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FIRST PROGRESS REPORT ON THE UTILIZATION/EVALUATION OF AN AID HAND-OPERATED WATER PUMP

Prepared for the
U. S. Agency for International Development

by

Phillip W. Potts
Senior Research Scientist

Office of International Programs
ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
June 1977

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Summary

In September 1976, the Engineering Experiment Station, Georgia Institute of Technology (Georgia Tech) entered into an agreement with the Agency for International Development (AID) to evaluate (1) the performance and acceptability of a hand-operated water pump, previously designed for AID, in comparison with other pumps used in developing countries, and (2) the feasibility of local manufacture of the AID pump. This program has involved Georgia Tech in planning, installing, monitoring, and reporting upon a field test of the AID pump in Costa Rica and Nicaragua, using a counterpart organization, the Central American Research Institute for Industry (ICAITI, El Instituto Centroamericano de Investigacion y Tecnologia Industrial).

Costa Rica and Nicaragua were chosen as test countries because of sizeable loans that had been made to them by AID and because of their need for an expanded water-pump program. Provisions of the loan specifically included installation of water pumps on a large-scale basis, and it was felt that using Costa Rica and Nicaragua as test countries would enable them to get a better start on their own programs. Ministry of Health and AID officials also strongly felt that a locally-manufactured hand pump offered by the Georgia Tech/ICAITI program had many advantages that should be included in each country's respective loan program (mainly employment generation and spare parts availability).

Active work began in Costa Rica in January 1977, when AID/Washington and Georgia Tech jointly agreed that Costa Rica and Nicaragua should be the test countries for the program described herein. A machine shop, subcontracting to a local foundry for iron castings, was contracted with for the manufacture of 20 AID pumps (eleven deep-well and nine shallow-well) which were produced and delivered to a Ministry of Health warehouse for storage, prior to installation, in April. Two different kinds of pumps were chosen to compare the AID pump with: a Dempster model 210F and a Japanese Kawamoto Daiichi "Lucky" pump. Thirty sites, representative of Costa Rica, were chosen to receive the test pumps (15 AID pumps and 15 competitive pumps), all of which already had installed pumps varying in condition from broken to fully operational. Wells were randomly tested by chemical and bacteriological analyses prior to test-pump installation and found to contain large amounts of intestinal bacteria,

indicating that contamination was not being sealed off from the water. Pumps are now being installed, the wells are being disinfected with a chlorine-yielding compound, and the contamination sources are being sealed off (bacteriological testing will continue throughout the project to determine if the contamination is, in actuality, being sealed off). The monitoring of pump performance for a 12-month period is now under way and will continue through July 1978.

Program activities also began in Nicaragua in January of this year. A local foundry was chosen to manufacture 20 AID pumps (eleven deep-well and nine shallow-well) which were produced and delivered to a Ministry of Health warehouse for storage, prior to installation, in May. Three kinds of pumps were chosen to compare the AID pump with: Dempster, a Brazilian Marumby pump, and a pump developed by the International Development Research Centre (IDRC) of Ottawa, Canada. Thirty sites, representative of Nicaragua, were approved to receive the test pumps (15 AID pumps and 15 comparative pumps), all of which required extensive preparatory work before pumps could be installed. Pumps are now being installed, and the wells are being disinfected with a chlorine-yielding substance. As in Costa Rica, the sites have been randomly sampled for chemical and bacteriological analysis prior to installation of test pumps and show intestinal bacteria, requiring further testing to determine if the contamination is being sealed out by the addition of a closed well and the use of a hand pump for lifting the water. The 12-month monitoring period has begun and will continue through July 1978.

There are no indications at the present time that would discourage further manufacture, installation, or use of the AID pump in Costa Rica or Nicaragua. The AID pump can be manufactured in a developing country at a competitive, profitable price and at an acceptable level of quality if adequate facilities (foundries, pattern makers, machine shops and skilled machinists, raw materials, etc.) are available; however, the availability of adequate facilities is a matter that must be determined for each individual developing country. Public acceptance by rural villages has been good, both from an aesthetic standpoint and from a standpoint of the pump being used easily by men, women, and children. Lastly, the AID pump should have a positive impact in developing countries on the health of rural people, on employment generation, and on installing national pride within the people when it is seen that these countries

do have local capabilities for manufacturing a complicated product rather than importing it.

INTRODUCTION

In September 1976, the Engineering Experiment Station, Georgia Institute of Technology (Georgia Tech) entered into an agreement with the Agency for International Development (AID) to evaluate (1) the performance and acceptability of a hand-operated water pump, previously designed for AID, in comparison with other pumps used in developing countries, and (2) the feasibility of local manufacture of the AID pump. This program has involved Georgia Tech in planning, installing, monitoring, and reporting upon a field test of the AID pump in Costa Rica and Nicaragua, using a counterpart organization, the Central American Research Institute for Industry (ICAITI, El Instituto Centroamericano de Investigacion y Tecnologia Industrial).

Organizationally, Georgia Tech has had overall responsibility for the AID water-pump field testing. Members of the Engineering Experiment Station have been, and are currently, involved in national and international programs of community and area development, management and technical assistance to business and industrial firms, industrial and economic development training, market analyses, studies of new manufacturing opportunities, manpower resources and labor productivity, stimulation of small-scale industry, technology assessment, development and conservation of energy resources, housing resources, industrial economics, economic uses of industrial wastes, adaptive technology research and development, audiovisual presentations and multimedia documentation, and professional guidance in planning industrial and economic development programs.

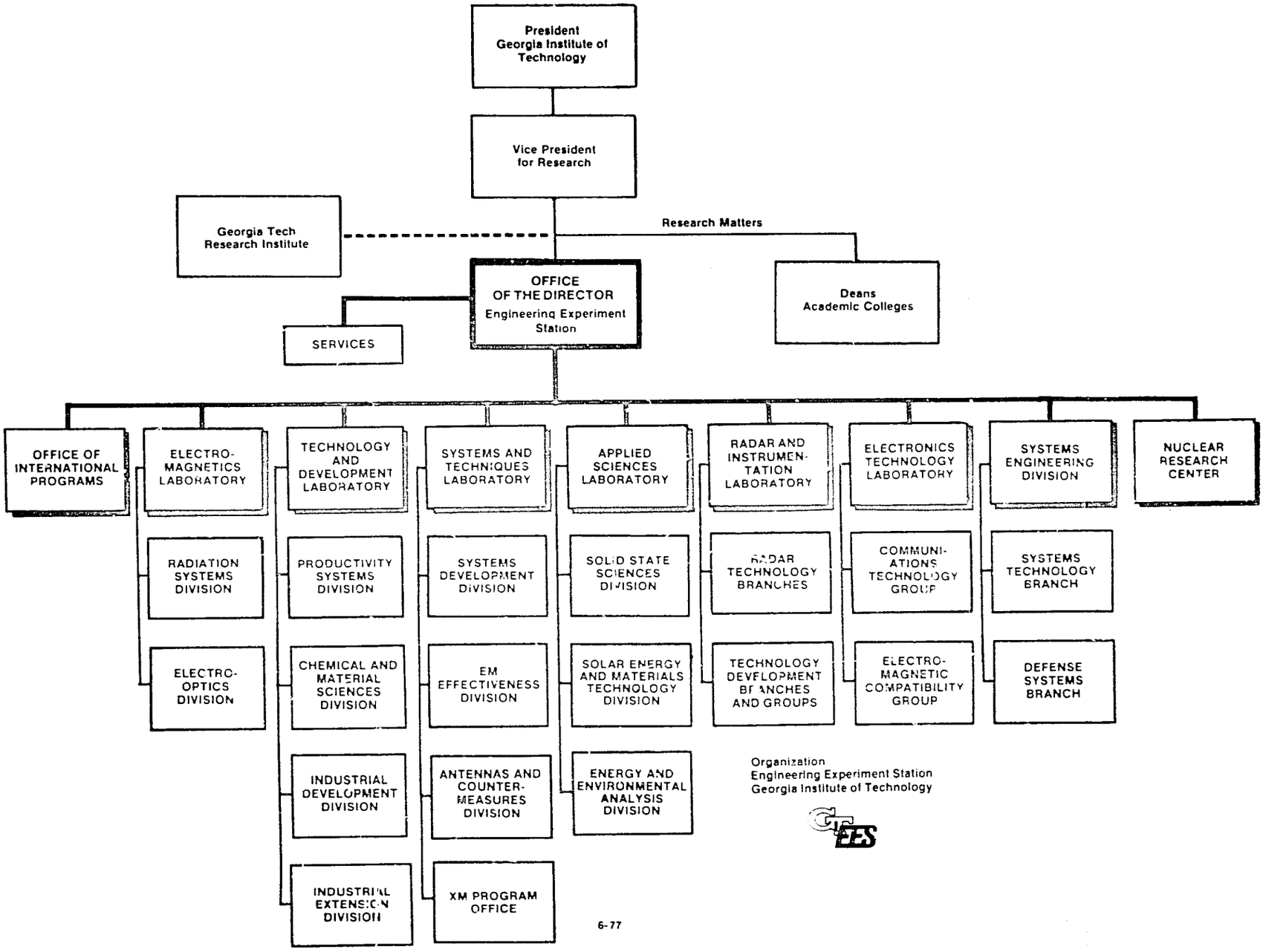
ICAITI, chosen as a Central American counterpart to enable efficient utilization of travel funds, to provide quick response to AID and to the Ministries of Health in Costa Rica and Nicaragua, and to take full advantage of its established working relationships with existing communities, industries, lending institutions, and governmental departments of Costa Rica and Nicaragua, is very similar to the Engineering Experiment Station. For more than 14 years, ICAITI has made significant contributions to the industrial development of Central America and has also completed a considerable number of related projects that have aided in the accomplishment of this program.

The program, more specifically, consists of participation by Georgia Tech and ICAITI in the following activities:

1. Providing technical assistance for selected foundries and machine shops to locally manufacture the AID pump.
2. Purchasing the AID pump and comparative pumps available on the local, open market.
3. Selecting 60 field-test sites for installation of 30 AID pumps and 30 locally-available pumps (30 sites to be located in each of the two test countries).
4. Determining the quality of water through chemical and bacteriological analysis.
5. Preparing sites (preparing new wells or rehabilitation of existing wells, as necessary).
6. Installing pumps.
7. Monitoring pump performance for a 12-month period.
8. Collecting and analyzing field data.

In gathering and analyzing data on the AID pump, seven areas have been of major concern:

1. Operational performance in the field.
2. Maintenance requirements and pump reliability.
3. Competitive cost and analysis of the economics of in-country manufacturing.
4. Manufacturing problems encountered.
5. Needed design changes and future utilization.
6. Public acceptance and marketability.
7. AID pump design characteristics and specifications.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COSTA RICA

It is universally accepted that an adequate supply of water for drinking, personal hygiene, and other domestic purposes, and an adequate means of waste disposal are essential to public health and well-being. Unfortunately, vast numbers of people in the developing world, most of them living in rural areas, do not have access to a safe and convenient source of water. When safe and convenient sources are available, satisfactory sewage disposal faciliites normally are still unavailable.[1/]

Costa Rica was chosen as a test country because of a sizeable loan that has been made to that country by AID and because of the country's need for an expanded water-pump program. Provisions of the loan specifically included installation of water pumps on a large-scale basis, and it was felt that using Costa Rica as a test country would enable that country to get a better start on its own program. Costa Rican Ministry of Health and AID officials also strongly felt that a locally-manufactured hand pump offered by the Georgia Tech/ICAITI program had many advantages that should be included in the Costa Rican loan program (mainly employment generation and spare parts availability).

One aspect of this project that has been obvious from the beginning is that, even though Costa Rica is a developing country, it is much more developed than Nicaragua, and this shows up in the availability of potable water supplies for the two countries. For instance, based on early surveys, representative test sites chosen for this project show an average usage by approximately 75 persons in Costa Rica and 150 persons in Nicaragua. In Costa Rica, most communities of 250 inhabitants or more have some form of piped water system, while in Nicaragua, the size of the community will usually exceed 2,000 inhabitants before piped water is found. In Costa Rica, most communities will have at least one well with a pump, if not piped water, and in Nicaragua, springs, rivers, and open, dug wells are the common sources of water. Costa Rica has a greater degree of electrification in rural areas, allowing the installation of motorized pumping systems that are not possible in many areas of Nicaragua. Further, the Ministry of Health in Costa Rica has had a hand-pump

---

1/ Robert J. Saunders and Jeremy J. Warford, Village Water Supply, (Baltimore, Maryland: The Johns-Hopkins University Press, 1976), p. 3.

water program for some fifteen years, while Nicaragua is just now in the beginning stages of such a program.

This does not mean that Costa Rica is without a need for improvement in its potable water delivery system. The Ministry of Health, for instance, estimates that, at the present time, as many as 47,000 hand-operated water pumps are needed to provide a suitable water supply to the country's rural citizens. Further, many existing water pumps are inoperable because of a lack of maintenance and, where there are functioning pumps, many of the well structures are poorly designed and ineffective in sealing out contamination. There is, as a result, a great need for a proper governmental infrastructure that does not now exist to carry out an effective overall health plan.

Active work began in Costa Rica in January 1977, when AID/Washington and Georgia Tech jointly agreed that Costa Rica and Nicaragua should be the test countries for the program described herein. A machine shop, subcontracting to a local foundry for iron castings, was contracted with for the manufacture of 20 AID pumps (eleven deep-well and nine shallow-well) which were produced and delivered to a Ministry of Health warehouse for storage, prior to installation, in April. Two different kinds of pumps were chosen to compare the AID pump with: a Dempster model 210F and a Japanese Kawamoto Daiichi "Lucky" pump. Thirty sites, representative of Costa Rica, were chosen to receive the test pumps (15 AID pumps and 15 competitive pumps), all of which already had installed pumps varying in condition from broken to fully operational. Wells were randomly tested by chemical and bacteriological analyses prior to test-pump installation and found to contain large amounts of intestinal bacteria, indicating that contamination was not being sealed off from the water. Pumps are now being installed, the wells are being disinfected with a chlorine-yielding compound, and the contamination sources are now being sealed off (bacteriological testing will continue throughout the project to determine if the contamination is, in actuality, being sealed off).

The monitoring of pump performance for a 12-month period is now under way and will continue through July 1978. It will consist of regular monthly inspections by ICAITI and Ministry of Health designated personnel to obtain data on overall performance of all test pumps, including maintenance requirements, number of people using the pumps, pump output, daily water requirements by

users of the pumps, ease or difficulty of pumping water, and public acceptance of the pumps.

Printed report forms have been designed and given to responsible individuals (for example, school directors) in each community where test pumps are installed. These forms are to be filled out and forwarded to Ministry of Health representatives if an unexpected pump failure should occur. Shortly thereafter, a repair truck will be dispatched to the site for investigation and repair of the failure.

Manufacture of AID Pumps

A contract was signed with Mecanizados Mofama, S.A., located near San Jose, on January 28, 1977, for the manufacture of nine shallow-well type AID pumps and eleven deep-well type AID pumps. The prices of the pumps were as follows:

Shallow-Well	$ 98 (each)
Deep-Well	128 (each)
Patterns	498 (one-time charge only)

These prices represent an order for only 20 pumps. It is expected that further analysis will show economies of scale from larger quantity orders and allow significant savings to both the manufacturer and the purchaser of the pumps (permitting, hopefully, a retail price in the range of $60 to $70 for the shallow-well pump and $70 to $80 for the deep-well pump).

The pumps were manufactured according to the AID-approved drawings contained in the appendix to this report and with the following additional instructions:

1. The plunger rod was made from one-half inch diameter rod, rather than seven-sixteenths inch, because of difficulty in locating a reliable supply of seven-sixteenths inch stock. The pump rod nut, the rod end, and the plunger assembly were also changed to accommodate the one-half inch plunger rod.

2. The handle pivot pins were to be hardened to 40 R_c and steel bushings (60-64 R_c) inserted in the pump handle holes. By taking this approach, the pins are expected to wear out before the handles, allowing easier repairs at the least cost.

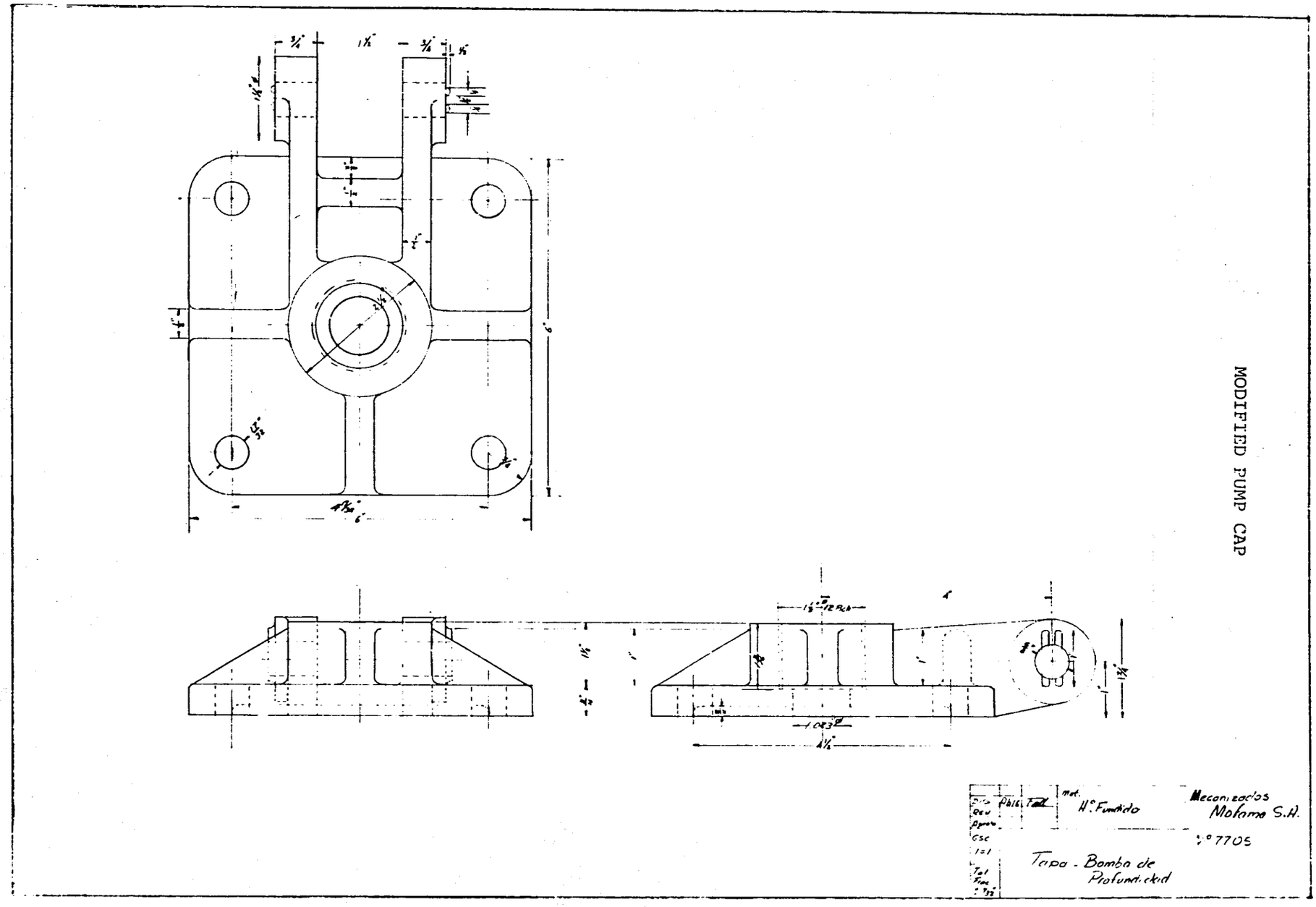
3. For the shallow-well pump, the three-inch support pipe was internally coated with epoxy for a smoother-surfaced cylinder finish. Option A (drawing No. 2001), using the bolted pump cap, was chosen in preference to a pin-mounted pump cap.

4. For the deep-well pump (drawing No. 2002), Option A was chosen, using the bolted pump cap in preference to a pin-mounted pump cap. The pump cap was modified, however, because of concern by the manufacturer that he could not cast this particular complex part. (The following pages contain working drawings of the modified cap and its accompanying handle fulcrum.) The pump cylinder was constructed from the standard PVC pipe.

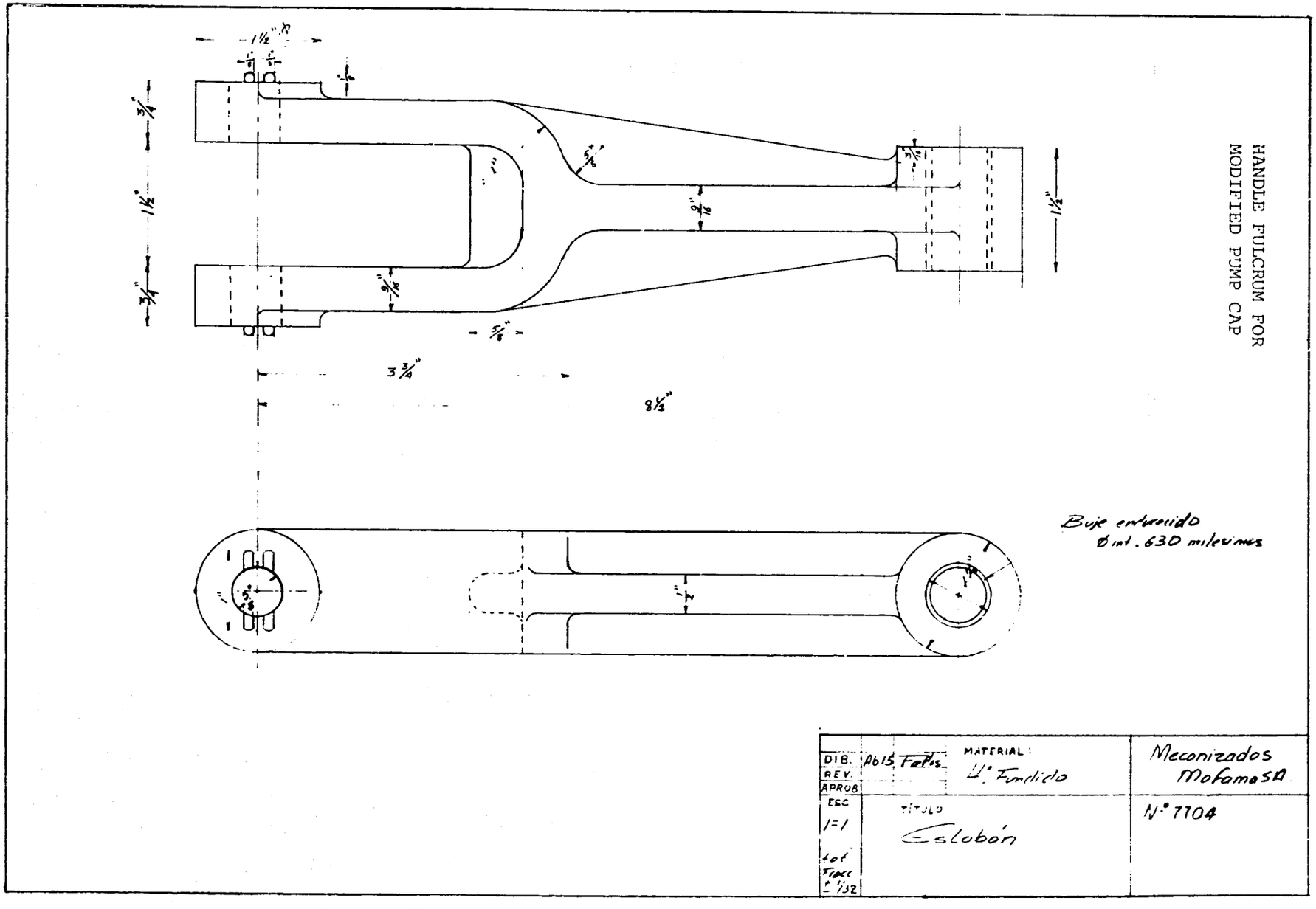
In addition to the above, all pumps were painted with an anticorrosive coating and consecutively numbered for identification purposes. Other than the pump cap, no unusual manufacturing problems were encountered besides those to be expected from unfamiliarity with the pump itself on the first production order. If a prototype of the pump had been available for the manufacturer, it is felt that he could have easily produced the proper cap.

It should be noted that the foundry producing the castings had no laboratory facilities and used scrap metal as the source of raw materials. High-quality castings require a level of technology not generally expected to be found in developing countries and, without this technology, quality (such as degree of hardness) will vary from pump to pump and from one production order to the next. The pump castings produced in Costa Rica appear to be rough in texture but adequate for that which they were intended.

Proper machine shop facilities and skilled machinists are also necessary for the manufacture of the AID pump. While the Costa Rican AID pump manufacturer had only a small shop (four employees) for the machining operations required, it was sufficient for pump production. The machine shop contained a multiple speed lathe, a vertical lathe, welding equipment, a drill press, a metal cutter, and assorted hand tools. Sand blasting equipment was not available but would have been useful in smoothening out the rough texture of the castings. Additionally, access to an oven which the machine shop did not have was necessary for hardening the steel bushing inserts and the handle pivot pins.



MODIFIED PUMP CAP


HANDLE FULCRUM FOR
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Comparative Pumps

Two pumps were chosen for comparison with the AID pumps manufactured in Costa Rica, a Dempster 210F pump and a Japanese Kawamoto Daiichi "Lucky" pump. The Dempster model is considered one of the better hand-operated water pumps in the world, has the cylinder below water level so that it can be used for wells of shallow or deep depth, and costs approximately $257 in Central America, delivered (the $257 includes the pump, the cylinder, and transportation). The "Lucky" pump is for shallow wells only (25 feet or less, in depth), appears to be of good quality, has a porcelain-lined cylinder, and costs approximately $63 in Central America, delivered. (Further information on these pumps follows.)

Field Test Sites

Table 1 shows those sites originally selected for the field testing in Costa Rica and which were chosen primarily because of their relative high usage and accessibility. All sites were existing wells, dug (rather than drilled), and classified as either deep wells (as used herein, more than 25 feet in depth) or shallow wells (25 feet or less in depth). The average site had been used by 75 persons and already had an existing pump, with the condition of the pump varying from broken and inoperable to good. The general areas of site concentration are in the northwestern quadrant of Costa Rica in the vicinity of Nicoya, Santa Cruz, Liberia, and Las Canas, and the eastern area of Limon (see Map 1).

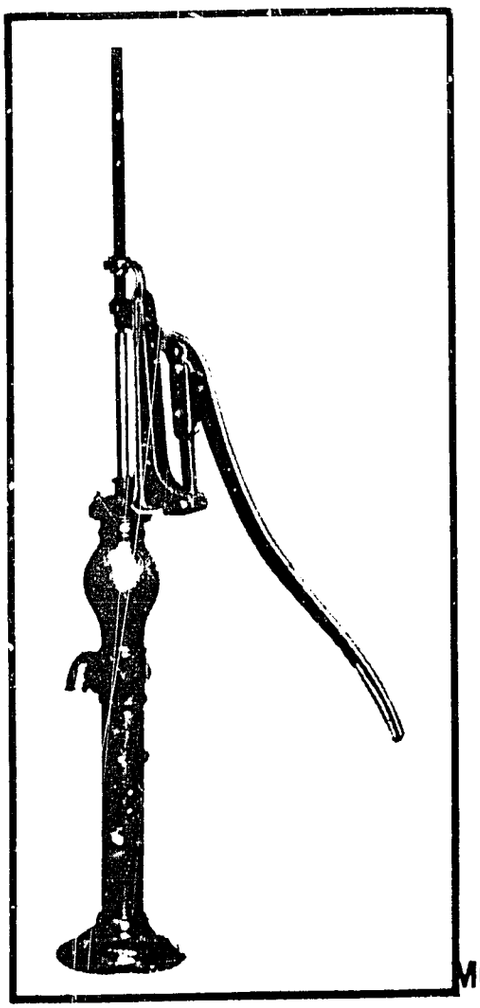
Selection of the sites was made during the dry season months of January, February, and March so that the water column figures would indicate annual low-water levels. However, the dry season of 1976-1977 has taken its toll on the sites, and, by the middle of May, many of the sites had dried up completely and must be deepened before all pumps can be installed. In some cases, the wells have been dug as deeply as possible and now must either be drilled deeper, or substitute sites must be found.

By June 1, 1977, approximately one-half of the 30 test pumps had been installed without any significant problems, and the balance of the pumps has been scheduled for installation during the month of June. All installed pumps are functioning properly, and there are no obvious weaknesses that have shown up in the first several months of operation. The AID pumps appear to

PUMPS and CYLINDERS

DEMPSTER

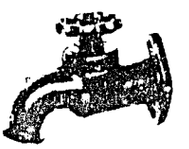
DATA SHEET 380-3
ISSUE DATE 1976



CONSTRUCTION

CAST IRON

Dempster hand and windmill pumps are adapted for wells of any depth. Neat in design and substantially built, equipped with a 4-bolt adjustable flanged top, extra long handles and heavy steel bearer pins. Tops fitted with stuffing box and packing for tight seal on the piston rod. 4-position handle adjustment for up to 10 inch stroke. Large capacity air chamber for smooth force pumping. Furnished with syphon or compression spout. Syphon spout furnished unless otherwise ordered. 2 x 1-1/4-inch suction bushing furnished with each pump.



MODEL 36
Compression Spout
Furnished at slight Additional Cost.

MODEL 210F

MODEL 210F is a heavy duty hand or windmill force pump. It has a 1-1/16-inch polished steel piston rod securely threaded to the flat bar. For wells of extreme depth, with large cylinders or continuous operation. This model is available with 2-1/2-inch tapping in the base at slight additional cost.

Type	Hand & Windmill
Suction Tapped	2 in.
Piston Rod Threaded for,	
Rod	7/16 in
Pipe	3/8 in.
Tapping in Rear	1¼ in.
Approx Weight	71 lbs.

MODEL 210F(CS) same as Model 210F except equipped with Model 36 Compression Spout

MODEL 226F

MODEL 226F is normal duty hand or windmill force pump. It has a 11/16 inch steel piston rod fitted to the flat bar with a heavy cast set screw connection. For wells of shallow to moderate depth at normal farm and ranch operation.

Type	Hand & Windmill
Suction Tapped	2 in.
Piston Rod Threaded for,	
Rod	7/16 in
Pipe	3/8 in
Tapping in Rear	1¼ in
Approx. Weight	70 lbs

MODEL 226F(CS) same as Model 226 F except equipped with Model 36 Compression Spout

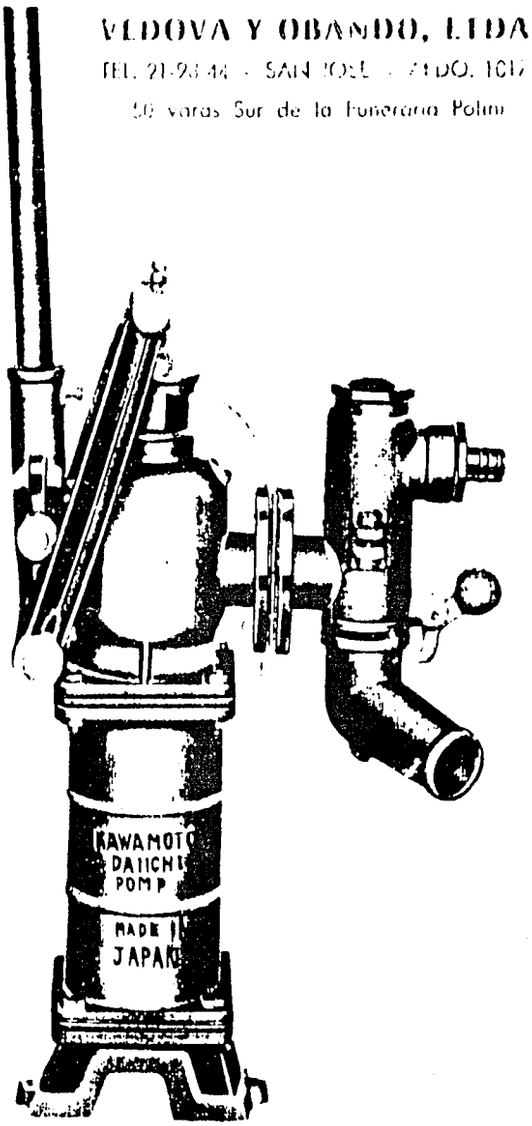
DEMPSTER INDUSTRIES INC., Beatrice, Nebraska 68310 (402) 223-4026

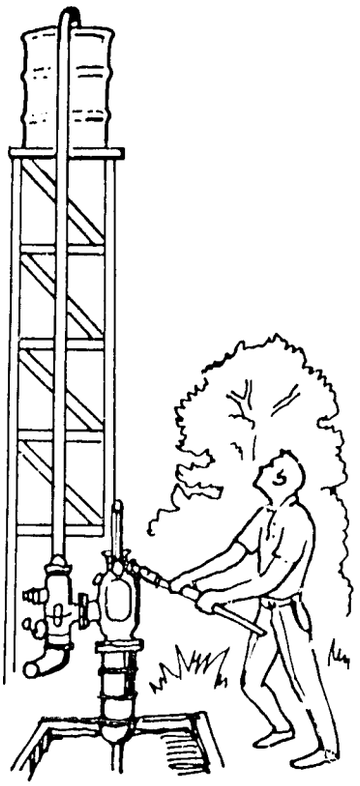
TRADE MARK

LUCKY PUMP

The most outstanding and unique feature of the "LUCKY" Hand Pump is the ConVertibility in its usage from an ordinary suctioning to pushing up water as illustrated.
No other brand of hand pump offers this double usage. Thus, it makes "LUCKY" a very economical buy, "TWO PUMPS FOR THE PRICE OF ONE"

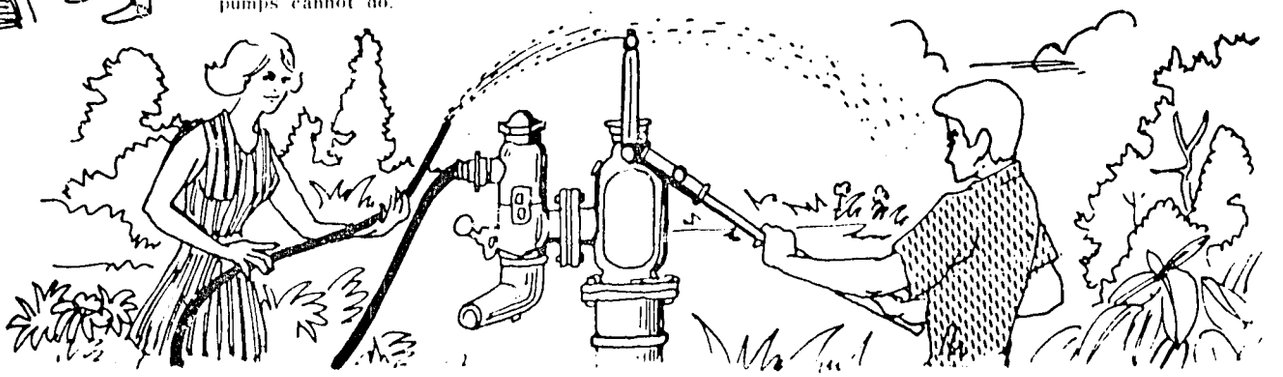
VEDOVA Y OBANDO, LTDA.
TEL. 21-93-44 - SAN JOSE - APDO. 10171
50 varas Sur de la Funeraria Polini



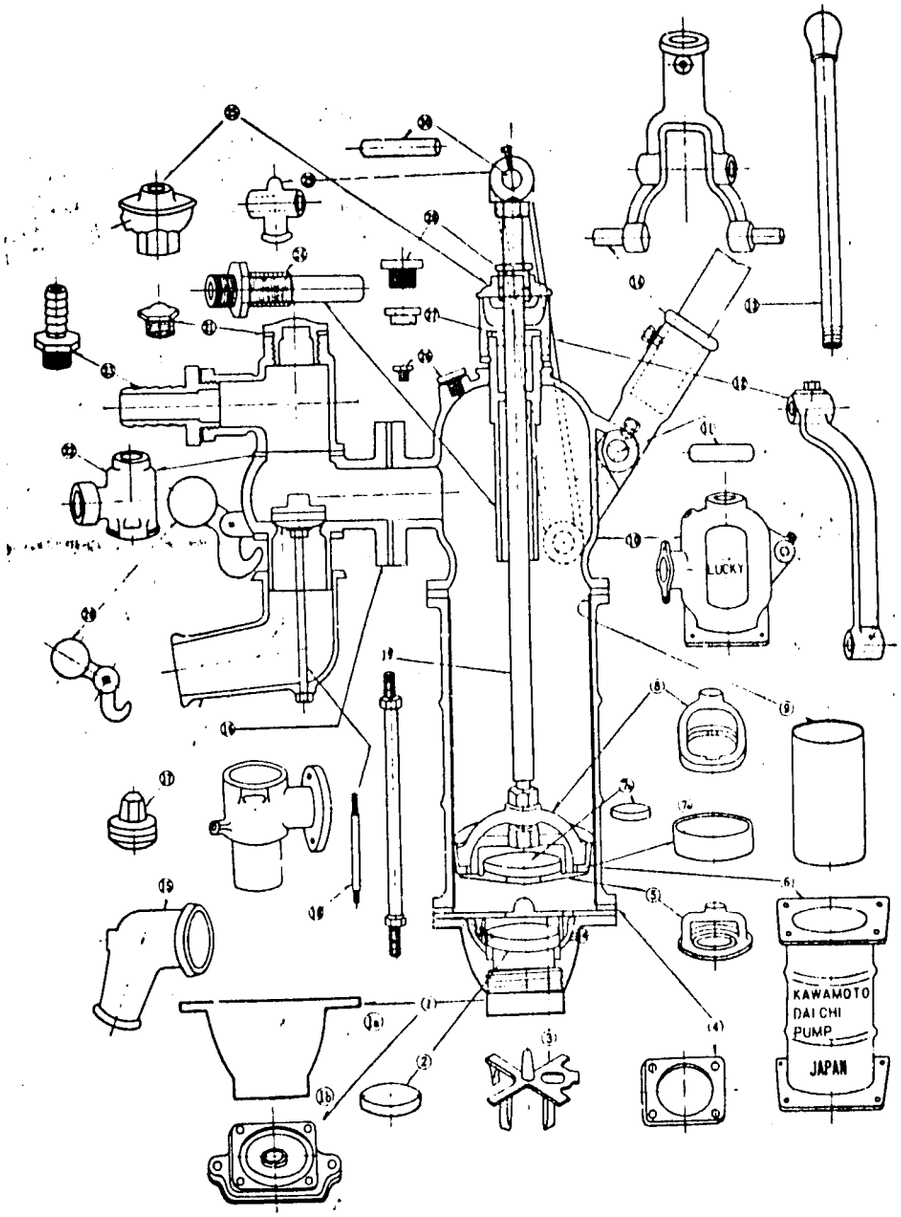


Special Features:

1. **Chrome Pump Rod:** A special hard chrome around the pump rod gives "LUCKY" added durability. Only gun-metal and steel used in main parts and casted with the best pig iron.
2. **Porcelain Enameled Cylinder Liner** Unlike other pumps, "LUCKY" has a porcelain enameled cylinder liner which prevents rusting of the pump lining. Very little physical effort is required to get maximum amount of water in less time.
3. **Leakage Impossible:** A special double gland packing prevents water leakage which is very common in other kinds of pumps.
4. **Vertical Pumping Motion:** This kind of pumping motion makes it easy to connect the pump rod of the artesian wells, without any alteration.
5. **Mud Free :** The unique construction of "LUCKY" pumps eliminates mud which ordinary pumps cannot do.

