underground water. To date more than 20 exploratory wells have been drilled and by the end of the Third Plan it is expected that the number of producing wells will exceed 200.

Parallel with these developments the project for the transmission of power from the Empress Farah dam (Sefid Rud) to Tehran was begun. The route of the transmission line passes through Ghazvin and by March 1967 some 60 of the wells of the Ghazvin Region development project were being operated by electric pumps powered by this source. All future wells in the Ghazvin region will be so operated.

E Conveyance and Distribution of Water

Differences between the location of water supply and demand are usually overcome by means of conveyance lines and irrigation networks. The question of water conveyance and the construction of canals and irrigation networks has always been of great importance in Iran, but because of the long distances involved and inadequate supervision and building materials networks were so constructed that water losses were excessive.

The average loss of water in open irrigation channels between the river from which they draw their water and the point where they discharge it in the fields is about 34 per cent, provided they are constructed in accordance with proper engineering principles. In the USA, for example, where the total length of irrigation canals is about 200,000 kilometres and the annual flow is about 110 billion cubic metres, the loss is about 38 per cent, i. e. more than 41 billion cubic metres. In ordinary canals, constructed like natural streams and not properly engineered, the water loss is far higher, especially in summer when their importance is greatest. It can even run as high as 60 or 50 per cent.

In Iran, as we saw in our study of the nation's water resources, in order to ensure the supply of the 16 billion cubic metres of water required for agricultural purposes, about 45 billion cubic metres of water have to be taken from rivers, of which 29 billion cubic metres is wasted in dams and before reaching the fields. Bearing in mind that as much as 7 billion cubic metres drains back to the rivers we see that the net wastage is about 22 billion cubic metres, in other words about 1.4 times the amount usefully consumed. This fact offers clear proof of the great importance of the question of water wastage especially in countries suffering from a shortage of water, and there is no doubt that the area of irrigable land can increase in inverse proportion to the reduction of water wastage. The causes of wastage can be summarized as follows:

1 Use of old water-courses: instead of flowing along irrigation canals designed on correct technical principles, the water flows in open canals, resulting in wasteful evaporation.

2 The permeability of the soil through which many existing water courses pass, such as sandy soil.

3 The failure to dredge water courses, which results in a reduction of the rate of flow and an increase in the rate of evaporation.

4 The growth of weeds in the water-courses which reduces the rate of flow and increases wastage by evaporation or evapotranspiration.

5 The principle of allocating river water to villages on the basis of proximity to the head of the river, since according to local customary law the right to first use of the water belongs to the village nearest the head of the river, and after that to the next village downstream, and so on.

One result of this is that some villages which are situated in valleys have abundant water supplies which they waste on permeable or stony soil. Another result is that the crop rotation necessary to obtain the maximum utilization of the water and proper distribution of water is not practised in such land.

6 The lack of a spirit of cooperation and the inclination of the population of each village to have an independent water supply are factors which lead to an increase in the wastage of water, because in order to ensure confidence and independence for their agriculture, most villages try to create an independent water channel free from any possible upstream interference and as a result instead of utilizing only one or two principal channels and a number of secondary channels they sometimes have more than a hundred long-distance channels running parallel to each other, each carrying only a small quantity of water. For this reason in some cases three or four times the quantity of water actually required for irrigation has to be brought by these channels.

7 The lack of information on the part of the villagers regarding correct technical methods of irrigation and agriculture and their lack of sufficient capital mean that when they want to bring water to their village or to the fields they make a separate channel leading off the main stream at a point higher up and naturally further away, while in most cases it would be perfectly possible by following quite simple techniques and using pipes or creating a syphon to bring the water direct to the fields or the village and thus avoid the present wastage of water.

8 When land is not properly levelled the distribution of water to the fields is not uniform, so that one part of a field may receive too much water which results in waste while another part receives less than its proper share or even none at all.

Recently, to overcome some of these deficiencies, the question of creating surface reservoirs and new irrigation networks, and controlling the flow of rivers, has received attention, and work has begun to implement such schemes.

a) Moghan Irrigation Network

At its present stage of development this network irrigates more than 18,000 hectares (44,500 acres) of land in the Moghan plain. The 20 million cubic metres of water required by this area are supplied from the Aras river by means of a network of main irrigation channels the total length of which is 75 kilometres. After the completion of the joint Irano–Soviet Aras dam project and the resulting control of the river, the area utilizing the irrigation network will reach 60 million hectares (148 million acres) and the water required will be supplied from the dam reservoir.

b) Karkheh Irrigation Network

The installations forming the Karkheh dam project consist of a diversion dam and two main water channels on each side of the river and a "water distributor". The dam is of the earthfill type, with a total length of 192 metres, a height above the river bed of 4.5 metres, and ten sluice gates for flood control. The channel on the left bank is 11 kilometres long and has a capacity exceeding 40 cubic metres per second. The channel on the right bank is 6.5 kilometres in length and has a capacity of 8 cubic metres per second. The left bank channel has a number of devices which divert the water back to the old bed of the Karkheh river which was dry for many years. In addition, in order to ensure a more plentiful supply of water during the summer, which is the period when it is most needed, the Tavana channel, 8.6 kilometres in length and with a capacity of 20 metres per second, has been built. This channel links the Dez river to the Karkheh and during times of water shortage brings some of the former's excess waters to the latter. The Karkheh project was completed in 1965 and its facilities are now in use. This network will irrigate 60,000 hectares when completed. To date, the main channels for 10,000 hectares have been built.

c) Sefid Rud Irrigation Network

The construction of this network was planned as part of the Empress Farah dam project and as soon as the construction of the dam itself was completed work began on the construction of the principal network. The area of land which will ultimately be irrigated by this network will reach 238,000 hectares (588,000 acres). The construction of this network, which may be termed the project for the development of the whole Gilan plain, is being implemented in several stages because of its vast size and importance and its exceptionally high cost, and the experience gained in implementing each stage is incorporated in each subsequent stage.

In this regard the difficulties over credits and social problems which have occurred in giving the farmers a share in the completion of some parts of the project (namely, the creation of tertiary and lateral channels) must be borne in mind.

The first stage of development consisted of the construction of diversion dams on the Sefid Rud and the main channels.

In the Sefid Rud delta this stage consisted of the Sangar dam and the main channels on the left and right banks of the river, and in the Fouman region it consists of the Tarik dam and the Fouman tunnel and channel as far as the Masuleh river. The second stage consists of the diversion dams on the various Fouman rivers and the main channels and channels linking the new network with the old streams (such as the reconstructed Nowrud and Tushajub channels) and also the last part of the Fouman channel up to the village of Shandermen. After that comes the third stage during which the secondary channels will be built and the project for turning copse-land into arable land will be carried out. Figure 4 gives a general outline of these installations. At present all the operations relating to the first stage of development and a large part of the operations of the second stage have been com-

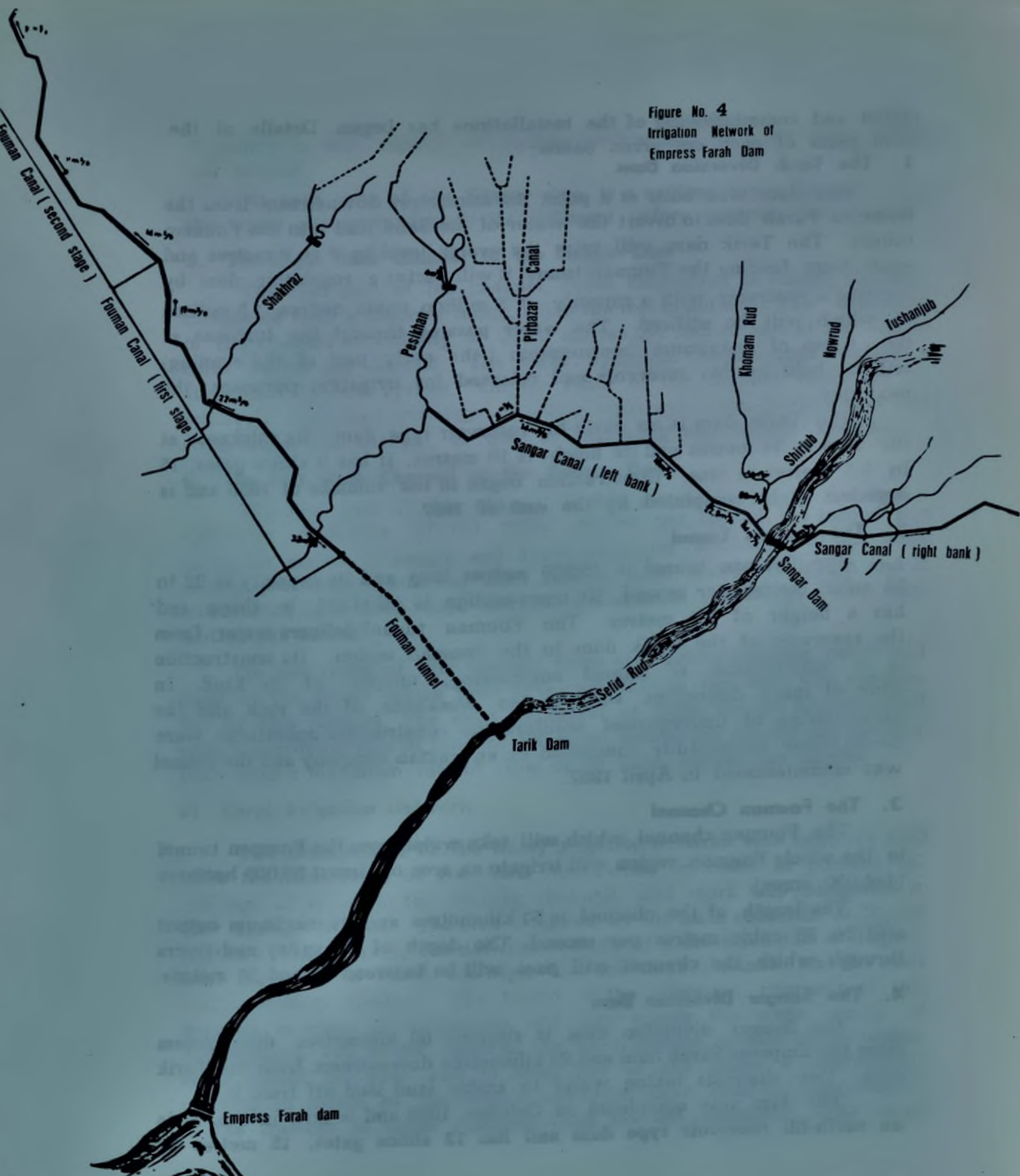


Figure No. 4
Irrigation Network of
Empress Farah Dam

pleted and commissioning of the installations has begun. Details of the main parts of each are given below:

1. The Tarik Diversion Dam

This dam was built at a point 35 kilometres downstream from the Empress Farah dam to divert the water of the Sefid Rud into the Fouman tunnel. The Tarik dam will raise the water level by 8 to 9 metres and apart from feeding the Fouman tunnel it will act as a regulating dam by creating a reservoir with a capacity of 5 million cubic metres, 1.5 million of which will be utilized. The water passing through the turbines at the times of maximum consumption (the early part of the evening) will be held in this reservoir and released for irrigation purposes the next day.