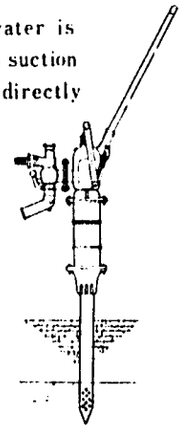


(1a) DRIVEN SUCTION VALVE BOX
(1b) DUG SUCTION VALVE BOX
(2) VALVE
(3) VALVE GUIDE
(4) RUBBER PACKING
(5) LOWER PISTON
(6) CYLINDER
(7a) BOWL RUBBER
(7b) PISTON VALVE
(8) UPPER PISTON
(9) SLEEVE PORCELAIN ENAMELED
(10) CHAMBER
(11) HANDLE PIN
(12) DOUBLE ROD
(13) STEEL PIPE HANDLE
(14) LEVER
(15) UNIVERSAL SPOUT
(16) FAUCET BOX
(17) FAUCET VALVE
(18) VALVE SPINDLE
(19) PISTON ROD
(20) STOP WATER WEIGHT
(21) FAUCET COVER
(22) UPPER FAUCET
(23) HOSE COUPLING
(24) INNER GLAND BOX
(25) GLAND BOX
(26) LEAKAGE SPOUT
(27) INNER GLAND
(28) GLAND
(29) ROD HEAD
(30) GUIDE PIN



DRIVEN-WELL

The underground water is sucked up through a suction pipe that is driven directly underground.



AVAILABILITY:
Good for every existing dug well and fit for driven wells.

USE:
General home use, sucking, pushing up to a height, fire-preventing and watering.

SPECIFICATION:
Vertical size, 85cm high, steel-pipe handle of 70cm long equipped.

Art. No.	Sort of Well pump	Inside Diameter of Suction Pipe	Suction Capacity Per Hour	More Than Suction Lift	More Than Pushing Lift	Weight
G-700	Driven	1 ¼"	1,100 imp. gallon	30 feet	50 feet	20 kg
G-701	Driven	1 ½"	1,100 imp. gallon	30 feet	50 feet	20 kg
G-702	Dug	1 ¼"	1,100 imp. gallon	30 feet	50 feet	20 kg
G-703	Dug	1 ½"	1,100 imp. gallon	30 feet	50 feet	20 kg

Table 1

SELECTED SITES FOR AID PUMP FIELD TESTS IN COSTA RICA

Site No.	Location	Well Situation	Well Type	Classification by Depth	Depth to Water (mt.)	Depth to Water (ft.)	Water Column (mt.)	Estimated Usage - No. Persons 30-60	61-100	>100	Type of Existing Pump	Condition of Existing Pump	Type of Pump to Install[3]
1	Margarita (schoolhouse)	Existing	Dug	Shallow	2.30	7½	1.70		X		None	--	AID-SW
2	Bristol (Square No. 1)	Existing	Dug	Shallow	2.20	7	0.90		X		None	--	Japanese
3	Bristol (Square No. 2)	Existing	Dug	Deep[1]	--	--	--			X	Dempster	Good	Dempster
4	Baltimor	Existing	Dug	Shallow	3.20	10	1.00	X			None	--	AID-SW
5	Corina	Existing	Dug	Shallow[2]	--	--	--	X			Japanese	Poor	AID-SW
6	Corina (schoolhouse)	Existing	Dug	Deep	7.60	25	1.00		X		Dempster	Good	Dempster
7	Zent (Sr. Pedro Bustos)	Existing	Dug	Shallow	2.60	8½	1.60	X			None	--	AID-SW
8	Zent (Sr. Mariano Grijado)	Existing	Dug	Shallow	2.95	9½	1.85	X			None	--	Japanese
9	Zent (schoolhouse)	Existing	Dug	Shallow	3.30	11	1.60	X			None	--	AID-SW
10	El Brillante	Existing	Dug	Deep[1]	--	--	--		X		Dempster	Fair	AID-DW
11	Judas de Chomes	Existing	Dug	Shallow	5.70	19	4.10		X		Dempster[4]	Poor	Japanese
12	La Palma de Abangares	Existing	Dug	Deep	11.00	36	0.75		X		Japanese	Broken	AID-DW
13	San Joaquin de Abangares	Existing	Dug	Deep	10.30	34	1.40	X			Dempster	Poor	AID-DW
14	Pueblo Nuevo de Abangares	Existing	Dug	Shallow	5.20	17	1.40	X			Dempster	Fair	Japanese
15	San Buena Ventura de Colorado	Existing	Dug	Deep	7.00	23	2.70		X		Dempster	Good	Dempster
16	Penas Blancas de Colorado	Existing	Dug	Shallow	5.95	19½	1.55		X		Dempster	Good	AID-SW
17	Nicoya (Barrio San Martin)	Existing	Dug	Deep[1]	--	--	--	X			Dempster	Good	Dempster
18	Curime de Nicoya	Existing	Dug	Deep	30.35	99½	1.00	X			Dempster[4]	Poor	Dempster
19	Caimitalito de Nicoya	Existing	Dug	Deep	8.95	29	1.60	X			Red Jacket	Broken	AID-DW
20	Conjunto IMAS, El Torito, Samara	Existing	Dug	Shallow	5.43	18	.43			X	Dempster	Good	AID-SW
21	Terciopelo de Nicoya	Existing	Dug	Deep	7.23	24	1.04	X			Dempster	Poor	AID-DW
22	San Francisco de Santa Cruz	Existing	Dug	Deep	8.20	27	1.10	X			Dempster	Fair	Dempster
23	Hernandez de Santa Cruz	Existing	Dug	Shallow	2.45	8	1.85		X		Dempster	Good	Japanese
24	Villa Real de Santa Cruz No. 1	Existing	Dug	Deep[1]	--	--	--		X		Japanese	Poor	AID-DW
25	Villa Real de Santa Cruz No. 2	Existing	Dug	Deep	11.00	36	--		X		Dempster	Poor	Dempster
26	Villa Real de Santa Cruz No. 3	Existing	Dug	Deep[1]	--	--	--			X	Dempster	Fair	AID-DW
27	Los Pargos de Santa Cruz	Existing	Dug	Shallow	5.85	19	0.70	X			Dempster	Good	Japanese
28	San Jose de Pinilla	Existing	Dug	Shallow	2.55	8	2.00			X	Dempster	Good	Japanese
29	Pijije de Bagaces	Existing	Dug	Deep	10.90	36	2.40	X			Dempster[4]	Good	Dempster
30	La Javilla de Canas (Puerto Canas)	Existing	Dug	Deep[1]	--	--	--	X			Dempster	Poor	AID-DW

[1]Assumed deep: well sealed, depth unknown.

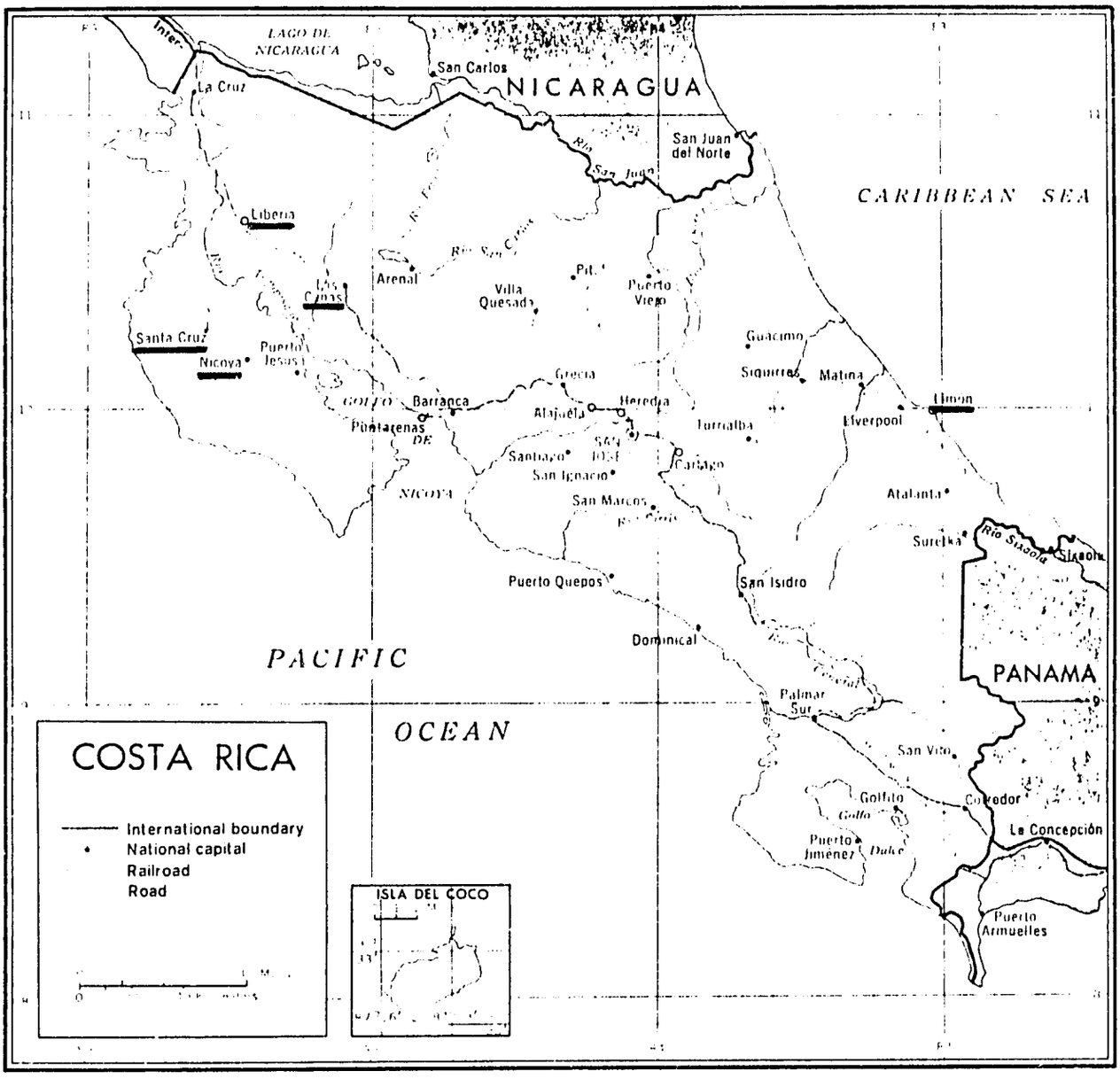
[2]Assumed shallow: well sealed, depth unknown.

[3]AID-DW: AID pump for deep well; AID-SW: AID pump for shallow well; Dempster: Dempster deep well type pump; Japanese: Japanese made shallow well type pump.

[4]Pump being used for forced pumping to storage tank.

Map 1

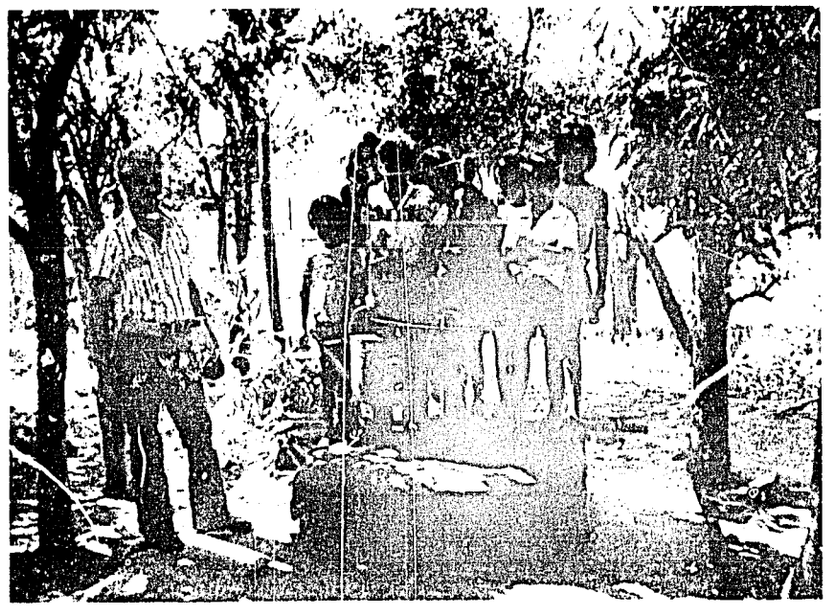
COSTA RICA



Sites in Costa Rica are concentrated in two major areas: (1) the northwestern quadrant around Nicoya, Santa Cruz, Liberia, and Las Canas, and (2) the eastern area of Limon.

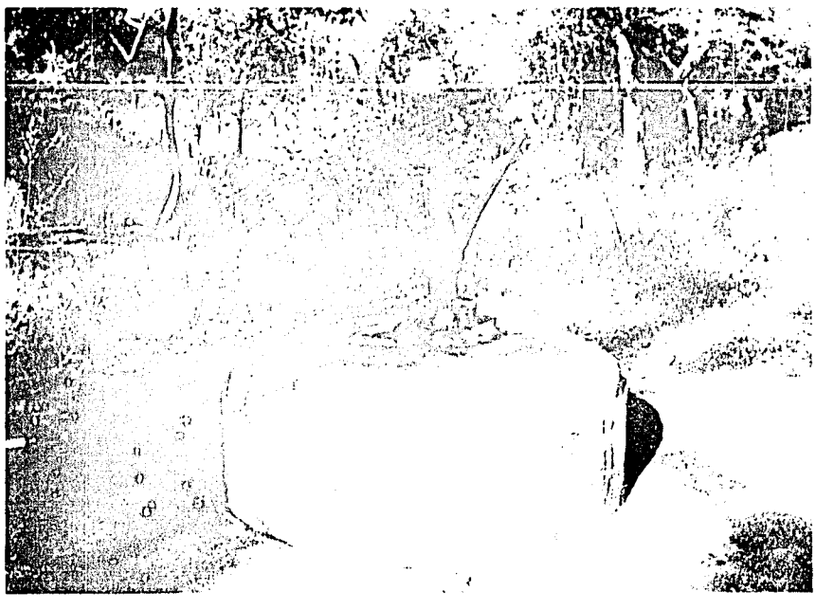
COSTA RICA

Costa Rica Site No. 10, located at El Brillante, prior to installation of field test pump. Photo taken January, 1977.

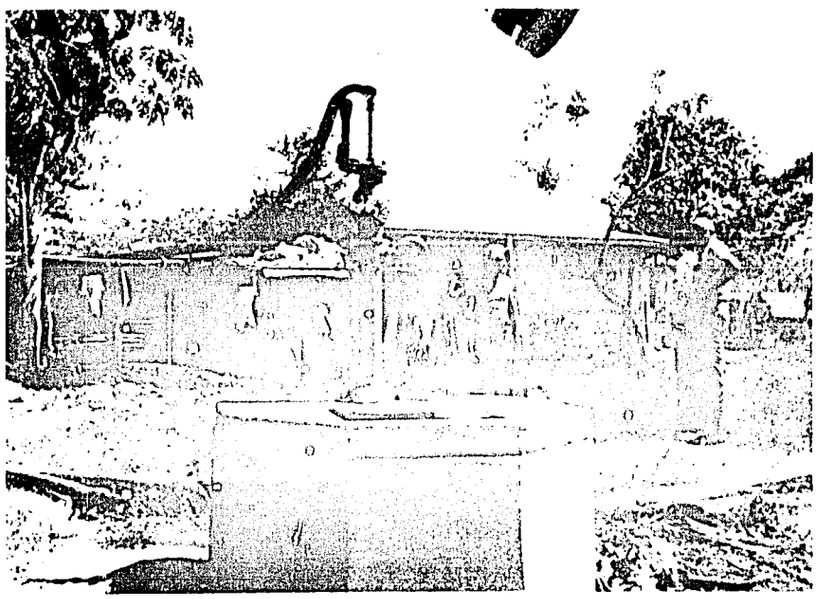


Costa Rica Site No. 11, located at Judas de Chomes, prior to installation of field test pump. Photo taken January, 1977.

COSTA RICA



Costa Rica Site No. 24, located at Villa Real de Santa Cruz, prior to replacement of broken Japanese pump with field test pump. Photo taken January, 1977.



Costa Rica Site No. 15, located at San Buena Ventura de Colorado, prior to installation of field test pump. Photo taken January, 1977.

be well designed and well manufactured, but the shallow-well type is not self-priming, a very disturbing factor from the standpoint of health. (In the next several months, efforts will be concentrated on designing a seal that will create enough of a vacuum to make the shallow-well pump self-priming.)

Water Quality

Water samples have been taken from 13 Costa Rican locations prior to installation of pumps to determine the level of bacteriological contamination in the water being used by rural villagers. All locations, except one, contain Escherichia coli in concentration ranging from 3.6 to 1,100 per 100 ml sample:

Site No.	Location	Total Coliforms per 100 ml @ 35°C	E. coli per 100 ml @ 44°C
11	Judas de Chomes	210	150.0
12	La Palma de Abangares	1,100	460.0
13	San Joaquin de Abangares	460	21.0
14	Pueblo Nuevo de Abangares	1,100	290.0
15	San Buena Ventura de Colorado	460	240.0
16	Penas Blancas de Colorado	1,100	1,100.0
17	Nicoya (Barrio San Martin)	210	20.0
18	Curime de Nicoya	43	3.6
19	Caimitalito de Nicoya	1,100	120.0
20	Conjunto IMAS, El Torito, Samara	290	290.0
21	Terciopelo de Nicoya	0	0.0
29	Pijije de Bagaces	150	3.6
30	La Javilla de Canas	93	3.6

Note: All tests performed in accordance with Standard Methods for the Examination of Water and Waste Water, 13th Edition APHA, 1971.

Inasmuch as the presence of E. coli indicates fecal contamination, ideally none should be present. It is not surprising to find this existing condition, however, due to the circumstances of the individual wells themselves. While the wells were properly disinfected at the time of their construction, imperfect sealing of the top, seepage of surface water, and other conditions have

lead to subsequent contamination. Bacterial quantity is subject to considerable variability, and frequent analysis of each site would be required to provide definitive data; it is noteworthy, on the other hand, that there has been only one location free of coliforms. (World Health Organization water quality standards for total coliforms and for E. coli consider 10/100 ml. and 0/100 ml., respectively, as highest permissible levels.)

Water disinfection has been a routine matter in Costa Rica prior to installation of pumps, but there has been no laboratory analysis to reveal the extent of assumed contamination in the wells. Because many of the sites in Costa Rica have been disinfected in the past and the wells were supposedly sealed off from contamination, only to result in continued contamination, the sites will also be tested periodically after pump installation to measure the effectiveness of pump programs such as this one now being carried out in Costa Rica and Nicaragua. In other words, if wells with hand-operated pumps installed on them have the advantage of an easier delivery system without an improvement in the quality of the water, the expenditures for the pumps hardly seem justifiable.

A chemical analysis is available at the present time from only one site, and it is obviously not possible to draw any general conclusions from such limited data. Nevertheless, when comparing the results from this one site (Bristol, Square No. 2) with standards prescribed by the World Health Organization (WHO), the water represented by the sample was found to be quite hard (199.0 ppm Ca CO_3) and was within recommended limits on all items except iron (1.4 ppm reported, as compared to the maximum permissible level of 1.0). While the iron is not a desirable condition, it is not a source of great concern other than from the standpoint of taste and, possibly, staining of laundry. Because more data are needed on chemical quality of the water represented by the field-test sites, further sampling of the water will be carried out during the remaining time period of the project.

NICARAGUA

Data from 1975 show that 56% of the total population of Nicaragua has relatively easy access to piped water supplies; however, when this figure is broken down into urban and rural areas, it is seen that 100% of the urban population has easy access to this type of water system, while only 14% of the rural population has easy access. Comparative figures for Costa Rica are 72% (total), 100% (urban), and 56% (rural).[1/]

Nicaragua was chosen as a test country for this program also because of a loan by AID to that country involving the installation of hand-operated water pumps. The loan provisions included a potable water program that will construct 300-340 wells by the end of 1979, which the Georgia Tech/ICAITI program will complement, and will enable the Ministry of Health in Nicaragua to take advantage of locally-manufactured hand pumps.

Program activities also began in Nicaragua in January of this year. A local foundry was chosen to manufacture 20 AID pumps (eleven deep-well and nine shallow-well) which were produced and delivered to a Ministry of Health warehouse for storage, prior to installation, in May. Three kinds of pumps were chosen to compare the AID pump with: Dempster, a Brazilian Marumby pump, and a pump developed by the International Development Research Centre (IDRC) of Ottawa, Canada. Thirty sites, representative of Nicaragua, were approved to receive the test pumps (15 AID pumps and 15 comparative pumps), all of which required extensive preparatory work before pumps could be installed. Pumps are now being installed, and the wells are being disinfected with a chlorine-yielding substance. As in Costa Rica, the sites have had chemical and bacteriological testing prior to installation of test pumps and show intestinal bacteria, requiring further testing to determine if the contamination is being sealed out by the addition of a closed well and the use of a hand pump for lifting the water. The 12-month monitoring period, which will continue through July 1978, has begun and will use the same system for measuring performance as in Costa Rica.

1/ World Health Statistics Report, Water and Sanitation, Volume 29, No. 10, published by the World Health Organization, Geneva, 1976.

Manufacture of AID Pumps

In manufacturing the AID pumps in Nicaragua, a somewhat surprising situation was encountered -- foundries were plentiful, but pattern makers, a very necessary requirement for local production, were almost nonexistent. A foundry was located that appeared to have the resources, including pattern makers, to manufacture a quality AID pump, and a contract was signed January 22, 1977, between Georgia Tech and Complejo Matalurgico Especializado, S.A. (Cometales) for the manufacture of eleven deep-well pumps and nine shallow-well pumps. The prices of the pumps were as follows:

Shallow-Well	$ 69	(each
Deep-Well	75	(each)
Patterns	1,000	(one-time charge only)

Cost data are still being collected and analyzed to determine if these prices are sufficient to cover all expenses, including overhead, and to allow a reasonable profit for the manufacturer.

The AID pumps in Nicaragua were also manufactured according to the approved drawings contained in the appendix to this report and with the following additional instructions:

1. The plunger rod was to be made from one-half inch diameter rod, rather than seven-sixteenths inch, because of difficulty in locating a reliable supply of seven-sixteenths inch stock. The pump rod nut, the rod end, and the plunger assembly were also changed to accommodate the one-half inch plunger rod.

2. The handle pivot pins were to be hardened to 40 R_c, and steel bushings (60-64 R_c) were to be inserted in the pump handle holes.

3. For the shallow-well pump, the three-inch support pipe was internally coated with epoxy for a smoother-surfaced cylinder finish. Option A (drawing No. 2001), using the bolted pump cap, was chosen in preference to a pin-mounted pump cap.

4. For the deep well pump (drawing No. 2002), Option A was chosen, using the bolted pump cap in preference to a pin-mounted pump cap. The AID pump manufacturer in Nicaragua neither foresaw nor experienced any problems with producing the deep-well pump cap

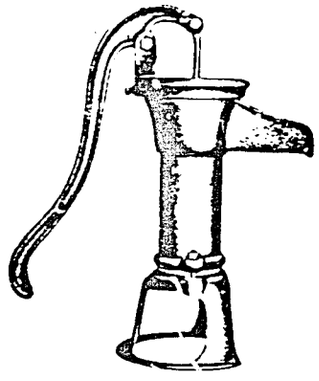
in accordance with specifications, in contrast to the case in Costa Rica.

All pumps were painted with an anticorrosive coating and were numbered consecutively. No unusual internal manufacturing problems were encountered other than unfamiliarity with the pump's characteristics for the first production order, and subsequent orders, if they should materialize, are not expected to present any difficulties. However, Nicaragua has experienced a severe drought during the 1976-1977 dry season. This drought has seriously curtailed electrical power generation to a point where in some areas, electricity has been rationed to as little as four hours per day. As this occurrence has been present for several months, extended delays in pump production have resulted.

It should be mentioned that the AID pump manufacturer in Nicaragua had a complete, integrated foundry and machine shop with trained metallurgists in the day-to-day management of the company. The manufacturer also possessed, and used, laboratory analysis facilities for the casting process, a quality control ingredient that is not normally expected to be found in developing countries. While it appears that the AID pump is adaptable to local manufacture in Nicaragua, the requirment of casting facilities will most likely restrict the use of the pump in developing countries.

Comparative Pumps

Three pumps were chosen for comparison with the AID pump and were locally available to the people of Nicaragua. These pumps also include the Dempster 210F, a Brazilian Marumby pump (for shallow wells only), and a pump developed by IDRC (for shallow wells and deep wells). The Dempster 210F is designed for heavy-duty use in both shallow and deep wells, has a brass-lined cylinder, is made of cast iron, and has a very good worldwide reputation, as pointed out earlier. The Brazilian pump is for shallow wells only, uses a one-and-one-fourth-inch drop pipe (as do the Dempster and AID pumps), has a cylinder slightly over three inches (3.1") of smoothened, cast iron, and is a pitcher-type pump. The pump developed by IDRC uses a three-inch diameter drop pipe (PVC) that also serves as the cylinder for the piston assembly. (Further information on the Brazilian pump is enclosed. Drawings of the IDRC pump are being prepared and will be included in the next progress report.)

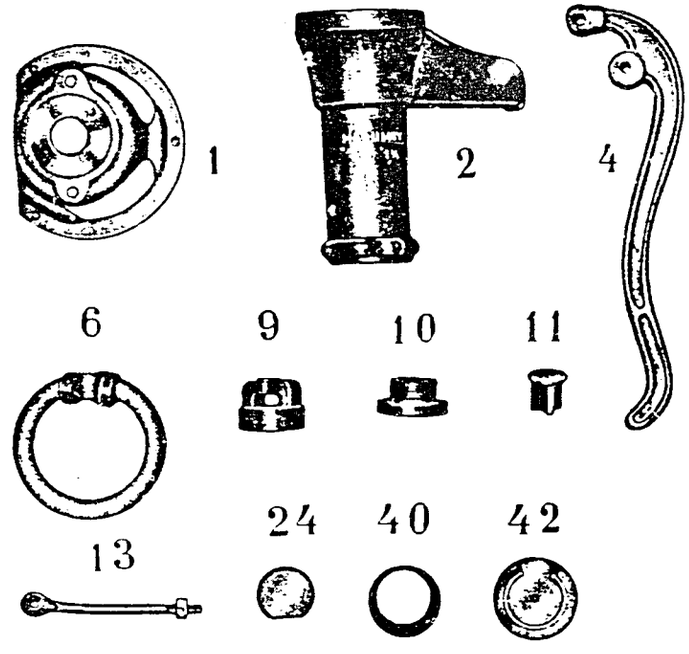


BOMBA SIMPLES

(BICA DE JARRO)

Tipo BJ

Para cano de 1¼" com pistão de ferro CrS.....



Peça n.º 1 - Prato (Plate)
2 - Corpo (Body)
4 - Alavanca (Handle)
6 - Anel suporte alavanca (Support ring)
9 - Corpo do pistão (Piston body)
10 - Porca do pistão (Piston nut)
11 - Válvula do pistão (Piston valve)
13 - Haste do pistão (Piston rod)
24 - Pêso da válvula (Valve weight)
40 - Manga de couro (Leather sleeve)
42 - Válvula de couro p/ prato (Leather valve for plate)

ESPECIFICAÇÕES:

Sucção cano de (Suction tube)	1¼"	
Altura do corpo (Height of body)	280	mm.
Diâmetro interno do cilindro (ID of cylinder)	80	mm.
Rendimentos em 55 movimentos do pistão por minuto (Flowrate/min.)	22	L.
Sucção até (Suction depth)	7	m.
Pêso líquido (Weight of liquid)	13	kg.

MARUMBY (BRAZILIAN) PUMP

The Dempster 210F cost approximately $257 in Central America, the Brazilian Marumby approximately $45, and the IDRC pump $70 (this estimated $70 cost is for comparison only and can vary widely, depending on the materials and the pricing systems used by the fabricating shop). It is interesting, at this point, to recap all pumps included in the field testing of the AID pump, especially noting the difference in the cost of the AID pumps in Costa Rica versus Nicaragua. For the AID pump to be considered truly low cost in Costa Rica, it is felt that the $98 and the $128 will have to be reduced in order to more closely approach the Nicaraguan figures of $69 and $75, respectively.

	Costa Rica	Nicaragua
1. AID Shallow-Well (for shallow wells only)	$ 98	$ 69
2. Japanese "Lucky" (for shallow wells only)	63	--
3. Brazilian Marumby (for shallow wells only)	--	45
4. AID Deep-Well (for deep and shallow wells)	128	75
5. Dempster 210F (for deep and shallow wells	257	257
6. IDRC PVC Cylinder (for deep and shallow wells)	--	70

Another approach to analyzing the relative costs of the field-test pumps is to consider the total estimated cost of installing each pump complete with drop pipe (average price @ $.70 per foot), plunger rod (average price @ $.71 per foot), drop pipe connectors (average price @ $.91 each), and plunger rod connectors (average price @ $1.06 each) at various depths:

	25 ft.	50 ft.	75 ft.	100 ft.	150 ft.	200 ft.	250 ft.
AID Shallow Well (C.R.)*	$116	$ --	$ --	$ --	$ --	$ --	$ --
AID Shallow Well (Nic.)*	87	--	--	--	--	--	--
Japanese "Lucky"*	81	--	--	--	--	--	--
Brazilian Marumby*	63	--	--	--	--	--	--
AID Deep Well (C.R.)	135	172	210	251	324	398	474
AID Deep Well (Nic.)	106	143	181	222	295	369	445
Dempster 210F	294	331	369	410	483	557	633
IDRC PVC Cylinder**	123	167	212	254	355	452	537

* Cannot be used for depths of more than 25 ft.

**PVC priced @ $1.20 per foot.

The above figures indicate that the AID shallow-well pump can be competitive with comparative pumps. The AID deep-well pump is, in all cases, relatively lower in cost than the Dempster 210F and becomes much cheaper than the IDRC pump as the depth increases (because of the high cost of PVC versus galvanized iron drop pipe).

Selection of Field Test Sites

Table 2 shows the sites selected for field testing in Nicaragua. Most of the wells were already in existence. There was one spring, Site No. 9, that was adapted to support a pump. The wells are equally divided between deep and shallow. Usage is quite high for the sites, averaging 150 persons, and all wells have required site work of some kind (well deepening, lining applied to the well, slab and other concrete work performed, and cleaning and disinfecting of the well). There are at least seven sites that pose problems demanding a search for substitute wells with the problems including the striking of hard rock during excavation, wells caving in, water sources polluted beyond present ability to correct, and villagers deciding that they would prefer an electric pump and storage tank to a hand-operated water pump (even if the villagers have to pay for the electric pump and storage tank). The general areas of site concentration are in the northern section of Nicaragua in the vicinity of Esteli and Matagalpa (see Map 2).

Site Preparation

It was the original intent of this project to use existing wells with pumps that were inoperable or in a state of disrepair and to merely replace the broken pumps with the test pumps. This approach was impractical in Nicaragua because there are few existing hand-pump installations and most of those that do exist are privately owned, belonging to the more affluent rural villagers. Therefore, it was necessary to dig five new wells, deepen 24 wells, provide a lining for 12 wells, construct slabs for 24 well structures, and disinfect all 30 wells to complete installation of the pumps. In addition to problems previously mentioned, many others have been encountered, including dissention among villagers as to where the new wells and pumps would be located, failure to find water at a reasonable depth, and lack of logistical resources within the country.

Table 2

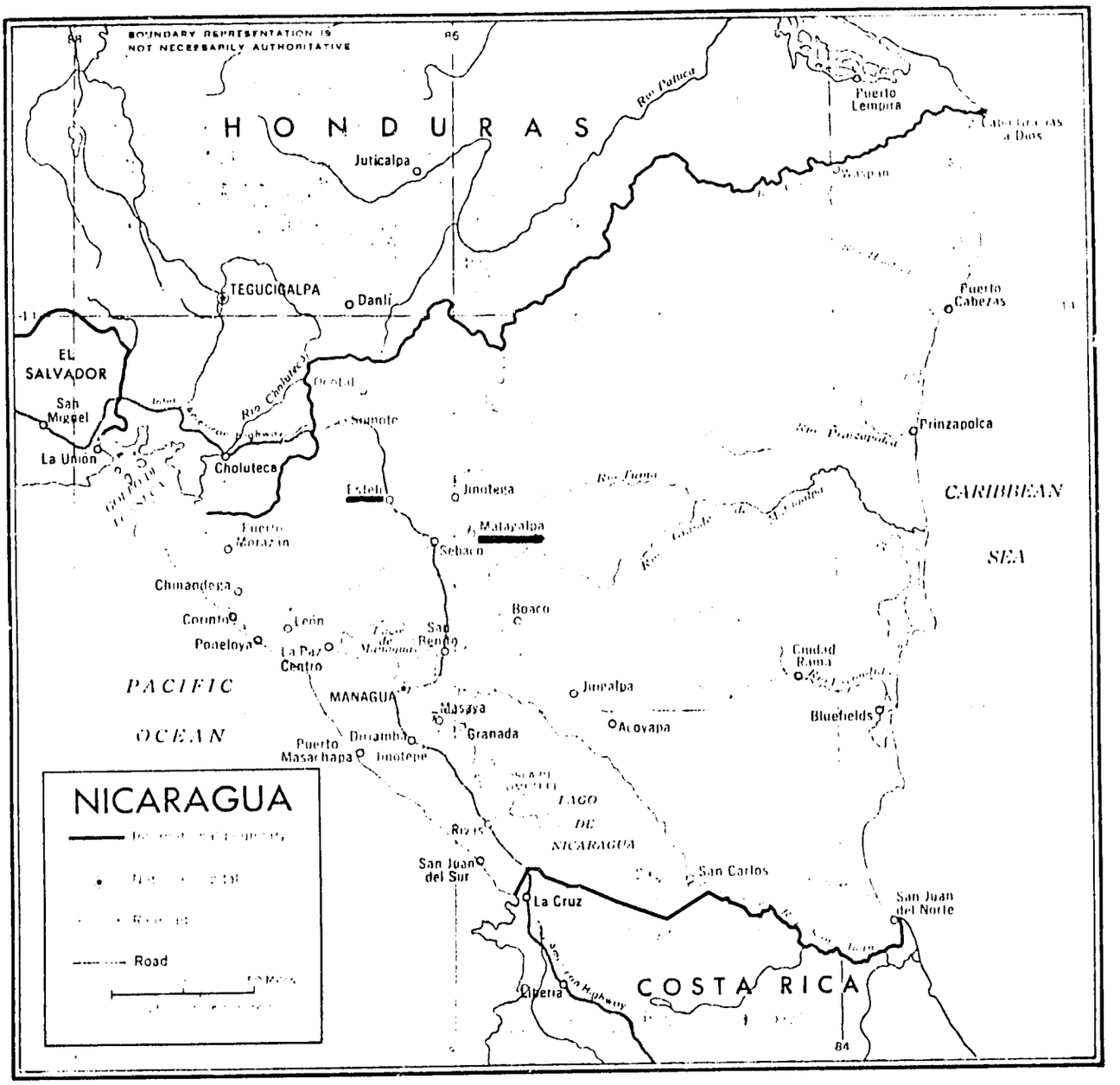
SELECTED SITES FOR AID PUMP FIELD TESTS IN NICARAGUA

Site No.	Location	Well Situation	Well Type	Classification by Depth	Depth to Water (mt.)	Depth to Water (ft.)	Water Column (mt.)	Well Diameter (mt.)	Estimated Usage (No. Persons) 50-100	101-150	>150	Site Work Required: New Well	Deepen Well	Lining	Slab	Disinfect	Install Pump	Type of Pump to Install[1]
1	La Garita (schoolhouse)	Existing	Dug	Deep	8.20	27	0.78	0.80	X				X		X	X	X	Dempster
2	Las Mesas	New well required	Dug	Shallow	--	--	--	--			X	X		X	X	X	X	Braz.
3	Llano Grande	Existing	Dug	Shallow	2.20	7½	1.77	1.20		X			X		X	X	X	CAN-SW
4	Chaquite Grande	Under construction	Dug	Shallow	--	--	--	--		X			X	X	X	X	X	CAN-SW
5	El Horno	Under construction	Dug	Deep	--	--	--	--	X				X	X	X	X	X	AID-DW
6	Mechapa	Existing	Dug	Deep	17.80	58	0.95	1.23		X			X			X	X	CAN-DW
7	Las Lajitas	Existing	Dug	Shallow	5.40	18	0.45	1.45	X				X		X	X	X	Braz.
8	Los Rastrojos	Under construction	Dug	Deep	12.00	39	2.00	1.20			X		X	X	X	X	X	Dempster
9	El Naranjo	Existing	Spring	Shallow	2.12	7	1.00	2.0x2.0			X		X		X	X	X	AID-SW
10	Isidrillo	Existing	Dug	Deep	24.10	79	2.00	1.20			X		X			X	X	AID-DW
11	Rio Abajo (Santa Teresa)	Existing	Dug	Shallow	3.50	11½	0.85	1.2x1.2			X		X			X	X	CAN-SW
12	Rio Abajo (Los Laureles)	Existing	Dug	Shallow	4.08	13	0.34	1.2x1.2		X			X			X	X	AID-SW
13	Quebrada Arriba	New well required	Dug	Shallow	--	--	--	--			X	X		X	X	X	X	AID-SW
14	Los Rincones	Existing	Dug	Deep	19.20	63	1.00	1.20			X		X			X	X	AID-DW
15	Rio Grande	New well required	Dug	Shallow	--	--	--	--		X		X		X	X	X	X	Braz.
16	San Antonio	Existing	Dug	Deep	9.87	32	0.55	0.70			X		X	X	X	X	X	Dempster
17	El Rodeo	Existing	Dug	Deep	15.91	52	0.33	1.20	X				X		X	X	X	AID-DW
18	Los Calpules (stream)	Existing	Dug	Shallow	1.37	4½	1.18	1.20	X				X		X	X	X	AID-SW
19	Los Calpules (schoolhouse)	Existing	Dug	Deep	8.45	28	0.51	1.20			X		X		X	X	X	AID-DW
20	Motolin (Sr. Umanzor)	Existing	Dug	Deep	15.56	41	0.42	1.00		X			X		X	X	X	AID-DW
21	Ducuale Grande	New well required	Dug	Shallow	--	--	--	--		X		X		X	X	X	X	AID-SW
22	La Concepcion (No. 1)	Existing	Dug	Shallow	--	--	--	--	X				X		X	X	X	AID-SW
23	Valle Santa Rosa	Under construction	Dug	Deep	--	--	--	--		X			X	X	X	X	X	Dempster
24	Sabana Grande	Existing	Dug	Deep	14.17	46½	0.23	0.91	X				X		X	X	X	AID-DW
25	San Diego	Existing	Dug	Shallow	--	--	--	--		X			X			X	X	Braz.
26	La Lamilla	Under construction	Dug	Deep	14.00	46	1.80	1.20			X		X	X	X	X	X	Dempster
27	Valle Santa Lucia	Under construction	Dug	Shallow	--	--	--	--			X		X	X	X	X	X	AID-SW
28	Los Curritos	New well required	Dug	Shallow	--	--	--	--		X		X		X	X	X	X	Braz.
29	Las Mangas	Existing	Dug	Deep	8.76	29	5.90	1.09			X				X	X	X	AID-DW
30	La Majadita	Existing	Dug	Shallow	6.15	20	0.80	1.00	X				X		X	X	X	CAN-SW

[1]AID-DW: AID pump for deep well; AID-SW: AID pump for shallow well: Dempster: Dempster deep well type pump; Braz.: Brazilian shallow well type. CAN-SW: Canadian pump for shallow well; CAN-DW: Canadian pump for deep well

Map 2

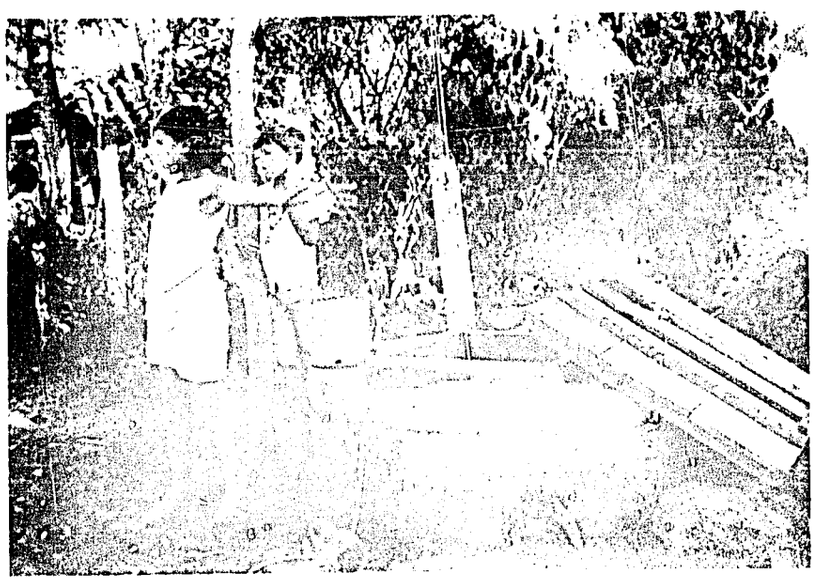
NICARAGUA



Sites in Nicaragua are concentrated in the northern part of the country, near Matagalpa and Esteli.

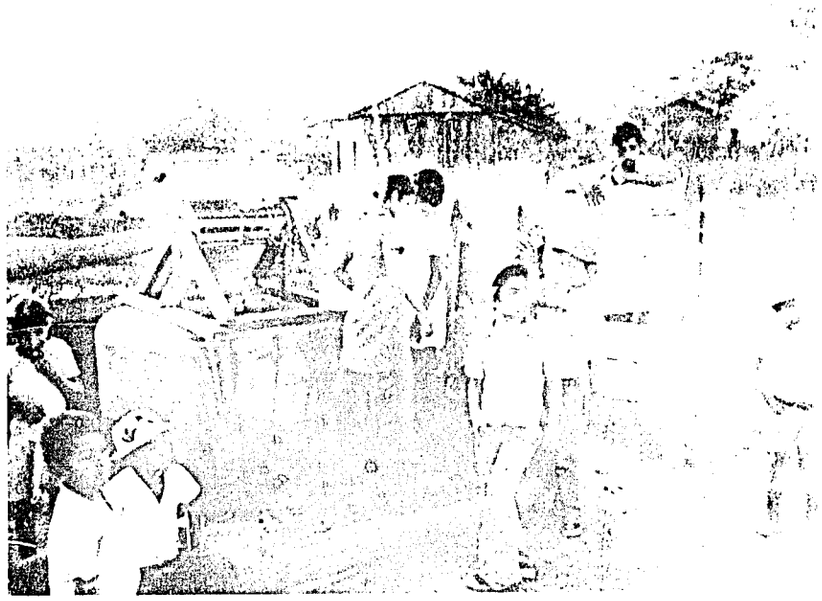
NICARAGUA

Nicaragua Site No. 2, located at La Garita. This spring has been replaced as a source of water by a nearby dug well and a field test pump. Photo taken January, 1977.

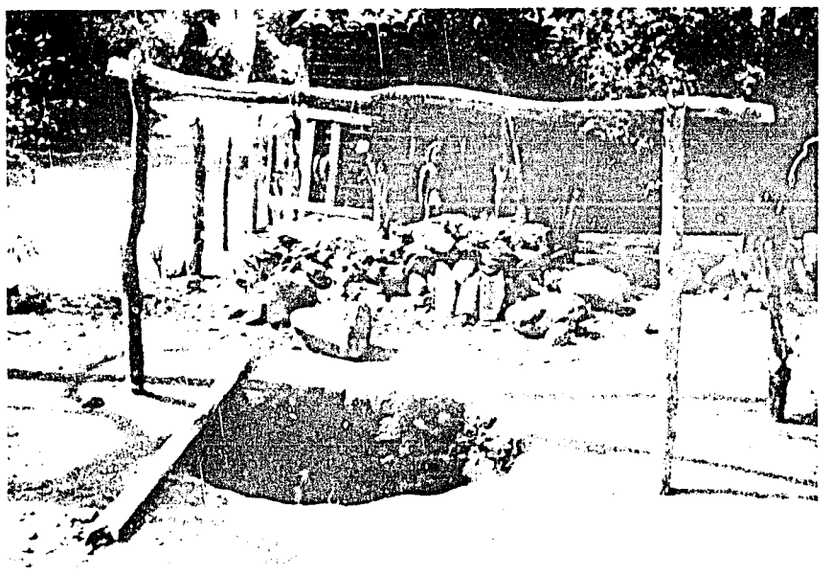


Nicaragua Site No. 6, located at Mechapa, prior to field test pump installation. Photo taken January, 1977.

NICARAGUA



Nicaragua Site No. 10, located at Isidrillo, prior to field test pump installation. Photo taken January, 1977.



Nicaragua Site No. 27, located at Valle Santa Lucia, during construction of well. Photo taken January, 1977

Water Quality

The results of chemical analyses of 19 sites are given in Table 3. For comparison, the limits established by the World Health Organization are also included.[1/] In general, the water sampled is quite hard, and at Los Rastrojos (Site No. 8), it is extremely hard. Water at Los Rincones (Site No. 14) is given as a hardness of 70, but this may be in error if the high total solids content of the water (608 mg/l) is correct; therefore, this value of 70 is being verified by an additional analysis. The total solids content of all other samples is in an acceptable range with the notable exception of Los Rastrojos (Site No. 8) where the level of 1,600 mg/l is more than three times the highest desirable limit and actually above the maximum allowable limit. Iron content exceeds the highest desirable concentration in two locations while manganese was found to exceed the highest desirable level in six samples and to exceed the maximum permissible in one additional instance.

Nitrate levels are low with the single exception of Isidrillo (Site No. 10) where the reported nitrate level of 306.5 mg/l exceeds the 100 mg/l total solids. It appears likely that a clerical error has occurred, and this value is being rechecked. The levels of fluoride present may offer considerable resistance to tooth decay, as the WHO-recommended concentrations in the United States where water supplies are to be fluoridated are 0.6-1.7 mg/l, depending on the air temperature. Both chloride and sulfate are at sufficiently low concentrations.

An examination of the bacteriological data (Table 4) shows that all sites are significantly contaminated with common intestinal bacteria. Salmonella was initially reported at Los Laureles (Site No. 12), and this point has been rechecked. (A second sample was negative, but an additional analysis will be performed at a later date to determine if any continuing hazard is present.) All sites will be analyzed further during the next 12 months to provide more insight into whether or not contamination is being sealed off from the water by the preparation of the wells and the installation of the pumps.

1/ International Standards for Drinking Water, Third Edition, published by the World Health Organization, Geneva, 1971.

Table 3

SUMMARY OF WATER CHEMICAL ANALYSES[a] -- NICARAGUA

Site No.	Location	pH	Hardness as $CaCO_3$	Alkalinity as HCO_3^-	Total Solids	Fe	Mn	Ca	NO_3^-	F	Cl	$SO_4^=$
1	La Garita	7.0	350	26	218	0.07	0.05	70.0	3.76	0.30	22.5	2.0
3	Llano Grande	6.4	200	120	161	0.07	0.00	30.0	9.96	0.70	12.5	3.0
6	Mechapa	7.7	325	30	330	0.06	0.00	80.0	13.10	0.40	12.5	8.0
7	Las Lajitas	7.5	200	190	225	0.02	0.40	50.0	4.43	0.35	5.0	2.0
8	Los Rastrojos	7.6	840	260	1,600	0.27	0.58	292.0	0.66	1.62	20.0	67.5
9	El Naranjo	6.9	400	420	426	0.05	0.00	100.1	3.54	0.70	15.0	3.0
10	Isidrillo	7.6	400	180	100	0.07	0.00	90.0	306.50	0.35	62.5	10.0
11	Santa Teresa	8.1	240	265	383	0.01	0.00	62.0	9.52	0.35	15.5	11.0
12	Los Laureles	7.7	250	265	340	0.01	0.00	64.0	6.42	0.60	15.0	6.0
13	Quebrada Arriba	7.5	180	280	360	0.10	0.28	44.1	1.76	0.20	15.0	8.3
14	Los Rincones	8.1	[illegible]	445	608	0.01	0.00	20.0	16.60	0.25	20.0	20.0
15	Rio Grande	8.0	190	250	336	0.25	0.28	52.1	4.80	0.20	25.0	10.5
16	San Antonio	7.9	240	270	404	0.01	0.00	68.0	2.65	0.50	19.5	11.0
18	Los Calpules (Stream)	7.9	290	330	394	0.01	0.10	80.0	0.00	0.55	10.0	2.0
19	Los Calpules (School)	7.9	210	200	237	0.01	0.00	50.0	5.10	0.60	12.5	4.0
20	Motolin	8.2	240	250	298	0.05	0.00	62.0	22.40	0.65	14.0	4.0
22	La Concepcion	7.5	350	30	264	0.00	0.10	80.0	0.00	0.40	10.0	3.0
25	San Diego	7.6	260	290	398	0.10	0.00	56.1	2.35	0.40	25.0	15.0
29	Las Mangas	6.4	100	100	38	0.02	0.00	20.0	2.21	0.50	15.0	2.0
WHO limits:												
	Highest desirable	7.0-8.5	100	--	500	0.10	0.05	75.0	(b)	(c)	200.0	200.0
	Maximum permissible	6.5-9.2	500	--	1,500	1.00	0.50	200.0	(b)	(c)	600.0	400.0

(a) All values mg/l except pH.
(b) Values above 45 mg/l considered potentially harmful, especially to children.
(c) Limit depends on daily air temperature. Upper limits range from 0.8 to 1.7 mg/l.

Table 4

SUMMARY OF BACTERIOLOGICAL ANALYSIS -- NICARAGUA

Site No.	Location	Coliforms per 100 ml	Salmonella Presence	Shigella Presence	Comments
1	La Garita	2.4	Negative	Negative	Positive Enterobacter
3	Llano Grande	430.0	Negative	Negative	Positive Enterobacter and Citrobacter
6	Mechapa	1,100.0	Negative	Negative	Positive Proteus and Citrobacter
7	Las Lajitas	150.0	Negative	Negative	Positive Enterobacter
9	El Naranjo	1,100.0	Negative	Negative	Positive Enterobacter
10	Isidrillo	1,100.0	Negative	Negative	None
11	Rio Abajo (Santa Teresa)	24.0	Negative	Negative	Positive Enterobacter
12*	Rio Abajo (Los Laureles)	64.0	Positive	Negative	Positive Salmonella sp, Enterobacter, and Citrobacter
12*	Rio Abajo (Los Laureles)	350.0	Negative	Negative	Positive Escherichia coli
14	Los Rincones	54.0	Negative	Negative	Positive Pseudomonas
16	San Antonio	120.0	Negative	Negative	Positive Escherichia coli
17	El Rodeo	540.0	Negative	Negative	Positive Escherichia coli
18	Los Calpules	23.0	Negative	Negative	Positive Escherichia coli
19	Los Calpules	920.0	Negative	Negative	None
26	La Lamilla (replacing La Concepcion)	350.0	Negative	Negative	Positive Escherichia coli
30	La Majadita	64.0	Negative	Negative	Positive Escherichia coli

* This site (Los Laureles) was retested because of earlier findings of positive Salmonella. A third sampling is under way to verify the presence or absence of Salmonella. (Note: all tests performed in accordance with Standard Methods for the Examination of Water and Waste Water, 13th Edition APHA, 1971.)

CONCLUSIONS AND RECOMMENDATIONS

Monitoring of pump performance is in its early stages of the budgeted 12-month period, and sufficient data are not available for arriving at reliable conclusions. However, there are no indications at the present time that would discourage further manufacture, installation, or use of the AID pump in Costa Rica or Nicaragua. The AID pump can be manufactured in a developing country at a competitive, profitable price and at an acceptable level of quality if adequate facilities (foundries, pattern makers, machine shops and skilled machinists, raw materials, etc.) are available; however, the availability of adequate foundry facilities is a matter that must be determined for each individual developing country. Public acceptance by rural villagers has been good, both from an aesthetic standpoint and from a standpoint of the pump being used easily by men, women, and children. Lastly, the AID pump should have a positive impact in developing countries on the health of rural people, on employment generation, and on instilling national pride within the people when it is seen that these countries do have local capabilities for manufacturing a complicated product rather than importing it.

Appendix A

AID-APPROVED PUMP DESIGN

CHAPTER IV

COUNTRY REPORTS

AFGHANISTAN

Agriculture is the backbone of the Afghan economy. To cultivate more land and to use the water resources of the country to the fullest extent are main goals in order to increase over-all production and raise the standard of living.

To cultivate more land properly and efficiently, improvement and development works are needed, and in most cases major operations with regard to these works are required. The Government of Afghanistan, considering the economy and the financial capability of the country, has taken important steps toward such improvement and development. These operations have been accelerated during the last ten years and additional development works are planned and included in the second five year plan of the country (1962-1966).

In the past few years, some major irrigation improvement and development programs were completed or extended into the second five year plan. In the Helmand Valley, a 100-meter high storage dam with a capacity of 1,500,000 acre-feet and three major modern diversion dams on the Helmand River, along with a 50-meter high storage dam of 388,000 acre-feet capacity and a major diversion dam on the Arghandab River, were constructed and are in use for irrigation and flood control purposes. The hydropower generation from the structures is also being considered. Main canals of various capacities and lengths with necessary regulative and protective structures are constructed. The Boghra Canal, 111 kms in length and with 2,600 cubic feet per second capacity at the intake, the Shamalan Canal, 66 kms. long and with 750 cubic feet per second capacity, the Darweshan canal, 51 kms. long and with 1,000 cubic per second capacity with reinforced concrete intake structures, divert water from the Helmand River. The Zahir Shahi Canal, 43 kms. long and with 1,500 cubic feet per second capacity, the Tarnak Canal 14 kms long and with 750 cubic feet per second capacity, and its two branches together with some modern intake structures to the existing canals, take water from the Arghandab, the major tributary to the Helmand River. All of these canals are completed and are in use. About 600 kms. of laterals, 1,200 kms. of sublaterals and farm ditches with distributary structures, 500 kms. of deep drains, 650 kms. of secondary drains with pertinent structures, and about 2,500 kms. of on-project and interproject roads have been constructed. The irrigation and drainage networks mentioned above are serving an irrigable area of about 200,000 acres, but the rest of the irrigated land in the Helmand and Arghandab valleys receives water from the rivers in the customary old existing methods. Control of the river discharge by means of the two storage dams is important, however, as far as the availability of dependable water for the total area is concerned. Extension of the development work in the Helmand Valley is planned and will be carried out with the cooperation and help of AID, as in the past.

Throughout the country, inefficient use is made of water and,most often due to over-irrigating, the ground water table rises. In valley lands with proper slope and natural drainage channels close by, the rise of the ground water table may not be great, but in the desert and flat land, for example in the southern arid part of the country, the situation is of a critical nature where natural drainage channels do not exist. Due to low rainfall and high evaporation and temperature in the desert area, the natural leaching of soluble salts is limited. Therefore the washing of salt is done by artificial

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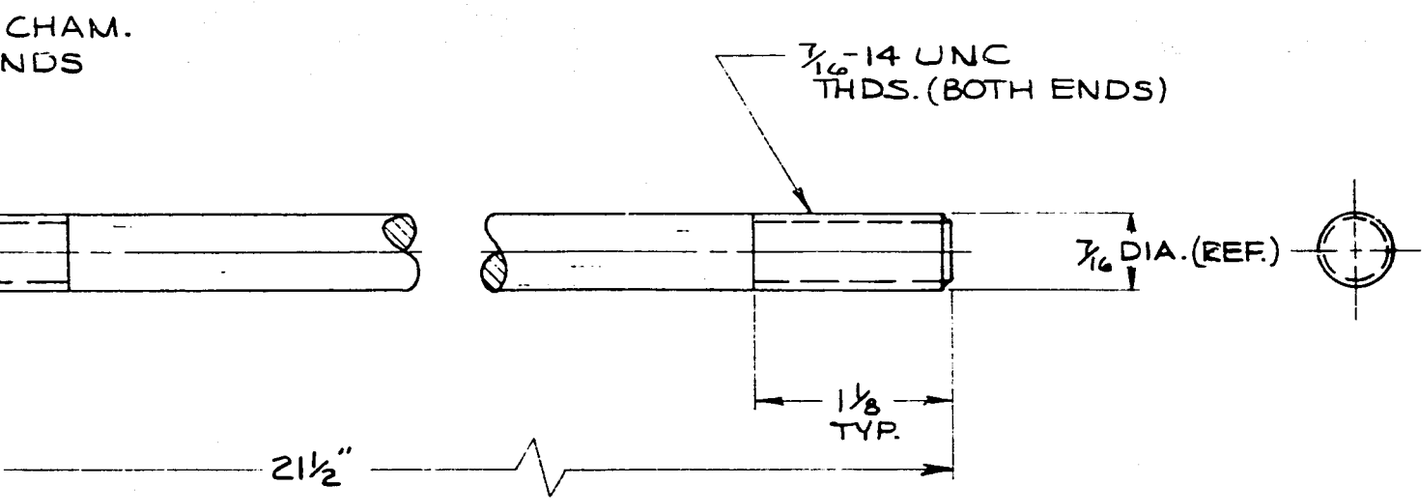

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7/16 DIA. GALV. PUMP ROD

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BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

TITLE: PLUNGER ROD

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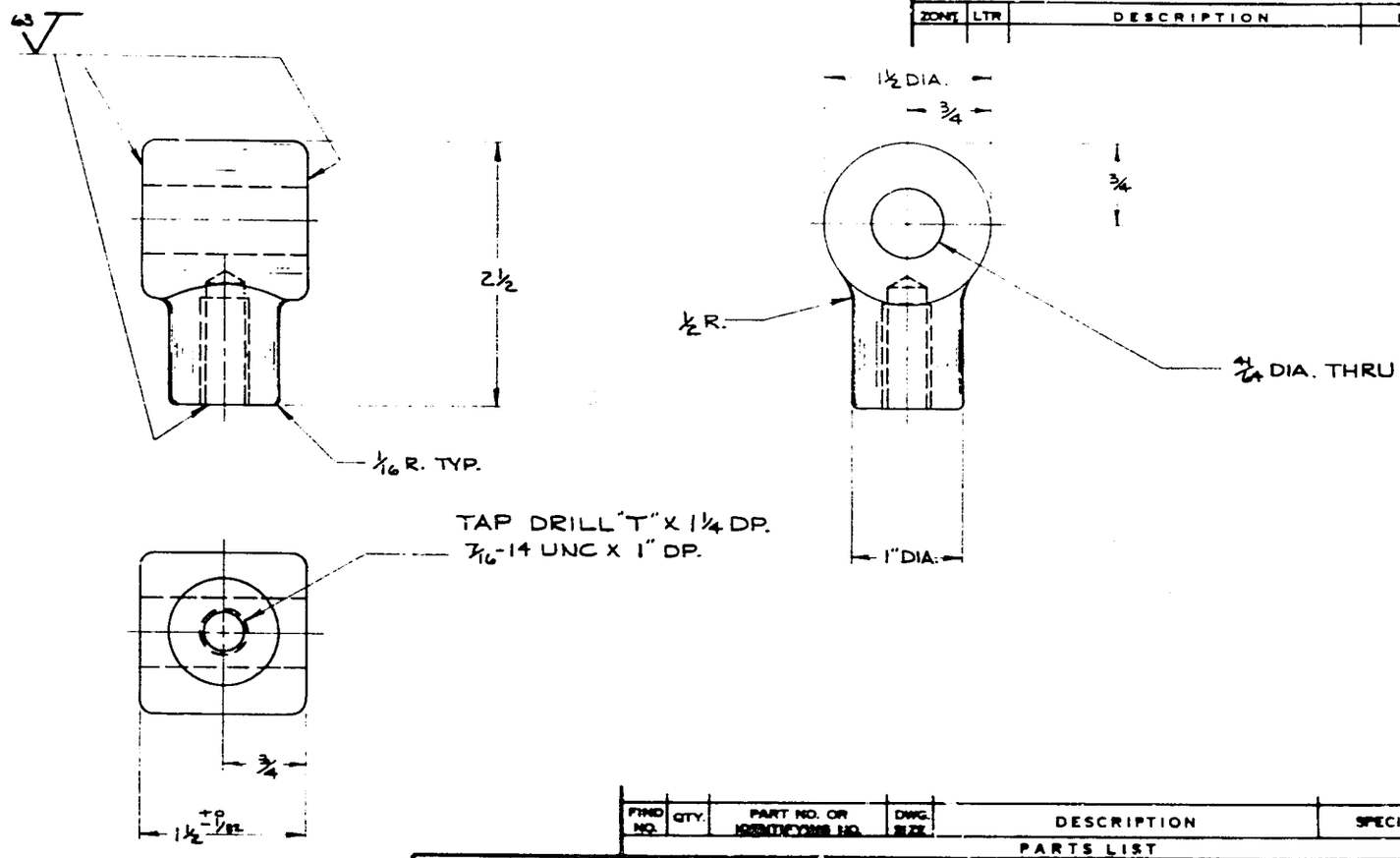

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Columbus, Ohio 43201
Telephone (614) 253-9161

TITLE
ROD END

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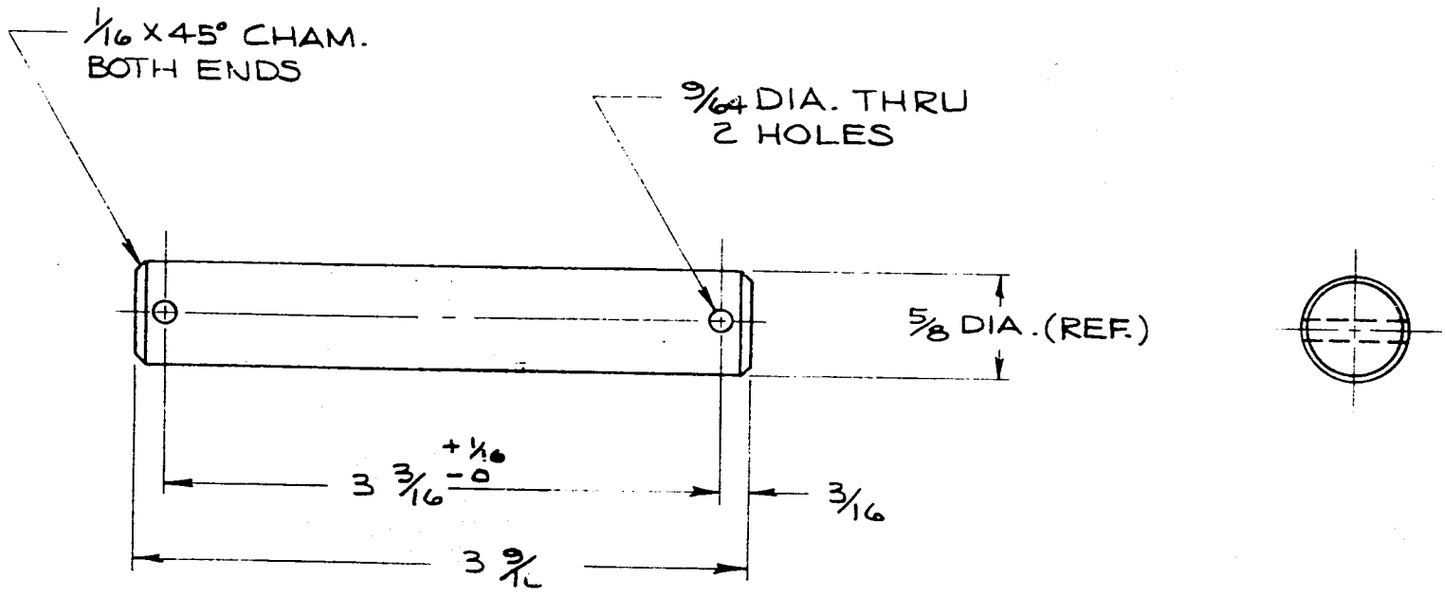

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TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

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505 KING AVE., COLUMBUS, OHIO 43201

TITLE
HANDLE PIVOT PIN

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CEYLON

1. INTRODUCTION

The country report presented at the Third Regional Seminar in 1960 covered land and water resources, the mode of execution of irrigation works, and the organization through which the work is carried out. These facts are not repeated, except to report further progress. Institutional and administrative means adopted for irrigation works are emphasized.

2. RAINFALL

The northeast monsoon of 1959-60 deviated from the average by the incidence of heavy rainfall in February, causing widespread floods in the eastern sector.In the northeast monsoon of 1960-61, the rainfall in October and December was below average, while the rainfall for November was above. There was no serious shortage of water throughout the country for irrigation.

3. FLOODS

Periodic flooding of the eastern zone of Ceylon was observed due to the northeast monsoon. Some flooding was also experienced in the southern and southwest zones due to the southwest monsoon. Nevertheless, after the experience of the 1957 floods, irrigation authorities were on the alert and all possible precautions were taken.

Several «safety measures» have been undertaken during the last two years for the purpose of minimizing the danger to irrigation works from major floods. These measures, which were based on the experience gained and the observations made during the floods of December, 1957, consisted mainly of providing additional spillway accommodation, strengthening embankments and providing additional rock filters for irrigation works which had either been damaged by the floods or were endangered in 1957.

4. PROGRAM OF DEVELOPMENT

The Second Six-Year Plan was replaced by a ten-year plan providing for development on both long-range and short-term bases. The short-term plan of development classified irrigation works under: (a) Large Scale Development Works; (b) Major Irrigation Works; and (c) Village Irrigation Works. This is a three-year plan and contemplates the provision of irrigation facilities to 53,000 acres in the next three years.

This program has been incorporated in the Government's Ten-Year Plan, which extends to 1968 and envisages the provision of irrigation facilities to 400,000 acres of land. The acreage contemplated in the program includes the work to be done by the Irrigation Department and the Gal Oya Board as well as the acreage that is to be developed for sugar.

5. PROGRESS ON IRRIGATION DEVELOPMENT

(i) CONSTRUCTION WORKS

The following are some of the larger irrigation works carried out:

(a) **The Mahakanadarawa Scheme,** in the Anuradhapura District of the N.C.P., involves restoration of an ancient reservoir designed to irrigate 6,000 acres of paddy. The spill, sluices and breach filling have been completed and channel construction is in progress.

(b) **The Morawewa Scheme,** in Trincomale District, is also a restoration of an ancient reservoir, to irrigate 4,000 acres. The sluice and breach filling have been completed and the tank is now

storing water. Channel works are in progress.

(c) **The Kaudulla Scheme,** in the Polonnaruwa District of the N. C.P. This is one of the largest of the ancient reservoirs situated in the Tamankaduwa District of Ceylon, now known as the Polonnaruwa District. The reservoir is being restored in three stages.

The first stage consists of closing the ancient breaches and constructing channels to serve an irrigable extent of 4,000 acres. The second stage involves the extension of the channel system to cover 10,000 acres in all. The third and final stage provides for increasing the storage capacity to serve an irrigable extent of 27,000 acres. The headworks for Stage I have now been completed and channel construction is under way.

(d) **Chandrika Wewa** is a new reservoir and is one of the seven reservoirs proposed for construction in the Walawe Gange Basin, situated in the southern region of the Island. This reservoir will command an extent of 5,000 acres of paddy and construction of the embankment was continued. Construction of the spill is expected to start in the near future.

(e) **The Hakwatuna Oya Reservoir Scheme** is also an old reservoir situated in the Kurunegala District of the Northwestern Province of Ceylon and is intended to irrigate 4,000 acres of paddy land. Embankment construction was undertaken and a 300-ft. concrete clear overfall spillway is nearing completion.

f) **The Minipe Yoda Ela Extension Scheme,** in the Kandy District of the Central Province, is an ancient scheme for diverting the waters of the Mahaweli Gange by a diversion weir commanding lands on the left bank. The scheme was revived to irrigate 3,345 acres about 20 years ago, and is now being completely remodelled and extended to increase the irrigable command to 18,500 acres. At the present stage of construction, the improvements to the headworks are almost complete, while work on improvements to the existing 18 miles of main canal, on construction of the extended main canal, and on the distribution system for the new lands is in progress.

(ii) **LAND DEVELOPMENT**

The works mentioned earlier and some other smaller projects deal with the construction aspects of irrigation. The amount rendered irrigable during the past two years by Government departments was 38,000 acres. In addition to this, the Gal Oya Development Board has now developed a total of 87,600 acres of the 120,000 acres proposed under this scheme.

The Kantalai Irrigation Scheme, which was originally designed to grow only paddy, was later modified for sugar. This scheme is in two stages. Stage I envisages the development of 6,400 acres altogether, of which 4,800 acres will be in sugar and 1,600 acres in paddy, grown in a four-year rotation. The second stage envisages the cultivation of a further 15,000 acres with sugar, irrigated by Kantalai Tank. At Kantalai 5,000 acres have been cleared and prepared, of which 4,000 acres were cultivated with sugar. The Gal Oya Sugar project is designed to cultivate 10,000 acres with cane, and this project commenc-

ed with an initial planting of 1,000 acres, which is being extended in stages.

(iii) PROGRESS AT FARM LEVEL

Considerable progress has also been achieved in educating farmers in scientific methods of cultivation through the use of high-yielding disease-resistant varieties, fertilizers, and improved cultivation practices such as transplanting and row sowing, etc. These efforts have shown good results and the average yields for the two seasons of 1960 were the highest on record. The improved yields are best illustrated by the following yield figures for the last five years:

Maha (Oct.-March)		Yala (April-Sept.)	
Year	Yield	Year	Yield
1955-56	30.9 bu/acre	1956	28.4 bu/acre
1956-57	32.7 » »	1957	31.8 » »
1957-58	34.8 » »	1958	35.5 » »
1958-60	34.0 » »	1959	37.1 » »
1959-60	36.1 » »	1960	36.8 » »

The Maha season is the main cultivation season in Ceylon.

6. IRRIGATION PLANNING AND MAJOR INVESTIGATIONS

In earlier years irrigation works in Ceylon were taken up in a piecemeal fashion to meet the immediate needs of a land-hungry peasantry, and it was not until a few years ago that river basin planning was embarked upon in a systematic way. This was achieved by the creation of a Planning Branch of the Irrigation Department in charge of a Deputy Director. This Branch was entrusted with assessment of the water resources of the country and preparation of plans for their utlization. As a first step, eight major river basins were selected for development and preliminary proposals were framed for harnessing available water resources for the development of irrigation and power. The eight river basins were:

1. Mahaweli Ganga
2. Walawe Ganga
3. Malwattu Oya
4. Kelani Ganga
5. Nilwala Ganga
6. Kala Oya
7. Yan Oya
8. Maduru Oya

Each of these is being taken up separately and detailed investigations have been made in the Mahakeli, Walawe, Malwattu Oya, Kelani Ganga and Nilwala Ganga basins. The progress of these investigations is as follows:

(a) The Mahaweli Ganga is a river originating in the central hill country and discharging into the sea near Trincomalee on the northeastern coast of Ceylon. The total area of the drainage basin is 4,034 sq. miles, and the estimated annual yield is 6,000,000 Ac. ft. The investigation of this basin is being carried out jointly by the Irrigation Department and USAID. The first phase of this investigation has resulted in the submission of a feasibility report for the diversion of 2,500 cusecs of water from the Mahaweli Ganga near Kandy to irrigate 325,000 acres of land for two crops in the dry zone of Ceylon, by means of a diversion weir and a 124-mile conveyance channel. The scheme also proposes the construction of two large storage reservoirs for regulating discharges, and four hydropower plants, aggregating an installed power supply of 243 Megawatts. Further investigations are proceeding on the plan for the rest of the basin. Under this joint venture an opportunity is afforded engineers of the Irrigation Department to gain experience in river basin planning.

(b) A comprehensive basin plan for the Walawe Basin has now been evolved, which is being implemented in stages. The Walawe Basin drains an area of 965 sq. miles, with an estimate yield of 1,110,000 Ac. ft. and the proposals envisaged at present are for the construction of seven reservoirs for the irrigation of 105,000 acres of land and the production of 60,000 K.W. of installed power. Of these, one reservoir, Chandrika Wewa, is under construction. World-wide

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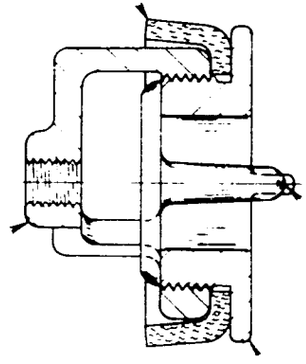

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2	1	2018	A	PLUNGER POPPET		
1	1	2017	B	PLUNGER CAGE		

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SPECIAL APPD		

Buckle Columbus / Aurora
905 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3161

TITLE THREE INCH PLUNGER ASSY. SINGLE CUP

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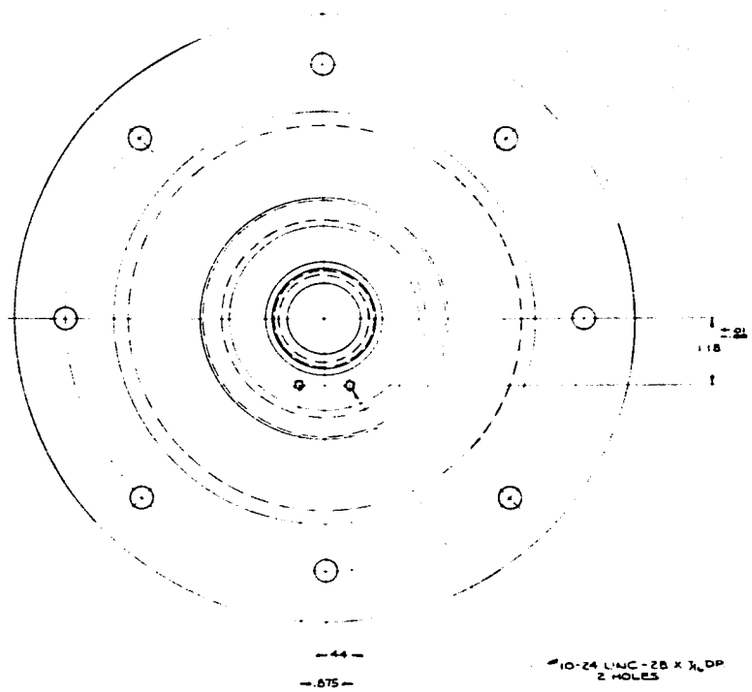

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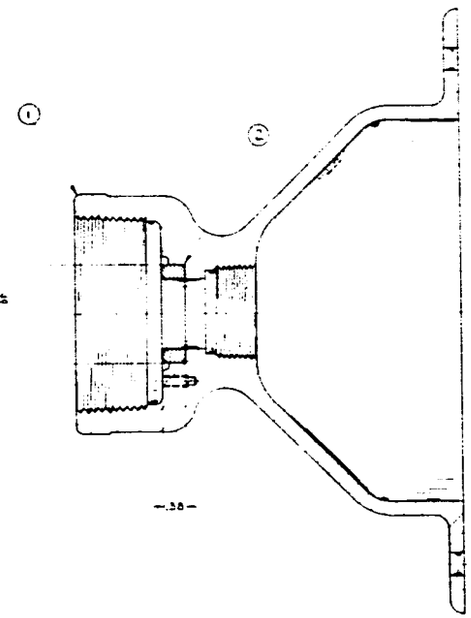

REVISIONS			
ZONE LTR	DESCRIPTION	DATE	APPROVED

FIND NO	QTY	PART NO OR IDENTIFYING NO	DWG SIZE	DESCRIPTION	SPECIFICATION	MATERIAL
2		2024	A	BRASS VALVE SEAT		
1		2023	D	PUMP STAND		

PARTS LIST

APPLICATION			
THIS ITEM IS USED ON ASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001			
TO WHOM ITEM ORIGINALLY			TOTAL REQ'D

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE

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MATERIAL AND TREATMENT

SIGNATURE	DIV.	DATE
DRAWN		
CHECKED APPR		
ENGINEER APPR		
APPR		
APPR		
PRODUCT APPR		
SPECIAL APPR		

Bendix Aerospace Systems Laboratory

TITLE

PUMP STAND ASSY.