The Tarik dam is an earth-fill reservoir type dam. Its thickness at the base is 54 metres and its height is 10 metres. It has 9 sluice gates, 15 by 5.5 metres in size. Construction began in the summer of 1965 and is expected to be completed by the end of 1967.

2. The Fouman Tunnel

The Fouman tunnel is 16,569 metres long and its capacity is 32 to 35 cubic metres per second. Its cross-section is elliptical in shape and has a height of 3.5 metres. The Fouman tunnel delivers water from the reservoir of the Tarik dam to the Fouman region. Its construction is a masterpiece of tunnel engineering, unique of its kind. In spite of many difficulties such as the weakness of the rock and the encountering of underground aquifers the construction operations were nevertheless successfully completed by an Iranian company and the tunnel was commissioned in April 1967.

3. The Fouman Channel

The Fouman channel, which will take water from the Fouman tunnel to the whole Fouman region, will irrigate an area of almost 60,000 hectares (148,000 acres).

The length of the channel is 51 kilometres and its maximum output will be 35 cubic metres per second. The depth of the valley and rivers through which the channel will pass will be between 10 and 15 metres.

4. The Sangar Diversion Dam

The Sangar diversion dam is situated 60 kilometres downstream from the Empress Farah dam and 25 kilometres downstream from the Tarik dam. Two channels taking water to arable land lead off from it.

The dam was completed in October, 1963 and is now in use. It is an earth-fill reservoir type dam and has 13 sluice gates, 15 metres by

5 metres in size, capable of dealing with a flow of 5,200 cubic metres per second.

At each side of the Sangar dam is a settling basin through which the water passes to deposit its sediment before entering the channel.

5. The Right Bank Channel of the Sangar Dam

The first part of the channel, three kilometres in length, has been completed with a concrete lining, while the rest is unlined. The discharge of the channel is initially 67 cubic metres per second and at the end 14 cubic metres per second. The main hydraulic installations include a suspended syphon system. On the route of the channel there are 38 relatively important crossings including highways. some passing over and some under the channel, as well as regulating and offtake systems.

6. The Left Bank Channel of the Sangar Dam

The first part of this channel is 833 metres in length and has a maximum discharge of 114 cubic metres per second, the second part is 20,995 metres in length and has a maximum discharge of 2.5 cubic metres per second, and the third part is 2,581 metres in length and is constructed on a steep slope and has a maximum discharge of 6 cubic metres per second.

On the route of this channel there are various crossing points and most of the rivers which used to branch off from the Sefid Rud are now fed by this channel. The most important of them are the Khomam Rud with a maximum rate of flow of 68 cubic metres per second and the Shir Joub with a maximum rate of flow of 38 cubic metres per second.

d) Karaj Irrigation Network

The construction of the Karaj irrigation network was begun in 1963 after the completion of the Amir Kabir dam in order to prevent the wastage of water in the existing channels, and work was completed in the spring of 1967. The area irrigated by the main channels is 25,000 hectares (62,000 acres). The network consists of a diversion dam at Bilghan, near the town of Karaj, the right and left bank channels, and the main and subsidiary dividers. The length of the irrigation channels of this network is about 70 kilometres, and they supply the water needs of 116 villages. The water rights of the Karaj villages amount to 160 million cubic metres per year and to bring this to the fields a considerable quantity in excess of this amount had to be taken from the river because of the wastage of water resulting from the old channels. The construction of this network prevents this wastage and as a result in addition to the controlled irrigation of 14,000 hectares (35,000 acres) of arable land a further 7,000 hectares (17,000 acres) of virgin land have been brought under irrigation on a temporary or permanent basis.

e) Golpayegan Irrigation Network

The purpose of building this network was to ensure the complete and proper utilization of the water stored in the reservoir of the Shah Esmail dam.

The water rights of the Golpayegan district amount to 900 litres per second, while the useful capacity of the reservoir of the Shah Esmail dam, is about 24 million cubic metres. The run-off from the dam is between 1.5 and 3 cubic metres per second and the irrigation network was built in order to utilize the amount in excess of the water rights by cultivating virgin land.

The project consists of the construction of a diversion dam, water conveyance canals and syphons and nearly 70 kilometres of access roads. The construction of this network began in August 1964 and was completed in September 1966. The total length of the water conveyance canals is about 4770 metres.

f) The Dez Irrigation Network

One of the objectives in building the Mohammad Reza Shah Pahlavi dam, with its capacity of 3.3 billion cubic metres, was to supply the water needs of the land south of Dezful. The completion of this task was planned in two stages. During the first stage it was planned to acquire useful and necessary data and experience on 20,000 hectares of land allocated to the Dez irrigation project, as a pilot project, and then to develop the scope of activities to the entire 120,000 hectare area.

The population resident in the region of the Dez irrigation project exceeds 12,000 in 28 villages. Formerly only 20 per cent of the project land was irrigated during the summer and 65 per cent during the winter, and the irrigation was carried out by 13 old fashioned canals. Earth dams, which were built at great expense, were washed away by the first floods and were troublesome and costly to dredge. The new network consists of the following principal installations:

The weir. The water from the river is diverted to the main canals in the quantities required by means of this weir. The height of weir is 3 3 metres and its length is 200 metres.

Main canal. The length of this canal is 1.7 kilometres and its discharge is 67.5 cubic metres per second. It takes water from the weir and conyeys it to the eastern and the western canals. At its end are four radial gates which control the flow of water entering the canals. The eastern canal, which has a capacity of 54 cubic metres per second, and a length of 28 kilometres, provides two-thirds of the water required for the pilot irrigation project. There are 17 water control devices along its route and 20 feeder canals, with a total length of 126 kilometres, branch off it. The western canal has a capacity of 13.5 cubic metres per second and is 13 kilometres long. It supplies water for six feeder canals, with a total length of 25.4 kilometres.

The pilot irrigation project began in September 1962 and was completed in May 1965. Work has now started on Phase Two, which will irrigate a further 100,000 hectares.

Conveyance of Water from Karaj to Tehran

In addition to measures taken to utilize the Amir Kabir dam for irrigation purposes, which has already been fully described, a project was also approved under the Third Plan for the conveyance of water from the dam to Tehran. As a result of this, regulated run-off from the dam is conveyed to Tehran for the consumption of the population by means of a downstream diversion dam on the Karaj river and two pipelines.

ECONOMIC STUDY

Economic studies are conducted so as to determine how proposed projects would contribute towards achieving and accelerating the economic and social growth and development of the country. Clearly all the objectives of such development cannot be reached by means of a single project but can be approached by a number of complementary projects designed to meet the specific needs of the country.

Generally speaking, an economic survey of any project takes the form of three separate stages, and examines it at the national level, the economic sector level and the project level. In other words we must first make an estimate of the funds available for investment and determine whether allocating part of these funds in the sector under review (for example, in the development of water resources), rather than in other sectors, such as communications, industry or education, is advisable or not. If the answer is affirmative, and investment in this sector can be as effective in achieving the principal objectives of national development as it would be in other sectors, then the second phase, that of establishing the priorities at the sector level, can begin. This entails selecting from among all projects put forward those with the highest priority and greatest importance, within the framework of the investment funds allocated to the sector involved. The third phase involves examining a project at the level of the project itself, for example in order to develop the water resources of a given region the various alternative ways of doing so must be examined and the simplest and least expensive one— provided of course that it meets the technical requirements of the project — is then selected and recommended for implementation.

An important aspect of an economic evaluation of a project is that care must be taken in making the assumptions on which the calculations of the economic study of the project are based. If these assumptions change the economic calculations will also change. As an example of this point let us examine the Sefid Rud project. According to the normal method in Iran five factors of agricultural production (land, water, seed, labour, ploughing) are considered. Usually water accounts for one fifth (in some cases one tenth) of the cost of production per hectare. Thus for each hectare of land used for the cultivation of rice and irrigated by the Sefid Rud reservoir, which according to studies made in 1962 gave an average yield of 3800 kilogrammes of rice, worth an average of 11 Rials per kilogramme (this figure is based on the relative proportions of sadri and champa rice grown and their respective value), the annual income exceeds

40,000 Rials ($533), of which water will account for between 4000 Rials and 8000 Rials.