SIZE	CODE IDENT NO.	DWG NO.	SIZE	REV
D	79986	44	2010	

SCALE 1:1 SHEET G13ZD-1 SHEET 1 OF 1

2010

revenue district in Ceylon. This committee is appointed by the Government under the provisions of this Ordinance and consists of a chairman, who is the Government agent of the revenue district, representatives of Government departments concerned with irrigation and agriculture, Members of Parliament from the areas and representatives of local farmers. All irrigation works proposed for a district are channeled through this committee, which advises the Government on all matters connected with irrigation and paddy cultivation within the district.

(3) **Meetings of Proprietor:** Before an irrigation work is taken up for construction, the proposals relating to it require ratification at a meeting of the proprietors. The proprietors' meeting has the power to make rules for the encouragement, extension, regulation or management of cultivation which is capable of being assisted by irrigation.

(4) **Irrigation Headmen :** The irrigable area under an irrigation scheme is divided into irrigation headmen's divisions for the control and issue of water. An irrigation headman is a farmer elected by a majority of the proprietors within that division.

(5) **Construction and Maintenance of Irrigation Works:** The Irrigation Ordinance also makes provision for the construction and maintenance of irrigation works under general provisions and special provisions. General provisions provide for:

(i) The construction and maintenance of irrigation works,

(ii) Division of responsibility between the Government and the proprietors,

(iii) Variation in the conditions relating to the construction or maintenance of an irrigation work or the supply of irrigation water, or the maintenance of any scheme,

(iv) Division of the irrigation area into tracts and the conditions and methods of distribution of water to such tracts,

(v) Adjustment of the expenses of maintaining of the irrigation work between land comprised in the original irrigable area and the new lands rendered irrigable by extension of the scheme,

(vi) The abandonment of any irrigation scheme or work,

(vii) Any other matter which in the opinion of the Minister may be included in any scheme.

Special provisions applicable to major irrigation works provide for periodical revion of all irrigation rates, provided that:

(a) Rates are not increased above the limits specified in the scheme, and

(b) The rights of the proprietors of any irrigable area to the continuance of any property rate under any scheme in force is not prejudiced.

(6) **Protection of Irrigation Works and Conservation of Water:**

The ordinance provides for:

(i) Prevention of the obstruction, deviation or cutting of any drainage line, channel or watercourse in irrigation schemes or any damage thereto,

(ii) Prevention of any encroachment upon any such channel or watercourse,

(iii) Prevention of any interference with any sluice, dam or regulating structure within a scheme,

(iv) Prevention of obstruction or damage to roads,

(v) Construction of field channels in approved places in accordance with approved alignments,

(vi) Prevention of the wastage of irrigation water,

(vii) Prevention of any unauthorized diversion or tapping of water from any channel or watercourse,

(viii) Limitation of the amount of land

to be cultivated under an irrigation work for a season and the fixing of dates for commencement and completion of cultivation.

(ix) The conditions under which water will be supplied for irrigation after the dates fixed for the completion of cultivation, and the charge to be paid for such water,

(x) Any other matters necessary for the protection of the irrigation work or for the conservation of water.

(B) A second important piece of legislation called the Paddy Lands Act is now in operation in Ceylon. This act has the following objectives:

(1) To provide security of tenure to tenant cultivators of paddy lands,

(2) To specify the rent payable by tenant cultivators to landlords,

(3) To enable the wages of agricultural labourers to be fixed by cultivation committees and to permit agricultural labourers to be appointed as tenant cultivators and as collective farmers,

(4) To provide for the consolidation of holdings of paddy lands, the establishment of collective farms for paddy cultivation and the regulation of the interest on loans to paddy cultivators and the charges made for the hire by paddy cultivators of implements and buffaloes,

(5) To make provision for the establishment of cultivation committees and to specify the powers and duties of such committees,

(6) To confer and impose certain powers and duties on the Commissioner of Agrarian Services:

(7) To abolish the liability of proprietors paying remuneration to irrigation headmen,

(8) To control the alienation of paddy lands to persons who are not citizens of Ceylon.

All regulations under this Act are subject to the general directions of the Minister in charge and regulations for the operation of this act are gazetted from time to time. The act also provides for the appointment of a Board of Review by the Minister for the purpose of determining appeals that may be made under this Act.

(C) The Crop Insurance Act No. 13 of 1961 is an Act to provide for compulsory insurance against loss of crops due to any specified cause and to make provision for the establishment of a Crop Insurance Advisory Board. The date of assent of this act was 25th April, 1961.

(a) **Administration:** This generally deals with the nomination of the Government official who is to administer the Act, his functions and powers, and organizations such as cooperative agricultural production and sale societies and others that the Minister determines are to be used in administering this act. This section also deals with specified crops, insurable acreage, and insurance units. Provision is further made for insurance premiums, policies, and claims against policies.

(b) **Crop Insurance Advisory Board:** This section deals with the Crop Insurance Advisory Board, consisting of the Commissioner, who is the Chairman of the Board, the Director of Agriculture, the Director of Census and Statistics, the Director of Social Services, the Commissioner of Cooperative Development, an officer of the General Treasury, an officer of the Central Bank of Ceylon nominated by the Monetary Board, and a person appointed to the Board by the Minister to represent the paddy grower and selected from a list of names submitted by the cultivation committees. This section also defines the duty of the board to advise the Commissioner in the administration of the Act.

(c) **Financial and General Provisions:** This section deals with the establish-

ment of an insurance fund, inspection of lands, powers to direct owners to take precautionary measures against loss of crop, and release of any land from the insurable acreage upon occurrence of damage to insured crops. This section also provides for prohibition of the cultivation of crops other than those specified in the insurance policy, and obligation of the owners of the lands covered by the policy to maintain records.

This Act also provides for the promulgation of regulations by the Minister in charge for the administration of the Act.

10. IMPLEMENTATION OF THE RECOMMENDATIONS OF THE LAST SEMINAR

(1) **Education and Training:** Training of farmers is carried out at two levels; namely, for young farmers and adult farmers. Young farmers are boys just out of school who are trained in agricultural practices at practical farm schools run by the Government in different parts of the country. Instruction and advice is also imparted to embryo farmers by an organization of Young Farmers' Clubs under the direction of the Department of Agriculture. The adult farmer is given guidance in the field by agricultural instructors colonization officers and food production overseers. Considerable improvement in cultivation practices has been observed in recent years and this is borne out by the increasing yields that are being obtained.

Extension workers in Ceylon are trained by the Government in accordance with an approved scheme of training. A colonization officer is attached to a major irrigation scheme to administer the colony on behalf of the Government agent. He exercises supervision over the work of the farmers and directs the control and issue of water. No special training class is conducted for this category of worker but appointments to this grade are made from persons with practical experience in farming. Their training is carried out by attaching them to experienced colonization officers in the service and training is provided in the field. Village cultivation officers are trained by the Government to carry out minor irrigation works and they are also responsible for maintenance of these works after completion. Agricultural instructors and food production overseers are trained by the Department of Agriculture, and these two categories of officers carry out the agricultural extension work under the direction of the district agricultural extension officer. Special departmental training classes are held for them before they take up their appointments.

Irrigation engineering has not yet been taken up by the University of Ceylon as a main subject, but in view of the increasing contribution that this branch of engineering is making toward the economic development of Ceylon, the subject will no doubt receive the active consideration of the University authorities.

The national organization for irrigation techniques in Ceylon is the Department of Irrigation, through which matters pertaining to the subject are channeled. Irrigation offices have been established in all districts in the Island and the engineers in charge of these districts are responsible for the development of irrigation in their respective areas.

(2) **Consumptive Use and Water Requirements:** Two independent studies have been made, by the Department of Irrigation and the Department of Agriculture. The Irrigation Department carried out investigations at several major projects in the dry zone to determine the working duty for irrigated paddy. The data are still being analyzed and results have not yet been published. The Department of Agriculture carried out tests on the consumptive use of different crops at the dry zone

research station, and a paper on this subject has been published in « The Tropical Agriculturist.» Further investigations are proceeding.

(3) **Agricultural Requirements for Irrigation Projects:** Close cooperative between irrigation engineers and agriculturists is achieved at all levels. At the departmental level, there is the Planning Committee of the Ministry of Agriculture, Lands, Irrigation and Power, at which the heads of the departments concerned plan the activities of the entire Ministry. All projects are revised by this Committee and its decisions are put into effect by the divisional irrigation engineers and the district agricultural extension officers. At the executive or district level, cooperation is achieved by means of the District Agricultural Committee. There is a further sub-division of the District Agricultural Committee into several divisional agricultural committees, at which officers of both Departments are represented at the farm level.

With regard to drainage, the drainage channels on all irrigation projects in Ceylon are designed and constructed along with the irrigation channels. No major problems have arisen with regard to this aspect of irrigation. In the case of major projects, soil and topographical surveys are always undertaken before the designs are begun, and final proposals are made in accordance with the results obtained from these surveys.

The irrigation system adopted in the major development schemes is based on an individual holding of three acres per farmer. It is expected that this unit of allotment will permit individual farmers to devote personal attention and care to his cultivation and thereby derive the maximum benefit from his holding at minimum cost.

The Department of Agriculture maintains several field research stations, including a special dry zone research station, which study agricultural problems in general. Attention has now been focused on consumptive use and water requirements of various crops. In addition, the Hydraulic Research Laboratory of the Irrigation Department in Colombo concentrates on the hydraulic problems of irrigation.

The extension services to educate farmers are conducted by the Department of Agriculture at both district and farm levels, and these include demonstration plots in farmers' fields. Distribution of water is controlled by colonization officers in major development schemes, and the distribution to individual fields is done by irrigation headmen, who are elected by the cultivators in accordance with the Irrigation Ordinance. Thus there is active participation by the cultivators in the control and issue of water.

(4) **Assistance to Farmers for Improved Irrigated Agriculture:** The control and issue of water are handled by the Government through the Irrigation Department, revenue officers or their representatives and irrigation headmen. The control of headworks is done by the Irrigation Department, based on the requirements of the revenue officers. Distribution to the field channels is done by the representatives of the revenue officer, while the issues to the fields are made by the irrigation headmen, who are under the administrative control of the revenue officer. Thus Government organizatons convey water right up to the individual field. Participation of the cultivators in this operation is insured by their election of the irrigation headmen.

Land preparation on colonization schemes is accomplished by the farmer under the guidance of Government extension workers, but private land holdings are not given such assistance. Information and advice on improved agricultural practices are disseminated by the Department of Agriculture and assistance for purchase of

improved seed, implements and fertilizers is provided through the Cultivators' Co-operative Societies, under the direction of the Cooperate Department of the Government. These Societies provide credit facilities to individual farmers for the purchase of these items and also to cover expenses in connection with cultivation. Credit facilities are also provided by these Societies for the hire of Government tractors for ploughing operations.

(5) **Drainage and Salinity Control:** Drainage and salinity control do not constitute a major problem in Ceylon except for a few isolated areas on the southwest coast. The recommendations of the Seminar have been noted by the Government for future schemes of this nature.

The Government has also recently carried out soil tests in various parts of the country to ascertain the degree of salinity and its adverse effects on crop yields. While salinity is not a major problem, yet investigations are being made in order to collect as much data as possible with a view to devising corrective measures should such a problem arise.

11. PROBLEMS

There are several problems connected with irrigation practices in Ceylon, the foremost of which is the lack of trained personnel in the engineering grades. It is becoming increasingly difficult to attact engineering graduates from the University into the Irrigation Department and recruitment for the years 1959, 1960 and 1961 has been nil. The University of Ceylon turns out approximately 60 engineers a year, all of whom are snapped up by other Government departments and corporations, which offer less arduous conditions of service, and by the private sector, which pays better salaries. To counter this, all facilities are now being afforded to promising youngsters in the technical supervisory grade, called «Technical Assistants,» to obtain study leave for the purpose of obtaining professional qualifications.

A major problem encountered by irrigation authorities is excessive use of water. This is a recurrent problem due to the belief on the part of cultivators that water should constantly flow through the field. They believe that stagnant water in a field will heat up and spoil crop. The truth of this argument has not been established and experiments are being conducted on selected plots in the dry zone to check the optimum application of water to the field. A reduction in the consumption of water has, however, been effected by the increasing use of tractors for dry ploughing, followed by sowing with the rains. In traditional ploughing by cattle, preparation of the field commences only after irrigation water floods the fields, so that tractor ploughing saves at least a month of issue.

The Ceylon farmer also tackles the problem of weed control by flooding his fields, which in turn causes excessive use of water. To counter this, research is being carried out on the use of weedicides, and promising results have been observed so far. Problems also arise through late sowing, which completely upsets the systematic control and issue of water. While the Irrigation Ordinance provides for action against defaulting cultivators, deterrant action is now always taken so as not to financially embarrass the small cultivator, whose holdings are always under three acres. As a result of late sowing, the closed season for maintenance of channels and structures becomes curtailed, and this causes further problems.

INDIA

INTRODUCTION

Physiographically, India is divided into four segments of totally dissimilar characteristics:

(i) The Peninsula of the Deccan, lying in the south of the Vindhyan mountains, which is a solid and stable block of the earth's crust largely composed of some of the most ancient rocks, and carved into a number of mountain ranges, plateaus, valleys and plains; (ii) the Himalayas and associated mountains surrounding the plains in the north and northeast; (iii) the Thar desert, an arid region in the northwestern part of the country occupying a large part of Rajasthan and, (iv), the Indo-Gangetic alluvial plains of northern India extending from the Punjab to Assam. The Indo-Gangetic plains, which have been formed by the alluvium brought down by the rivers, constitute one of the most fertile tracts of the world; and although they have been cultivated from times immemorial, show little signs of exhaustion.

CLIMATE

India lies partly in the tropics and partly in the sub-tropics. The sub-tropical zone shows extremes of climatic condition, while the tropical zone is more equitable. In most of the country, there are three seasons: (i) summer, which is from April to June, (ii) the rainy season-from July to October, and (iii), the winter-from November to March. The exact duration of each season varies in different parts of the country.

RAINFALL

The average annual rainfall of India is 50 inches, but it is only of the order of five inches in the desert in the northwest, increasing gradually across the plains of northern India from west to east until it is about 100 inches in Assam. In Central India, the mean rainfall is of the order of 50 inches a year, and in the Peninsula, except along the west coast, the mean annual rainfall is of the order of 30 inches. Almost the entire rainfall in the country is due to the southwest monsoon and is received during the four months June to September, with the exception of the southeast portion of the Peninsula where the rainfall varies from one-half to two inches except in the northeast monsoon areas, and from March till the onset of the southwest monsoon the country is almost rainless. Apart from its unequal distribution in the year, the rainfall shows considerable variation from year to year. It is not uncommon in many places for rainfall in a year to be less than half of normal; even one fourth of normal during a critical period in crop rotation has been experienced.

SOIL

The soils of India can be classified into four major types:

(i) Alluvium soils, spreading over Punjab, Uttar Pradesh, Bihar, Bengal, parts of Assam and the coastal areas of South India, particularly in the deltic region.

(ii) Black cotton soils, the typical soil of the Deccan trap extending over Bombay, the western parts of Madhya Pradesh and Mysore and some parts of Madras.

(iii) Red soils extending from Bundelkhand to the extreme south and embracing South Bengal, Orissa, parts of Madhya Pradesh, Eastern Andhra Pradesh, Mysore and a major part of Madras; and

(iv) Laterite soils, a soil type peculiar to India, existing in Mysore, Kerala, parts of Madhya Pradesh, the coastal region of Orissa, South Bombay, Malabar and part of Assam.

LAND RESOURCES

The geographical area of the country is 806 million acres, of which land utilization statistics are available for about 724 million acres for 1958-59.

	Million Acres
(i) Total geographical area	806.3
(ii) Area under cultivation	323.6
(iii) Cultivable lands not yet cultivated	97.4
(iv) Fallow lands	59.4
(v) Forests	128.1
(vi) Land put to non-agricultural uses	33.5
(vii) Unculturable land	82.1
Total reported area	724.1

It will be seen that the cultivable area is about 60 per cent of the gross area, and of this about two-thirds is under cultivation.

WATER RESOURCES

Successful agriculture in most parts of the country is not possible without the use of river waters. The rivers of India may be broadly divided into two groups: (i) The snow-fed rivers of Northern India and, (ii), the rivers of Central and Southern India.

A recent appraisal of the water resources of the country, based on an empirical formula correlating the river flow in each basin with its rainfall and temperature, gives the total annual flow as equivalent to 1356 million acre feet, of which it is estimated that because of physiographical conditions, only about 450 million acre feet can be used for irrigation. Up to 1951, about 76 million acre feet, i.s., about 17 per cent of the usable flow or 5.6 per cent of the total annual flow, had been utilized. By the end of the Second Five-Year Plan, it is estimated that about 120 million acre feet, representing about 27 per cent of the usable flow, will be utilized. An additional 40 million acre feet are likely to be used during the Third Five-Year Plan, bringing the proportion to about 36 per cent of the usable flow.

No assessment has yet been made of underground water resources but they are of considerable magnitude. This resource is more readily available in alluvial plains, where surface water resources are also normally plentiful. In planning irrigation in these areas, therefore, a balance has to be struck between the use of surface water resources and the underground water resource.

AGRICULTURE

About 70 per cent of the people are dependent on land for their living. Agriculture and allied activities account for nearly half of the country's national income. India enjoys a virtual monopoly in lac and ranks first in the world in the production of ground-nuts and tea. The areas of major crops during the six years ending 1960-61 are given below:

TABLE 1. AREAS OF MAJOR CROPS IN INDIA

Crops	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61
1	2	3	4	5	6	7
Rice	78	79	79	81	83	83
Jowar	44	40	42	43	42	42
Bajra	28	28	27	28	27	28
Maize	9	9	10	10	11	11
Ragi	6	6	6	6	6	6
Small millets	13	12	12	12	12	12
Wheat	31	34	29	31	33	32
Barley	8	9	8	8	8	8
Gram	24	24	23	25	25	23
Tur	6	6	6	6	6	6
Other pulses	28	28	27	29	29	28
Total Foodgrains	275	275	269	279	282	279

Crops	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61
1	2	3	4	5	6	7
Other Crops						
Potatoes	0.7	0.7	0.8	0.9	0.9	0.9
Sugarcane	4.6	5.1	5.1	4.8	5.2	5.7
Black pepper	0.2	0.2	0.2	0.2	0.2	0.2
Chillies	1.5	1.5	1.6	1.5	1.5	1.5
Tobacco	1.0	1.0	0.9	0.9	0.9	1.0
Ginger	1.04	0.04	0.04	0.04	0.04	0.04
Groundnut	13	13	15	15	15	15
Castorseed	1.4	1.4	1.2	1.2	1.2	1.1
Seasamum	6.0	5.4	5.2	5.5	5.4	4.9
Rape and Mustard	6.3	6.3	6.0	6.0	7.2	7.3
Linseed	4.0	4.1	3.1	3.9	4.1	4.2
Cotton	20	20	20	20	19	19
Jute	2.0	2.0	1.7	1.8	1.7	1.5
Mesta	0.6	0.7	0.8	0.8	0.7	0.7
Coffee	0.2	0.3	0.2	0.3	N.A	N.A.
Tea	0.8	0.8	0.8	0.8	N.A.	N.A.
Rubber	0.2	0.2	0.2	0.3	0.3	N.A.
Coconut	1.6	1.6	1.5	1.7	1.7	N.A.

CROP SEASONS

There are two well-defined crop seasons, namely: (i) Kharif (summer) and (ii) Rabi (winter). The major Kharif crops are rice, jowar, bajra, maize, cotton, sugarcane and seasamum, and the main Rabi crops are wheat, barley, gram, mustard and linseed.

TABLE 2. SEASON AND DURATION OF PRINCIPAL CROPS

Crop	Season	Duration
Rice	Winter	5½ — 6 months
	Autumn	4 — 4½ »
	Summer	2 — 3 »
Wheat	Rabi	5 — 5½ »
Jowar	Kharif	4½ — 5 »
	Rabi	4½ — 5 »
Bajra	Kharif	4½ »
Maize	Kharif	4 — 4½ »
Ragi	Kharif	3½ »
Barley	Rabi	5 — 5½ »
Gram	Rabi	6
Sugarcane	Perennial	10 — 12 »

Crop	Season	Duration
Seasamum	Kharif	3½ — 4 months
	Rabi	5 »
Groundnut	Kharif	4 — 4½ »
	Kharif Early	4 — 4½ »
	Late	4½ — 5 »
Rape and Mustard	Rabi	4 — 5 »
Linseed	Rabi	5 — 5½ »
Castor	Kharif Early	6 »
	Others	8 »
Cotton	Kharif Early	6 — 7 »
	Late	7 — 8 »
Tobacco	Kharif	7 »
Jute	Kharif	6 — 7 »

IRRIGATION DEVELOPMENT

The practice of organized irrigation in India has been traced back to well before the Christian era. In the Deccan a large number of irrigation tanks have been in existence for many centuries. The Cauvery Delta Canals date back to the Second Century. The Yamuna Canals were constructed originally in the Fourteenth Century, and were later remodelled by the British in the Nineteenth Century. The first major irrigation works constructed in India was the Ganga Canal in Uttar Pradesh, opened for irrigation in 1854. This was followed by the Upper Bari Doab canal in the Punjab and the Godavari Delta system and the Krishna Delta system in the South. Then came the Sirhind Canal in the Punjab and the Lower Ganga and Agra Canals in Uttar Pradesh and the Mutha Canals in Bombay, the last-named being from a storage reservoir. Further irrigation works were constructed toward the end of the last and the beginning of the present century, a few more after the end of the First World War and others since then.

CLASSIFICATION OR IRRIGATION WORKS

Irrigation projects are classified in the following three groups:

(i) Major projects — costing more than Rs. 50,000,000

(ii) Medium projects — costing between Rs. 50,000,000 and Rs. 1,000,000.

(iii) Minor projects — costing less than Rs. 1,000,000

Minor irrigation works include open wells, tubewells, tanks and irrigation from small streams. Old schemes executed under different price indices, irrigating less than 4,000 acres, are classed as minor works.

RELATIVE MERITS OF MAJOR AND MINOR SCHEMES

A balance has to be struck between major and medium irrigation schemes on the one hand and minor irrigation schemes on the other. Minor schemes are advantageous in that:

(i) The initial outlay involved is small,

(ii) They can be executed quickly and yield quick results,

(iii) They generally require no special assistance by way of foreign exchange, and

(iv) Local resources can be easily mobilized for their execution.

The disadvantages of such schemes are:

(i) Their high cost of maintenance,

(ii) Their relatively short life, and

(iii) The limited water supply protection they give.

There has been long neglect of minor irrigation works, with the result that many of then are in disrepair. Areas irrigated by them have been diminishing.

The major schemes, on the other hand, have the merit of:

(i) Utilizing surplus waters of the river systems, which otherwise run to waste,

(ii) Giving better protection in years of scarcity when water is needed most, and

(iii) Being ofte.. multipurpose in nature.

They, however, take longer to execute and have a higher initial cost, In regions of low rainfall, however, such as part of Rajasthan and certain areas in Andhra Pradesh, major irrigation schemes are the only satisfactory means of providing irrigation.

DEVELOPMENT OF IRRIGATION

At the beginning of the First Plan, i.e., in 1950-51, the area irrigated from all sources was 51.5 million acres, of which 22 million acres were irrigated from major and medium irrigation projects. Land utilization at the end of the First Five-Year Plan was 56 million acres of net irrigation and 83 million acres of gross irrigation. At the end of the Second Five-Year Plan, the net area irrigated was 70 million acres, including major, medium and minor irrigation schemes. During the Third Plan, an additional irrigation potential of about 13.8 million acres is expected to be created from continuing schemes and 2.4 million acres from new schemes of the Third Plan. The total utilization in the Third Plan period is expected to be 12.8 million acres (gross). Some of the projects, such as the Rajasthan Canal, Gandak, Ukai, Narmada, Nagarjunasagar, etc., will continue beyond the Third Plan.

ACHIEVEMENTS

Major and Medium Schemes. During the First Plan period, 250 schemes were initiated, of which 196 were carried over to the Second Plan period. In addition, 187 new schemes were included in the Second Plan. During the Second Plan period, the total number of schemes completed was 99, leaving 284 schemes to continue during the Third Plan period. In addition, 102 more new schemes are proposed during the Third Plan period. The total cost of the new schemes included in the Third Plan will be approximately Rs. 3,500,000,000.

Tubewell Schemes. There were about 2,500 tubewells in India prior to 1951, about 2,300 of which were in Uttar Pradesh. These irrigated about one million acres. During the First and Second Five-Year Plans, 6,351 tubewells were drilled, 5,871 completed with pump sets and 5,812 energized and put into commission by the end of the Second Five-Year Plan. These include 700 completed with «Grow More Food» assistance financed partly from A.I.D. funds. The area irrigated by tubewells is now about 3 million acres, depending on weather conditions in a given year.

An underground water exploration project was started in 1955. Out of 425 exploratory bores drilled in the States of Madhya Pradesh, Gujarat, Rajasthan, Kerala, Madras, Bihar, Andhra Pradesh, Punjab, Orissa, Uttar Pradesh, West Bengal and Assam, up to the end of January 1962, 217 have been successful and converted into production tubewells.

FINANCIAL OUTLAYS

The aggregate estimated cost of major and medium irrigation schemes included in the First and Second Plans is of the order of Rs. 14,000,000,000, and on full development they are expected to irrigate about 38 million acres. By the end of the First Plan, an outlay of Rs. 3,800,000,000 had been incurred. The outlay in the Second Plan is estimated at Rs. 3,700,000,000. In the Third Plan, these schemes will require a total outlay of about Rs. 4,260,000,000, leaving a balance of about Rs. 2,224,000,000 for the Fourth Plan. The estimated cost of the new irrigation schemes included in the Third Plan is Rs. 3,500,000,000, of which outlay during the Third Plan period is only Rs. 1,700,000,000. Thus the net outlay for irrigation during the Third Plan period is Rs. 6,000,000,000.

IRRIGATION ORGANIZATION

Irrigation is a state responsibility. In most states, there is now a separate irrigation department to handle both major and minor schemes. Small schemes costing a few thousands of rupees are dealt with by the state revenue, agriculture and community development departments. Cooridination of minor schemes is by the Ministry of Food and Agriculture of the Central Government and of major and medium schemes by the Union Ministry of Irrigation and Power. The ministry is assisted technically by the Central Water and Power Commission.

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

The states have constituted working groups at various levels, starting from the state right up to the Block, to ensure the full use of irrigation facilities in relation to each project completed or initiated in the First and Second Five-Year Plans and to review carefully and at regular intervals the progress of such projects. The working group at the state level is generally composed of the Development Commissioner and officers of the agriculture, cooperative, irrigation and community development departments. Half-yearly reviews are submitted to the state cabinet regarding measures taken and progress made, with a copy to the Planning Commission of the Central Government. It has also been suggested that for each project there should be a working group of officers directly concerned with it, so that they could follow the various steps needed at each level down to the village. Working groups are new functioning in almost all the states.

IRRIGATION RESEARCH

The Central Board of Irrigation and Power

has been the coordinating authority for research work in the field of hydraulic and hydro-electric engineering. The Board has established contacts with about 231 engineering research organizations throughout the world for exchange of publications.

The following are the research stations which conduct research on hydraulic, hydro-electric and irrigation problems;

(1) Central Water and Power Research Station, Poona.
(2) Silt and Construction Materials Directorate (Flood Wing), New Delhi.
(3) River Research Institute, Gauhati, Assam.
(4) Hyderabad Engineering Research Laboratories, Hyderabad (Andhra Pradesh).
(5) Nagarjunasagar Project Research Laboratory, Vijaypuri North (Andhra Pradesh).
(6) Bihar Institute of Hydraulic and Allied Research, Khagaul, Patna (Bihar).
(7) Kosi Project Research Laboratory, Birpur (Bihar)
(8) Engineering Research Institute, Baroda (Gujerat).
(9) Kerala Engineering Research Institute, Peechi (Kerala).
(10) Soil and Material Testing Laboratory, Raipur.
(11) Maharashtra Engineering Research Institute, Nasik.
(12) Poona Irrigation Development Division, Poona, Bombay.
(13) Concrete Research Laboratory, Koyna Project, Koyna.
(14) Irrigation Research Station, Poondi, Madras.
(15) Concrete and Soil Engineering Research Station, Chepauk, Madras.
(16) Indian Institute of Science, Bangalore.
(17) Mysore Engineering Research Station, Krishnarajasagar,
(18) Hirakud Research Station, Hirakud.
(19) Punjab Irrigation and Power Research Institute, Amritsar.
(20) Rihand Project Research Laboratory, Pipri, Uttar Pradesh.
(21) Uttar Pradesh Irrigation Research Institute, Roorkee.
(22) River Research Institute, West Bengal.

AGRICULTURAL RESEARCH

The Indian Council of Agricultural Research, established in 1929, sponsors and coordinates research in both agriculture and animal husbandry. States are represented on the governing body of the Council. The program of agricultural research has continued to be progressively strengthened. There are 483 agricultural research stations in the country. Most of these in the states carry on research on a number of crops but a few work on particular crops, such as rice, wheat and horticultural crops. On the basis of crops handled, the state research stations and farms in the states are given in Table 3. Some of the important research includes the evolving of new strains of paddy resistant to salinity, flood, blast and drought, and the breeding of maize and of important millets. Creation of institutions for research on cotton, oil seeds, fruits, cashew nuts, spices and other crops is called for. Research work on the application of water to land is being conducted in a number of agricultural research stations and agricultural colleges. Model agronomic experiments for determining the optimum manurial, irrigation and cultural requirements of various crops are also in progress. To organize the work more effectively, research problems have been considered under three main categories; namely, (i) fundamental, (ii) regional, and (iii) local. Fundamental problems are allotted as far as possible to central institutes and universities.

EDUCATION AND TRAINING

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

For disseminating the results of research, the Indian Council of Agricultural Research has continued to expand facilities for training the agricultural and veterinary personnel required for the production, distribution and use of various types of extension teaching aids and mass communication

methods. Good progress has been made in distributing literature pertaining to improved technique of agriculture, animal husbandry, etc. Arrangements have also been made for producing agricultural films.

In addition to the activities of the agricultural departments, the Community Development Program, initiated in 1952, aims at the individual and collective welfare of the rural population on an aided self-help basis. Over 3,900 blocks have already been set up, comprising over 463,000 villages with a population of about 255 million, and the entire country will be covered (by about 5,200 blocks) by October, 1963. Agriculture receives the highest priority in the program among other activities such as communications, health and sanitation, housing, education, etc.

In order to provide trained personnel to man the Community Development Blocks, the Directorate of Extension (Ministry of Food and Agriculture) was entrusted with responsibility for organizing a suitable extension training program. A structure of extension training sufficient to train nearly 50,000 gramsevaks and 12,000 gramsevikas was quite a problem. The experience gained by the operation of the Community Development Program offered opportunities to strengthen the extension training program at various levels. So far, 100 extension training centers have been established, which are engaged in two-year integrated training programs for village-level workers. Also, 43 home science wings have been established in various parts of the country to provide suitable education and field training to the gramsevikas, who work for the welfare of women in the development blocks. Considering the important role of agricultural implements, 25 workshop wings have also been set up at the campuses of extension training centers to provide suitable training to the gramsevaks and village artisans. All of this will be extended to the 100 extension training centers. The gramsevak has been accepted as a multi-purpose extension worker and will continue to remain so for some time to come. Accordingly, he is provided adequate opportunities for practical training in agricultural engineering, irrigation methods leading to soil and water conservation, horticulture, plant protection, animal husbandry, panchayat, cooperation, extension and social education, public health, minor engineering programs and rural industries. Training centers have been equipped in all the subject-matter areas.

The usefulness of irrigation-cum-agriculture demonstrations is fully appreciated. Trial-cum-demonstration farms are set up under various irrigation projects to evolve proper use of water, manure and fertilizers, and cropping patterns best suited to the area. In addition, demonstrations on the cultivators' own fields are also organized by the state agriculture and community development agencies.

INTENSIVE AGRICULTURAL DISTRICT PROGRAM

An agricultural production team sponsored by the Ford Foundation, following a survey of Indian agricultural problems, recommended that selected areas in the country, with the greatest potentialities for rapid food grain production, be chosen for intensive agricultural development. Accordingly the Government of India, in consultation with the State Governments, selected one district in each of seven States having maximum irrigation facilities and minimum natural hazards for this program, popularly known as the «Package Program.»

This program involves the application of scientific 'know-how', the provision of fertilizers, pesticides, improved seeds, improved implements, etc., and composite scientific demonstrations. Credit is made available on the basis of farm production plans which reflect the potential capacity for production.

Stations selected include Aligarh (Uttar Pradess), Ludhiana (Punjab), Pali (Rajasthan), Raipur (Madhya Pradesh), Shahabad (Bihar), Tanjore (Madras), and West Godavari (Andhra Pradesh). Encouraged by the excellent progress in these districts, the Government of India decided to extend the program to the remaining States.

The responsibility for implementing the program rests with the State Governments. The State Coordination Committee, representing the Development, Cooperative and other related Departments, assists the Secretary of the Agriculture Department of the State in coordinating all activities and in resolving difficulties, if any. The district collector, assisted by the district project officer (an

officer of the Agriculture Department), is helped by a team of agricultural specialists and an officer of the Cooperative Department. At the block level, the block development officer is responsible for the program. He is assisted by agricultural extension officers, specialists in agriculture and cooperation, and also by a sufficient number of village-level workers. Each district has a District Coordination Committee to solve problems at the district level.

Water development and management are accomplished by the State departments. After the water is delivered at the outlet, responsibility for its conveyance and distribution rests with the cultivators. At this stage cultivators require education and technical assistance in the following two aspects of water management:

1. Use and management of water on individual farms and fields,
2. Inter-farm conveyance of water beyond the canal outlet and the disposal of excess water into State drains from the fields of individual cultivators.

Adoption of improved water management practices will not only be a contribution to the achievement of program goals and objectives, but will be of tremendous benefit to Indian agriculture in general. Sound and practical methods of solving irrigation and drainage problems will be demonstrated. A comprehensive water management scheme has been prepared. A pilot project in improved water use techniques is proposed in each of the program districts. This will serve as a training ground to the extension staff in the districts, who will subsequently train others in other areas. Due attention has been given to the staff, equipment, and medium and long-term credit required. The scheme will operate in close collaboration with local irrigation authorities and soil chemists. It will also serve as 'on-the-field training' for trainees under the «Minor Irrigation Training Scheme» of the Government of India.

Conferences and seminars on the subject are organized at regional as well as national levels, the main objectives being identification of difficulties and problems, pooling of ideas and experiences, and formulation of further action programs. Recently a scheme of training specialists for minor projects has been introduced for the different regions of the country.

DISCUSSION. A «panchayat» is a sort of village council. However, such a panchayat may serve more than one village. On an average, one panchayat exists for every two villages, although some panchayats may cover three or four villages and others only one. The panchayat has responsibility for planning village-level activities. The next body is the Community Development Block, which is the unit of planning and development and contains about 100 villages. In the nation there are 5,200 Community Development Blocks. In the past the district tended to function as the planning and development unit and, in some cases, the State.

Trial-cum-demonstration farms are run mostly by the state governments but may be run by a project authority. In each Community Development Block there are eight or nine subject-matter specialists, and approximately 10 village extension workers or gramsevaks. Gramsevaks are selected from among high school graduates and then are given a two-year integrated course in which, again, agriculture is emphasized although other extension matters are covered. Since 1952 the program has been evaluated annually by the Program Evolution Evaluation Organization of the Planning Commission. Other groups, including a United Nations team, have been invited to make evaluations from time to time.

Approximately 3,000,000 acres in the Punjab are waterlogged or saline, but compared to the total irrigated acreage in India this is not a relatively extensive problem. Dr. Tamhane stated that lands in which the water table is from 0-5 feet need immediate reclamation; where the water table is from 5-10 feet, the reclamation need is imminent. Even at ten feet some salinity effects due to the water table appear in the surface soils.

TABLE 3. CROPWISE CLASSIFICATION OF RESEARCH STATIONS AND FARMS IN THE STATES

	General	Rice	Wheat	Millets	Maize	Potato	Tapioca	Cotton	Sugarcane	Jute	Tobacco	Coconut	Arecanut	Oilseeds	Mango	Citrus	Banana	Apple	Cashewnut	Cloves	Cardamom	Total main research stations
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Andhra	15	16	2	8	4	1		4	5		2	2		5	3	2			2			33
Assam	6	7					1	2	1	4	1	1	1	3			1		1		1	15
Bihar	20	3	3	1	2				2	1				3		1						22
Bombay*	41	20	13	36	5			26	6	1	3			27	3	4	3					66
Himachal Pradesh	15	3	3		4	6			2									1				21
Jammu & Kashmir	13	7	9		6				1													18
Kerala	5	8					4	1	1			4	2	1	1	3	3		2		2	15
Madhya Pradesh	44	21	36	15		2		8	12					15								52
Madras	14	9	1	5	2	1		8	2			1		6		1	3	1		1		27
Manipur	6	3	4		5	5		1	2	1					1	5	1	1				7
Mysore	36	16	8	14	2	—		12	6			1		9		1	1		1			40
Orissa	41	2				—		2	1			2				1						46
Punjab	38	5	23	10	13	2		16	10		3			8	3	3	1	2				46
Rajasthan	9		5	4	3	—		1	2					1								10
Uttar-Pradesh	34	9	14	2	1	3		4	7	1	1			2				1				41
West Bengal	20	7	6		1	4		4	3	5				6	1	1	2					24

* Now Gujarat and Maharashtra.