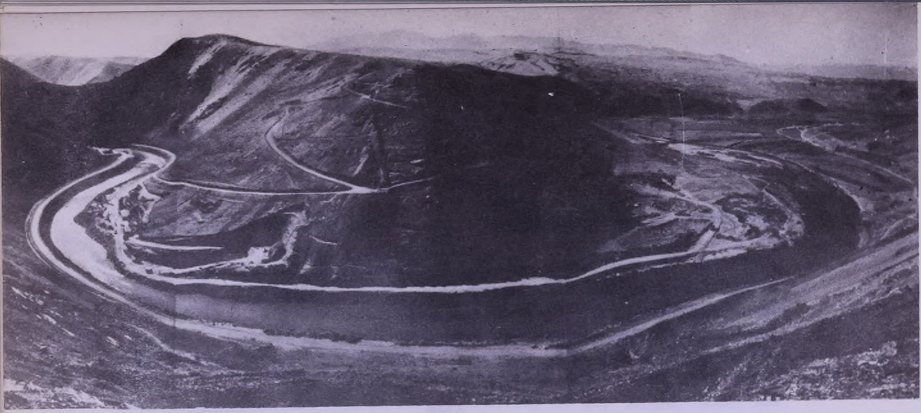
If for the purposes of proving the accuracy of the economic calculations involved we take the minimum figure of 4000 Rials for all virgin land irrigated by the dam and only half of that for land which was previously inadequately and irregularly irrigated and which now receives adequate water from the dam, then the income from the construction of the Sefid Rud dam is as follows:

	Area (thousands of hectares)	Income (millions of Rials)
Land previously not fully irrigated	110	220
Virgin land now under rice	69	276
Virgin land now under other cash crops (1)	59	236
	238	732

It can therefore be seen that based on the above assumptions the minimum annual income resulting from the construction of the Sefid Rud dam from the sale of water alone (i. e excluding income from power generation) would be more than 700 million Rials, whereas after the dam was built and its installations completed it was decided that in order to raise the income of farmers and to reach the goal of even distribution of income, which in turn is one of the basic objectives of the national economic development plans, instead of charging 4000 Rials for the water required for each hectare of water only 750 Rials would be charged. This of course resulted in a proportionate decrease in income.

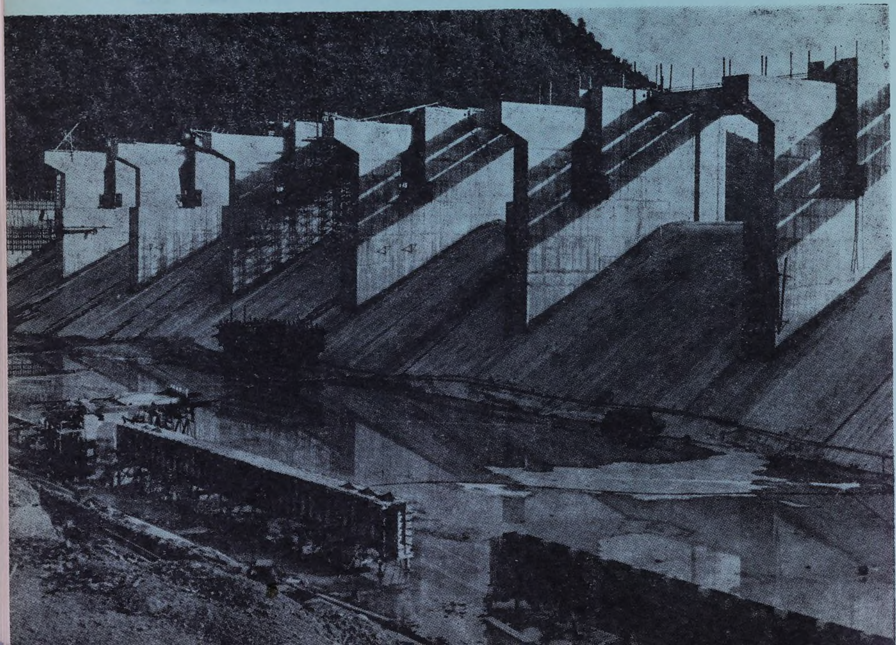
Clearly, then, we would be wrong to judge the economic viability of the Sefid Rud project in terms of the actual annual income. Another point worth mentioning in connection with changes in the original assumptions of a project is that in most projects the proposed crop pattern is based on achieving the maximum income, whereas after the installations are finished, social difficulties, arising from persuading the farmers to plant these crops or in order to meet essential national needs, mean that in practice other

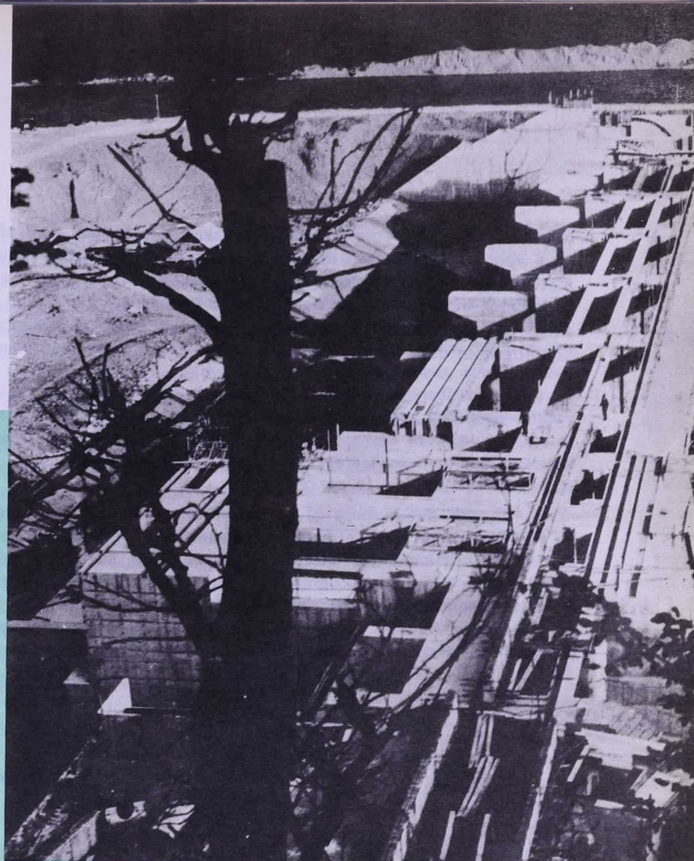
(1) Although the income from this land might well exceed that of land under rice, the latter figure has been used.



Rivers: another source of water

The Tarik dam under construction





Another view of the Tarik dam, Gilan province crops are planted. To avoid such mistakes, the simplest way of making such appraisals is not to make a comparison of costs and income, but, since the principal objective of development projects is to raise production and hence increase the national income, to compare the capital invested with the output of the project, in other words to establish the incremental capital/output ratio as the basis for the economic evaluation of a project.

In this chapter, therefore, an attempt will be made to evaluate the various irrigation projects completed under the development plans on this basis. In order to make such an appraisal possible it is first necessary to examine the overall state of water resources development projects and their relationship to agriculture.

Although the purpose of water resources development projects may be for agriculture, navigation, power generation, prevention of flood damage, or a combination of any or all of these, the rapid growth of population in developing countries and the pressing need for agricultural products, especially in countries whose economies are primarily based on agriculture, usually mean that in most water resources development projects the principal objective is an increase in agricultural production.

Although this is not a universal rule — in the United States, for example, the amount of water consumed in industry is equal to that consumed for irrigation, both being about 3.4 per cent of total atmospheric precipitation or 200 billion cubic metres per year — in most countries of the world especially those where industry is not yet highly developed the water required for agricultural irrigation is of primary importance.

In cases where the purpose of developing water supplies is agricultural, a long time is required for the complete execution of the projects involved and obtaining the desired results from them, the reasons being not only the vast scale of construction work necessary but fundamental problems arising from entrenched customs and traditions in agriculture, because to change these traditions, especially in countries with a long history of agriculture, requires long-term programmes which are only fully accepted after several generations.

This factor, coupled with the rapid development of industry and the resulting increase in industrial investment with its quick returns, led to a rapid decline during the years following the Second World War in private investment in agriculture and irrigation, especially since during this period the price of agricultural raw materials also declined sharply in comparison with the price of manufactured goods. Because of the vital importance of agricultural products, however, governments and international organizations had begun to think of taking comprehensive measures to assist investment in the agricultural sector, especially in the development of water resources. For this reason numerous organizations, such as the Food and Agricultural Organization of the United Nations, were formed to strengthen this sector of the world's economy by means of free technical assistance and appropriate guidance. Even in water-rich countries like the United States, apart from the entire preliminary studies and project design being paid for by the U. S. Bureau of Reclamation, 40 to 50 per cent of the initial costs of irrigation projects are covered by outright grants and the balance is made available to private individuals and firms in the form of long-term low-interest loans. In order to encourage farmers even more and to protect the country's agriculture the U. S. Government spent in 1960 some $7223 million on purchasing agricultural produce, especially grain, so as to prevent a fall in prices which would have resulted from an over-supply position.

In Iran, apart from all the problems and difficulties already mentioned, the low rainfall, aridity of the country, shortage of skilled labour, lack of domestically-manufactured machinery and spare parts and most important of all the shortage of investment credits, have led to high costs and slow returns on investments in large-scale irrigation projects. It was therefore inevitable that Plan Organization should have to invest directly in this important branch of development and should emerge as the only source of credits for the execution of projects in this sector of the economy.

Plan Organization, aware that water is one of the principal elements of the country's economic development, has given priority to water resources development projects in its programme for the development of agriculture and irrigation.

During the First Seven-Year Development Plan, which ran from 1948 to 1955, total development credits amounted to 26 billion Rials ($ 346.6 million) of which 7.3 billion ($ 97.3 million), or 28 per cent of the total, were allocated to agriculture and irrigation projects. Because of the cut in foreign exchange revenue from oil and the financial crisis, however, only 5.25 billion Rials ($ 70 million) of these credits was actually utilized.

The total credits of the Second Seven-Year Development Plan (1955-1962), which were increased by 20 per cent in 1957, amounted to 84 billion Rials ($ 1120 million). Of this sum, 25.5 billion Rials ($ 340 million), or 30 per cent of the total, was allocated to agricultural and irrigation projects. Finally, only 75.25 billion Rials ($ 1003.3 million) was utilized, of which 23.46 billion Rials ($ 312.8 million), or 31.1 per cent of the total, went on agricultural and irrigation projects.

Fundamental and extensive work to develop Iran's water resources, such as the construction of the Amir Kabir (Karaj), Empress Farah (Sefid Rud) and Mohammad Reza Shah Pahlavi (Dez) dams, was accomplished during these two Plans. About 76 per cent of all credits for agriculture and irrigation, or 17.75 billion Rials ($ 236.6 million) were utilized on work related to irrigation and the construction of dams, and of all credits allocated to irrigation 15.85 billion Rials ($ 211.3 million), or about 89.3 per cent, went on dam–construction, 1.46 billion Rials ($ 19 4 million), 8.2 per cent, was for irrigation studies and 0.44 billion Rials ($ 5.9 million) , or 2.5 per cent was for work on ghanats and deep wells. In the Third Plan (October 1962 to March 1968) Plan Organization has allocated development credits totalling 230 billion Rials ($ 3066 million), of which about 49 billion Rials ($ 653 million), or 21.3 per cent, was earmarked for agriculture and irrigation. Of the latter sum, 21.7 billion Rials ($ 289.3 million), or 45 per cent, and almost 10 per cent of all credits, was allocated to the development of water resources. Table No. 5 shows credits allocated to irrigation, as well as the total credits allocated to agriculture during the First, Second and Third Plans.

Table No. 5

Credits utilized for Irrigation and Agriculture, and for Irrigation alone, during the First, Second and Third Plans

(in millions of Rials)

Plan	Total Development Credits	Credits for Irrigation and Agriculture	Irrigation and Agriculture Credits as a percentage of total development credits	Credits for Irrigation alone	Irrigation credits alone as a percentage of total irrigation and agriculture credits	Irrigation credits as a percentage of total development credits
First	21	5.25	25	—	—	—
Second	75.2	23.46	31	17.75	75.66	44.25
Third	230	49	21.3	21.7	44.28	9.4
Total	326.2	77.71	23.8	—	—	—

Altogether Plan Organization has invested more than 42 billion Rials ($ 560 million) on increasing water supplies and extending and improving irrigation work. Of this, 20.5 billion Rials ($ 273 million) was spent on the construction of the Mohammad Reza Shah Pahlavi, Empress Farah, Amir Kabir, Shah Esmail, Farahnaz, Kuhrang and Karkheh dams and 1.64 billion Rials ($ 21.5 million) in developing the irrigation networks of the Empress Farah and Shah Esmail dams.

Table No. 6 gives economic details of the reservoir dams, and Table No. 7 shows the area of new or improved land irrigated by these dams, now and in the future.

As can be seen from the last column of Table No. 6, the average cost of providing water to irrigate one hectare of land by means of the dams completed during the Third Plan is 14,850 Rials ($ 198), while the equivalent figure for dams currently under construction is 20,460 Rials ($273), and for dams now being planned it is estimated that the figure will rise to 30,250 Rials ($403). If these figures are presented in graphic form (Figure No. 5) it will be seen that an attempt has always been made to begin by developing the least costly and most abundant water resources and then gradually, after these low-cost resources have been tapped, to utilize in subsequent development phases the more costly and ones with greater problems of execution.

The objectives of the Third Plan as regards irrigation were described in the Introductory Report of the Plan as follows:—

1. to obtain the necessary water to raise the area of irrigated arable land by 140,000 hectares.

2. to obtain sufficient water to improve the irrigation of 260,000 hectares of arable land at present inadequately irrigated.

3. To prepare water resources studies in order to provide complete statistics for future plans.

The policy outlined in the introductory report on irrigation in the Third Plan was of implementing relatively small irrigation projects instead of the large-scale, multi-purpose projects which were emphasized during the Second Plan. In practice, however, for reasons which will be gone into later, the most important being the fact that many

Table No. 6

Economic specifications of reservoir dams built, under construction or under consideration

Name of Project	Technical specifications			Economic Specifications				
	Capacity (in millions of cubic metres)	Annual volume water regulated (in millions of cubic metres)	Area irrigated by dam (in thousands of hectares)	Total cost of dam (in millions of Rials)	Cost allocated to irrigation (in millions of Rials)	Cost per cubic metre of reservoir capacity (in Rials)	Cost per cubic metre of water regulated (in Rials)	Cost per hectare irrigated (in Rials)
Section One **Dams Already Built:**								
Shah Esmail	28	50	5	160	160	5.7	3.2	32,000
Amir Kabir (Karaj)	205	400	21(2)	4,360	–	21.2	10.9	–
Empress Farah (Safid Rud)	1,860	2,000	238	4,584	3,056	2.5	2.3	12,840
Shahnaz (Hamadan)	8	17	– (3)	1,200	–	150.0	–	–
Mohammad Reza Shah Pahlavi (Dez)	3,350	6,000	125	4,500	2,250	1.3	0.6	18,000
Farahnaz (Latiyan)	95	245	30 (2)	3,000	–	31.6	12.2	–
Total this Section	5,546	8,712	419	17,804	5,466	–	–	–
Average this Section	924	1,452	84	2,967	1,822	3.2	1.9	14,850
Section Two **Dams Under or Ready for Construction:**								
Washmgir (Sangarsavar)	60	100	20	380	380	6.3	3.8	19,000
Shah Abbas the Great	1,450	1,500	85-100(4)	3,000	2,000	2.1	2.0	23,530
Aras	675	1,400(1)	70	2,900	1,933	4.3	2.1	27,610
Darius the Great (Dorudzan)	993	526	76	1,200	1,200	1.2	2.3	15,660
Shahpour I	250	195	20	1,050	1,050	4.2	5.4	52,500
Cyrus the Great	610	535	95	925	925	1.5	1.7	9,730
Total this Section	4,038	4,256	366	9,455	7,488	–	–	–
Average this Section	673	709	61	1,576	1,248	2.3	2.2	20,460
Section Three **Dams Under Consideration:**								
Taleghan	195	450	50-70(4)	1,800	1,800	9.2	4.0	36,000
Jiroft	400	325	20	1,300	867	3.3	4.0	43,350
Minab	–	400	25	750	750	–	1.9	30,000
Reza Shah the Great	2,700	12,000	132	6,000	3,000	2.2	0.5	27,730
Nader Shah	1,620	1,150	62	3.100	2,325	1.9	2.7	37,500
Total this Section	4,915	14,325	289	12,950	8,742	–	–	–
Average this Section	983	2,865	58	2,590	1,748	2.6	0.9	30,250
Total all Sections	14,499	27,293	1,074	40,209	21,696	–	–	–
Average all Sections	853	1,605	67	2,365	1,549	2.8	1.5	20,200

(1) Iran's share (2) In addition the dam supplies drinking water for Tehran (3) The dam supplies drinking water for Hamadan
(4) The lower figure has been included in totals.

Notes :

a) The cost of dams constructed for irrigation purposes which also generate up to a maximum of 2000 kilowatts of power has been allocated entirely to irrigation.

b) The cost of dams already constructed is based on final accounts or the latest estimates, while that of dams ready for or under construction is based on the estimates of consulting engineers.

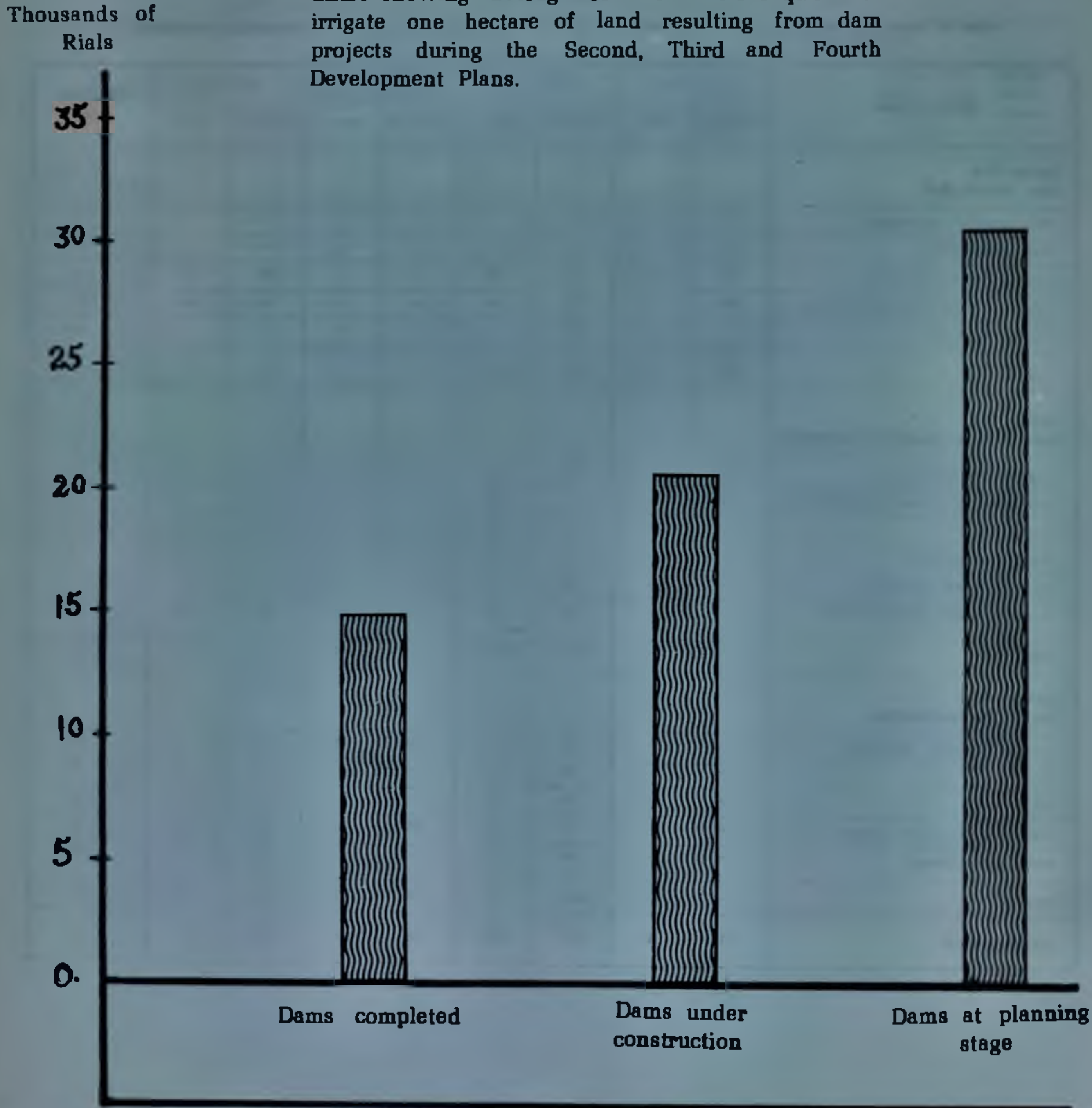
Table No. 7

Area of land to be irrigated by dams constructed under Iran's Development Plans (in thousands of hectares)