IRAN

This statement of Iran's activities in irrigation and water resource development during the past two years is divided into the following phases:

1. Investigation and Planning
2. Design of Projects
3. Operation and Construction of New Projects
4. Training Program for People Involved in Irrigation and Technical Phases

1. INVESTIGATION OF IRRIGATION PROJECTS:

A. Soil Survey

The general soil maps covering 165 million hectares of Iran have been prepared by the Irrigation Bongah's technicians with the help of an F.A.O. expert. These maps were completed in 1961. On behalf of all Iranian engineers, thanks are expressed to Dr. L. M. Dawan of F. A.O., who has accomplished a great job which will help to develop other phases of agriculture and irrigation.

During the last two years, 560,000 hectares of semi-detailed land classification have been made and 35,000 hectares of detailed soil survey have been completed.

B. Hydrology:

Records at 200 gauging stations have been continued and 20 new stations have been installed since two years ago.

Four laboratories for determining sediment have been established with the help of U.S. AID in the following ostans: Azarbayejan, Esfahan, Kermanshah and Khozestan.

The Ground Water Branch was established in 1959 with the help of U.S. AID and F.A.O. There 27 geologists, 10 hydrologists and 16 technicians are being trained.

A groundwater hydrology investigation has been started on 250,000 hectares and information had been collected on deep and shallow wells. The Irrigation Bongah hopes to complete its hydrological information during the next five years.

C. Land and Water Use Investigation and Water Economics:

During the last two years an area of 470,000 hectares in nine irrigation regions has been studied and reports have been submitted in six different volumes.

D. Planning:

A plan has been prepared to develop 320,000 hectares of irrigated area in nine regions of the country.

2. DESIGN OF PROJECTS:

Projects have been designed to provide water 93,000 hectares in nine regions of the country by the Irrigation Bongah's engineers. In addition, the Plan Organization, with the help of foreign consultant engineers, has prepared water resources development and hydro-electric projects for Guilan, Khuzestan, Mazandaran, Gorgan, Sistan and Bluchestan which are estimated to cover 1,000,000 hectares of land.

3. OPERATION AND CONSTRUCTION OF NEW PROJECTS:

A. Water Resources Development and Construction of Reservoirs:

Four dams were under construction during the past five years.

The Karaj Dam was completed and operation started in October, 1961.

Construction of Manjil Dam on Sefidrud river has been completed and His Majesty the King will dedicate it on May 10, 1962.

Seventy per cent of Shahnaz Dam in Hamadan has been constructed and it is

expected to be in operation in three months.

Construction of a storage dam on the Dez River in Khuzistan Province is in progress and this is scheduled to start operation in the year 1963.

With the completion of the above-mentioned storage dams, the area under cultivation will increase by 221,000 hectares.

Description of storage dams:

Name	Karaj	Sefidrud	Shahnaz	Dez
Location	21 Km above Karaj	Manjil	18 Km to Hamadan	30 to Dezful
Height	180 m.	110 m.	53 m.	203 m.
Kind	Arch	Gravity	Storage	Storage
Capacity in million of Ci. m.	209	1700	14	3300
New area served or irrigated	City water of Tehran	76000	City water of Hamadan	145000 h.

B. **Rehabilitation of Existing Projects:**

1. **Maintenance of Canals for Water Distribution:**

   To prevent water loss and seepage in five projects and 26,000 hectares of land, lining has been completed and head water works have been constructed. Thus 40 per cent of the loss through seepage is prevented and problems of water users and water rights are being solved.

2. **Drainage:**

   In three projects a total of 18,000 hectares have been drained. Drainage works include 40 kilometers of main and sub-drains, and in one of the projects agricultural income has been raised by 300%.

4. **TRAINING PROGRAM:**

During the last two years a training program has been scheduled in the different branches of irrigation and hydraulics, sponsored by the University of Tehran, the Irrigation Corporation Bongah and the Agricultural Engineering Department.

Activity are as follows:

a. The University of Tehran and the agricultural college in the province have taken serious steps toward starting laboratory classes and technical courses for students who are interested. The number of students in 1961 was twice as many as in 1959.

b. The soil and hydraulic laboratories of the Agriculture College in Karaj, which are considered to be among the best in the world, have been used by the students and they can work toward their higher degrees in irrigation.

c. The Irrigation Bongah, with the help of F.A.O. and U.N.E.S.C.O., have trained 25 engineers in operation and maintenance.

d. Twenty geologists, 15 technicians of hydrogeology and 30 topographers were trained for different branches of irrigation and groundwater investigation.

e. During the last two years, the Department of Agricultural Engineering has trained 160 mechanics for heavy machinery, 80 ditch riders and 15 irrigation engineers for extention services.

Generat Information About Agriculture in Iran

1.	Total Area of the Country	sq. Km. 1,650,000
2.	Total Area of Forest Land:	hectares
	Area of Northern Forest	3,500,000
	Area of Zagress Forest	15,500,000
	Total:	19,000,000
3.	Total Cultivated Area	33,000,000
4.	Total Area under Cultivation (considering rotation system)	17,000,000
5.	Area under Annual Cultivation	6,000,000
	Dry Farming Area	3,500,000
	Irrigation Land	2,500,000

Note: Three-fifths of the agricultural land is irrigated by groundwater and gravity systems.

6.	Area under Pastures	17,000,000
7.	Population	21,000,000
8.	Number of Villages	50,000
9.	Ghanats	40,000

General Information on Hydrology and Meteorology:

1. Average discharge of rivers per year: 3,000-3,500 cubic meter/sec.

2. Discharge of Karoun River, the largest river in Iran: 500 c.m.s. maximum; 700 c.m.s. average.

3. Overall rainfall:
   Maximum rainfall, 2,000 m.m. in Fumenat and Tavalesh along the southwest area the of Caspian Sea.
   Minimum rainfall, 18 to 90 m.m. per year in Sistan and the central desert.

4. Temperature:
   Minimum, 28° C. below zero (Ardabil, Hamadan and Bakhtiari mountains).
   Maximum high temperature, 55° C. in the shade (Bampoor-Bandar Abas, and Iranshahr).

5. Relative humidity:
   Minimum, 12 per cent in the dry country of Salty Kavir and Kerman.
   Maximum, 65 per cent.

DISCUSSION: Iran does not consider economic factors such as development costs and plant protection costs in land classification, but includes them in soil and water use investigations. Topographic surveys are followed by soil surveys. Then an agricultural investigation, which includes economic studies, is made. These lead to determination of the size of the agricultural unit. At this point, the investigational group studies the water used under practice in order to arrive at the water requirements. This latter information leads to the design requirements for the secondary and main canals and the diversion. In Iran, there is both the Independent Irrigation Corporation (Bongah) and the Plan Organization. The Plan Organization has, the past seven years, developed a large irrigation program totalling nearly 2 billion dollars. Shahnaz Dam is being constructed by a Development Society. The Government has about a 95 per cent share in this society and the landholders the rest. There is another independent society involved, the Sefidrud Irrigation Society Authority; however, this is 100 per cent owned by the Government.

The law creating the Independent Irrigation Corporation was passed in 1943. Under the first Five-Year Plan, the Irrigation Bongah had charge of irrigation development. In the Second Plan, the Plan Organization received authority to build some works by contract and contracted with foreign organizations to do this. The Bongah has eight divisions:

1. Administration
2. Soil Institute
3. Investigation and Planning
4. Hydrology Institute
5. Design
6. Construction
7. Operations and Maintenance
8. River Control

Among the divisions there are the many branches commonly characteristic of a water resources development group. A new branch is the Village Construction Branch which works with the Ministry of Agriculture, Agricultural Engineering Department.

Stream gauging was started in 1954, and until 1959 there were only about 80 stations. With the help of U.S.A.I.D., these have been increased to

220 and the number is expected to reach 400 in the next five years. There are one or two F.A.O. and one A.I.D. advisor, the former for groundwater, The A.I.D. advisor, Mr. Pendleton, is the only advisor for surface water. A yearbook for all the rivers is distributed annually.

With regard to the use of land classification in the land reform program, each village has a cooperative society in which each farmer owns one share. The village owns the farm land jointly and land classification is used in planning. Pointing out the advantages of individual ownership in furthering individual initiative, Dr. Asgkar asked if this wouldn't be better than the communal system. Mr. Arzarnia stated that although the farmers knew where their lands were after they were distributed by the village landlord, the lack of cadastral maps prevented giving the farmers title officially.

JORDAN

Jordan has a total area of 100,000 square kilometers. More than 86 per cent of the area receives an average annual rainfall of less than 200 mm (7.9 inches). The total area irrigated from all sources is 1,000 square kilometers, and the dry-farmed area is 7,000 square kilometers.

The country is divided into five well-defined regions. The first constitutes the western uplands (west of the Jordan River), which are comparatively well-watered, receiving more than 400 mm of rainfall. This region grows most of the olives and grapes.

The other major agricultural region is the eastern uplands (east of the Jordan River). Rainfall is variable and the areas suitable for dry farming received from 400 to 600 mm. This region is the major cereal-producing area.

The third region is the Jordan Valley, which lies between the two upland regions. The Jordan and the Yarmouk rivers flow through this valley. The length of the valley is approximately 100 kilometers and its width varies from 5 to 15 kilometers. Its distance below sea level is between 220 meters in the north to 392 meters at the Dead Sea in the south. This region depend entirely on irrigation, as the rainfall is not sufficient to support a crop.

The Ministry of Agriculture, recognizing that the the Jordan Valley is of great economic importance has established a number of research stations at Deir Alla, Fara'a and Jericho to obtain information on the major agricultural problems of the area. The information obtained is published and made known to farmers through the Extension Service.

The major problem of this region is water, which is needed, not during the winter when the area is not planted, but during the summer when the crops transpire heavily.

A study of some weather data of this region (Table 1) shows the amount of water that theoretically should be supplied through irrigation during the growing season. August has the highest average temperature of about 30°C., and January is the coldest month, with a temperature of about 15°C. Rainfall is highest during January and February. There is hardly any rain from April until the end of November. Although August has the highest average temperature, July is the critical month of the year, having an average maximum of 37.3 and total daylight hours of 395 (11.65 per cent), an f value of 10.25 for consumptive use. (Table 2), which has been calculated by the Blaney-Criddle formula, gives the water requirements of the major irrigated crops of the area. One experiment on the water requirement of Stavium and Alfalfa in the Deir Alla Station, using irrometers, showed that Stavium required during July to the end of October 451 M^3/dunum supplied at intervals of 10 days (25 M^3 per irrigation), while Alfafa required from July to the end of September a total of 61 M^3/dunum supplied in 10 M^3 per irrigation at intervals of 10 days. More studies are needed in this field and the Department of Research has a good program for this type of study.

QUALITY OF IRRIGATION WATERS:

The quality of irrigation water is a limiting factor in irrigation agriculture. Table 3 shows the water quality of major rivers, streams and some wells used for irrigation. The electrical conductivity of the River Jordan varies, reaching a maximum of 2,590 micromohs/cm in summer, when irrigation is maximum and evaporation is high. The sodium percentage is also high, reaching 57 per cent at times. Therefore this water presents a salinity and alkali hazard if improperly used, especially on fine textured soils with restricted drainage.

The Yarmouk River water (which supplies most of the water to the East Ghor Canal) has an electrical conductivity ranging from 725 to 760 micromohs/cm and a sodium percentage of 43 per cent, putting it on the border line between C_2S_1 and C_3S_1. It is good-quality water and can be used if moderate leaching occurs, which usually is the case during winter. Generally speaking, the quality of most irrigation waters lies in the C_2S_1 class range. The river water varies but other streams have a more constant and better quality. The sodium hazard is not present in most irrigation water.

THE FIVE-YEAR PLAN FOR WATER DEVELOPMENT:

Jordan's water program for the coming five years will give major emphasis to:

1. The development of surface waters;
2. The location of new sources of ground waters;
3. The preservation and restoration of existing cisterns, wells, dams, irrigation channels, etc.;
4. The development of more rational distribution, conservation and treatment system;
5. The irrigation of the Jordan Valley.

Two agencies now bear primary responsibility for water development in Jordan. They are: (1) The East Ghor Authority, for the development of irrigation from waters available from the Yarmouk River or from other sources in the area irrigated thereby; and (2) the Central Water Authority (CWA), for the development of all other sources and areas.

The East Ghor Authority was established by law in 1960 and is solely responsible for the planning and construction of the East-Ghor Canal. The first stage of the canal, which includes an intake on the Yarmouk River, 23 kilometers of main conveyance canal and 99 kilometers of distribution canals serving 956 farms totaling 37,000 dunums of irrigable land, is now in use. The capacity of the main canal is 10 cubic meters per second with provisions for future increase to double this capacity. The distribution canals have a capacity ranging from one-eighth to one cubic meter per second.

For the 37,000 dunums served by the first stage, approximately 15 kilometers of drains have been excavated for draining run-off waters.

To insure controlled water distribution, a Water Office was established within the Authority. The Office plans to follow a rotational system of water delivery during periods of low and a demand system of delivery during periods of relatively high flow. The cost of water to farmers at the delivery boxes will be one Fils (0.26 U.S. cent) per cubic meter per dunum per year and two Fils per cubic meter for anything over 1,500.

Through the Agricultural Credit Corporation farmers can obtain long term loans for the development of their land, whether irrigated or not. The Corporation has already advanced credit toward putting 64,000 dunums under irrigation, and for terracing and leveling 152,000 dunums of dry farming lands.

The second stage will include the Adasiya diversion dam, the Wadi Khalid storage dam of 50 million cubic meters which will regulate the Yarmouk River flow, and 43 kilometers of main canal extending from the Zerqa River to the Dead Sea and serving 100,000 additional dunums. The dam is designed to be raised in the future so as to store a maximum of 500 million cubic meters. There is also provision for a hydro-electric plant producing 1,000 kilowatts.

The Central Water Authority was established by law in 1959. This Authority was created for the purpose of, «Investigating, planning, establishing, promoting, implementing, constructing, and to the extent necessary managing and operating a comprehensive program for development, conservation and control of the water resources of the Kingdom

of Jordan for maximum feasible use for domestic, municipal, livestock, industrial, irrigation, hydro-electric power and other beneficial purposes.» All elements of water resources development therefore come under this Authority with the exception of the East Ghor Canal Scheme. It is hoped that during five years, 120 small irrigation projects will be completed, affecting 60,000 dunums, through the assistance of this Authority to small farmers to develop their water resources. It is also hoped that during the same period 46 dams will be constructed, of which one is completed and two are under consideration.

IRRIGATION RESEARCH PROGRAM:

The Research Department in cooperation with the East Ghor Authority is conducting research on the most pressing problems of the Ghor Area. The program is outlined as follows:

1. Investigating plant-water-soil relationships for the whole Jordan Valley. This will include:

   a. Permanent wilting per cent

TABLE 1. TEMPERATURE, HUMIDITY AND RAINFALL AT DEIR ALLA, 1959

Weeks and Readings	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
First Week:												
Temperature												
Maximum	24.9	19.5	16.2	33.4	36.2	43.0	37.5	40.2	38.4	34.7	36.0	25.5
Minimum	9.5	4.1	4.6	10.7	12.1	17.6	19.6	21.2	21.3	16.7	16.6	8.4
Average	17.0	12.6	10.3	19.6	24.6	27.8	28.5	30.4	30.0	25.3	25.4	17.2
Humidity	60	68	79	73	62	52	59	59	65	63	55	57
Rainfall	2.4	15.0	21.4	1.6	—	—	–	–	–	—	—	4.3
Second Week:												
Temperature												
Maximum	22.4	21.9	29.0	34.6	40.0	45.6	38.0	40.7	39.8	35.7	31.5	26.6
Minimum	8.3	4.5	6.9	10.6	10.6	17.7	20.5	21.6	18.5	15.5	13.5	9.3
Average	15.3	12.9	18.1	22.6	25.5	30.6	28.8	30.7	28.1	25.4	22.0	17.9
Humidity	69	63	63	61	57	49	58	63	58	61	62	54
Rainfall	16.9	30.4	—	—	—	—	–	–	–	–	–	–
Third Week												
Temperature												
Maximum	23.4	16.4	29.4	36.7	39.4	40.9	40.3	38.0	35.5	32.7	27.6	25.6
Minimum	8.4	3.5	10.1	12.1	16.2	17.9	20.4	21.0	19.1	16.4	13,4	9.9
Average	14.7	10.3	17.7	22.3	26.0	29.2	29.8	29.6	27.0	24.5	20.7	16.8
Humidity	72	86	79	60	57	61	61	67	64	64	57	47
Rainfal	39.4	30.1	7.8	—	1.3	—	—	–	–	—	0.3	—
Fourth Week:												
Temperature												
Maximum	21.9	19.1	24.9	40.8	41.6	38.5	40.5	39.5	37.5	31.7	26.5	24.4
Minimum	8.5	3.3	10.1	11.9	17.9	18.5	21.5	20.6	18.0	14.3	7.2	8.5
Average	15.0	10.7	16.8	24.4	29.4	27.7	30.5	30.0	27.4	23.2	16.8	16.6
Humidity	70	74	74	59	·47	61	61	65	61	64	56	58
Rainfall	9.0	25.9	1.7	—	—	—	–	–	–	—	8.5	8.3

Temperature In °C. Humidity % and Rainfall in m.m.

TABLE 2. WATER USE BY TRANSLATION AND EVAPORATION OF IRRIGATED CROPS, DIER ALLA, CUBIC METERS PER DUNUM BY MONTHS.

Crop	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alfalfa	71.63	54.10	91.69	133.10	180.34	198.63	221.23	210.82	151.38	144.53	106.68	85.09
Beans (lima)	54.86	41.40	70.10	101.60	137.92	151.89	169.16	161.04	115.82	110.49	81.53	65.02
Beans(Castor)	54.86	41.40	70.10	101.60	137.92	151.89	169.16	161.04	115.82	110.49	81.53	65.02
Berseem	71.63	54.10	91.69	133.10	180.34	198.63	221.23	210.82	151.38	144.53	108.68	85.09
Carrots	54.86	41.40	70.10	101.60	137.92	151.89	169.16	161.04	115.82	110.49	81.53	65.02
Citrus	46.23	35.05	59.44	86.11	116.84	128.52	143.26	136.40	97.80	93.47	69.09	54.86
Corn	63.25	47.75	81.03	117.35	159.26	175.26	195.33	185.93	133.60	127.51	94.23	74.93
Cabbage	63.25	47.75	81.03	117.35	159.26	175.26	195.33	185.93	133.60	127.51	94.23	74.93
Cauliflower	63.25	47.75	81.03	117.35	159.26	175.26	195.33	185.93	133.60	127.51	94.23	74.93
Grain sorgh.	58.93	44.45	75.44	109.47	148.59	163.58	182.37	173.48	124.71	119.13	87.88	70.10
Grain & hay	63.25	47.75	81.03	117.35	159.26	175.26	195.33	185.93	133.60	127.51	94.23	74.93
Onions	46.23	35.05	59.44	86.11	116.84	128.52	143.26	136.40	97.80	93.47	69.09	54.86
Pasture	46.23	35.05	59.44	86.11	116.84	128.52	143.26	136.40	97.80	93.47	69.09	54.86
Potatoes	54.86	41.40	70.10	101.60	137.92	151.89	169.16	161.04	115.82	110.49	81.53	65.02
Rice	84.33	63.50	107.95	156.46	212.34	233.68	260.35	247.90	178.05	170.18	125.73	100.08
Sudan grass	58.93	44.45	75.44	109.47	148.59	163.58	182.37	173.48	124.71	119.13	87.88	70.10
Suger beets	71.63	54.10	91.69	133.10	180.34	198.63	221.23	210.82	151.38	144.53	106.68	85.09
Sunflower	63.25	47.75	81.03	117.35	159.26	175.26	195.33	185.93	133.60	127.51	94.23	74.93
Tomatoes	67.56	50.80	86.36	125.22	169.93	186.94	208.28	198.37	142.49	136.14	100.58	80.01
Watermelons	46.23	35.05	59.44	81.11	116.84	128.52	143.26	136.40	97.80	93.47	69.09	54.86

b. Field capacity
c. Bulk density
d. Permeability

2. Determining the consumptive use of water for the major irrigated crops: this will include:
   a. Amount
   b. Frequency
   c. Appropriate practice
3. Large scale experiments on irrometers and Bouyoucos Blocks
4. Survey of soil fertility
5. Land reclamation
6. Soil conservation

It is our hope that our findings will be presented in future meetings.

During the past two years the water level in the Jericho Area has dropped extensively. The deeper one drills, the saltier the water gets. To what extent the aquifer has been depleted, how much decrease in its volume has taken place due to the depletion and whether it can be recharged are questions to be answered. The C.W.A. now has responsibility for solving this problem

DISCUSSION: The sources of the water on the small projects was springs and Wadis and these developments are felt to be economically justifiable.

The U.S. Salinity Laboratory's classification is being used in connection with water quality. In some cases it has been observed that agriculture flourishes even though the water does not meet these standards. Studies will be made of these cases in order to ascertain the reasons for this condition. It was pointed out that an inferior quality of water

TABLE 3. CHEMICAL COMPOSITION OF SOME RIVERS AND WELL WATERS USED FOR IRRIGATION IN JORDAN

River or well	Location	Date Sampled	Ec X 10^6 at 25°C	Dissolved Solids PPM	Sum of Cations Me/liter	Milliequivalent per liter										
						Ca	Mg	Na	Cl	SO_4	CO_3	HCO_3	%Na	SAR	PH	Class
JORDAN R	DAMYEH Brd	Nov. 10.1959	1960	1254	19.40	3.60	5.00	10.50	11.90	3.95	0	3.55	54	5.4	7.7	C_3S_2
JORDAN R	DAMYEH Brd	July 10. 1960	2590	1658	26.60	4.10	7.30	15.20	18.20	4.25	0	4.15	57	6.5	7.7	C_4S_2
YARMOUK R.	ADASIYEH	Nov. 10. 1959	725	464	7.80	2.40	2.10	3.30	2.50	1.80	0.10	3.40	42	2.2	7.9	C_2S_1
YARMOUK R	ADASIYEH	July. 10. 1960	760	486	8.04	2.40	2.20	3.44	2.90	2.14	0.15	2.85	43	2.3	8.3	C_3S_1
Wadi el Arab	—	»	720	461	7.70	3.10	3.10	1.50	1.60	1.60	0	4.50	19.50	1.0	7.7	C_2S_1
Wadi Zerka	—	»	1500	960	15.25	3.40	4.10	7.75	7.50	4.55	0.10	3.10	51	4.2	8.0	C_3S_1
Wadi Fara'a	—	»	660	422	6.90	3.00	2.40	1.50	2.10	0.45	0.05	4.30	22	0.8	7.8	C_2S
Wadi Ziglab	—	»	650	416	6.75	2.80	2.90	1.05	1.40	0.65	0	4.70	16	0.5	7.9	C_2S_1
Well No. 14	GHOR AREA	April 8.1961	4500	2280	50.48	12.40	14.70	23.38	25.70	19.63	0	5.15	46.37	6.7	7.4	C_4S_2
Well No. 27	GHOR AREA	April 8.1961	780	499	8.17	3.40	2.80	1.97	2.70	1.02	0	4.45	24.11	0.90	7.7	C_3S_1

may be used for long-term irrigation if adequate drainage is provided. The salts will build up in the soils unless there is an additonal water allowance given over and above the consumptive use, however. An inquiry was made about the use of rice as a reclamation crop and for specific information on the accumulation of salts in the topsoils. Rice is not grown because too much water is used. Jordan does not have information on the rate of salt accumulation. The soil extract is usually roughly ten times more saline than the water. The soils will be leached in the winter time. Mr. Kakesh stated that some of the lands in the East Ghor were formerly irrigated by water pumped from the Jordan and the deterioration mentioned was noticed. No quantitative studies of the water use and leaching requirement were made, however. Under the East Ghor project, more water will be available and this water, which is from the Yarmouk River, will be of better quality. Mr. Atallah stated that the Jordan Valley soils are particularly rich in gypsum, which is an advantage where low quality waters must be used. Both the waters and soils of this region are also relatively rich in magnesium, and American University at Beirut is studying the effects of magnesium.

Mr. Sawaya asked if the new underground water law in Jordan would affect the problem of fresh water depletion at Jericho. It was stated that this law requires the Central Water Authority to regulate pumping and drilling. In reply to a question by Mr. Atallah as to what would be the effect on the investment in citrus development at Jericho if pumping were regulated, Mr. Nemri stated that it would be better to regulate than to ruin everything.

Following considerable discussion about the effect of magnesium, the consensus was that it might be toxic to plants as well as affecting the structure of the soil.

In reply to a question by Mr. Iravani regarding the method by which excess water deliveries were controlled, Mr. Natur stated that while the land resources are in excess of the water resources, Jordan believes in intensive irrigation rather than in irrigating the whole area partially. In order to avoid waste of water, the farmer pays one fils per cubic meter up to 1,500 cubic meters per dunum.

Over that, he pays two fils per cubic meter. This is a cash payment.

Mr. Nimri pointed out that the Seminar had overlooked a very important point in connection with the use of irrigation water, namely, the spread of parasitic diseases such as bilharzia. Mr. Atallah said that this would be beyond the scope of the Seminar and urged that the scope be limited in order to have effective discussion. Mr. Nimri, however, stressed the importance of bilharzia and stated that the spread was through irrigation and thus the attack on the problem might well be made through instruction in connection with irrigation practice. Mr. Hamid stated that although there are large areas of rice in both wings of Pakistan, bilharzia is unheard of in that country. Mr. Jones mentioned the widespread prevalence of the disease in Egypt, the Sudan and other areas of Africa, stating that it is carried by a host snail. There is increased danger that the host snail may be transported to other countries due to increasing travel and commerce among them, especially by air.

LEBANON

Lebanon is a small country, having an area of about 10,000 square kilometers. The population of over 1,500,000 is crowded into this mountainous area, of which about 30 per cent is currently cultivated. The density of population is more than 375 per square mile and over 1,200 per square mile of cultivated land.

Lebanon has two mountain ranges: The Lebanon, paralleling the coast line and rising to elevations exceeding 2,250 meters, and the Anti-Lebanon, paralleling the Lebanon mountains along the eastern side of Lebanon at a distance of about 40 kilometers and rising to about the same elevation. Between these two ranges is the Valley of Bekaa, which is the northern end of a geological fault which extends south through the Jordan Valley, the Dead Sea and the Gulf of Aqaba. The soil in the Bekaa is generally fertile.

The coastal plains lie along the Mediterranean shore with widths varying from a few hundred meters to fifteen kilometers in the north, where the plain is called the Akkar Plain.

The climate is of the Mediterranean type, moderately cold, windy and wet in winter and dry in summer. The coastal plain is semi-tropical but the mountain slopes and interior valleys are cooler, with snow occurring in winter. The average annual precipitation varies from 500 to 1,600 mms, practically all of which falls between November and April.

The agricultural products are varied, ranging from citrus, bananas and vegetables on the coastal plains to olives, grapes, apples and cereals in the mountainous slopes and interior valleys.

Irrigation practices have been carried on in Lebanon since Biblical days by primitive means and subject to limitations of land and water. At present every available source of water is used to some extent for irrigation. The springs from which the water can be easily brought to the land are utilized to the fullest during the summer. During the last few years, many power pumps have been installed for pumping water for irrigation and domestic supply. This is most extensive in the northern and middle Bekaa, where the pumps installed on the Litani River and its tributaries pump the Litani dry before it reaches the southern Bekaa. Furthermore, a great number of wells have been drilled since 1952 to provide water for new areas being put under irrigation. These wells have overpumped the underground water resources, as is indicated by the drying up of a number of springs and a considerable lowering of the water table.

Presently the cultivable land in Lebanon is estimated at 310,000 hectares and the land under full or part irrigation at 65,000 hectares. It is estimated that 5,000 hectares were put under irrigation during the last three years by private landowners who are either rich landowners or merchants.

Due to a shortage of water for irrigation, a

great number of villagers and small landowners abandoned or sold their land and went abroad or came to the capital, Beirut, in search of work.

Recently the Government of Lebanon decided to carry out a plan of development for improving the status of all the villagers in Lebanon. During the year 1961 the Government nominated a board of Lebanese experts, «The Authority of Large Projects», to carry out a development plan in a period of five years (1962-67). The total estimated cost of this plan is 450 million Lebanese pounds (150 million United States dollars) and it covers the following aspects of development:

1. **Highways:** A program for a network of highways to connect practically all villages in Lebanon. The greater part of these roads will be for the north and south, where they are most needed. Actual work was started in the beginning of 1962 and it is expected that by the end of 1967 the program will be fully executed and terminated.
2. **Electrical Power:** A program for generation, transmission and distribution of electrical power is underway to supply all the villages in Lebanon with electrical power. The main power supply will be from the Litani Project. All steps for the fulfillment of this program are now in hand and this program again is expected to be fully executed and termined by the end of 1967.
3. **Irrigation:** Water is of great importance to Lebanon, where practically all available water during the summer (the period of irrigation) is used for irrigation and domestic supply; hence the emphasis placed on its conservation and efficient utilization in order to increase agricultural output. The available new water that can be used for irrigation and domestic supply should be either from storage of runoff water during winter or from the underground water resources. The Government made arrangements with the United States Bureau of Reclamation to investigate. The report has been completed and, as a result, the Litani River Authority and the Authority of Large Projects were formed to design and execute the storage reservoirs and irrigation projects. The detailed designs and execution have been started, and by the end of 1965 the newly irrigated area will amount to 25,000 hectares; by the end of 1967, to 60,000 hectares. The irrigable area in Lebanon will be double the present area, i.e., 120,000 hectares.
4. **Underground Water Investigations:** There is great enthusiasm on the part of rich private landowners for drilling wells to obtain water for irrigation. This, as previously mentioned, has resulted in the drying up of some springs and a considerable drop in the water table levels. The new wells are being sunk deeper and pumping has caused earlier, shallower wells to become dry. The Government consulted some American experts and as a result requested the assistance of the Special Fund of the United Nations to send a group of specialists to investigate and report on:
   a. The existing groundwater resources of the country and the estimated economic and physical limits of annual extraction;
   b. Steps to be taken to increase natural inflitration by various methods.

Furthermore, a new water law is being drawn up prohibiting the drilling of wells without prior permission from the Government. The law will put the Government in full control of surface and underground water resources.The present law, which is based on Moslem laws, mentions that all surface and underground water resources are public property and individuals have the right of use without prior authorized perimssion. In the case of wells, the law mentions that all wells are to be drilled not more than 120 meters deep and that no pumping over 100 cubic meters per hour may be done without prior Governmental permission. This is no longer adequate under present conditions and in view of future plans. The new law will be strictly enforced by the different local authorities in order

to safeguard the irrigation projects and the interests of the irrigators.

The Government also made arrangements with the F.A.O. to have soil experts sent to Lebanon to work with the «Lebanese Agricultural Research Institute» in preparing a complete and detailed soil analysis of all the cultivable area of Lebanon.

Future prospects in Lebanon are very encouraging, due to the Government projects and the enthusiasm and interest of Lebanese farmers, who are always eager to learn new techniques. Generally speaking, Lebanese farmers are the most advanced in the Middle East.

DISCUSSION: Present power pumps are diesel and are privately owned and pump from both wells and streams. There will be joint use of surface and pumped water. There is no concern about water quality from wells; drainage is no problem. Underground water must be controlled because it is being rapidly depleted and springs, for example, are drying up. Unless there is a balance between in-put and output, the Bekaa will become a desert. The water table has receeded 60 meters in the last two years. The U.N. Special Fund project is seeking a way to increase input. The water running out of the country is to be conserved by storage. Mr. Sawaya stated that the Litani project will double hydropower production by 1972 and will furnish 90 per cent of all the power in Lebanon.

Cropping patterns are suggested by the Extension Service. Soil classification started as reconnaissance. It is now being detailed and will be completed in a few years.

Economic patterns have caused widespread selling of lands by small farmers to large holders. This has caused a problem of displacement of villagers to Beirut.

PAKISTAN

INTRODUCTION

Information on the geography, climate, irrigation systems and water supply available was given in the country report for Pakistan in the last seminar. The problems of irrigation practices in the country were stated. In East Pakistan irrigated agriculture is not yet fully known except for the Ganges-Kobadak scheme, which has come into operation very recently. This is so because the province receives a heavy precipitation and most of the crops are rainfed. In the winter season when rain is very uncertain and also inadequate, it is necessary to provide irrigation facilities in case a major crop is to be raised. This province is intersected by a large number of rivers and tributaries. In 1956 a pilot project was taken up to raise water from these rivers and supply irrigation water to adjoining areas along the banks in the winter season for growing Boro rice.

The pumping sets used consist of a diesel engine coupled with a centrifugal pump and were generally mounted on a steel trolley and supplied with about 50'-60' of pipes. The sets are installed along the banks of rivers and water is lifted and delivered directly to the fields. No elaborate canals or distributaries are, therefore, required. The pumps are operated throughout the growing season (December-April) of the crop. The entire cost of operation and maintenance is borne by the Government and the cultivators are charged at a fixed rate per acre per crop season. When the sets are used for supplemental irrigation to rainfed crops, the charges are realized on an hourly basis.

Encouraging results were achieved and the program has steadily expanded. The table below indicates the trend of this development during the course of the last few years.

Year	Power pumps used	Area irrigated (in acres)	Production of clean rice in tons
1955	40	2,658	1,329
1956	135	10,000	5,000
1957	554	29,000	14,500
1958	848	32,793	16,396
1959	1,150	47,370	23,685
1960	1,367	62,143	31,071

Until now the work has been concentrated mostly on irrigation of Boro rice in the winter season. This method of irrigation is now being expanded to provide supplementary irrigation to rainfed crops in periods of drought.

The province is very densely populated and 85% of its population is engaged in agriculture. The individual holdings of the cultivators are therefore very small and they are required to form cooperatives to take power pumps on a hire basis. The cooperative movement in this province has been a great success in the field of power-pump irrigation.

In order to produce technicians in large number both for operation and maintenance of these power pumps, training courses are arranged by the Government in collaboration with companies dealing with machinery in various departmental workshops. On an average, 1000 pump operators are trained annually. Cultivators who purchase such pumping sets themselves also get facilities in these workshops for training their operators and mechanics free of cost.

The project areas are mostly the low-lying tracts of the province, which remain under water for about six months of the year and are available for cultivation only in winter months. By providing irrigation through power pumps it has been possible to get a major rice crop with an average yield of 25 maunds (2050 lbs). Cost of production, including irrigation charges, comes to approximately Rs. 125/-per acre, which gives a cost benefit ratio of 1:2,4 say 1:2.

This low lift pump irrigation project has so far been financed and executed entirely through Government agencies and will shortly be passed over to the Agricultural Development Corporation, a semi-autonomous body. This Corporation will have more freedom for work than Government departments and the project will be rapidly expanded in the coming years. The target fixed by the Corporation for the next three years will indicate the trend of future development of this project.

Year	Area in acres to be irrigated by power pumps.	Tons of food grains to be produced.
1962	292,000	146,000
1963	456.000	224,000
1964	630,000	315,000

West Pakistan is in the arid and semi-arid zone and agriculture is dependent almost entirely on irrigation. The Indus river and its tributaries have been harnessed for providing water for irrigation and the Indus basin canal system is one of the biggest irrigation systems of the world. There are 20 headworks across its rivers. The main canals and the distributing systems have a length of about 40,000 miles with a total irrigated area of 33 million acres, of which 25 million acres are cropped annually. In addition, there are 4600 miles of drains for disposing of storm water and for lowering the watertable in waterlogged areas.

Problem No. 1 of West Pakistan is the salinity and rising watertable. The flat topography of the Indus plains, a progressive decline in the porosity of the soil towards the sea, and non-provision of efficient artificial drainage simultaneously the canal system are contributary causes of a rapid rise of the sub-soil watertable and also salinity. Although the salinity problem arises even when the watertable is not yet high, it is accentuated with a

rising or high watertable. Currently the emphasis is on providing tubewells for drainage as well as a supplemental water-supply for irrigation. The irrigation practices adopted were evolved with the objective of cropping the maximum area with the minimum water supply. The consequences are the salinity problem and dependence on an irrigation water supply less than the consumptive use requirements of crops.

The problems of irrigation in tracts of sandy soils are soil stabilization, crop protection from sandstorms, conveyance losses of water, frequency and depth of irrigation. The microtopography of the Indus plains puts the fields at higher contour level at a disadvantage and attention is required to land grading and terracing.

Some of the irrigation systems are non-perennial; i.e., these are run only in summer. Evaporation at the soil surface is quicker if it is uncovered. With non-perennial irrigation there is no crop cover in winter and the higher rate of evaporation leads to movements of salts upward at a higher rate. Also the period in which irrigation supply is available falls short of the growing period of cash crops of cotton and sugarcane. It leads to a single crop economy, generally dependent on rice.

In the last decade West Pakistan, particularly the Upper Indus basin, has experienced heavy floods caused by river spills and storm waters brought down by streams having their origin in the upper catchments in India. What made things worse was the unprecedented heavy precipitation in this tract, which synchronized with heavy rainfall across the border. Extensive damage was caused to agriculture crops, canal systems, rail and road communications and other public and private utilities and for months on end the entire economic life of the vast region was paralysed. Over a greater part of the flood-affected area the land has a very flat slope and no defined natural drainage. Artificial drainage existing in the area proved totally inadequate for timely disposal of the accumulated spill and storm water. This delayed disposal of accumulated water, apart from the initial misery it brought in its wake, also resulted in damage of a more permanent and drastic character by adding to the already serious situation of waterlogging of agricultural land. To tackle this serious problem, the Government of West Pakistan has constituted a Flood Commission which is engaged on planning and approval of schemes to cope with the floods.

ACCOMPLISHMENTS ON FARM IRRIGATION

(i) Training and demonstrations

Two important developments have taken place in the country since the last seminar. One is the establishment of the Universities of Agriculture in East and West Pakistan on the recommendation of the Education Commission. Colleges of Agriculture had existed for education in agricultural sciences up to the graduate level. The turn-out of personnel trained in various fields of agriculture was, however, very much below the requirements for the development of scientific agriculture in the country. None of these colleges had been able to provide facilities for advanced education and research on soils and rrigation.

The other development is the creation of the Agricultural Development Corporations in East and West Pakistan on the recommendation of the Food and Agricultural Commission, which was at the stage of panel discussions at the time the last seminar was in session at Lahore. The members of the Commission also attended one of the meetings of the seminar. The commission observed «Ill-equipped as are the present departments to handle even the 'five firsts', there is no machinery at all for tackling the novel problems of changes in farming patterns. Little has been done yet to find out by experiment and pilot schemes what to advise the farmer to do. The chief project needs of the country after the 'five firsts' are guidance on irrigated and mixed farming in East Pakistan, elimination of salinity in West Pakistan, fully organised agriculture in new colonies through testing and mechanisation, harnessing of hill streams, conservation of catchments, exploitation of productive regions like 'hoor' in the Chittagong Hills. All these needs remain totally unsatisfied by such small adjustments in the departmental machinery as are currently suggested. Potentialities for increasing agricultural production in the country are very great and unless they are properly exploited

higher incomes and viability are not possible. Each individual farmer is like an industrialist and the job of increasing production has to be done by him and not by Government, but he is not in a position to do it unless the necessary tools are placed in his hands. The Government, therefore, have an urgent and immediate responsibility for providing these means.» It arrived at the conclusion that a new organisation should be set up which «should be free from the handicaps of the existing Government departments, be effective, comprehensive enough to make an impression on the farmer, big enough to be a force in the highest counsels of the nation, should have resources which permit the development of a programme matching the immensity of the problem and flexible enough to meet the variation inherent in the panorama of Pakistan's agriculture.» It recommended that to undertake the task of increasing the agricultural production and income of the farmer, an Agricultural Development Corporation should be established in each province. The Corporation will have two wings — a supply wing and a field wing. The supply wing produce or procure, transport and distribute seeds, fertilizers, plant protection material and farm implements throughout the country. The field wing will operate in selected project areas. Its task will be:

(i) To ensure the intensive and coordinated use of the «five firsts,» including supervised credit.

(ii) Solution of the special and more complicated problems of land reclamation, range management, soil conservation, irrigation management, organisation of agriculture in new colonies, harnessing of hill streams, conservation of catchment and exploitation of potential areas.

(iii) To introduce planned agriculture through suitable crop rotation and mixed farming.

(iv) Organization of marketing and processing and the creation of cooperatives.

(v) To organise small farms through cooperatives or through large blocks for joint planning. In non-project areas the existing departments will continue their activities.

The Agricultural Universities and the Agricultural Development Corporations will be in full operation soon. It is hoped that these will change the picture of agriculture in the country in years to come.

(ii) Land Classification and soil surveys

The Ground Water Development Organization of the Irrigation Department became part of the West Pakistan WAPDA in 1960 as its Water and Soil Investigations Division. The soil and water surveys in the Rechna, Chaj and Thal Doabs have covered about 16 million acres out of the total area of 18 million acres. The work is now being extended to the Lower Bari Doab.

The soil survey in the Taunsa project area was taken up by the Irrigation Department and remained with it. Out of the total area of 1,3 million acres, about 1.0 million acres have been covered.

For the Sukkur/Guddu/Ghulam Muhammad Drainage and Salinity Control Project of WAPDA, Hunting Technical Services, Limited, of London were entrusted with investigations which included soils, agricultural and drainage investigations and engineering studies. They have completed phase I of these investigations. The soil investigations were carried out by making a reconnaissance soil survey of the areas.

A very important step in land development in the country is the soil survey project for the whole of Pakistan to be undertaken jointly by the Food and Agriculture Organization of the United Nations and the Government of Pakistan. The project is about to commence and when it is in operation it may be possible to integrate the work of the agencies mentioned above with the over-all project.

(iii) Land Reclamation Research

Land reclamation research has continued during the last two years. A set-back to the work was received with the Soil and Water Testing Wing of the Ground Water Development Organization, which was part of the Directorate of Land Reclamation, going over to WAPDA. Investigation and research must go together in the interest of either of the two. Research work completed during these two years deals with the following subjects:-

(1) Water quality.

(2) Salt tolerance of crops.

(3) Consumptive use of crops.

(4) Re-appearance of salts after reclamation.
(5) Lysimeter studies — crop planning for salinity control.
(6) Economics of land reclamation.
(7) Feasibility of cropping patterns.
(8) Agronomic practices.
(9) Salinity statistics—Sample salinity survey.
(10) Drainage studies.

The results of these studies are being reported in one of the technical papers. The studies in the economics of land reclamation and on the feasibility of cropping patterns for soil protection and reclamation have a great bearing on the application of research in the field and returns to the cultivator. The former study was a detailed investigation into the cost of production of crops for share-cropping tenants at two reclamation farms—one with perennial irrigation and the other with non-perennial irrigation and a single crop economy. It brings out the difference in returns from the un-reclaimed, partially reclaimed and reclaimed land. An important observation is that an adult male worked for only 700 to 900 hours during the year, which is about 1/4th to 1/3rd of full employment. A pair of bullocks on the average worked for 400 to 500 hours during the year. This shows the huge wastage of agricultural labour in a country with backward farming and also shows that the low wages of agricultural labour can be very considerably increased without raising the cost of agricultural production.

The study into the feasibility of the recommended cropping patterns deals with labour requirements, the farmer's income, cash investment and water requirements. It shows that these cropping patterns are all within the cultivators' resources ; however, the Government has to provide the water resources and easy credit facilities.

(iv) Progress Made on Land Reclamation

Temporary relief to lands affected by salinity has been provided by the Irrigation Department on a limited scale for the last 20 years. This relief consists of providing additional water supply from the canal during the summer months when the rivers have a surplus. This extra supply is provided for three years to leach down the salts in the soil, and thereafter the land reverts to its normal allowance of water, which is generally 3 cts/1000 acres. This relief is temporary, as with such a low permanent water allowance the salts rise and accumulate again after a few years and also because it does not include any drainage relief for lowering the watertable and maintaining it below the crop root zone. The total area which has received such relief is less than half a million acres, while the area affected is more than 10 million acres.

Projects for permanent relief were undertaken by the Soil Reclamation Board which has at this stage 14 projects under operation covering an area of one million acres. It also has some nine projects in different stages of planning. These projects are now expected to be taken up by the Agricultural Development Corporation, whose functions will include those of the Soil Reclamation Board. These projects involve the installation of tubewells for lowering the watertable and supplementing the irrigation water supply from the canals, and other means of drainage like open drains or tile drains. All these engineering works are entrusted to WAPDA. As more than 50% of the 22 million acres of canal-irrigated area in West Pakistan is already in different stages of deterioration and the rest of the area is passing into these stages at a very rapid rate, the problem has assumed such immensity that unless it can be effectively dealt with, the national economy will suffer. The Planning Commission of Pakistan has estimated that the entire programme will cost a sum of Rs. 55,000 million made up as follows:

Item	Million Rs.
Storage	13,500
Revamping of canals	500
Drainage	40,000
Sea water barrier	100
River channel rectification work	1,000
Total:	55,100

The Second Five-Year Plan has a provision of only Rs. 103.2 million for drainage of irrigated areas. This is intended to cover only the cost of completing tubewells in the Rechna Doab at an estimated cost of Rs. 68 million, the cost of drilling similar tubewells in other suitable areas and the cost of improvement or provision of a limited number of storm water drains. The West Pakistan

WAPDA has also prepared a master plan which will require a capital outlay of Rs. 3400 million drainage plus a sum of Rs. 2500 million for provision of necessary electrification facilities.

The Planning Commission visualized an expenditure of Rs. 1500 million during the Second Plan period over and above the amount provided in the Plan. To cover all the affected areas in about 25 years, an annual expenditure of Rs. 800 million is required. During this period the major portion of the cultivated area not yet affected will have deteriorated. It is, therefore, considered that the maximum period for completing the whole program of reclamation and drainage should not be more than 10 years. The capital and foreign exchange resources required for the works are beyond the country's means. The help of U.N. and friendly countries is being negotiated. The capital required to be invested has either to come from foreign aid or ways have to be found for providing cheaper remedies. It may be that the major item of Rs. 40,000 million can be reduced if deep pumping to the depth of 200 feet and more proves unnecessary, and if we do not aim at lowering the watertable ultimately to that depth. Shallower pumping, if feasible, may provide the required relief and cost much less.

While planning in terms of such colossal capital costs, the importance of protecting the soil from deterioration cannot be over-emphasized. The Government appointed a committee to suggest such measures. The committee made a number of suggestions. The following are some of the steps which can be taken by Government departments or by the farmer:

(i) In areas where sweet water from open drains and shallow acquifer is available, and which are not likely to be taken up under the projects for permanent reclamation, farmers should be encouraged to supplement the available canal supply with available groundwater for raising the water allowance;

(ii) In order to encourage use of groundwater by farmers, facilities should be provided for free-of-cost drilling through the Agriculture Department and other Government organizations;

(iii) Every effort should be made by the Irrigation Department to provide the maximum additional water supply for temporary relief during the Kharif season;

(iv) More efficient distribution of the existing water supply for which the union councils and officers of the Revenue and Agriculture Departments can help to draw the attention of the irrigation engineers to complaints of shortage at the tail ends of irrigation channels;

(v) The cultivator can raise the intensity of cultivation by restricting water use to a smaller area within his holding. For small holdings it may not be possible to follow this procedure, but on big holdings a part of the area will have to be excluded from cropping. Such an area can be used for afforestation for some time until an increased water supply becomes available. Restriction of cultivated area raises a dangerous social problem in old areas. In new areas the measures can be easily adopted. In the old canal colonies, cultivation can and should be decreased at least to the authorized intensity.

(vi) As fallowing causes movement of salines from deeper layers upward, it is necessary to give maximum crop cover to soil throughout the year. In high water table areas this is even more necessary. Perhaps legislation at the proper stage can supplement the results of persuasion and demonstration.

Accurate demarcation of high and low watertable areas is necessary for planning for scientific crop patterns.

(vii) For the preparation of soil and seedbed, heavy presowing irrigation of 6 to 8 inches instead of the 3 to 4 inches generally given by the farmer should be applied to push down the salts.

(viii) Proper layout of fields for uniform application or irrigation water is very necessary for depressing salinity. The irrigation basin should not be bigger than 1/4th of an acre. More than one inlet should be used for irrigating the basin.

(ix) In non-perennial areas cotton or sugarcane is grown but does not give good yields. Actually, however, these cash crops can be developed properly with a schedule of irrigation including heavier application of water during the months of the Kharif season. By this method the salines are washed down, last and enough moisture is stored in the soil so that the cash crops can mature after the water supply is withdrawn. Proper

layout for irrigation and salinity control may also need legislation in addition to extension.

(x) More efficient and effective use of water delivered to the farmer is necessary. The provision for maintenance of water courses existing in the Canal Act should be strictly enforced and availability of water supply at the outlet head can be made conditional on proper water-course maintenance.

(xi) The use of mulches for storage of moisture in the soil and checking of capillary movement should be popularized.

(xii) Although cultivation of salt-tolerant crops is not an anti-salinity measure, it affects the economics of the cultivator. Stress should be laid on research on seed treatment for better germination in saline soil, on crop patterns, including rotations inducing salt tolerance, and on the evolution of salt-tolerant varieties by selection and breeding.

(xiii) Chemical fertilizer should definitely not be used on sodium soil.

(xiv) In connection with anti-waterlogging and anti-salinity measures, importance should be give to green manuring for increasing the humus content of the soil. Added stress should be laid by the Extension Service on this practice while propagating scientific cropping patterns in all areas in general and in areas like Thal in particular. Rabi green manuring should be encouraged by remission of water rate and land revenue charges.

(xv) In non-project areas, the Government should concentrate attention on providing proper drainage. Adequate funds should be made available for maintenance of the drainage system. Drainage should be given priority over other projects. In areas at the foot of the Salt Range, the disposal of salt-charged rainfall run-off through a main drain should be provided for.

(xvi) The banning of rice cultivation as an anti-waterlogging measure without taking into consideration the soil conditions is not justified except for urban areas from a sanitation point of view. For agricultural land, provision of a well-maintained drainage system is the only anti-waterlogging and anti-salinity measure to take.

(xvii) In high watertable areas, mechanical cultivation may cause a tight soil layer problem. Mechanical cultivation with tractor and heavy machinery should not be allowed in areas where the watertable is within 5'.

(xviii) The Cooperative Department should provide readier facilities to the farmer for his drainage and cropping liabilities. If adequate funds are not forthcoming from the cooperative societies, the Government should provide credit facilities from other sources.

(v) Progress Made on the Recommendation of the Previous Seminar.

1. **Education and Training.** Before the soil problems of salinity and waterlogging gained importance, very little attention was paid to training the farmer in those irrigation practices best adapted to his conditions. The Agriculture Department has facilities for training village extension workers at the Agriculture Colleges. Matriculates are given a general agricultural education for one year. The teachers for this course are college graduates. The strength of these village workers employed by the Agriculture Department is one worker in a tehsil (or thana in East Pakistan), which is very much below the requirements for any intensive work. These extension workers confine their activities to better seeds and fertilizers and no not interest themselves in irrigation practices.

The Soil Reclamation Board is the only organization which has extension workers in the project areas to train cultivators in improved irrigation practices. These workers do not, however, have a background of general agricultural training. The Board is now establishing a training centre for extension workers to give them a good background in agriculture and irrigation. It is also reorganizing its Extension Service on a bigger scale which will include soil protection measures in non-project areas. The Agricultural Development Corporation, when it takes over the project areas, will now be the agency that will provide the full strength of the right type of extension workers.

The Universities of Agriculture recently set up are expected to establish majors in irrigation science and irrigation engineering. Facilities for research in irrigation problems will be available in these Universities.

The establishment of a national organisation for the development of improved irrigation tech-

niques and practices and the dissemination of such knowledge has not yet reached the stage of planning.

2. **Consumptive use and water requirements.** The progress of research on this subject is being reported in one of the technical papers. The subject is receiving increasing attention in the country.

3. **Agricultural requirements for irrigation projects.** The points raised in the recommendation made by the Seminar are receiving increasing attention for new irrigation projects. Soil and topographical surveys and drainage planning are now considered pre-requisites. Mention of the soil and topographical surveys being carried on has already been made. In the project areas that are being taken up by the Agricultural Development Corporation, experiment stations will be established for research work on irrigation problems. The water distribution system will be worked out with the participation of the farmers. Extension services will be provided to educate farmers on scientific irrigation farming. Demonstration plots in farmers' fields will be part of the Extension Service.

4. **Assistance to farmers for improved irrigation agriculture.** The functions of the Agricultural Development Corporation will cover the recommendations made by the last seminar.

5. **Drainage and salinity control.** The work on drainage and salinity control carried on since the last seminor is described in the technical papers contributed by the Pakistan delegation. This seminar provides a very good opportunity for interchange of experience among the NESA region countries. However, it is felt that the Fourth Seminar should make specific recommendations for exchange of scientific information among these countries and with other of the world on irrigation problems as a continuous process.

6. **Organisation for operation and management of irrigation projects.** The stage for legally constructed organisations, like water users' associations, for encouraging cultivators to assume certain responsibilities in the operation and management of minor irrigation and drainage sections of projects has not yet arrived in this country, due to the general lack of education among the peasantry. However, the distribution of water from an off-take is effected by an order of turns sanctioned by the Divisional Canal Officer under the Canal and Drainage Act, which is implemented by the farmers under their own supervision. In the course of time, the functioning of the Agricultural Development Corporation is expected to lead to developments in this direction.

The importance of encouraging cultivators to take an active interest in the operation and maintenance programme of the over-all project is being realized more and more. The objectives of the Agricultural Development Corporation centre around respecting and taking full cognizance of the existing status of the cultivator and of the practices he is following so that he willingly cooperates in the programme of development of scientific land and water use.

DISCUSSION: Regarding water delivery in West Pakistan, the entire stream delivered to a field channel is rotated among the several farmers under that field channel. Excess use of water is not a problem in Pakistan. Only about 50 per cent of water requirements are delivered.

Mr. Hamid explained that a «Tehsil» is an administrative subdivision of a district.

High sodium soils exist, but the use of chemical fertilizer, which is limited, should be on soils which are non-saline. For the present, the limited supplies of fertilizer should be used on good soils. Certain kinds of fertilizers used on certain soils tend to increase the soil dispersion.

Regarding the reasons for developing small pumps in East Pakistan rather than gravity diversions, there was no irrigation in East Pakistan prior to 1947. From 60 to 100 inches of rain feed three rivers carrying as much as 2,000,000 c.f.s. each. At maximum discharge these become flooded and inundate the land. This condition leads to a crop pattern based on rice. If rice is sufficiently established before the floods come, it will survive them, but it is damaged by droughts if floods are late. Rice cropping is thus very hazardous. These conditions, over the last ten years, have resulted in a shortage of 1,000,000 tons of rice in one year and at least half a million tons in every year. Hence a stable food crop must be developed during the dry season. In this climate, this crop can be rice, but irrigation is needed for that purpose.

The quickest way to start the project was to pump directly from the river to those areas lying adjacent to the river. In order to acquire gravity command of large areas during the non-flood season, a fairly high diversion is required. Construction of this in a river whose flood stage is 2,000,000 sec. ft. presents something of a problem. The pump irrigation scheme provides some relief and makes people familiar with irrigation. A barrage is being planned for the Ganges which commands a fairly large area. However, there are high areas within the command which will still need to be supplied by pump. Gravity irrigation development using barrages in the northern part of the province is still under consideration. Construction of the required barrages is very expensive and unless there are large areas which can be commanded, the expense would not be justified. Individual areas in the northern part may be too scattered and may have to be served by individual pumping. Tubewells are being tried in the northern part of the province, where the sub-soils are coarser. Farther down, they are too fine, and near the sea, the groundwater is saline.

In West Pakistan drains are classified as main drains, secondary drains and field drains. Only manual labor is used in maintaining the secondary drains. Large drains are cleaned by machinery every year or two. Field drains are the farmer's responsibility and are maintained by hand. Chemical control of weeds has not been used in drainage systems in Pakistan. Tile drains require slope and machinery to install. Cost estimates range in the order of Rs. 400-500 per acre. Use of tile drains would require electrical pumping machinery and its maintenance. Skilled labor to install tile drains is not available. Capital costs of open drains is Rs. 20 per acre, with about Rs. 15 for maintenance. The value of land and productivity is not sufficiently high to justify tile drainage. In East Pakistan flood-ways through levees with one-way gates are being developed to protect the tidal lands. These also permit rain flood-waters to drain out on the ebbing tide. Pumps will be provided where the water level in the river is insufficiently low to provide drainage. During the periods of low rainfall, fresh water may also be added by gravity and pumped or drained on the ebb tides to assure leaching of the salts.

Fertilizer is not generally now used in rice culture. However, this will be done in the future and research stations have been established to study the use of fertilizer under conditions of irrigation. In one instance, rice production was increased from 12 maunds per acre to 50 maunds per acre by the use of fertilizer with irrigation, although a fairly large amount of fertilizer, more than may be practical under cultivation, was used. General drainage is good in East Pakistan; however, there are many saucer-like depressions which will need to be pumped out. Salinity is not a problem except as it relates to tidal flooding. The production estimates in the report are based on average experience not using fertilizer, and while there is a fertilizer plant being constructed in East Pakistan, the present figure was used because so much of agriculture is only under development and would not use fertilizer at first. The «five firsts» referred to in the paper are feed, fertilizer, plant protection, credit and improved cultural practices.

Wells in West Pakistan are a minimum of 200 feet deep. They are drilled until coarse sand strata at least 40 feet thick are encountered. This may be between 200 and 350 feet. Above this, water-bearing strata are of limited thickness. Some of the wells are sweet, some may need to be mixed with river water. The salts arise from the soils, which are inherently salty, not from the water itself. The well installation must be large enough to control the water table in order to provide drainage. The spacing of one 3 to 5 c.f.s. well per square mile is justified on hydrological considerations. Pakistan plans to lower the groundwater by at least 15 feet in order to accommodate reclamation operations. The soil profile indicates water table connection with the deep aquifer and trial schemes have shown the water table to be lowered five feet in two years. It is planned to pump tubewells 22 hours out of each 24 hours, on an average, 300 days per year. The well water is needed for reducing the duty of irrigation to one second foot per 150 acres. Wells will furnish 1.2 second feet for each second foot from the surface system. Ghanat systems are not prevalent in the area affected by the wells. In India the capacity of the tubewells is 1½ second-feet on an average.

TURKEY

INTRODUCTION

The total area of the Republic of Turkey is 77,698,000 hectares. Of this total area, a section of 2,350,000 hectares is in the European portion. The breakdown of the land areas of Turkey is as follows (1959):

Total Area	77,698,000 Ha.
Wastelands (mountains, lakes, etc.)	13,132,000 Ha.
Forests	10,584,000 Ha.
Pastures	28,658,000 Ha.
Agricultural Lands	25,324,000 Ha.

The foregoing figures show that the majority of the land (approx. 70 per cent) is not physically suited for agricultural use. These lands consist of mountains, lakes, deserts, lands with steep slopes, barren rock, etc. Considering that population increases at the high rate of 3 per cent annually and that cultivable lands are limited, it becomes necessary to increase the yields per unit area in order to provide food for the population and to raise living standards. In this aspect irrigation practices gain importance in agricultural activities in Turkey.

LAND FEATURES

Physiographically, Turkey can be divided into four segments having dissimilar characteristics:

1. COASTAL LANDS

Lands lying along the coasts are included in this segment. In the north and in the south, high mountain ranges stretch parallel to the coasts, forming small terrace and bottom lands, with the exception of some big alluvial deltas formed by rivers. Elevations vary between sea level and 150 meters. Soils are formed of clay and lime materials underlaid by deep sand, silt and clay strata. Salinity and drainage constitute the main problems on these lands.

2. CENTRAL ANATOLIAN PLATEAU

This is a high plateau located in the central part of the country and it is divided into many irregular areas by rivers. This region also has various landscapes, such as mountains, bench lands, closed basins and some narrow alluvial plains. Elevation varies between 900 and 1,500 meters. The greatest part of this plateau is suited for agricultural use, especially for grain production.

3. MOUNTAINOUS LANDS

The Taurus mountain range in the south, the Black Sea Mountains in the north and the Istrance Mountains in the northwest are the main landforms in this group, with elevations between 1,500 and 4,000 meters in general. These lands show very rough relief and steep slopes, having hundreds of meters of difference in elevation within very short distances. Vegetal cover changes from weedy, mostly barren rocky surface to dence forests. A major part of these lands are covered with snow for several months each year.

4. LOW BASIN OF TRAKYA

These lands consist of the whole European portion of the country except the Istranca Mountain Ranges. It is an open and divided plain having undulated topography in the center. Soils are clay in texture overlying clay and gravel strata. The largest part of these lands is suitable for agriculture.

CLIMATE

Turkey has several types of climate. However, it may be considered to be in the subtropical zone of the world. As a whole, in the country four seasons are distinguished. Along the coast winter is mild and rainy, while it is cold in the central and eastern regions where snow remains a long time.

RAINFALL

The main characteristics of the rainfall in Turkey are its nonuniform distribution during the year and its variation from region to region with respect to quantity, incidence and duration. In some parts of Central Analotia, the annual mean rainfall is as low as 300 millimeters, while it is as much as 3,000 millimeters in the eastern Black Sea Region.

According to the monthly variation of rainfall, Turkey is divided into two parts. As a result of a typical Mediterranean climate, in western and south Turkey it rains in winter whereas the summer is extremely dry. In the Black Sea Region the greatest amount of rainfall occurs in winter, with considerable amounts also in the summer. The eastern and central parts of the country receive a lower amount of rainfall in comparison with the other parts.

FLOODS

Floods in Turkey constitute a problem for human life and property and agricultural activities. Because of the physical features and the concentration of mountains in the country, practically every river basin has a flood problem. Investigations of flood damages were started in 1955. The results of these investigations may be summarized as follows for the five-year period 1955-1959:

Floods have occurred on 40,000 ha. in this period. Average annual damage was 30 million Turkish liras. However, the real amount of the annual damages from floods is much higher than this figure because there are other damages which are impossible to measure.

Damages have been recorded on 60 per cent of the 40,000 Ha. Fifty-seven per cent of the total damages occurred on agricultural lands. February is the month having the heaviest floods and is followed by September, March and June, which are given in their order of importance. The western part of the country is most liable to flood damages.

WATER RESOURCES

When considering water supply for irrigation, rainfall must be eliminated as a source because it is too small or unevenly distributed for good crop production. The remaining sources are:

1. Rivers and streams
2. Underground waters

Turkey is divided into 26 basins. At present, reconnaissance investigations have been completed on 15 of these basins. The total annual mean discharge from rivers and streams is 193 billion cubic meters in these 26 basins. In 11 basins, which have a total of 62 billion cubic meters of annual mean discharge, 32 billion cubic meters of water will be stored to irrigate 1,148,772 Ha. For this purpose 91 dams will be required.

2. Underground waters

In order to provide water for drinking, domestic use, and irrigation, resources and reserves of underground water have been investigated since 1956. Wells drilled up to March, 1961, total 1,469. Of these wells, 295 were dry and 167 were artesian. The total yield of these wells reaches 14.5 cubic meter/sec.

EXISTING IRRIGATION IN TURKEY

Government Irrigation Projects: At present there are 28 irrigation projects. These projects were planned to irrigate 190,000 hectares of land. During 1961, assistance was provided in irrigating 104,110 hectares. The whole area was not irrigated during the period because the irrigation systems were not completed.

In many of the existing projects, efficient use of water is limited because of the following factors, which were also mentioned in the Third Seminar:

a. Insufficient land levelling
b. Inadequately developed farm irrigation systems
c. Inadequate or no provision for main and farm drainage
d. Poor methods of irrigation
e. Large water losses from primary and distribution systems
f. Insufficient control structures in water supply and distribution systems
g. Need for proper rotation schedules for water application
h. Lack of weed control and decreasing capacity of ditches due to silting

Crop distribution in the existing projects during 1961 was as follows:

56.79 per cent, industrial crops (cotton, sugar-beets, etc.)
25.13 per cent, cereals (wheat, barley, etc.)
14.35 per cent, orchard and truck crops
3.73 per cent, forage crops

Irrigation Projects Under Construction: At present there are 11 projects under construction to provide water for 48,395 Ha. of land.

The network construction of two projects has already been completed. These two projects will be in operation in the irrigation season of 1962, providing water for 11,850 hectares.

PROPOSED IRRIGATION PROJECTS

In Turkey the main occupation of the people is agriculture. The Government has been giving full attention to this development, with emphasis on irrigation. For this purpose the following program is proposed. In the next six years (1963-1968), 83 major irrigation projects will be completed whereby 2,215,650 Ha. of land will be served. In addition, 476,000 Ha. will be protected from floods and 55,000 Ha. of swamps will be reclaimed.

Private Irrigation Projects: Turkey has two kinds of private irrigation projects:

1. Projects which are built by the Government and operated by farmers.
2. Projects which are built and operated by farmers.

The first group covers a total area of 68,000 Ha.

For the second group exact figures are not yet available.

Studies were completed for 15 provinces and they are continuing for the remainder. The total area covered by this group is estimated to be 400,000 Ha.

PROBLEMS IN IRRIGATION PRACTICES

Salinity. The most serious problem in existing and proposed projects is salinity. Most of the irrigation projects are located on bottom land. These lands consist of alluvial soils with fine texture and soluble salts are distributed both in the profile and on the surface. On some of these lands salinity is increasing each year.

Deficiency of Drainage. Much of the land irrigated or to be irrigated has a high water table with very poor quality. The electrical conductivity of these waters is in the range of from 5,000 to over 30,000 micromhos/cm. Mostly because more evaporation than rainfall occurs during the year, capillary rise is always present. This situation causes or increases the salinity hazard. Every year reclamation work is carried out in various irrigated areas.

Irrigation Practices. This is another serious problem of irrigation in Turkey. Many irrigators do not know the answers to questions such as how much water should be applied, what method be used, when to irrigate, etc. Farmers are usually very conservative and they insist on labor-saving practices of wild flooding without giving consideration to whether they have row crops or steep slopes on their lands. Knowing this fact, the Government emphasizes training them in several ways and is placing increased emphasis on this program every year.

Irrigation of Organic Soils. Draining of swamps which have peat and muck soils is creating new problems such as selection of the proper irrigation, fire protection and management practices. Exact information about these soils is not available but the total area is estimated to be around 100,000 Ha. Three of these swamps are already drained, and the water table is lowered. This creates a fire problem in these lands because the farmers are not familiar with the management of this kind of soil and are careless. In 1961 work and experiments on these lands were started.

Other Problems. In addition to the problems described above, the following problems still maintain their importance:

1. Insufficient land leveling
2. Inadequate farm irrigation systems
3. The land ownership pattern, which prevents efficient layout of farm irrigation systems
4. The use of suitable implements

IRRIGATION ORGANIZATIONS IN TURKEY

Irrigation is a state responsibilty and either major or minor irrigation schemes are financed and handled by state organizations. The responsibilities for irrigation are carried out by the General Directorate of State Hydraulic Works (DSI) under the

Ministry of Public Works, and the General Directorate of Soil Conservation and Farm Irrigation (Topraksu) under the Ministry of Agriculture.

The responsibilities and the organization of these two departments are as follows:

DIRECTORATE GENERAL OF STATE HYDRAULIC WORKS (DSI)

A. The responsibilities of DSI

In accordance with Law No. 6200, the responsibilities of DSI can be summarized as follows:

1. To build protective works against floods,
2. To build irrigation works,
3. To drain swamps,
4. To generate hydro-power provided that it is related to the above activities, and from other sources when necessary,
5. To review, approve, and control the water supply and sewage disposal plans for cities and towns and to carry out the planning and construction of village water supply works,
6. To improve streams and make navigable those which are deemed necessary,
7. To provide for the functioning of the projects referred to in the above articles ,including operation, maintenance and repair.
8. For the projects referred to above, to make gaugings, conduct experiments, compile statistics, conduct research and make various kinds of surveys to establish the type and character of soils and the kinds of crops to be raised, to evaluate the agricultural and economic benefits to be derived and the degree of productivity to be obtained, and, when deemed necessary, to prepare basin development plans,
9. To make or have made all kinds of surveys and plans for the projects mentioned above.

B. The organization of DSI

The DSI has the following organizational set-up:

1. Central Office
   (1) Director General, and his staff
   (2) Divisions
   a. Investigations and Planning Division
   c. Groundwater Division
   d. Water Supply Division
   e. Machinery and Supply Division
   f. Research Division
   g. Operation and Maintenance Division
   h. Administration Divison
   i. Dams and Hydro-Electric Power Plants Division
2. Regional Offices

Regional Directorates in 13 Sections and their district offices. Regional directorates have, with some variations, the same units as the central office but on a smaller scale.

DIRECTORATE GENERAL OF SOIL CONSERVATION AND FARM IRRIGATION (TOPRAKSU)

A. The responsibilities of Topraksu

This organization (which is a part of the Ministry of Agriculture) was established on February 28, 1960, by Law No. 7457.

The duties of this organization are mentioned in Article 2 of Law No. 7457 as being:

1. To stop the erosion of lands suitable for agriculture, to prevent the accumulation of flood waters, to conserve the water in the soil, and to secure the continuity of the soil yields.
2. To improve, restore and develop the areas covered with wild olives, carobs, mastics, brushlands, maquilands, and native pastures, owned by the state or private parties.
3. To render suitable for agriculture alkali, acid, stony or turfy lands which are owned by the state or private parties.
4. To level lands suitable for agriculture, to arrange field irrigation turnouts, to secure any agricultural irrigation work

and all other important works for the purpose of realization of land irrigation by profiting from existing irrigation networks owned by the state or private parties.

5. To install and operate irrigation in installations with a requirement of up to 500 lit/sec of irrigation water.
6. To perform all kinds of studies and analyze and prepare soil maps in order to classify and group the soils from yield, irrigation, drainage and reclamation points of view.
7. To determine the procedure and standards to be followed in soil classification and soil studies.
8. To perform experimental and research work, to train qualified personnel and to provide technical assistance related to conservation of soils and soil yields, land reclamation, and irrigation.
9. In order to carry out activities such as irrigated agriculture, and soil conservation, Topraksu is empowered to enter into joint ventures with operational organizations that have rotating capital, to arrange partnerships among the operational organizations and corporations, to provide leadership in ventures dealing with irrigation and conservation, and to sign contracts with construction organizations or contractors.
10. Upon the suggestion of the Ministry of Agriculture and with the approval of the Council of Ministers, to provide land groupings in accordance with existing regulations, so that restrictions in land use may be imposed for good soil conservation and agricultural practices.

B. The Organization of the General Directorate of Topraksu

I. Central Offices

1. Director General and his staff (work units and Advisory Committee)
2. Sections
   a. Small water development section
   b. Farm irrigation section
   c. Drainage and reclamation section
   d. Soil conservation section
   e. State land improvement section
   f. Soil survey and land classification section
   g. Cartography section
   h. Machinery section
   i. Research works section
   j. Education information and foreign relations section
   k. Administration section
   l. Accounts section

II. Regional Offices

Regional Directorates, Soil and Fertilizer Research Institutes, Irrigation Research Institutes and Stations, Experimental Farms for Irrigated Agriculture, Soil Conservation Centers, Training Centers, Equipment Supply Department and Field Division.

At present, the General Directorate has the following active organizations: Main office, seven Regional Directorates, twenty-two works units, Soil and Fertilizers Research Institute, six Regional Soil, Laboratories, two Irrigation Experiment Stations, an irrigation Research Institute for Irrigated Agriculture, one Soil Conservation Center, one Equipment Supply Department, one Training Center, and nine Operational Organizations with Rotating Capital.

There are also the South Regional Directorate, the Adana District Development Section, the Tarsus Irrigated Agricultural Research Institute, the Topçu Land Conservation Station, the Alifaki Saline Soil Reclamation Substation, the Tarsus Training Center and two organizations having rotating capital which carry out construction contracts for the farmers. Organization and staffing of work units is also in progress.

ACCOMPLISHMENTS ON FARM IRRIGATION

Training. During 1961, the Tarsus Training Center trained 102 professionals (agricultural engineers) on different subjects and 32 sub-professionals

(surveyors) on land survey.

Presently training is being held at three differend levels.

At Bornova-Izmir an additional Topraksu Training Center has been established this year.

Demonstrations. Some demonstrations have been decreased as farmers learned how to do them by themselves, and some new demonstrations have been held in the northwest, west, central and southern parts of the country.

Land Leveling. During 1961, 3,485 Ha. of land were leveled with equipment provided by Topraksu and payment of the costs by the farmers under the suervision of Topraksu.

CREDITS FOR FARM PLANNING

In accordance with the Article 21 of Law No. 7457 (which describes the responsibilities and organization of Topraksu), work was started on the design and construction of irrigation projects for farmers by providing necessary credits from the Agricultural Bank. These credits are given following a joint protocol between Topraksu and the Agricultural Bank, with interest of 5 per cent for the term of 20 years.

In 1961 it was not possible to provide credit to meet all demands. The total amount of credit extended was 6,112,290 Turkish liras, which were distributed among 447 farmers to provide water for 3,227 Ha. of land. These credits will be increased in the coming years.

DRAINAGE, LAND CLASSIFICATION AND SOIL SURVEY FOR IRRIGATION PROJECTS:

Investigations on soils and drainage problems are in progress, with an increasing effort being made by DSI and Topraksu. The land classification work is carried out to determine the extent and degree of suitability of lands for sustained irrigation of proposed irrigation projects.

These investigations are of two types:

1. Land classification for planning purposes. This is between reconnaissance and semi-detailed types.
2. Detailed land classification, which is carried out for definite planning.

From 1954 to 1960 the planning type of land classification was carried out on 2,186,385 Ha.

In the period 1960-1961 the following soil investigations were completed:

1. Land Classification
   a. Planning land classification on 600,800 Ha.
   b. Detailed land classification on 16,500 Ha.
2. Basic Soil Surveys on 42,500 Ha.
3. Survey for Soil Conservation on 787,300 Ha.

Drainage investigations have been made since 1958. From 1958 to 1960, 663,500 Ha., and in 1961, 410,000 Ha. of lands were covered by drainage investigations.

CONTROL OF IRRIGATION PRACTICES

In order to prevent water loss and to train irrigators in irrigation methods, irrigation practices were demonstrated on land areas of 20,000 Ha. under the supervision of an irrigation engineer.

Farm irrigation System and Land Consolidation Demonstrations

For the purpose of showing good use of irrigation water and of getting high irrigation efficiency, a demonstration was carried out on 131 ha. of lands within the Çumra Irrigation System near Karkin Village in Konya Çumra.

In this area there were 90 fields belonging to 74 farmers. Considering the distribution of ownership, the number of fields was reduced from 90 to 74 by consolidation. After installing a new farm irrigation and drainage system, irrigation has been under control.

Another demonstration has been held on 364 ha. of lands belonging to 132 farmers for the development of unit Y–4 in the Tarsus-Berdan Irrigation System.

PROGRESS MADE ON RECOMMENDATIONS OF THE PREVIOUS SEMINAR

All of the recommendations of the last seminar are being carried out.

The progress made is summarized as follows:

1. **Administration.** As we mentioned above, the General Directorate of Conservation and Farm Irrigation, Topraksu, has been established.

Organization of this department is underway. Two new Conservation and Farm Irrigation Training Centers have been opened.

A joint committee of DSI and Topraksu staff members has been formed to discuss problems and programs, to establish priorities for mutual activities and to make the necessary decisions on every point for the irrigation development of the country and for better coordination between the two departments.

2. **Research and Experiments.** Two new substations have been established to find out the possibilities of reclamation in saline areas.

   At Izmir a joint drainage office has started to make a drainage design of the Menemen Irrigation System, and for this purpose an experiment has been held on 300 ha. of land in the system.

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

DISCUSSION: Regarding land levelling, Topraksu instructs the farmer in the use of equipment. The farmers disposed of animals when power equipment came in. Large equipment is favored because of the efficiency of technical supervision. Farmers are encouraged to use small equipment if they want to.

There are perched water tables in Turkey. Areas with the more favorable conditions are being developed first. In the Adana region some soils are underlain by impermeable material.

Topraksu develops plans for land levelling. The farmer repays the revolving fund on completion. This is about a 50 per cent subsidy. At present there is no way to use the subsidy on jobs done by private contractors, although this is being studied. In addition to its revolving funds, the Agricultural Bank may loan money for levelling under a plan approved by Topraksu. Repayment terms are based on the crop.

Demonstrations are at first single-purpose. Multiple-operation demonstrations are now carried out in the larger areas.

Most projects are initiated under the demand system, but this is switched to rotation as the project develops. Penman or Blaney Criddle methods are used to estimate requirements. A common allowance is one liter per second per hectare.

Pan formation by heavy equipment has not been considered a problem. Plow pans at 15 cm. depth have been broken by deep plowing to 35 cm. in the Izmir region.

Sprinkler equipment has not been used extensively in Turkey. Since it is not manufactured in the country, other means of irrigation will be sought for areas where sprinkling might otherwise be desirable.