Name of Dam	Third Plan		Fourth Plan		Fifth and subsequent Plans		All Plans		Combined Total
	improved	new	improved	new	improved	new	improved	new	
Section One **Dams Already Built:**									
Shah Esmail (Golpayegan)	2	3	—	—	—	—	2	3	5
Amir Kabir (Karaj)	14	7	—	—	—	—	14	7	21
Empress Farah (Sefid Rud)	90	30	20	98	—	—	110	128	238
Mohammad Reza Shah Pahlavi (Dez)	25	5	65	30	—	—	90	35	125
Farahnaz (Latiyan)	—	—	30	—	—	—	30	—	30
Total	131	45	115	128	—	—	246	173	419
Section Two **Dams Under or Ready for Construction:**									
Washmgir (Sangarsavar)	—	—	10	10	—	—	10	10	20
Shah Abbas the Great (Zayandeh Rud)	—	—	70	25	—	—	70	25	95
Aras	—	—	18	39	—	13	18	52	70
Shahpour (Mahabad)	—	—	6	10	—	4	6	14	20
Darius the Great (Dorudzan)	—	—	16	54	—	6	16	60	76
Cyrus the Great (Zarineh Rud)	—	—	11	25	—	59	11	84	95
Total	—	—	131	163	—	82	131	245	376
Section Three **Dams Under Consideration:**									
Taleghan (without reservoir)	—	—	44	—	10	26	54	26	80
Jiroft	—	—	8	12	—	—	8	12	20
Minab	—	—	11	14	—	—	11	14	25
Reza Shah the Great (Karun)	—	—	7	25	48	52	55	77	132
Nader Shah (Marun)	—	—	56	6	—	—	56	6	62
Total	—	—	126	57	58	78	184	135	319
Combined Total	131	45	372	348	58	160	561	553	1114

Fig. 5

Chart showing average cost of water required to irrigate one hectare of land resulting from dam projects during the Second, Third and Fourth Development Plans.



rivers are ephemeral and the preparation of comprehensive plans utilizing both the water surface and groundwater of a region, during the execution of the Third Plan the emphasis was once again on large-scale projects Thus it was that the construction of the Shah Abbas the Great (Zayendeh Rud), Darius the Great (Dorudzan), Cyrus the Great (Zarineh Rud), Shahpour I (Mahabad), Washmgir (Sangar Savar) and Aras dams was begun during the Third Plan.

Early in the Third Plan the Ministry of Water and Power was established. One of its objectives was to co-ordinate activity which was previously carried out by various separate agencies.

Although the first two and a half years of the Third Plan were dogged by drought which had persisted since 1959, it is nevertheless expected that the objectives of the Plan will be realized before it finishes in March 1968. Table No. 8 shows the objectives of the Plan and the results obtained.

An analysis of the economic results of the above projects is beyond the scope of this study and such an account will require a separate publication A short summary of the results of certain projects can, however, be given here.

Project for the Empress Farah Pahlavi Dam and Sefid Rud Irrigation Network.

In order to develop the Gilan plain and utilize the waters of the Sefid Rud river, which is the main artery of the plain, a decision was taken during the Second Seven-Year Plan to build a dam on the river.

Before the construction of the dam the Sefid Rud was used to irrigate the agricultural land of the Gilan Plain downstream of Manjil. Most of the land was used for the cultivation of rice. The average annual offtake from the river was 1.7 billion cubic metres and in seasons when water for agriculture was required to a lesser degree about 2.3 billion cubic metres flowed into the Caspian Sea without being utilized. The purpose of constructing the dam was first to prevent most of this 2.3 billion cubic metres of water from being wasted, secondly to generate electricity by utilizing the difference in the water potential on either side of the dam, and thirdly to prevent the rice crop from becoming parched, which used to cause heavy losses each year, by regulating the flow of the river. The construction of the dam was completed early in the Third Plan and the main canals of the irrigation network will also be completed and commissioned before the end of the Third Plan. After the final stages of the work on the network have been completed, the

Table No. 8

Credits utilized for Third Plan irrigation projects and results obtained (in millions of Rials)

Type of Project	Credits utilized up to March 1966	Credits utilized from Marh 1966 to March 1968 (estimated)	Total credits utilized during period of Third Plan	Percentage of total	Increase in arable land (in thousands of hectares)	Improved irrigation (in thousands of hectares)
Completion of projects started in Second Plan	10,525	3,595	14,120	56	50	131
Drilling of wells	1,830	875	2,705	11	65	70
Improvements to ghanats	900	400	1,300	5	10	15
Development of surface water resources	316	3,822	4,138	17	20	15
Irrigation studies	1,455	965	2,421	10	—	—
Others	63	131	194	1	—	—
Total	15,089	9,788	25,040	100	145	231
Less investment from private sector	– 350	– 150	– 500	19	—	—
Total development credits for irrigation	14,739	9,638	24,878	—	—	—
Less loans for irrigation	2,977	1,160	4,137	—	—	—
Total development investment in irrigation projects	11,762	8,478	20,741	—	—	—

Notes :

1. Most of the investment from the private sector was for the drilling of deep wells.

2. By "loans for irrigation" is meant credits granted by the Agricultural Credits and Rural Development Bank of Iran (now the Agricultural Bank of Iran) from credits made available by Plan Organization for irrigation projects.

3. The majority of these projects will be completed and commissioned during the Fourth Plan.

area under rice cultivation, which before the start of the development programme had been 110,000 hectares with 20 per cent annual loss due to parching, will rise to 179,900 hectares, and 59,000 hectares of what had been copses and non-irrigated farmlands will be turned into irrigated fields able to produce other valuable crops.

If 12 per cent of the area of this land is subtracted to allow for roads, buildings and irrigation works, the remaining 88 per cent is all good productive farmland. Table No. 9 shows the estimated net area for each crop and the income per hectare before and after the development programme.

As can be seen, the increase in the Gross National Product will finally reach 3,253 million Rials ($ 43.3 million). If we consider, too. that 59,000 hectares of land will be used for the cultivation of crops other than rice and a further 9,000 hectares will be used for dry-farming, with a combined income of 1,615 million Rials ($ 21.5 million), the increase in income from rice cultivation alone will be 1,638 million Rials ($ 21.8 million). Figure No. 6 shows in graphic form the increase in income from rice cultivation resulting from the utilization of the Sefid Rud dam.

Since the total construction cost of the Sefid Rud dam was about 4,584 million Rials ($ 61.1 million) and that of the irrigation network and related installations will be, when completed, about 5,000 million ($ 66.7 million), the total cost to Plan Organization of the entire project will be about 9,600 million Rials ($ 128 million). Even if we assign the total cost of the dam to the account of irrigation, it appears that the entire expenditure on the dam and the irrigation network will be amortized over a period of three years, and if the income arising from power generation is considered, the Gross National Product will rise proportionately and the period of amortization will be less than three years.*

---

* In these calculations interest on capital lying dormant until the completion and commissioning of the works has been ignored.

Table No. 9

Type of Cultivation	Net Productive Area (in hectares)	Minimum Gross Income per hectare (in Rials)	Total Gross Income (in millions of Rials)
Present stage			
Ricefields	0.8 × 0.88 × 10,000	31,900	2.470
Other irrigated crops	—	—	—
Non-irrigated crops	0.88 × 71,000	14,000	875
Forests	4,300	5,000	21
Non-cultivated land and pastures	82,700	500	41
		Total	3047
Final stage			
Ricefields	0 88 × 179,000	31,900	5,024
Other irrigated crops	0 88 × 59,000	15,000	1,298
Non-irrigated crops	0.88 × 9,000	40,000	317
Forests	4,300	5,000	21
Non-cultivated land and pastures	16,700	—	—
		Total	6,660

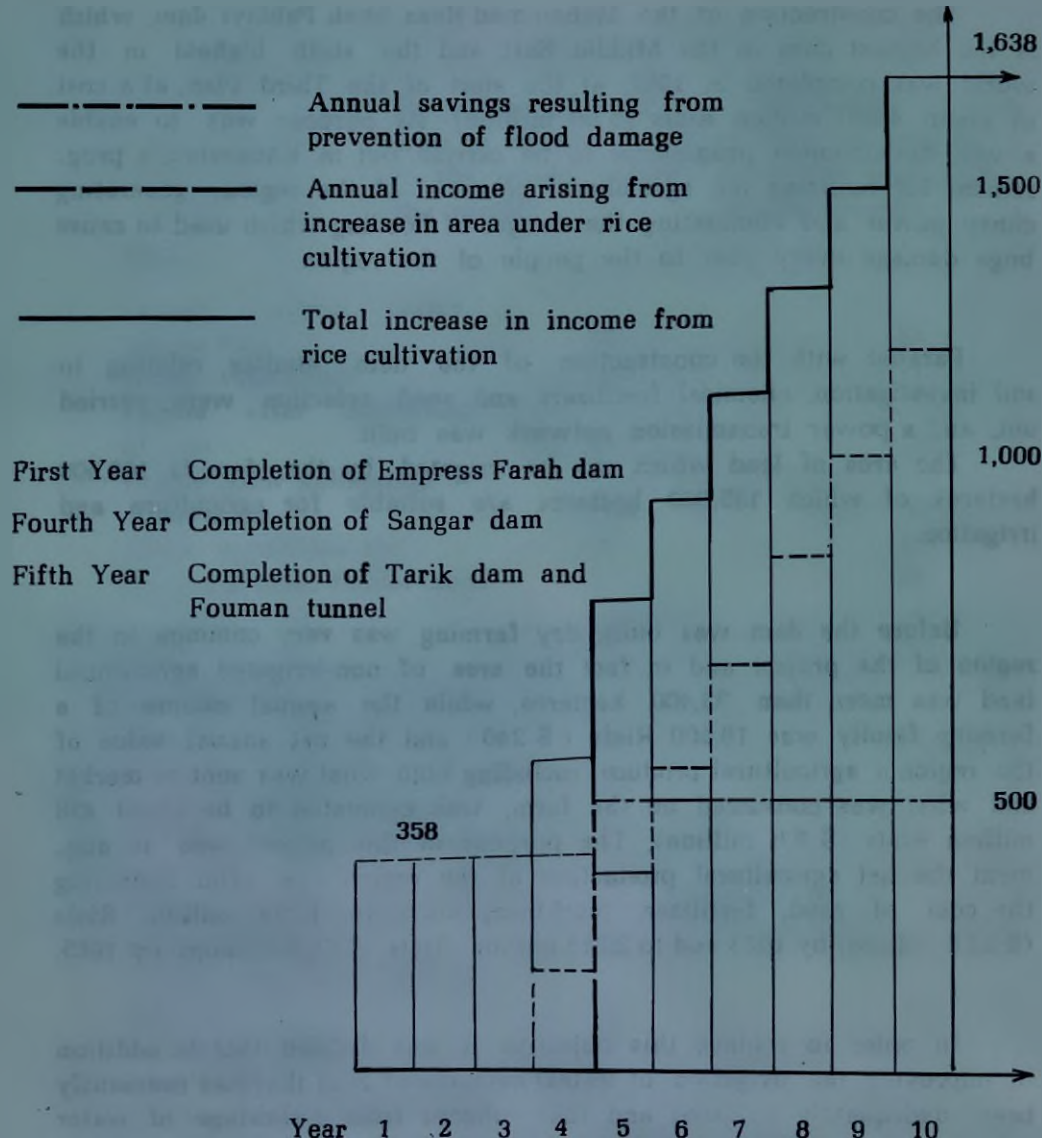
Notes: 1) Of the 110,000 hectares formerly under rice an average of some 20 per cent of the crop was lost through lack of water.