YEMEN

Yemen is a small country in Southwest Arabia, on the Red Sea between Saudi Arabia and the Aden Protectorate. It is the garden area of Arabia. With approximately 500 mm rainfall in the central mountainous area, and a considerable extent of arable land, its agricultural production supporting a population of 4,000,000 is perhaps greater than in all the rest of Arabia.

Yemen is now emerging from a long period of self-imposed isolation, has recently established diplomatic relations with several nations and is beginning to enjoy the advantages of these contracts.

Agriculture is the whole economy of the Yemen. There is no manufacturing, no extraction of minerals, no invisible exports such as tourism. The exporting of agricultural products has long been the principal source of foreign exchange. Coffee, qat and hides have earned the exchange by means of

which the country has imported the basic necessities-cloth, sugar, tea and manufactured goods.

In Yemen agriculture, irrigation plays a vital role. Lacking official statistics, it may be estimated that perhaps as much as one-fourth of all agricultural production comes from land that is irrigated to some extent.

The Yemen farmer is a very good farmer, diligent and industrious in the use of his land and the care of his crops. Most of the cultivated land in the hill and mountain country has been re-shaped into essentially level fields surrounded by dikes that retain rainstorm run-off water brought in by ditches from adjacent uncultivated areas. This supplemental irrigation, added to the rainfall, results in an important increase in hill-country production. Here, the Yemeni farmer is so careful in the management of his land that throughout the mountain region there is almost no rainstorm run-off from farmed fields and almost no soil erosion.

There are numerous small mountain streams with perennial flow extending from source areas high in the mountains to the point where the heights end abruptly on the flat, sandy coastal plain bordering the Red Sea. On the plain, the streambeds become so wide and sandy that the small perennial flow quickly disappears in the sands. Even the largest of the many streams reaches no more than two or three kilometers beyond the base of the mountains.

Generally, the mountain valleys are steep and narrow. Wherever small tracts of valley benchland occur, these are cultivated and irrigated. Water is diverted from the stream and applied to the land. Where ample amounts of animal manures are frequently used, crop yields are generally fairly good. The sum total of all these small irrigated valley benchlands is not large, however.

Intense rainstorms in the summer rainy season usually produce two or three short but intense floods. These floods, with high peak discharge rates, come rushing out of the mountains and flow out on to the flat coastal plain. On each of the major streams, the flat land adjacent to the stream channel is extensively developed for flood irrigation. Actually, the total plains area irrigated periodically, but usually inadequately, by flood irrigation is much greater than the sum of the better-irrigated valley benchlands alongside perennial streams in the mountains.

The flood flow is diverted from the stream channel onto the fields of the coastal plain through many diversion structures serving many irrigation canals. Thus, the stream ends in a true delta, with the flood flow divided into numerous small components, each of which is completely used up for irrigating adjacent land. Further, each of these deltas is completely land-locked, completely surrounded by desert land. The deltas themselves, however, benefiting by the centuries-long accumulation of fertile sediment brought down from the mountains in the floodwaters, produce good crops wherever sufficient floodwaters are available.

These deltas are all over-developed in the sense that a greater area is diked and prepared for cultivation than can adequately be watered by the normal seasonal floods. The reason for over-development is that large floods destroy the diversion dams at the upper part of the delta, and the floodwater continues on down the stream channel, its volume progressively diminished by infiltration into the sandy stream bed, until the flow becomes small enough to be diverted into the canals at the lower end of the delta. These lower-delta fields receive limited irrigation only once every two or three years-not frequently enough to produce very much. The failure of the upper delta diversions results in much water wasted by percolation in the stream channel and infrequent, ineffective irrigation of lower-delta fields.

The Government of Yemen has become interested in a program of water resource development, with the objective of accomplishing more adequate irrigation on land that is now under-irrigated. The U.S.A.I.D. has been requested to undertake some work that will augment the supply of available irrigation water.

The job to be done is that of taming the floods, controlling them so that flood peak discharge rates will be materially reduced and the period of floodflow extended in time. This calls for regulating reservoirs that will hold back a sizeable portion of the flood volume until some time after the flood peak has passed, subsequently releasing it at a controlled rate that the downstream irrigation diversion structures can withstand.

When streamflow regulation—that is, flood control—has been achieved to the extent that the diversion structures remain intact and keep their canals flowing throughout the floodflow event, there will have been accomplished a very significant increase in the amount of water placed on the fields; and, further, the upper-delta and central-delta fields will receive irrigations more frequently and more adequately. One suitable drainage basin has been selected for the first development project. Construction of the first flood-regulating dam is scheduled to commence shortly.

Other works will be needed in order to conserve the limited water supply as demand becomes more intense in the future. Following the accomplishment of streamflow regulation by regulating reservoirs, the next step is the construction of permanent diversion structures and lining of the canals which they serve. All the normal steps or processes of preparing lateral canals and field water control devices and reshaping the fields into a modern system can become the ultimate goal. For the present only the first step can be definitely anticipated and programmed.

There are other water resources that can be developed for irrigation. There is apparently a very large potential for development of groundwater. There is a cosiderable amount of irrigation from wells in two areas: (1) a mountain plateau area around the city of Sanaa, and (2) a long strip of the coastal plain adjacent to the mountains. It appears probable that the present extent of irrigation from wells can be expanded as much as ten times without an overdraft on the groundwater reservoir. Especially on the coastal plain, there is a nearly continuous strip of land more than 200 kilometers long by 10 to 20 kilometers wide, most of which is believed to be underlaid with groundwater at a depth that usually ranges, at different localities, between 10 and 30 meters below the surface of the land. Here there are large areas of good land, not now productive because rainfall is on the order of 100-150 mm annually, but suitable for irrigation. Any significant national program in the development of well irrigation will require time, skills and capital such that the program cannot be commenced at the present time, however.

DISCUSSION: Durum, or grain sorghum, is the principal irrigated crop. This crop can withstand droughts or intermittent rainfall and still produce better than any other crop. It is the principal food of the Yemeni. The second most important crop is maize or corn. This can be produced only where irrigation water is available essentially on demand. In the mountains where there are small perennial streams, maize is preferred.

The rain begins in March and tapers off in June, starting again in September and ending in November. There is some rainfall in every month; however, the November to February amount ranges from 50 mm. in the north to 100 mm. in the south. The Yemeni farmer keeps his ditches clean and allows no erosion. He permits no run-off from his cultivated land, and indeed captures run-off from adjacent rocky areas. Modern techniques such as plant breeding, pest control and commercial fertilizer are unknown.

CHAPTER V

EDUCATION AND ON-THE-JOB TRAINING

AFGHANISTAN

Education is needed, especially in techniques and in farmer education. Good production of agricultural materials is handicapped because there are not educated farmers. A number of educational projects have been undertaken in the past few years. Groups of extension workers exist to help farmers by giving them advice on the use of water and on irrigation practices. The program is handicapped because of the lack of experienced people who can train farmers. In the future, a great number of technicians at the farm level are proposed. At the end of five years these technicians might take care of at most 20 per cent of the farmer population. 90 per cent of the farmers are not trained and everything is done the customary old way. Irrigation practices are deficient. Modern machinery is not applied to any great extent and then only in modern projects. Use of modern machinery is prevented in many cases by the topography of the country, but where the topography permits, we are trying to utilize modern machinery.

The greatest problem so far is how to operate and maintain and get the most out of those projects which have been constructed by modern machinery. Training is the solution, but the expected capacity is not sufficient, and will not be sufficient for at least ten years. The low rural literacy in the country is the biggest and most important handicap. The Government administrative organizations, including the Ministry of Agriculture and the Helmand Valley Authority, have joined efforts with the farmer for on-the-job training programs.

For the Helmand Valley, extension workers and village improvement workers are also being trained. About 80 have been trained so far by a one-year program. There a limited number of farmers who can be trained. In the last year or so, some water masters and ditchriders have received training-mostly practical training in the operation of canals. A course to train those who are training water masters has been started. These trainees are mostly college graduates; these are in short supply.

DISCUSSION: Extension workers on new projects range from high school graduates to a limited number of college graduates. The standard of literacy among farmers is now only 5 per cent. However, their sons are 90 per cent literate and can be used to convey information to their fathers. An agricultural school was established eight years ago and graduates about 80 per year; an agricultural college was established six years ago and graduates about 30 per year. These numbers are not adequate, however.

CEYLON

The establishment and maintenance of an irrigation project may be subdivided into the following stages, each stage requiring the services of technical officers trained to execute the specialized work in every case: (a) Investigation, (b) Planning and Design, (c) Construction, (d) Maintenance of Completed Work, (e) Water Distribution, and (f) Cultivation Administration.

Although the basic principles of irrigation are the same, the amount of data that need to be collected for the execution of work undertaken will depend on the magnitude of the project envisaged; and the technical personnel that will be required for this full investigation will likewise be relative. The restoration or new construction of a small village irrigation reservoir for the benefit of a small rural community whose wants are few and limited will require less investigation and planning than a large project committed to rehabilitate a large interracial community and to provide all the necessary social and economic amenities.

Execution of the construction program and completing it in all respects will also require the services of technicians trained in their own branches of specialty. The strength and types required depend, as before, on the magnitude of the work undertaken.

Maintenance of completed work, water distribution, and cultivation administration will be more uniform and will therefore be independent of the magnitude of the scheme. The types of personnel required to deal with this aspect of the work will not be so varied as in the two categories aforementioned.

The types of technical personnel required and trained in Ceylon can be categorized into the following:

(1) Engineers
(2) Technical assistants
(3) Civil engineering draughtsmen
(4) Operational staff for foundation investigations-drilling crew
(5) Operational staff for water resources investigation
(6) Soil testers and analysts
(7) Supervising staff for construction work
(8) Supervising staff for maintenance of completed works
(9) Labor supervisors
(10) Cultivation officers
(11) Land development officers
(12) Operational staff for mechanical equipment and machinery
(13) Staff for maintenance and repair of mechanical equipment

1. **ENGINEERS:**

Of late, there have been no direct recruits to this grade. Most of them are promoted from the assistant engineer grade after they have had sufficient training and experience and gain their chartered membership. Direct entrants to the assistant engineer grade are recruited from engineering graduates, invariably from the University of Ceylon, in which irrigation as a subject is not established. They have therefore to gain their experience in the field. With the introduction of new concepts and theories in design and modern methods of construction, the training of the assistant engineer on the job has to be well-organized. Departments concerned with irrigation and its practices made every effort to make the young trainee follow an intensive four-year course in irrigation practices before he is deemed fit to undertake responsible work or be given charge of field work.

The four-year course consists of one to one-and-one-half years of training in field construction. During this period, the trainee is invariably attached to one of the major construction projects wherein he is trained in the method of constructing earthen bunds and channels using heavy earth moving equipment,

its operation and cost, the testing of its specifications in the field, construction of appurtenant structures, labor organization in the execution or its work, costing and completion. The training also includes site investigations and setting out and construction of the distributary system and structures. This involves surveying, foundation investigation, modifying or re-designing of working plans, and perhaps re-blocking-out of already alienated lands to suit the modified system. During the next year of training, he is attached to an office wherein he is trained in office administration and departmental procedure. During the next two years of training, he is attached to a central designs office wherein he is trained in design work, in coordinating and computing the data gathered in field investigations for such design work, and in estimating and costing. The trainee is not given one particular job during his period of training, but is made to shift from one type of work to another so that he gets technical experience in every branch of the work. During this period, he works under the guidance of an experienced engineer.

2. **TECHNICAL ASSISTANTS:**

There are three main established Technical Training Institutes that train junior technical officers. In addition to this, the Irrigation Department of Ceylon has established its own training center. The minimum qualification for a trainee entrant to this grade is a Senior School Certificate with mathematics and mechanics or physics as oftered subjects. To execute the country's development program, **technicians** are absorbed into many branches of engineering. The technical trainee has to follow a two-year academic course in any of the technical training institutes, during which period practical surveying and leveling are taught. Lectures are conducted on the following subjects:

(a) Higher mathematics
(b) Irrigation
(c) Hydraulics
(d) Surveying and leveling
(e) Elementary strength of materials and theory of structures
(f) Simple designs
(g) Mensuration and quantities
(h) Building construction

The training center established by the Irrigation Department places greater stress on practical work during the two-year course, wherein practice in surveying and leveling is given in the course of site investigations, full investigations into the restoration work of ruined irrigation reservoirs, road tracing and designs, and investigations into the proposed improvement to the existing work.

At the end of the two-year period, depending on the results of the final examination, the trainee is appointed to the field as a probationary assistant. In the field his training is in greater detail and is more varied. He is made to assist a senior technical officer attached to a worksite, and may be stationed there for a considerable period. During the course of field training, he may be attached to the Water Resources Investigation Division, the Soil Investigation Division, construction projects small and large, and to a division engaged in the maintenance of completed work. At the end of ten years, he gathers sufficient experience in all branches of irrigation practice and is eligible for promotion to a higher class in the same grade on showing merit in a qualifying, examination conducted by the Department.

3. **CIVIL ENGINEERING DRAUGHTSMEN:**

All three technical schools on the Island train officers for this grade. The minimum qualification for a trainee entrant is the same as that for a technical assistant, but this training course is limited to one year, during which time he is taught the rudiments of applied mathematics and mechanics, practical surveying and leveling. This training is limited to the translation of details from the surveyors' field books and level books for detail drawing, although sanitary engineering and the art of draftsmanship are introduced. His first appointment to a Government department is as

an apprentice and he gains his experience in the various drawing offices attached to the field. Success in the final examination conducted by the department qualifies him to be confirmed in the post. During his apprenticeship period, he is **made to assist** in the preparation of plans from design notes given by the engineer, modify working drawings, prepare plans for minor structures and distribution systems from design data given, or translate the field survey book data into working drawings. Periodic transfers to various worksites give him an opportunity to acquaint himself with every possible type of drawing work. After a given period of years, depending on the department to which the trainee is attached, he must be successful in the senior qualifying exam to gain promotion to the higher class.

4. **OPERATIONAL STAFF FOR FOUNDATION INVESTIGATIONS:**

Drilling crews, soil testers and analysts can be included in this category.

A trainee at this grade is recruited from the junior technical officers, who have to follow a two-year course at the technical training institute. His training consists of one year in the central laboratory, where he is trained to carry out laboratory tests on specimens sent from field. He is also given instruction in the theory, so far as is necessary to carry out these tests. After this period, he is attached to the field, working under the guidance of an experienced technician engaged in collecting specimens in the field, carrying out tests on them to collect relevant data, and carrying out specification tests during construction.

5. **LABOR SUPERVISORS:**

At worksites where large gangs of unskilled labor are employed, the services of labor supervisors are necessary. They are required to control the labor employed on routine work such as clearing of bunds and channels, road maintenance, etc. The only qualification necessary for entering this grade is the ability to read and write and competence to control labor. The more able officers are attached to worksites where skilled work is executed, but in the same capacity. This affords them an opportunity to gain experience in setting out and executing skilled work and the control and distribution of labor.

6. **STAFF FOR SUPERVISION OF CONSTRUCTION WORK:**

Except in the case of very important worksites where specialized superintendence is required by a higher grade of technical officer, the execution of routine work on small worksites and the labor management on larger ones is entrusted to this officer. This grade of officer earns his promotion from the previous one and his admission depends entirely on the merit shown and the experience gained as a labor supervisor, the records of which are maintained in his personal file. During his early stages of training, when he is attached to a work site **under the control** of the senior technical officer, he is instructed in methods of setting out, specifications for different types of work, the rudiments of surveying and leveling, the maintenance of cost records and the proper distribution of labor.

7. **SUPERVISORY STAFF FOR MAINTENANCE OF COMPLETED WORK:**

These officers are promoted from the grade mentioned above, i.e., (6). In the early part of training, these officers are instructed in the control and issue of water and its proper distribution and consumptive rates. As they are a more independent class of officer, they are trained to be competent in the setting out of work, the estimating and carrying out of minor repairs to the distributary system, and in taking measurements of such works.

8. **CULTIVATION OFFICERS:**

The land alienated for development under an irrigation project is under the control of the Revenue Officer of the area, who also

controls the type of cultivation to be done, the extent of such cultivation to be undertaken for the season, and the cultivation period. The direct control of this program and the superintending of its specifications is done by the Village Cultivation Officer, who also acts as liaison between the cultivator and the Revenue Officer. Recruitement to this grade is from the junior technical officers who have undergone a two-year course at a technical institute. The trainee gets his training entirely in the field while working under the guidance of the cultivation superintendent. During his period of training, he is instructed in surveying and leveling, the consumptive rates of water, estimating and executing minor repairs, measurements of completed work and routine administration. After a period of two years, he is eligible for promotion to a higher class if successful in the senior qualifying exam conducted by the Irrigation Department.

9. LAND DEVELOPMENT OFFICERS:

On completion of an irrigation project, the land under it is alienated for development. The land development officer is in charge of the amenities necessary for the rehabilitation of the cultivator in his new surroudings. The trainee is a junior technical officer from one of the technical institutes and gets his early period of field training under the guidance of an experienced field officer. He is instructed in practical building construction and jungle clearing, leveling and ridging of the area to be cultivated and generally in making the land alienated to the cultivator ready for cultivation.

10. OPERATIONAL STAFF FOR MECHANICAL EQUIPMENT AND MACHINERY:

There is a training program for all grades of mechanical engineers and technicians within the department. Although these officials help operate and maintain the many mechanical pieces of equipment and appliances necessary for the field execution of irrigation programs, their work has no relation to irrigation practices, and, as such, no details of their training program will be given here.

In the execution of construction and the maintenance of irrigation works and the practices of irrigation, many technicians of different grades and skills are required. A country that has undertaken a heavy program of development work must have within its organization an organized scheme of training for its personnel.

Countries whose economy is dependent on agricultural development might consider it prudent to establish irrigation as a subject in at least some of their universities, and request these universities to pursue research into new and more efficient methods that may, in time, turn out to be established practices.

DISCUSSION: Considerable discussion arose regarding the role of the revenue officer. The question was raised of whether the revenue officer would give the best cropping pattern from the point of view of the farm because of his interest in tariffs. It was pointed out that the revenue officer is responsible to a farmers' committee. However, he is the chairman. This system may not be the best, but is the law. The problem is mitigated somewhat, however, since only one crop, rice, is ordinarily grown.

INDIA

The India Country Report covered also education and on-the-job training. Further discussion by Mr. Mital amplified these subjects, as summarized below.

In order to provide practical training to engineers and cultivators and to give them more intensive training in irrigation practices, various seminars and conferences are provided. These are organized not only by the departments but by other agencies as well. The village-level worker or gramseval is expected to provide training for the farmer in the field. Schools for village people wherein the use of modern agricultural equipment will be taught have been started. Demonstrations are held both on demonstration farms and in the cultivators' fields. Water-saving methods are demonstrated to the farmers on these farms. Under the «package program,» there will also be facilities for demonstration at the seven chosen sites. We are now using village workers who are farmers trained by the gramsaveks and who can persuade other farmers to follow the advice of the village extension worker. Even so, extension of the work directly to the farmers is the most immediate problem. Setting up farmers' schools and irrigation extension services in all of the states is under consideration. To train those responsible for the training of extension workers, schools are being set up. The first of these will be held in south India next month.

IRAN

The training of farmers is under the Extension Service. There are about 700 extension workers and 200 to 250 agricultural engineers. There are about 200 home economics agents, who work with the women. Specialists are available in the various technical fields. Every year there is a training course and there are regional seminars for training extension people. During the two years, two new agricultural colleges were established, which brings the number to six in the country. These are in Karaj, Dabriz, Shiraz, Abas, Isafan and Meshed. Karaj College has eight divisions, one of which is irrigation. It is a four-year course leading to a degree in engineering. Students work on the farm; there is one 100-hectare farm at Karaj and another one of 500 hectares. Now the agricultural colleges can accept 250 students each year. Under the five-year plan, this will be increased to 1,000 students in three years. The irrigation curriculum includes hydraulics and structures. The Karaj faculty is all Iranian. Faculties in Shiraz and Dabriz contain a small percentage of French, German or American teachers.

There are more than 100 agricultural high schools. Towns of more than 1,000 population also have primary schools where agriculture is taught the fifth and sixth years. Like the 4-H in the United States, and the 4-K in Turkey, Iran also has the 4-T for young farmers. There are two civil engineering schools in Iran in addition to the one at Abadan, which is in connection with the oil industry. There are six science faculties in Iran. Also there is a Polytechnic Institute which has about 18 branches in technical subjects.

There are about 400 secondary schools to which students go after they finish primary school. Students from primary schools may enter one of approximately 100 agricultural high schools. Karaj College has been accepting about 250 students per year, the other colleges only about 25. However, Shiraz and Tabriz have increased this to about 100 this year. About 400 graduates are produced each year, most of whom go to work for the Government, although some go to work for private societies or for farms. Some go on for advanced education overseas. The six universities of Iran accept from 4,000 to 6,000 students each year. Approximately 14,000 are graduated from high school.

JORDAN

The Jordanian Government realizes the need for training in irrigation. Considerable agricultural and irrigation development work has been done recently by both the Central Water Authority and the East Ghor Canal Authority. It has not been possible to start training in irrigation in a formal manner. The new Agricultural College has been in existence for one year and is planning to offer courses in soils, irrigation, drainage and surveying. This would be the start. The East Ghor Canal Authority therefore had to plan a special program of its own to train its extension agents in irrigation. This program served the purpose of training both Authority employees and Ministry of Agriculture employees. This paper will report on this special program. It is hoped that it will be expanded in the future to serve as a training program in other parts of Jordan.

SITUATION

A. The East Ghor Canal Project is an irrigation project designed to irrigate upon its completion about a half million dunums. The first section of the first stage, 34,500 dunums (8,500 acres), was brought under irrigation about nine months ago. Roughly 8,500 dunums never had received irrigation water before. Eighty per cent of the land slopes from 1 to 5 per cent, the remaining less than 1 per cent. The supply of irrigation water for lands of a 1 to 5 per cent slope greatly exceeds the farmers' demand. However, in the future they will have more available land than water for irrigation. Thus irrigation water will become very scarce and each drop of waste will count.

B. **Farmers background and experience in irrigation farming:**
In the first section we have 750 farmers; farms vary in size from 30 to 150 dunums. About 40 per cent of the farmers have been irrigating for some time, about 30 per cent are irrigating for the first time and experienced in farming on dry land, while the remaining have had little experience.

C. **Agents' background and experience:** There are eight extension agents, all graduates of agricultural schools. These have worked an average of five years as agricultural agents in other areas of the country before joining the project. However, none of them has had the experience of working in an irrigated area.

For the reasons mentioned and many others, it is necessary to train our extension agents on the job. Courses so organized are designed to teach these extension agents to do the following things :

1. To read and interpret contour and soils maps
2. To handle simple survey instruments

3. To survey and construct farm ditches.
4. To assist farmers in designing and constructing suitable irrigation systems.
5. To understand methods of water control.
6. To operate simple land levelling equipment.
7. To know the water requirements for different crops and their reltionships to increased production.

PLANNING TRAINING COURSE

A field committee drafts the training program and conducts the training course. In the draft the following are taken into consideration:

1. The type of job or jobs for which agents will be trained
2. Delegation of responsibilities
3. Time, duration and location of training ground
4. Needed equipment and materials

In training, the «clinic» method has proved very successful. Usually one day will be classroom work, then two to three days will be work in the field.

During the past 14 months, four training courses and one seminar were held in the field.

The latest training course took place a month ago. Those trained in the early courses took an active part in planning and conducting this course. The course was attended by eight extension agents for a period of four days. In accordance with the course plan, the division's civil engineer, with the help of extension agents and a surveyor, made a grid map for a farm unit (30 dunums). In the first day of the course, in the classroom with the grid map at hand, agents and subject-matter specialists discussed and agreed upon the following:

1. The soil type of the farm
2. The amount of fill and cut needed for levelling the land
3. The most efficient equipment needed for doing the levelling
4. The irrigation system to be constructed
5. The location of head and tail ditches
6. The best method for controlling water

In the three days that followed, agents and specialists worked in the field, levelled the land, built head and tail ditches, constructed furrows and irrigated the farm unit, using siphon tubes.

THE FOLLOW-UP

For building self-confidence, each extension agent will choose a farm unit, and with the owner's assistance and the subject-matter specialist's supervision, will carry out what he learned in the training course. Unlike other set-ups in other extension service agencies, subject-matter specialists in the East Ghor Project are readily available in the field to train and advise agents in their everyday work with the farmer.

Because of the scarcity of trained personnel in the field of irrigation and the lack of training institutions in the country of Jordan, on-the-job trainning is the only way available to equip extension agents with the skill and know-how that are vitally important for carrying out their assigned duties. However, the Government is planning to send extension agents to training courses outside Jordan where similar projects exist.

DISCUSSION: Two additional training programs were mentioned. Fifteen farmers will go to the United States for three or four months, where they will work on farms in that country. They will then return home, place this new knowledge into action on their farms, and demonstrate it to their neighbors. They are not hired by any Government agency.

Several months ago, a farmer who is paid by the agency was brought in. He will accompany the Extension Agent in his rounds. He will be paid about 38 piastres a day; that is, about 7.50 TL per day. The duration of this training has not been set. It will depend on how much the farmer learns and on his interest. An improvement in this farmer's fields has already been noted.

About 5 per cent of the farmers in the East Ghor Project use siphon tubes, whose use was started only two months ago. The average size of a farm is 30 dunums in the East Ghor (one dunum equals 1,000 square meters). Approximately 50 per cent of the levelling is done by the Authority. However, the farmer is charged for it. The remaining easier part of the levelling is left to the farmer to do.

LEBANON

Most of the problems of irrigation faced by the other countries in the region are not faced by Lebanon. The Lebanese farmer has had much more intensive self-development, so that the problems with which he needs help are different. There is no on-the-job training program in Lebanon. However, there are extension programs belonging to several different institutions. The best-developed extension service is that of the Ministry of Agriculture, which has several extension farms throughout the country, each with several extension agents. Agents are required to be college graduates with degrees from universities in Lebanon, the United States, or Europe. The extension agent does not go out to the farmer; rather the farmer comes to him and asks for help when he needs it. The budget of the Extension Service is about $2,000,000 annually. The extension worker is required to live near the station or in the vicinity and is given extra salary for hardship conditions. The American University of Beirut has a pilot extension program in the Bekaa serving about 11 villages, these villages having populations of 1,000 to 2,000 people each. The extension worker resides at the University farm in the valley. Again, this agent responds only when a farmer requests his help.

Many of the more well-to-do landowners hire private consultants to assist them with their agricultural programs. Most are not full-time consultants but are connected with equipment distributors.

Most of the land now under cultivation has been irrigated since time immemorial. With the development of new projects, such as the Litani Project, new land will be brought into production. The Litani Authority is considering setting up a separate extension service. Several stations are contemplated, with two agents at each station: one general agricultural agent, one irrigation agent. Under this arrangement, the extension agent will go directly to the farmers where new land is being brought in.

There are some training programs for extension workers coming from other countries, particularly at the American University, where there is a one-year training program having about 50 graduates annually. This program presents a general course in agriculture with emphasis on the elective subjects in which the student may be interested. This course has been going for several years and it is hoped that it may continue.

DISCUSSION: Extension assistance is rendered primarily on technical points such as disease, varieties, etc., and there is a considerable amount of soil testing. A question was raised regarding the relative merits of having the extension agent go out to the farmer or having the farmer come to the office with his problems. It was suggested that this depends quite definitely on the nature of the problems to be solved. Extension workers need to go out to the farmer, especially where new land is being brought under irrigation. There are intermediaries who transmit information,who do not have college degrees; however, the answers in specialized areas are furnished by college graduates.

PAKISTAN

The two main agents of agricultural production are soils and water. Agricultural rotations are the most important factors on which results will depend. Pakistan has been trying for a number of years to help the farmer on all three of these points. For water, their agents are known as overseers. These have a three-year diploma from an engineering course beyond high school and are trained for a few months in the Irrigation Department. Their responsibility is to make a certain amount of water available at the gate, based on a fixed schedule already decided upon. In case of rain, the gates are closed and this fact is transmitted through channels to headquarters. The overseer is stationed in the field, not at headquarters.

For soils, there are two departments: one, the Agricultural Department; the other, the Irrigation Department. New personnel are employed on the basis of an examination and are trained in the use of the soils under experienced officers in these two departments. The Irrigation Department specialist is concerned primarily with soils. The Agricultural Department specialist is a general extension worker and must handle a great many subjects, including pest control, fertilizer, etc.

Recently agricultural development corporations were formed in both provinces. The extension work has been earmarked for these new agencies. Nevertheless there will still be some work in the anti-salinity and anti-waterlogging project areas under the Soil Reclamation Board, which gives three months of training at headquarters dealing with various subjects connected with the use of water and soils. As an example, a 100,000 acres project will provide a graduate extension agent at headquarters. This man will be trained in agriculture, especially in soil and water. Under this man there will be extension workers responsible for areas of from 10,000 to 20,000 acres. If an extension worker meets a problem he cannot solve, he discusses this with the other extension workers in the area. If this fails, it is referred to the project extension agent and, if necessary, to general headquarters. The Soil Reclamation Board has worked out a schedule of reclamation procedures which is given in detail to the extension agents.

The situation in West Pakistan will be complicated by the introduction of well water into the supply. In case water delivery schedules are not met, extension workers have been trained to assist farmers in using the best practices during this time. More than half of the water supply will be groundwater and it will have a variable quantity different from that of surface water.

An effort is made to arouse the interest of the cultivators by discussing the program with them and inviting cirticism and suggestions from them. Competitions in certain types of crop yields leading to prize awards are established. A leadership program whereby certain leading farmers are invited to work with the extension staff has given good results. Extension people must visit the farms and try to interest the farmers in following improved practices. Extension work is also done by the Revenue Department, because of the personal relation between the tax collector and the farmer. The projects are good; the question is whether the blueprints are being carried out on the land or not. The progress of extension is measured by the bushels of wheat produced. The extension worker is the link between the technician and the farmer. We have only created this link in the last 10 or 15 years. This link can be successful if we can produce confidence in the extensionist and if the extensionist can produce confidence in the farmers. The number of farmers served by a single agent is about 166, on an average. One function of the extension worker is to prevail on farmers to produce crops which might result in foreign exchange, even though these may be less profitable than other crops.

TURKEY

One of the most important factors for increasing agricultural production is irrigation. Only wise and technical irrigation will pay. This requires qualified personnel. This paper will report developments in the past two years for professional and sub-professional personnel.

Training Activities within the Soil Conservation and Farm Irrigation General Directorate (Topraksu), Ministry of Agriculture

TRAINING CENTERS

Two training centers have been established to train professional and sub-professional personnel who are already employed and those who will be coming into Topraksu General Directorate. One is at Tarsus (1961) and the other is at Izmir (1962).

TRAINING OF PROFESSIONAL TECHNICIANS

I. General Courses:

For technicians employed in Topraksu General Directorate, a general course that will take 2.5 months is given to introduce the subject matter and duties of the organization and at the same time to give Topraksu an idea of the branch in which each person will be best qualified.

In these general courses, the technicians receive brief instruction in the following subjects:

1. Engineering surveying
2. Mathematics
3. Project planning and design
4. Geology
5. Soils
6. Cartography
7. Farm irrigation
8. Land reclamation and drainage
9. Agricultural economics
10. Soil and water conservation
11. Administration

In the three courses held in 1960-1962, 102 technicians were trained.

II. Special Courses:

After taking the general courses, professional technicians will go to their own working places and undertake practical work under the direction of qualified technicians. Later they will be trained in the special subject-matter on which they'll be working. Special courses are held in the following three main subjects:

1. Soil
2. Engineering
3. Farm planning

A. Special Course in Soil:

The technicians to be employed in soil surveying are trained in this course. The course term is 2.5 months. The program outlined below is followed:

a. Function of soils in growing plants
b. Soil formation
c. Soil classification
d. Soil maps
e. Soil, water and air inter-relationships
f. Organic matter and soil fertility
g. Characteristics that affect the lime requirement of soils
h. Development of the soil
i. Introductions to soil groups
j. Duties and responsibilities in national soil survey cooperative works
k. Land use capability ratings

Ten technicians have been trained in a recently-held special soil course.

B. **Special Course in Engineering:**

Technicians to be employed in engineering work are trained in these courses. The term is 4.5 months. This course is largely based on project studies.

The subjects within the training program are as follows:

a. Mathematics
b. Hydrology
c. Hydraulics or fluid mechanics
d. Mechanics
e. Soil foundation mechanics
f. Dams
g. Soil conservation and irrigation structures
h. Construction materials and techniques
i. Engineering drawing
j. Irrigation
   1. Irrigation and its importance
   2. Factors to be considered before irrigation
   3. Climate-soil-water and plant relationships
   4. Time of irrigation and quantity of irrigation water to be applied
   5. Irrigation water
   6. Pumping for irrigation
   7. Irrigation methods
   8. Preparing the land for irrigation
   9. Application of irrigation
   10. Irrigation layout
   11. Planning and designing farm irrigation projects
k. Land reclamation and drainage
   1. Importance and function of drainage in agriculture
   2. Soil factors related to reclamation and drainage
   3. Climate and drainage relationship
   4. Types of drainage systems
   5. Depth and spacing of drains
   6. Types of drainage structures (installations)
   7. Outlet for drainage systems
   8. Drainage investigations
   9. Drainage theories and solving special problems
   10. Planning and designing of farm drainage projects
l. Soil and water conservation
   1. Principles of soil erosion
   2. Control of wind erosion
   3. Contour farming
   4. Vegetative outlets and waterways
   5. Terracing
   6. Bench terraces
   7. Contour trenches
   8. Gully control
   9. Earth embankments and reservoirs
   10. Flood control in small watersheds

A special course in engineering has not been possible up to this time, but one is planned for this year. At present, the course instructors are preparing lecture notes.

C. **Farm Planning**

The course program for the training of agricultural engineers in the field of farm planning isn't ready yet. For the time being, studies are in progress.

D. **Training Sub-Professional Technicians**

Technicians who will work as helpers to the engineers are trained in the courses established in training centers. Graduates from high school or the equivalent participate in these courses. In a topography course (surveying) established in 1961, 32 technicians were trained.

E. **Instructors for the Courses**

There are no specified instructors at the training centers. The instructors giving the lectures during the courses are those qualified people in the Topraksu Organization who have the ability to teach.

Training of the Research People

Agricultural engineers employed in Irrigation Research Institutes or Stations and in the Soil Re-

search Institute are trained in short-term courses in research methods and techniques and recent improvements.

Training Technicians in the Extension Service

The training of agricultural technicians employed in the Extension Service is among the programs prepared by Topraksu regional offices. They are trained in such a way that they can give technical help to farmers. These practical courses are short-term (one to two weeks).

Training of Farmers

The training of farmers is done through demonstrations, farmer publications, and radio broadcasting. In 1961 training camps were established for young farmers who had completed their military service. During the camping period, the young farmers were given on-the-job and classroom training in soil conservation and were also paid for their work. Such camps will also be established for the purpose of giving farm irrigation training.

Training Activities in the State Hydraulic Works General Directorate, (DSI), Ministry of Public Works

The qualified sub-professional technicians required by the DSI General Directorate, who can't be secured from abroad, are trained in the DSI training center as topographers, welldrillers, surveyors etc. According to the subject matter of the courses held, graduates of high school or the equivalent and of secondary or primary schools are employed to be trained. Those people who come into DSI are selected according to their education, military service and age. Each of these groups is trained in different courses. Those people who are working in the organization are trained in courses outlining recent improvements. The term of the courses is generally one to eight months. The instructors are engineers, geologists or administrators within the DSI organization.

During 1960-1961, of the 780 sub-professional technicians trained, 726 were successful in these courses. In 1962, 206 technicians are being trained in various courses.

DISCUSSION: One or two-week courses for extension training are repeated each year. As people gain experience these repeat courses may contain some new people or they may be the same ones. The Topraksu course for technicians lasting two and a half months cannot cover all of the field in one session. It was indicated that these also are repeated as personnel gain experience. In reply to a question about the reaction of farmers to the extension workers, Mr. Yegin stated that although the extension service is quite old, it has encountered difficulties because most of the farmers did not have the resources to do what the workers suggested.

YEMEN

Yemen is looking forward to the establishment of an operating program in agricultural development. Up to now, the Ministry of Agriculture has not been sufficiently staffed or provided with facilities and funds. There are no educated and trained agriculturists in the Government.

The Government is keenly aware of the necessity of acquiring skills through on-the-job training. On the currently operating program of road construction being carried out by U.S.A.I.D., each equipment operator, mechanic or technician has a young Yemeni trainee beside him, on full-time employment, for the purpose of training this man in doing this particular job. This On-the-Job Training Program is already showing results; in less than one year's time, some of these trainees have become qualified operators, craftsmen or technicians.

The program in water resource development will likewise carry on a program of on-the-job training.

SCHEME FOR TRAINING SPECIALISTS FOR MINOR PROJECTS AND WATER USE IN INDIA

by

Mr. Jagat Kishore Jain[1]

The total irrigated area in India at present is of the order of 65 million acres. This area is the highest in the world after China. More than 50 per cent of this irrigation is contributed by minor projects like dug wells, drilled wells, small tanks (storage works) and diversion schemes. These minor projects are scattered in large number all over the country. They have many advantages over irrigation projects of bigger sizes. They require comparatively smaller outlays, take less time in construction, yield quicker results and aim at maximum utilization of local resources of man and material. Considerable importance and priority are, therefore, being given to these projects in India's five-year development plans.

Although minor projects are small, they also involve certain special types of problems, in construction and maintenance as well as operation, which require special knowledge. For instance, a dug well is a small structure which is fairly easy to construct under normal conditions. However, to decide where the well should be located, what its size should be, which particular layers of water-bearing strata it should tap, at which particular sub-strata the straining walls of the well should be left, and what particular water lifting appliances should be installed for raising water from this well, specialized technical knowledge is required. When construction of such works is undertaken in large numbers, timely adoption of such measures as may prevent undue over-draft of ground-water supplies and other similar hazards becomes very important. These again pose problems of a technical nature.