2) Net productive area is 88 per cent of gross area, the difference being for roads, buildings etc.

Figure No. 6

Increase in income from rice cultivation arising from completion of various phases of Empress Farah dam and associated projects

(figures in millions of Rials)



Project for the Mohammad Reza Shah Pahlavi dam and its irrigation network

The construction of the Mohammad Reza Shah Pahlavi dam, which is the highest dam in the Middle East and the sixth highest in the world, was completed in 1962, at the start of the Third Plan, at a cost of about 4,500 million Rials ($ 60 million). Its purpose was to enable a vast development programme to be carried out in Khuzestan, a programme for realizing the agricultural potential of the region, generating cheap power and eliminating the danger of flooding which used to cause huge damage every year to the people of the region.

Parallel with the construction of the dam, studies relating to soil investigation, chemical fertilizers and seed selection were carried out, and a power transmission network was built.

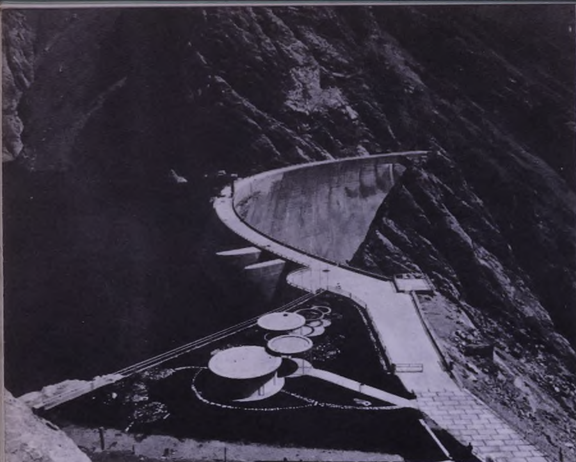
The area of land which can be irrigated by the dam is 169,500 hectares, of which 125,000 hectares are suitable for agriculture and irrigation.

Before the dam was built, dry farming was very common in the region of the project and in fact the area of non-irrigated agricultural land was more than 33,400 hectares, while the annual income of a farming family was 18,000 Rials ($ 240) and the net annual value of the region's agricultural produce, including both what was sent to market and what was consumed on the farm, was estimated to be about 438 million Rials ($ 5.8 million). The purpose of this project was to augment the net agricultural production of the region (i.e. after deducting the cost of seed, fertilizer, machinery etc.) to 1,714 million Rials ($ 22.8 million) by 1973 and to 2,213 million Rials ($ 29.5 million) by 1985.

In order to achieve this objective it was decided that, in addition to improving the irrigation of 90,000 hectares of land that had previously been inadequately irrigated and that suffered from a shortage of water in summer, to cultivate a further 35,000 hectares of virgin land and to change the crop pattern as shown below.

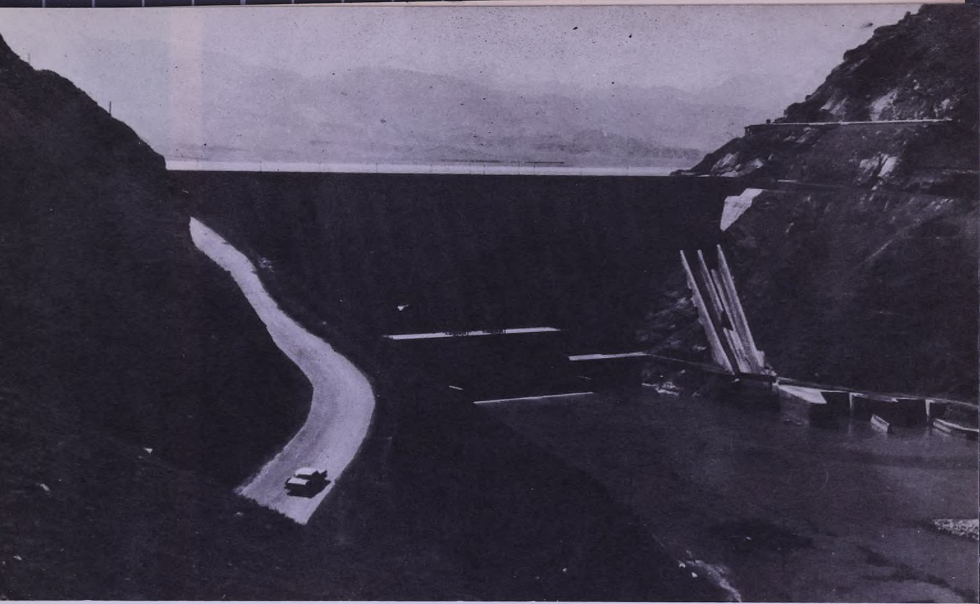
A comparison of the present pattern of crops and that proposed under the Dez Irrigation project

	Percentage of each crop in relation to the whole, before the project	Percentage of each crop in relation to the whole, after the project
Winter		
Cereals (wheat, barley, pulses etc.)	78	49
Green vegetables	0.5	1
Fallow after cultivation of rice	14	0
Fallow after cultivation of other crops	7.5	0
Green vegetables etc.	0	21
Grass and other fodder crops	—	29
Total	100	100
Summer		
Rice	14	41
Sesame	6	9
Summer green vegetables and fruit (melons, cucumbers etc.)	2	10
Cotton (after application of winter fertilizer)	0	11
Fallow (after cultivation of rice)	14	0
Fallow (after cultivation of other crops)	64	0
Grass and other fodder crops	0	29
Total	100	100

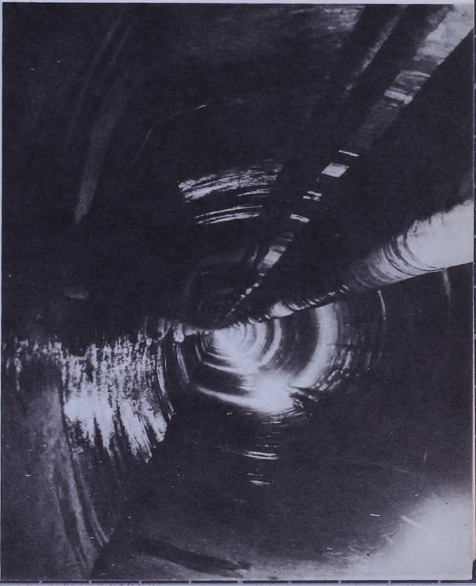


Amir Kabir Dam (Karaj), near Tehran

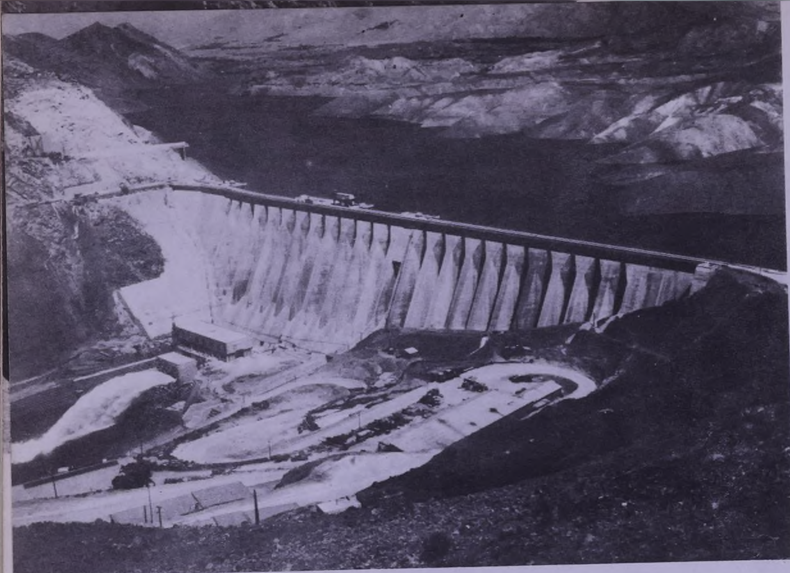
Shaft spillway of Empress Farah Pahlavi Dam, Gilan Province



The Empress Farah Pahlavi dam on the Sefid Rud river, Gilan Province



Inside the Fouman tunnel, Gilan province



Irrigation network of the Sangar dam
Irrigation canal of the Sangar dam (Gilan province)

The benefits resulting from the execution of the project are as follows:-

The addition of 125,000 hectares of arable land with an adequate and reliable supply of water, all of which can be cultivated in summer. Of this total some 35,000 hectares will be non-irrigated land, only about 61 per cent of which could be cultivated in winter and none of which could be cultivated in summer. Some 90,000 hectares of this land was previously inadequately irrigated, gave very low yields and only 23 per cent of it could be cultivated in summer, the remainder lying fallow. In addition, between one tenth and one fifth of the irrigable land will be allocated to the cultivation of sugar cane.

The history of cultivating sugar cane in Khuzestan goes back more than a thousand years, though for the past six centuries this useful and profitable crop has been completely forsaken. For the past forty years the Government of Iran has encouraged the domestic production of sugar, and consideration has been given to the cultivation of sugar cane. With the formation of Plan Organization the idea of reviving this cultivation, with all its agricultural and economic implications, received new impetus.

In 1958 a project for the cultivation of sugar cane on land at Haft Tappeh, which is located in the Mohammad Reza Shah Pahlavi dam region, was implemented by Plan Organization. An area of 10,000 hectares was set aside for this project, half of which was prepared for cultivation by the end of the Second Plan. During the Third Plan the harvesting of the first 4,000 hectares began. At present some 400,000 tons of cane are harvested annually, and this yields some 40,000 tons of refined sugar and 19,000 tons of molasses. By the end of the Third Plan the area under cultivation will increase to 4,300 hectares and the production of refined white sugar will be 43,000 tons. The Haft Tappeh project helps to produce about 20 per cent of Iran's total production of sugar (the rest is from beet), which is currently about 215,000 tons.

In addition to land used for the cultivation of sugar cane, the intensive cultivation of land downstream from the Mohammad Reza Shah Pahlavi dam, began during the summer of 1962, in other words at the start of the Third Plan. For this purpose an experimental area of 22,000 hectares was selected and cultivation began.

Previously only 20 per cent of the land of this project was irrigated in summer and 65 per cent in winter, but by utilizing the regulated run-off from the Mohammad Reza Shah Pahlavi dam, the entire area was made irrigable during the Third Plan.

As a result of the irrigation network and the introduction of proper irrigation and agricultural methods the productivity factor in the region has doubled or tripled. The following examples may serve as an illustration :

CROP	OLD YIELD	NEW YIELD
Wheat	675 kg/hectare	1600 kg/hectare
Barley	735 kg/hectare	1800 kg/hectare
Broad Beans	925 kg/hectare	1690 kg/hectare
Rice	1600 kg/hectare	3000 kg/hectare
Sesame	220 kg/hectare	800 kg/hectare

The results obtained from the cultivation of new crops such as winter fodder, alfalfa, sorghum and sudan grass have also been satisfactory. Yields of these crops are as follows:

CROP	Green weight per hectare
Winter fodder (Berseem)	65 tons
Alfalfa	45 tons
Sorghum	65 tons
Sudan grass	40 tons

Apart from the measures to cultivate sugar cane and the development of irrigation and agriculture on the 22,000 - hectare experimental area, in the last two years of the Third Plan work was begun on the construction of a main irrigation system, consisting of a diversion dam and main canals for the remaining land. Under the Fourth Plan the entire 125,000 hectares of land situated downstream from the dam will be utilized.

If the construction cost of the Mohammad Reza Shah Pahlavi dam — which was about 4,500 million Rials ($30 million) — is added to the cost of constructing the very large irrigation network, consisting of the diversion dam and the main and feeder canals, and the financial assistance necessary for the farmers, road construction, and village development, which are estimated at 6,000 million Rials ($80 million), the total cost of the entire scheme comes to 10.5 billion Rials ($140 million). The net increase in the agricultural production of the region, including sugar cane, after the whole project is completed and after allowing for the cost of seed, fertilizer, machinery, etc., will amount to 2,213 million Rials ($29.5 million), which means that the entire investment can be amortized in less than five years.

These calculations are based on the assumption that the entire cost of building the Mohammad Reza Shah Pahlavi dam is for the account of irrigation, whereas since the dam can generate 560,000 kilowatts of power, a large part of the cost can be amortized by the sale of electricity, which began immediately after the completion of the dam.

In the opinion of the consulting engineers, only about one fifth of the cost of the dam itself, (equivalent to 827 million Rials – Dollar 11 million) need be allocated to irrigation, and if instead of one fifth the amount of 2250 million Rials ($ 30 million), which is roughly half the total, is allocated to irrigation, the total cost of the irrigation system, including the half share of the dam itself and other installations, and the entire cost of road-construction, village development, etc, a figure of about 8,250 million Rials ($ 110 million) is reached. In this case the complete investment will be written off in less than four years, or in other words the capital/output ratio in the case of this project is about 1 : 3.7. Once again these figures ignore interest on capital during the construction period.

The Amir Kabir Dam Project

The construction of the main part of the Amir Kabir (Karaj) dam was completed in 1961 and the remainder was completed early in the Third Plan. The irrigation network serving the land downstrem from the dam was completed in 1966.

The objective in building this dam, as we have already seen, was not only to ensure an adequate water supply for the irrigation of 21,000 hectares of land downstream from the dam, but also to obtain an annual supply of 184 million cubic metres for the needs of the city of Tehran and to obtain 76,000 kilowatts of power for the city during the peak, early-evening hours. All these objectives were achieved during the execution of the Third Plan.

Ever since the commissioning of the Amir Kabir (Karaj) dam, it has been abundantly clear that unless the dam had been built, the nation's capital would have been faced with enormous, if not insoluble difficulties in the supply of sufficient potable water for the population. It has been forecast that if the population continues to expand at the present rate of about 6.6 per cent, by the end of the Fourth Plan (1973) it will have risen to 3.7 million and by the end of the Fifth Plan (1978) to 4.8 million. If the annual per capita consumption of water is taken as

70 cubic metres, the water required for Tehran in 1973 will be about 260 million cubic metres, of which 180 million cubic metres will be supplied by the Amir Kabir (Karaj) dam and the remaining 80 million cubic metres by the Farahnaz Pahlavi (Latiyan) dam.

The Farahnaz Pahlavi Dam Project

The Shahnaz Pahlavi dam was begun in the Second Plan to provide a source of potable water for the city of Hamadan and was completed during the Third Plan. With the recent completion of a mains system in Hamadan the dam is now fully operational.

Since the last three dams under discussion were all primarily built for the purpose of providing city water, which is a social necessity, the increase in the Gross National Product, which naturally goes up as a result of the provision of safe water supplies, is not easy to calculate. It is nevertheless clear that the provision of an adequate water supply for Tehran, in view of the rapidly increasing population, is a difficult problem and that steps must be taken as of now to utilize other sources or to prevent the centralization of the population in Tehran.

One point that should be borne in mind when considering all the reservoir dams is the lapse of time between the completion of construction work on the dam itself and the final commissioning of all the related facilities. This particularly applies to dams built for the purpose of agricultural development, as has already been observed. For instance, in the case of Mohammad Reza Shah Pahlavi and Empress Farah dams, which were practically completed by the end of the Second Plan, it is not expected that they will be fully utilized until the end of the Fourth Plan, in other words not until ten years have elapsed from the completion of dam construction. This fact does not only apply to Iran, of course. Everywhere in the world time-lapses of the same order occur. When the purpose of building a dam is to develop agriculture, the period of time necessary to build irrigation networks, drainage channels and other facilities, which are essential for the creation of a modern agricultural system and for the proper utilization of land, can run into several decades and in some cases even nearly a century. Take for example the case of the Carpentras canal in the south of France, which was excavated in 1853 but not fully utilized until 1950, or that of the Grand Coulee dam on the Columbia river, work on which began in 1923. Its purpose, apart from power generation, was to irrigate 1,029,000 acres (about 400,000 hectares). The first stage of irrigation did not start until 1950, and by 1963, i. e. 30 years after the project had begun, only 370,000 acres (148,000 hectares), or about 30% of the total, were ready for cultivation. The following table shows details of this vast project and the progress made at the different stages of its development*.

Objective: Irrigation of 1,029,000 acres.

Start of construction of dam: 1933.

Cost of dam and related installations: $ 970 million.

Cost of irrigation element: $ 690 million.

Year	Area for which irrigation network ready (in acres)	Area actually irrigated (in acres)
1948	5,790	119
1953	131,529	63,958
1958	359,456	238,312
1963	459,425	370,322

The absence of any economic effects of the dams built in the Second Plan, which was due to the unavoidable time-lag between the execution of a project and its full utilization and hence the relatively long period which the capital invested remains unproductive, coupled with the impatience of the people who naturally wanted to utilize the water from the dams as soon as possible, led to criticism being levelled at the construction of large dams at the start of the Third Plan. Things went so far that a number of economists, taking the general view that long-term, high-cost projects were not to be recommended for developing countries, were of the opinion that instead of large-scale projects for dam construction and irrigation smaller projects should be executed. Even the policy laid down in the introductory report of the Third Plan in the section on agriculture and irrigation was that relatively small irrigation projects should take precedence over the large-scale multi-purpose projects which were emphasized in the Second Plan.

During the course of the Third Plan, however, although strenuous efforts were made to implement small projects, the policy laid down

* Source: The Story of the Columbia Basin Project, U. S. Bureau of Reclamation, 1964.

for the Plan was in fact changed, and once again the construction of large-scale multi-purpose dams such as the Aras, Darius the Great, Cyrus the Great, Shahpour I and Shah Abbas the Great dams was considered and construction on them began.

The reasons for this change in policy can be summarized as follows:

1) The arid nature of Iran means that most of the rivers of Iran are of the ephemeral type. This in turn means that in order to utilize them completely large reservoir dams must be constructed to harness their water in winter and spring so that it can be stored and utilized during the seasons when it is needed.

2) The construction of small or diversion dams on perennial rivers with sufficient flow is useful, but the construction of small dams on rivers which run low or completely dry in summer cannot in itself lead to an increase in available water. For example, the Karkheh diversion dam built a few years ago cannot be used because of the water shortage in the summer months, and therefore in the Third Plan in order to solve the pressing problem of water shortages downstream from the dam it was found necessary to excavate a canal to convey water from the Dez river to the Karkheh river.

3) In general it can be said that in order to develop the water resources of any one region, what matters is not whether a project is large or small as whether it is comprehensive or not. This means that if the purpose of carrying out a project is the integrated and complete utilization of all the water resources of a region, both surface and underground, then the project can be called a comprehensive one. And if at any location in a region a project is carried out independently without reference to other projects in the region then the project is a piecemeal one and cannot be called comprehensive. In recent years, especially in regions which are short of water and where attempts have been made to achieve the maximum utilization of water, the execution of piecemeal projects has been completely banned, because they not only fail to achieve this goal but can also create difficulties in the subsequent development of the region's water resources.

To take some examples, if anyone were allowed to drill deep wells wherever he chose, first of all it is quite likely that such wells would not be located where they could tap the region's richest water resources, secondly drilling too many deep wells would obviously lead to the underground water resources becoming exhausted and the wells would all go dry. In the United States, for instance, because of incorrect exploitation California's water resources were exhausted in the space of 50 years. Again, if it had happened that in the region of the execution of the Dez project every village had built its own independent small dam and canal, there would not only have been many canals running parallel to each other, which would have resulted in heavy water waste, but there would also have been serious complications when the decision was made to build the Mohammad Reza Shah Pahlavi dam. This would have had to have been located further upstream in order to irrigate all the land it actually does. These examples serve to illustrate why all small dams and canals constructed independently of each other and without regard for regional resources should be strenuously avoided.

The question of drawing up a master plan for co-ordinating activities in developing the water resources of a region assumes greater significance when it is planned to utilize underground and surface water resources together, for example by utilizing the region's surface water in winter and spring, when sufficient is usually available, and injecting what is surplus into subsurface reservoirs and utilizing it together with other underground resources in summer. In such a case it is obvious that the small dams required must be located in strict accordance with the overall plan, for if wells or dams have been previously constructed in the area without regard to such a plan their existence is certain to hinder the execution of the plan and the optimum utilization of the surface and underground water resources.

The execution of comprehensive water utilization schemes in Iran dates from the start of the Second Plan and acquired greater importance during the Third Plan when studies relating to the preparation of projects for all the dams already mentioned were carried out in conjunction with studies relating to the underground water resources of the regions where they were located, so that if in any given region the utilization of underground water resources was possible this fact should be taken into account when drawing up the master plan. As an example, simultaneously with the studies made on the Shah Abbas the Great dam on the Zayendeh Rud river, parallel work was being done on the underground water resources of the Esfahan region. The results of these studies was that it was found most advantageous to utilize surface water for the irrigation of land upstream and underground water for the irrigation of land downstream. In the project for the development of the Ghazvin plain by the drilling of deep wells, which was one of the projects begun during the Third Plan, the utilization of flood waters, both in the region and conveyed to it from outside, was not overlooked, and the final plan now being executed will result in the optimum utilization of all the water resources of the region.

If the principle of preparing a master plan is accepted, small-scale irrigation projects obviously make no sense whatever, unless the development work, instead of enabling large regional and economic units to be farmed, is to be restricted to local activity, such as developing a single village by means of a ghanat system or irrigating a few hundred hectares of land alongside a river to receive inadequate irrigation only during the winter and early spring months by constructing one small dam.

It therefore follows that if a master plan is to be carried out, even if its objective is what is considered to be a small-scale irrigation project, the expenditure will nevertheless be high and the period of time required for its execution will be lengthy. As an example, the project for the development of the Ghazvin plain by drilling deep wells, although the construction of a reservoir dam is not contemplated and it is generally considered a relatively small-scale project, was begun in 1963 and is not expected to be completed until 1975 and the cost of the water resources development aspect of the whole project will probably exceed 4,750 million Rials ($ 63.3 million).

The above remarks should not be interpreted to mean that in regions where the execution of small-scale projects is appropriate their importance will be ignored. Unfortunately, however, the scope for such projects is extremely limited, and is usually confined to making better use of existing resources. Thus in places where there are no possibilities of building reservoir dams or utilizing underground water resources, or in other words where there are no new water resources to be tapped, we must be content to improve irrigation networks and introduce new methods of irrigation in order to make the maximum use of existing resources. In this sphere, too, Plan Organization has been active, and during the Third Plan, apart from completing the irrigation networks of the major dams, work was carried out to construct or improve the Karaj, Karkheh and Golpayegan irrigation networks, the water conveyance canals of the Bampour dam, and the irrigation works of the Shabankareh and Ganjancham dam projects. In addition, parallel to this activity, studies relating to the improvement of irrigation in the Varamin, Garmsar and Sistan regions, and the establishment of an irrigation network in the Shavour region, were completed, and work on some of these projects was begun towards the end of the Third Plan. Nevertheless, as has already been noted, the scope for implementing such projects and hence the results obtained from them is limited and does not meet the pressing needs of a developing country such as Iran.

Future Development Potential of Water Resources and Recommendations

An examination of the experience gained from previous development plans, especially in view of the physical possibilities for the development of Iran's water resources, will determine the basic policy for, and methods of execution of, such projects in the future. As was the case in previous plans the problem of the inevitable time-lag between the completion of the construction of the main dam and its full utilization, which leads to the capital investment temporarily lying idle, will continue to attract the public's interest.

A further subject which must be studied in the future with regard to the choice of policies and methods of implementing projects for the development of water resources is the nature of the physical possibilities for such development, and an overall study of the nation's water resources.

As has already been stated, of the 457.5 billion cubic metres which enter the country each year, 117.5 billion become surface flow, while an estimated 63 billion become underground water and the remainder return to the atmosphere in the form of evaporation or evapotranspiration. As the balence-sheet shows, in present-day circumstances only the following quantities of the country's water resources are utilized:

(in billions of cubic metres)

Surface water consumed for agriculture	16
Surface water consumed for urban and industrial use	1
Groundwater utilized for agriculture	13
	30

Against this, large quantities of water which might be used are lost in the following ways:

Leaving Iran as surface flow	78.5
Irrigation losses	29
Groundwater lost through evaporation	43
	150.5

The experience gained from previous development plans, coupled with the physical possibilities for the development of water resources and the present state of affairs could lead to the following far-reaching results, if these resources could be used:

a) The construction of further reservoir dams to prevent the 78.5 billion cubic metres of water at present flowing out of the country is essential. In order to minimize the period during which the capital invested lies idle, however, it is advisable that work on the construction of reservoir dams and their irrigation networks should be started simultaneously. A further point is that the problems arising in agricultural affairs and the long-standing customs and traditions of the agriculture of each province and district mean that the completion of an irrigation network does not in itself necessarily lead to the optimum utilization of the land it serves. To overcome this difficulty it is recommended that in regions where the lowest discharge of a river is sufficient and the river may be considered perennial, an irrigation network should first be created (within the framework of a master plan, of course) to serve land already under cultivation, so that when the irrigation of the region has been improved and the development of the land has reached the stage where new resources are required, then work on the construction of a reservoir dam or dams should be started. This method of approach has the following advantages:

1. The long period during which the huge investment required for the construction of a reservoir dam is unproductively tied up is thus avoided.

2. The construction of an irrigation network in cultivated land prevents losses to a considerable degree, and as a result the area under cultivation can be developed without the construction of a reservoir dam.

3. Farmers in the region can gradually learn how to utilize the water and land more efficiently by having a proper irrigation network and access to sufficient water. This means that after a reservoir dam has been constructed they can make the maximum utilization of the water and capital investment involved in the construction, thus minimizing the period required for learning new methods of irrigation and cultivation.

4. In cases where the utilization of surface and underground water resources is to be carried out jointly it is necessary to create the irrigation network first, and in cases where it is a question of obtaining

new water either from underground resources or from a reservoir dam a decision on the relative advantages of each should be taken by comparing the capital investment required and the cost of producing the new water by means of drilling wells or building a dam. Experience shows that in most cases, because wells can be drilled easily and thus the enormous capital investment required for a dam avoided, the use of underground water resources is preferable.

b) At present the amount of water wasted by existing irrigation networks and in the fields is almost 29 billion cubic metres a year. It therefore follows that the improvement of irrigation networks should receive special importance. For these reasons the following proposals have been incorporated in the policies of the Fourth Plan.

1. In localities where existing networks come within the framework of a regional master plan action should be initiated as indicated in a) above, and such existing networks should be improved within the framework of the regional master plan.

2. In localities where it is not possible to carry out a master plan, ad hoc steps must be taken to improve the state of offtake from rivers, to repair temporary dams and to establish irrigation networks.

This recommendation applies particularly to the upper reaches of rivers and also in regions surrounding the central plateau where the rate of evaporation and wastage of water is great, and especially in places where several channels, each of insignificant flow, run parallel to each other in wasteful fashion, for by taking the proposed steps better use can be made of existing water resources and improvements can be made both in terms of quantity and quality to the irrigation of land already cultivated.

c) Of the underground water resources of Iran, which are estimated at about 63 billion cubic metres, some 20 billion are extracted annually, while of this quantity only 13 billion are usefully consumed, the remainder forming irrigational loss. If the 43 billion cubic metres which return to the atmosphere by evaporating in lakes, deserts and other low-lying places can be brought under control and utilized, it will obviously be of immense significance for a country so short of water as Iran, for the amount involved is one and a half times that at present usefully consumed.

In order to utilize this water correctly the following methods have been recommended.

1. In areas adjacent to hilly and mountainous country, where the drilling of deep wells is not feasible groundwater can be obtained by means of ghanats or shallow wells, which can tap numerous horizontal galleries running in different directions, thus preventing these water resources from running off into salt lakes and swamps.

2. In alluvial plains which are surrounded by mountains, permeating water can be extracted by the drilling of a few deep wells which will often be artesian.

3. In alluvial plains which border on salt lakes or deserts a series of deep wells, acting like an underground wall, must be drilled around the lakes or deserts preventing these underground water resources frem permeating through to them. Apart from tapping an important new source of water this procedure will also prevent the expansion of the desert .

The above recommendations, if implemented, can result in a total of between 120 and 130 billion cubic metres of water being made available for agriculture out of the 180 billion cubic metres of existing surface and underground water, after allowing for wastage in irrigation canals and in the fields and the fact that some of these resources are not of suitable quality for agricultural purposes.

If arrangements are made to plant cash crops such as cotton, sugar beet, sugar cane and orchard fruit, it should be possible tc increase the area of irrigated land in Iran to 12 million hectares by advanced technology and the use of modern systems of irrigation, such as sprinklers and so on.

When we consider that in addition to the land at present farmed a further 43 million hectares are capable of being irrigated it is essential that in the years to come new water resources should be tapped for the development of agriculture. These are as follows :

- use of sea-water from the Persian Gulf and possibly also the Caspian Sea by means of desalination projects.

- use of fresh-water aquifers, which are presumed to exist at great depths beneath the deserts and the regions around the deserts.

- use of freshwater springs off the Caspian Sea and Persian Gulf coast-lines.

- use of weather modification methods, i. e., apart from making the maximum use of the rain-bearing clouds which pass over Iran, causing clouds which would otherwise shed their rain above the oceans and seas to do so over the land surface of Iran.

Published by the Bureau of Information and
Reports
Plan Organization