Similarly, design and construction of other minor projects, such as tanks and diversion works, introduce new problems. If the same design criteria and construction techniques usually adopted on major works are made applicable to these smaller works also, it is likely that their cost would be unnecessarily high. In the case of minor works, calculated a risk to a somewhat greater extent can be taken without leading to untoward damage or loss. It therefore becomes important to evolve a new set of design criteria and construction techniques for these works. All these works require trained personnel who have been specially oriented for the purpose

The engineering departments in the various States of India are well-equipped with fully-qualified and experienced engineering graduates and diploma-holders. They have, no doubt, adequate experience and competence to handle all the problems that arise in the execution of minor irrigation works. However, most of the minor projects come in the category of private works owned and maintained by individual cultivators or groups of cultivators, outside the State departments. The State Engineering Departments, moreover, are fully occupied with the construction and maintenance of bigger irrigation projects and have neither the time nor the staff to look after all the categories of minor projects which are scattered throughout the country.

There is considerable opportunity for improvement in India of the distribution and application of water. The irrigation engineers usually finish their role after construction of the works that deliver the irrigation supplies to the outlets. Water

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management beyond the outlets has not so far received the attention that it deserves. The cultivators usually adopt age-old methods and practices, which are wasteful of irrigation water. They do not possess sufficient technical competence to align and maintain the field channels properly and to prepare and level their fields in a scientific manner. A substantial portion of the water delivered at the source or at the canal outlets is lost in the distribution system and in the fields. Even that part of water that is used for meeting the consumptive requirement does not always yield optimum production, as the time and quantity of irrigation application is not scientifically adapted to the crop requirements. There is a general shortage of knowledge and personnel trained in the subject. Even the staff engaged in the community development blocks is not always fully conversant with these problems. The need for proper technical hands, who may function as effective extension workers in this direction, has become urgently pressing now, when new irrigation possibilities are being created at an unprecedentedly fast rate.

The above considerations lead to the conclusion that extension and other technical staff who come in intimate and direct contact with the cultivators and are concerned directly or indirectly with implementation of minor projects and promotion of the optimum use of irrigation water, should be properly oriented to deal with and advise on all problems that arise in the field on these subjects. To fulfil this need, the Government of India has sponsored a scheme for training on minor projects and water use during the Third Plan.

OBJECTIVES AND SCOPE OF THE SCHEME:

It is proposed to provide practical training to agricultural inspectors, engineering overseers and other staff of equivalent status engaged in the extension blocks and other departments, on works connected with minor irrigation and agricultural development. Among the trainees will be included: (a) the instructors who are in charge of the pre-service training of the village-level workers at the training centers; (b) the instructors in charge of the in-service training of village-level workers (which is a sort of refresher course for existing village-level workers likely to be taken up in the Third Five-Year Plan). These instructors will then be expected to give due attention to the important problems of minor irrigation and water use while they impart training to village-level workers. The benefits of the scheme would, thus, be extended to village-level workers.

PERIOD OF COURSE; NUMBER OF TRAINEES; SYLLABUS AND CURRICULUM

With due consideration of the objective and scope of the training program and the calibre of the proposed trainees, the scheme provides that each individual course may have a duration of three months or so, and that there may be three courses in a year at one training center. Each course would have about 30 trainees. Although, the curriculum will include lectures on theory, emphasis will be on practical training under field conditions. It is reckoned that a course lasting three months will roughly include about 150 hours of theoretical lectures and about 210 hours of practical training. In the delivery of lectures, liberal use will be made of visual aids, such as the showing of technical films and slides especially prepared for the purpose and the display of charts, diagrams, maps, etc. It is also proposed to distribute to the trainees, in addition to the notes taken by them, copies of papers carefully prepared for the purpose on various subjects pertaining to the course. These papers will contain useful material to which the trainees may freely refer in discharge of their duties after they have returned to their jobs.

The syllabus will broadly include the following subjects:

1. Minor irrigation schemes-scope, objectives and salient technical features of different types of schemes.
2. Open wells, their design, construction, boring and deepening.
3. Water lift appliances-different types of manpowered, animal-powered and mechanical-powered appliances in vogue; their design, construction, comparative performance and water output ; scope for further improvements in their design.
4. Design criteria and standards for construction and restoration of tanks, storage works and diversion schemes.

5. Surveys, levelling and investigations for minor irrigation works and preparation of fields.
6. Operation and maintenance of irrigation works, regulation of supplies and restoring of channels, concepts of duty, depth, water allowance, outlet factors, etc., crop planning for maximum production with available supplies in the irrigation system.
7. Plant-soil-water relations, the physical and chemical properties of soil, the suitability of soils for irrigated farming, the need for and advantages of scientific crop patterns; suitable crop rotations; the water requirements of different crops under varying conditions of soils and climate; crop evaluation in the field.
8. Irrigation methods and field preparation-selection of irrigation methods for cultivation of different crops under varying conditions of terrain and soils; levelling and preparation of fields with improved implements and in a scientific manner; fixation of field size and slope according to soils intake-rate and discharge of the water course.
9. Irrigation farm structures include water distribution, regulation and measurement-alignment, construction and lining of field channels; cheap designs for and construction of field channels, crossings and falls. The parshal flumes, wooden regulating boxes, canvas dams and syphon tubes, gated pipes and other devices for measuring water supply to fields are used.
10. Soil and water conservation practices-contour bunding; terracing; gully plugging, etc.
11. Drainage for water-logging; quality of groundwater; salinity and alkalinity problems and their cure; the taking of soil samples for salinity and alkalinity examinations; the taking of water samples, their collection and despatch; the taking of leaf samples, their collection and despatch; recognition in the field of saline soil and alkaline soil and deficiency symptoms to accompany the leaf samples are important parts of the syllabus.

LOCATION AND ORGANIZATION OF TRAINING CENTER

The scheme is being organized on a regional basis and each State is likely to have one training center in its territory. The syllabus at each center will be slightly modified and adapted to meet the special requirements of each region according to its local conditions and problems.

Responsibility for implementing the scheme will rest with the State Governments. The training center will be located at one of the existing agricultural colleges or research institutes considered most suitable for the purpose by the State Government. The principal head of the college institute will be in over-all charge of conducting the training course.

STAFF FOR THE TRAINING COURSE

The scheme envisages that at each training center some extra staff, including two specialists, one of whom may be an engineer with an adequate background in irrigation and the other an agronomist with a necessary background in soils and land management practices, will be provided. The authorities of the college/institute may appoint the specialists either from their existing staff, on deputation from other departments or by fresh recruitment. The work of these specialists may be supplemented by frequent lectures by the permanent staff of the institute, for which the latter may be paid some honorarium, as provided under the scheme. The scheme also provides for other essential staff, such as demonstrators, field superintendents, mechanics for up-keep of the implements, chain-men, field-men, laboratory attendents, etc., that may be considered necessary by the college/institute for effectively conducting the course in a proper manner.

EQUIPMENT — INSTRUMENTS, IMPLEMENTS, TOOLS AND MODELS REQUIRED FOR TRAINING PURPOSES:

The scheme provides for purchase of special equipment, such as instruments, implements, tools, models, etc., that may be required to fulfil the prescribed curriculum of the training course. Provision for recurring expenditures for the operation of models, the maintenance and repair of equipment and the regular display of such experiments and de-

monstrations in the fields and laboratories as may be required under the prescribed curriculum, has also been made under the scheme.

ARRANGEMENT FOR THE TRAINEES:

The State Government will make arrangements for deputations of 30 trainees in each successive course. The trainees will be entitled under the scheme to a training allowance, not exceeding 20 per cent of their basic pay, during the period of training, but the travelling allowance to and from the place of training will be borne by the State Government from sources outside the provisions made under this scheme.

PRELIMINARY ORIENTATION OF THE INSTRUCTORS:

As the proposed training is of a specialized nature, with particular emphasis on the practical aspects of irrigation problems in the field, it is considered necessary that the instructors and other staff of the institute/colleges who are selected for conducting the training program at each center, should themselves undergo in the first instance a sort of preliminary orientation training. For this purpose, training sessions are being arranged at suitable locations in the country. The main objective of this course will be to impress upon the instructors the real purpose and scope of the training they will be required to impart at their centers under the training scheme. Specialists working on the subject of irrigation in various departments of the State Government, the Government of India, the universities and the colleges, and the foreign specialists working in this country under the A.I.D. or the Ford Foundation, have been invited to give lectures to the trainees under this course.

PROGRESS OF THE SCHEME:

It is likely that training centers in about ten States will start functioning during the year 1962-63. The scheme may acquire full tempo by the end of the year.

DISCUSSION: In the beginning, the level of education for those accepted in the training program will be engineer overseers or agricultural inspectors. The function of the trainees will be to both construct and operate small, minor projects. The specialists trained may be employed on either Government or privately owned projects. If a private cultivator wants to take up a minor project, these personnel will render assistance to him.

TRAINING IN IMPROVED IRRIGATION PRACTICES IN MYSORE STATE, SOUTH INDIA

by

C. Ramaiah[1] and George C. Knierim[2]

Training in water use has been given increased emphasis in Mysore State, South India, during the past three years. Mysore is an area of low-income farmers; therefore, all levelling on the demonstrations was done with bullock-drawn implements. Fourteen Irrigation Workshops of seven to ten days in duration have been held, with 400 Soil Conservation, Agricultural Extension, and Community Development staff members in attendance. Demonstration fields have been laid out and levelled on 40 farms. More than 4,000 farmers have attended Irrigation Field Days. Progress has been slow, much remains to be done, but farmers are interested and the future is bright.

India is rapidly developing new irrigation facilities. Fourteen large dams and a great number of small projects will give India 120 million acre feet of irrigation water annually by 1966. This development brings problems. Farmers must be taught water use and drainage. Land is being ruined by water logging. In some new areas, 60 per cent or more of the water is wasted after it reaches the fields.

In Mysore State, experience thus far leads to recommendation of contour border strip irrigation as the method most acceptable to the Indian farmer's condition and suitable for all crops. Where row crops are grown, furrows must be made between the rows within the border strip. While there is no one method best for all farms, the contour border strip method has proved best with the low standards of farming practiced. Crops include: rice, sorghums, cotton, millets, sugar cane, maize, groundnuts, and vegetables.

The Mysore method of contour border strip irrigation is very low in cost. Land has been levelled in strips 33 feet wide on smooth slopes of a 2 per cent gradient at a cost of Rupees 30 to 50 per acre ($6.00 to $10.00). This is in contrast with Rupees 200 to 300 ($42.00 to $63.00) or more required by the conventional, small basin method normally practiced.

Furrow irrigation and contour ditch irrigation have also been demonstrated. These methods both have merit, but border strips are recommended. Also, with high intensity monsoon rains, border ridges will stop erosion on the cross slopes and provide uniform surface drainage. The Indian farmer needs permanent markers in his field to keep his rows in proper gradient.

In contour border irrigation, advantage is taken of the natural topography of the land to minimize levelling. Sometimes compromises on gradient must be made and strips of irregular length are unavoidable. Where cost is a primary consideration, this method has merit.

In preparing land for contour border strip irrigation by the Mysore method, procedure is as follows:

I. LAND PREPARATION

A. Land is plowed thoroughly and clods are broken.

B. Preliminary scraping of high areas and filling of low spots is done, using wooden buck scrapers.

C. Fields are floated crosswise and lengthwise for maximum smoothing.

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II. LAYOUT OF FIELD

A. Survey and map elevations at 50 feet intervals (cross sections). Draw map showing 1-ft. contours.

B. Study map to decide proposed irrigation layout.

C. Stake out a base (or key) line, in middle of field at 50 ft. intervals, giving suitable gradient for soil type. (About 0.2 per cent or 0.1 ft. per 50 ft. is the average gradient.) Refer to Table 1.

D. Smooth out curves in the base line to facilitate farming operations. It is best to move several stakes a short distance rather than move one stake a long distance. As a general rule, a maximum 3-ft. change of alignment is allowed.

E. Decide width of strips and mark parallel lines above for two strips and a like number below, thus laying out the first four strips. A good strip width is 33 ft[1].

F. Check and record levels at 50-ft. intervals down the middle of each strip. If the gradient is fairly consistent, continue to draw parallel strips until the entire field is laid out. If alignment does not have proper gradient, lay out a new base line, insert some short strips to fill the gap, and make parallels to the new base line.

G. After all lines are marked with furrows, border ridges are made with a wooden A-frame border ridger in preparation for levelling.

III. LEVELLING AND REMOVING CROSS-SLOPE BY MYSORE METHOD

A. A bullock-drawn scraper is worked back and forth across the entire field at right angles to the border strips. Bullocks will be walking up and down the slope the entire width of the field. Ridges will be made going up hill and the strip levelled going down.

1. In scraping **down hill,** soil is cut from the upper half of the strip, carried across the mid-point and slowly smoothed out within the lower half of the strip. **No soil** is deposited **on lower border ridge.**
2. On the return trip **up the slope,** pass two-thirds of the distance across each strip and start loading 10 ft. below each border ridge. Load scraper heavily and dump it **exactly on the border ridge.**
3. Loose soil will be removed by levelling. Only the upper half of border strip should be plowed again as the work progresses.
4. When side fall has been removed, check levels again throughout the length of the strips. It may be necessary to do some levelling up and down the length of the strip to insure a continuous gradient for irrigation and surface drainage.
5. A border strip may be dead level for 100 ft., provided there is a gradient below to allow water to flow.
6. Occasionally, much levelling can be saved by taking advantage of a gully in the middle of a field for natural drainage. Each half of the field is laid out separately and irrigated from opposite sides with the flow toward the natural drain.
7. Each border strip should be floated lengthwise for final smoothing before irrigation.
8. Irrigation water is applied to each strip. Two laborers can easily scrape the high spots with

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1 Refer to Table 1 for border strip width, gradient, and length.

shovels, thus completing the leveling operation.

9. Strips should be plowed again before crop is planted.

IV. HEAD DITCH AND DRAINAGE DITCH

A. Construct head ditch along upper side of field. Use V-ditcher after plowing a furrow.

B. Fill ditch with water and cut off flow. This allows ditch to settle before use.

C. Install drops in ditch at 1-ft. vertical intervals on steep slopes to avoid erosion of channel. Drops may be made of thin stone slabs, old oil drums, or scrap lumber.

D. Use canvas dam, turn-out gates, and bamboo spiles for water control.

E. Make drainage ditch at lower end of field to carry off excess irrigation water and monsoon run-off. Bamboo spiles or clay pipes are useful to bring water from border strips to drainage ditch.

V. WIDTH AND LENGTH OF BORDER STRIP

A. In Mysore State, border strips 33 ft. wide, or 20 ft. on steep slopes, are recommended. This width has the following advantages:

1. Acreage may be calculated easily. It is half a chain wide. Multiply the length of the strip in feet by 0.00076 to get the area in acres.
2. Farmers usually ask for wide strips, 50 ft. or more; so this is a good compromise.
3. Levelling costs are about one-half as much for 33-ft. strips as for 50-ft. strips. For information concerning gradient see Table 1.

Usually a 1-inch depth of water will wet sandy soil 12 inches or more deep; loam soil, 6 to 10 inches deep; and clay soil, 4 to 5 inches deep.

TABLE 1. BORDER LENGTHS IN RELATION TO SOIL TYPES

Nature of Soil:	Gradient:	Length of Border Strip:
Sand	.5 to .7 per cent	300 ft. or less
Mixed soils or loam	.2 to .4 per cent	300 to 600 feet
Heavy clay soils	.1 to .2 per cent	600 to 1200+ feet

DISCUSSION

Skilled operators are not needed. Experience has shown that an illiterate bullock driver may be trained in one-half day. The soil on the upper half of each strip is plowed to loosen it. It has been found advantageous simply to lay out the parallels for the terrace boundaries with a plow furrow rather than staking. Head ditches are run at the desired location and drops are placed as required. These drops are one foot high. A good drop may be made from a rusted-out petrol barrel. The slope of the head ditch between drops is dead level. Of 40 fields which have been levelled, 32 have been laid out by trainees, who have also conducted 14 training sessions. After one month of training, trainees may lay out fields for their farmers.

CHAPTER VI

NATIONAL ACTION FOR IMPROVED IRRIGATION PRACTICE

LOCAL IRRIGATION DEVELOPMENT METHODS AND CUSTOMS IN TURKEY

by

Mr. Yilmaz Karataban[1]

INTRODUCTION

The irrigation systems discussed in the following text are those small in size but great in number scattered throughout Turkey. Today these are administered and run by completely local organizations.

Because of their large number and mostly inaccessible locations, the statistical data related to such things as the quantities and qualities of their water and soil resources, the kinds and yields of crops produced, etc., could not be accumulated as complete and definite figures.

Another difficulty encountered in determining the area covered by this type of irrigation was the large-scale annual change in the total quantity of applied water because of uncontrolled sources, and the consequent variations in water quantity used per decare and in area irrigated.

However, a survey, which was started in 1959 and completed in 1960 by General Directorate of State Hydraulic Works, showed that there were 828 local irrigation enterprises and that approximately 4,200,000 decares of land were being irrigated by such operations. The total discharge of water applied to these lands was 450 cubic meters per second. Since the lands irrigated by local irrigation enterprises comprise an important total next to the lands irrigated by State operations, a three-year program was prepared and studies under this program started in order to accumulate more detailed data. The result of initial studies gave the impression that the above figures would increase.

HISTORY

In Anatolia, where great civilizations were founded and developed, the history of irrigation goes back to ancient times. Although the irrigation operations in Anatolia do not cover vast pieces of land as do those in Mesopotamia, their characteristics, from the standpoint of project planning and construction, may still be interesting to modern hydraulic engineers.

For instance, the Geyre-Eymir tunnel, transferring the waters of the Akçay (Akchay) Valley to the Karacasu Plain, and the old water tunnel transferring the waters of Golcuk, Isparta, to the Isparta Plain, may constitute typical examples of the problems of modern hydraulic engineering in transferring water from basin to basin. Also the Sihke Doni and Faruk dikes may be examples of dam construction and the Malatya-Besni-Kaysun irrigation system an example of groundwater irrigation through gravity.

Although there are more ancient ones, most

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of these works were constructed, preserved and developed during the day of the Romans and later on by the Seljuks and Ottomans. During the study of these old irrigation operations, it was noticed that various customs and methods of our time had been inherited from those days.

Even though there is unusual difficulty in finding written documents concerning the older ways, the Royal Registers containing the principles for the operation and administration of the irrigation systems inherited from the Ottoman Empire are still preserved in the State Archives. These principles had legal authority, since they were approved by the Ottoman Emperors. The Registers average 400 to 500 years old. The survival of these irrigation operations has been achieved through the significant attention paid to them and to some of the principles applied to their operations both by Seljuks and Ottomans. In those days, the inspection of irrigation operations by state authorities from time to time, the prohibition of iniustices and/or wrong applications of irrigation principles, and the consequent placing into effect of new and more upright principles by registering them in the above-mentioned Royal Books and later submitting them for the Emporer's approval, were customary procedures.

As an example of this type of code, which today may be called «Instructions for an Irrigation Operation» an irrigation statute which goes back 700 years to the Seljuk time and which has been copied from a 450-year old official book is presented below. The language employed has been simplified:

Water trenches of the town of Erzincan, Detailed Register, Province of Erzurum, No. 40, Page: 108.

«Some village lands and farms in the above-mentioned province execute an irrigation on the basis of 14 turns since the very old days and, in the meantime, though the village Perman had two day and two night-time turns, upon the villagers' application stating that the amount of water they received was not enough for the increased population of the village, the situation has been investigated locally, and their reason has been found to be correct and 3 day and 3 night-time turns have been determined for the said village and the fact has been recorded in the Royal Register.»

Çakirman (Chakirman) Trench

Village Çakirman		Village Köşnigar*		Village Islami**		Village Şeşne***	
Day	Night	Day	Night	Day	Night	Day	Night
3	3	1	1	3	3	1	1
(Turn)	(Turn)	(Turn)	(Turn)	(Turn)	(Turn)	(Turn)	(Turn)
1	2	3	4	5	6	7	8

Şeşne Farm		Kalenderhane Area.		Village Perman	
Day	Night	Day	Night	Day	Night
1	1	1	1	3	3
(Turn)	(Turn)	(Turn)	(Turn)	(Turn)	(Turn)
9	10	11	12	13	14

* **Keushnigar**

** **Islyami**

*** **Sheshne**

The basic principle in today's modern understanding that water resources are public property, and that they are in the possession and under the authority of the state, was a point adhered to with great care by the Ottomans five or six hundred years ago. Likewise, there are numerous judgments in the above-mentioned books stating that in some years, because of a water shortage, the villagers residing in the upper section of the stream violated the rights of lower-section residents and that influential and wealthy individuals oppressed the others by taking the day-time turns and even selling the water to them, and, further, that such actions were in violation of laws and had to be prohibited.

Thus, the following definite provision has been included in the chapter dealing with the water rights of the Royal Register No. 14, dated 1583: «Water is not the property of anyone. Selling it is a violation of the law. Administrators must prohibit and eliminate such actions.»

LOCAL ORGANIZATIONS ADMINISTERING IRRIGATION

It has been noticed that local irrigation systems are run by different types of local organizations. Those listed below are considered to be interesting:

a. Village eldermen's committees
b. Municipalities
c. Land-owners' cooperatives, although there is no official partnership statute among the cooperators
d. Water-users' unions headed by village mayors
e. Unions, including village mayors who are water-users too
f. Rice committees
g. Capital investing companies acting in accordance with their partnership contracts with the villagers

A majority of the administrative organizations are village eldermen's committees. This result is quite natural for Turkey, because in the villages, which constitute the smallest administrative units, the village eldermen's committes, next to the elected mayor of village, are equipped with vast authority . Such authority may even cover the establishment of obligatory service in order to provide the common necessities and solve the common problems of the village. Municipalities occur in places where the population is larger and which have progressed so as to require other municipal services. In their administration there is an elected mayor and a municipal committee, as in the case of a village eldermen's committee.

IRRIGATION FEES AND THEIR COLLECTION

In practice, the irrigation fees collected meet only operation and maintenance costs. If maintenance activities are handled by the villagers cooperatively without any charges, no fees are collected. Some typical forms of fees and their collection methods are indicated below:

a. In pumping irrigation, the cost of motor-pump fuel only
b. A charge equal to 1 to 2 per cent, or in some places 12 per cent, of the product
c. A charge per hour of irrigation (This charge varies from 10 to 60 kuruş)
d. One hundred and eighty kilograms of cereal crops for a 24-hour irrigation
e. Various monetary amounts as aids to a village fund
f. One grat* of wheat or two grats of corn per decare in return for the labor of water carriers
g. A charge per decare according to the kinds of products

HANDLING OF OPERATION AND MAINTENANCE

In most cases, the maintenance of irrigation canals is carried out by villagers cooperatively. Especially in the irrigation systems administered by the village eldermen's committees, maintenance activities are also handled by these committees. In larger-sized systems, the General Directorate of Hydraulic Works helps them. If the maintenance work is paid for by the Government, this cost is reflected in the irrigation fees. Some typical maintenance organizations are indicated below:

a. Together with the village eldermen's committees and the villagers

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* **Grat: An Ottoman measure.**

b. By municipalities
c. By a contractor
d. By the irrigation union
e. By the farmers cooperatively
f. By the mill-owner

METHODS OF WATER DISTRIBUTION AND APPLICATION

In most cases the rotation system is applied in distribution of water. Hourly, half-daily or daily turns are applied. The distribution principles are determined by the administrative authority and the services of waterworks laborers are utilized. In localities where the amount of water is insufficient compared to the amount of land, restrictions are put on the size of the land to be irrigated; thus, for instance, irrigation of only 30 decares of land is permitted.

The appication of water to the land changes according to the kinds of crops, and mostly flooding and furrow irrigation methods are utilized. In irrigation of rice fields, the method of borderstrip flooding is applied and, in order to avoid malaria, the field is irrigated periodically.

The distribution of local irrigation enterprises to the provinces is given in the following table, which also shows the total irrigation area in each province:

Provinces	Number of Local Irrigation Enterprises	Amount of Irrigation Water Lt/sn	Area Irrigated Decares
Adana	14	14585	61708
Adiyaman	12	4370	67450
Afyon	21	11185	81574
Agri	10	4400	58600
Amasya	9	4800	40680
Ankara	1	80	1500
Antalya	14	8065	96250
Aydin	14	593	8400
Balikesir	3	375	4000
Bilecik	4	3650	6500
Bingol	8	7575	15765
Bitlis	15	5953	30240
Bolu	1	300	1100
Bursa	4	1877	21400
Çanakkale	3	650	4700
Çankiri	9	1305	16300
Çorum	15	19575	47000
Denizli	21	7740	67250
Diyarbakir	12	3820	14500
Edirne	20	20765	109794
Elazig	11	1010	14905
Erzincan	7	6650	105000
Erzurum	128	37795	603650
Eskişehir	5	2250	32000

Provinces	Number of Local Irrigation Enterprises	Amount of Irrigation Water Lt/sn	Area Irrigated Decares
Gaziantep	3	440	3400
Gümuşhane	55	23075	193300
Hakkari	11	1325	6730
Hatay	14	2780	245874
İçel	16	22575	186672
İsparta	4	780	13500
İzmir	7	8270	66750
Kars	3	25450	107150
Kastamonu	20	33700	38800
Kayseri	5	850	12500
Kirklareli	7	1645	42950
Konya	4	12500	482207
Kütahya	1	100	1500
Malatya	47	31135	390500
Manisa	5	1750	26800
Maraş	26	22035	113700
Mardin	9	4580	22200
Mugla	12	9322	116000
Muş	5	7500	7460
Nigde	14	3270	72000
Ordu	2	550	1100
Sakarya	12	860	48000
Samsun	7	1400	6500
Siirt	6	12650	3925
Sivas	14	5150	114900
Tekirdag	1		3500
Tokat	53	10505	114250
Tunceli	2	260	6600
Urfa	11	7625	26450
Uşak	4	760	6425
Van	86	19023	164670
Yozgat	1	40	10000
Total ...	828	441293	4166380

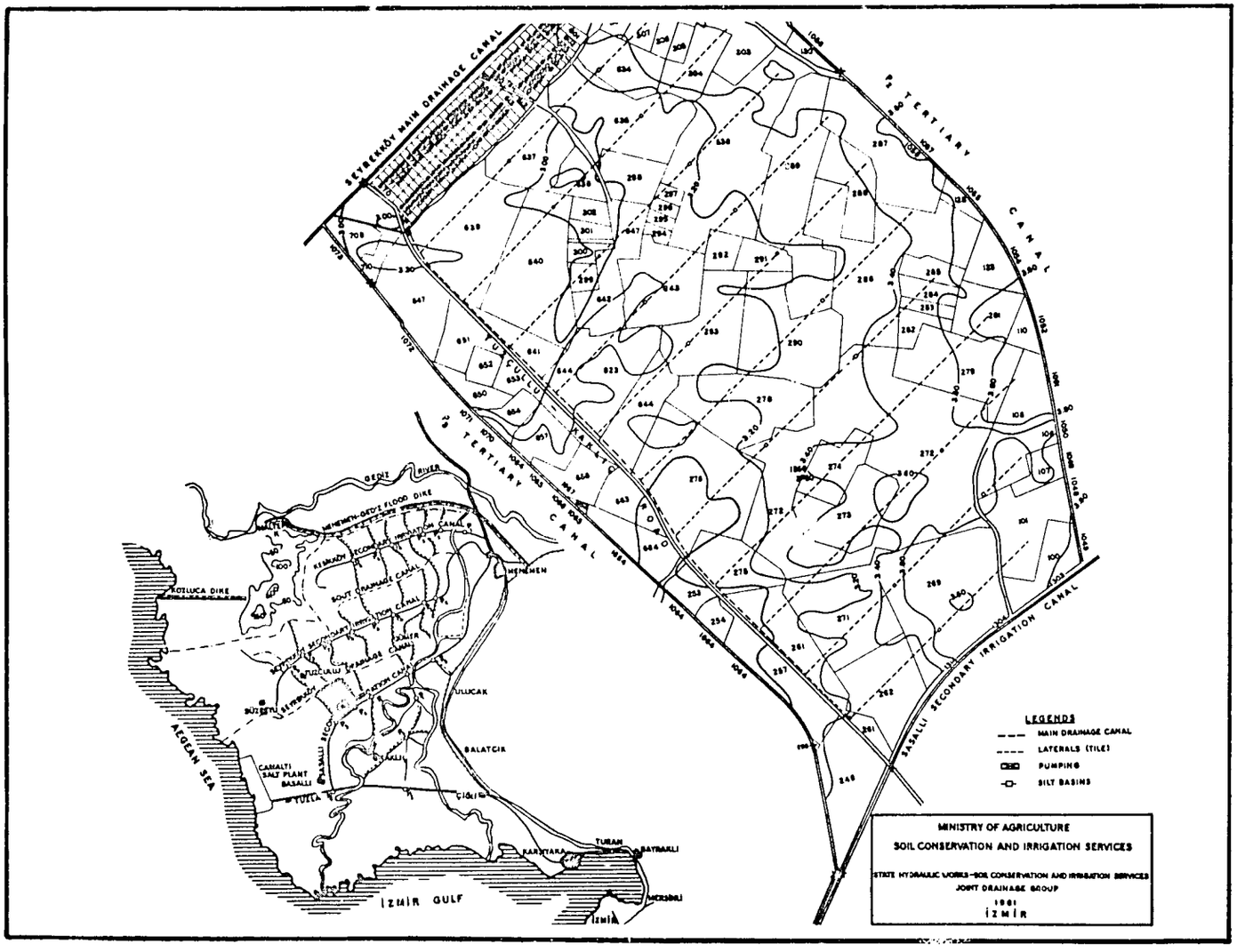
DISCUSSION: Existing rights cannot be abrogated and these stem from the Ottoman Empire. In many cases, farmers ask for recommendations; however, they cannot be forced to accept them under present law. Legislation pending may make it possible for the Turkish Government to purchase these rights.

There was considerable discussion about whether or not water could be transferred separate from the land. This was not clear, and apparently varies from place to place. Non-irrigation use

rights may be purchased for irrigation. The price is set by a five or six-man committee. Mr. Ozal stated that he had been involved in studies relating to water rights and that there are many variations. About 90 per cent of the water is somewhat related to the land, but not strictly so, in that it may be severed. For example, if a canal is built serving a certain piece of land, the owner is entitled to use that particular flow as he wishes by extending the area to be irrigated, for example, or by wasting it if he desires. The Government has the legal right to buy land for canal and drainage channel rights-of-way.

Rice irrigation is scheduled by committees and there is considerable concern regarding malaria. Public health authorities may require occasional drainage of rice paddies to kill mosquito larvae. The 450 cubic meters per second referred to in the paper is the sum of the canal capacities, not the average flow. Mr. Ozal stated that the water diversion is of the order of 4 to 5 feet.

If water is insufficient in the villages, the eldermen's committee can give an order restricting its use or the use of the lands to be irrigated. The eldermen's committee has the legal authority to enforce this decision. The rotation system applies to the local village systems whereas the demand system applies to the State-constructed systems. Local water users in Turkey may form an organization, procure financing and issue contracts for construction. This organization has to acquire the water rights, and is supervised by the country. In some cases, the more wealthy people may install pumps in the rivers and sell water to others for the production of crops. The law of 1583 mentioned on page 4 is not now in force. The right of the village eldermen's committee to enforce its decisions stems from the laws of the Republic of Turkey.



NATIONAL PROGRAM
FOR IMPROVED IRRIGATION PRODUCTION

by

Mr. M. Mortezavi[1]

This program will be discussed under the following four headings:

1. Land Levelling and the Development of Modern Irrigation Systems,
2. Canal Lining,
3. Drainage and Land Reclamation, and
4. Irrigation Research

LAND LEVELLING AND DEVELOPMENT OF MODERN IRRIGATION SYSTEMS

Old systems of irrigation, because of uneven lands, unstraight ditches, and small irrigation plots, waste too much water and need too much work. Plans for bringing about the correction of some of these difficulties are discussed below.

Establishing Experiment and Demonstration Farms

To show farmers better methods of irrigation and water delivery, in addition to improved use of farm machinery, one experimental and demonstration farm is planned for establishment in each ostan within the next five years. Three experimental and demonstration farms are already established, at Kanaj, Ahwaz and Miandoab.

The Karaj farm, located near Tehran, is the oldest and the best-equipped. Border, sprinkling, and special furrow irrigation methods are used in this farm. To establish these methods, soil characteristics such as texture; direction, degree and uniformity of the slope; and rate of infiltration of water into the soil are studied. Land was leveled to a good degree of uniform slope where the depth of the topsoil and the character of the subsoil permitted. Where low fertility was encountered and raw subsoil materials were exposed. The soil was treated with large quantities of farm manure and fertilizers to raise the content of organic matter and plant nutrients. The ease and efficiency of irrigation are increased about double on such levelled lands. Heavy equipment such as bulldozers and carryalls were used to move large quantities of soil. The finishing job was done by land-plane.

From the point where water is available on the farm, a good system of distribution is provided to convey the irrigation water to various fields. The system is designed to carry enough water to meet the demands of the crops on each field without erosion. To prevent erosion in steep earth canals, concrete, wooden, and stone drops and checks are installed at necessary intervals. Gates, water measurement equipment, and control structures such as division boxes are installed in open ditches where necessary.

In one part of the farm, underground concrete pipe is installed to carry the water from the deep-well pump station to a point about 600 meters away to be used for irrigation. Another branch of about 200 meters with stand pipes conveys the water to irrigation furrows.

Two other experimental and demonstration farms are located in Miandoab and Ahwaz, in the northwest and southwest, respectively. On these farms the groundwater table is too high, and the soil contains too many soluble salts. The first step in reclaim-

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ing these farms is to install a drainage system and then leach the soil to move the excessive salts. These activities will be discussed under a separate paragraph.

TECHNICAL AND PRACTICAL HELP TO FARMERS

Technical designs for land levelling, canal installations, and irrigation systems are prepared on the requisition of the farm owners for a small charge. At present some engineering teams are ready to do such a job in any part of the country. It is planned to train more teams as the need for them increases.

ACTIVITIES OF THE EXTENSION SERVICE

There are trained extension men in all parts of the country who go to villages and, by all available means, tell and show the farmers the advantages of modern agriculture, including irrigation

IMPROVEMENT OF THE SYSTEM OF IRRIGATION ON GOVERNMENT FARMS

Though the systems of irrigation on most Government farms, such as those of the Livestock Bongah and the Seed and Plant Improvement Institute, are not as old as the system on the average private farm, engineering designs for land levelling, water application and delivery systems are being prepared to gradually replace the old systems. In the Iranian year 1340 (March 21, 1961 to March 21, 1962), necessary designs were prepared for the following farms:

a. A Seed and Plant Improvement Institute Farm in Varamin (40 kilometers south of Tehran). Here engineering designs for levelling, water application and a delivery system have been prepared and executed for 20 hectares.
b. For a farm of the same Institute the same designs were prepared for 25 hectares in Karaj.
c. For the Livestock Bongah's 40 hectares of land in Karaj, canal installation and land levelling designs have been prepared and executed.
d. About 1,000 hectares of irrigated land at the Karkeh Dam Organization Farm have been brought under cultivation within the last two years. A water delivery system, including a main canal about 14 kilometers long with a capacity of 15 cubic meters per second, has been completed. Many large and small concrete division boxes, gates, drops and other water-control structures have been installed.

PUBLICATIONS

The advantages of land levelling and modern water application methods are explained and published in simple language to be utilized by ordinary people. These publications are freely distributed among farmers by the Extension Service Organization.

CANAL LINING

To prevent excess water losses through seepage from earth canals in permeable and porous soils, canal lining should receive careful consideration. Studies on the technical and economic feasibility of canal lining with different materials is at the top of the program of the Irrigation Research Branch of the Ministry of Agriculture. Karaj Agricultural College has also conducted some studies on the subject. In addition to general studies and research, individual designs are prepared and executed on different projects, some of which are briefly mentioned here as follows:

1. **Hableh Rud Project in Garmsar.** Garmsar is an important agricultural area located 100 kilometers southwest of Tehran. There are about 44,000 hectares of flat lands in this area, which are classified as follows:

Class 1	2,794 hectares
Class 2	18,748 hectares
Class 3	4,094 hectares
Class 4	4,581 hectares
Class 5 and 6	3,737 hectares

which are not suitable for agriculture

The irrigation water is provided from the Hableh Rud River, with an average annual discharge of about 7.8 cubic meters

per second, and from ghanats and some deep wells. The area is divided into four districts: Gheshlagh, Rikan, Yatry, and Aradan, which all together include 126 villages. One hundred and four of these villages have water rights to the river and the rest either buy the water from the others or use ghanat or deep-well waters. Eighty-three almost parallel canals carry the water from the river to the villages. These canals, for a distance of about 18 kilometers, pass through permeable sandy and gravelly land and lose, as measured last summer, about 60 per cent of their waters.

To prevent such great losses of irrigation water, a design including a diversion dam, two main canals, and 39 laterals has been prepared during the last year. The dam is about 800 meters long and has two gates for the two main canals. One of the two main canals is divided into three canals to convey the water to the four districts. The total length of the main canals is about 22 kilometers and, because of the high permeability of the soil, they will be lined with concrete. Since the natural slope of the land in which the canals are built is 1.0 to 1.4 per cent, there will be 33 chutes along the canals.

To prepare this design, the following work has been done.

a. A topographic map of 58,000 hectares on a scale of 1:10,000 has been prepared from aerial photographs.
b. A semi-detailed soil survey of 44,000 hectares has been made.
c. Water economy and agricultural studies of 44,000 hectares have been completed.
d. The course of the main canals has been laid out.
e. The topographic map of the dam site has been prepared on a scale of 1:2,000.

The time necessary for the execution of the project would be about two years and the cost would be 105,000,000 rials.

2. **Jajerud Project**

Preliminary studies have been made on improvement of the water delivery system of the Jajerud River basin. This river irrigates the Varamin area, located 40 kilometers south of Tehran. This area consists of four districts with a total area of 50,000 hectares, 20,000 hectares of which are irrigated each year. The study shows that by limiting the number of canals, lining them and fixing the river bed, forty per cent of the water can be saved. With this water, 10,000 more hectares can be irrigated. The annual income of these lands would be about 100,000,000 rials. The income would easily cover the necessary costs of carrying out the project within a few years.

3. **Kordan Project**

Kordan is located 75 kilometers northwest of Tehran. This area consists of three districts and receives its irrigation water from the Kordan River and some ghanats. This river has two branches, Chelengeh Dar and Aghasht. A concrete flume 30 meters long carries a flow of about 1 cubic meter per second from Aghast to the Chelengeh Dar branch. A small division dam 1.6 meters high has been built on the Chalengeh Dar branch to turn the water into the main concrete canal. The canal, with a capacity of 4 cubic meters per second and a length of 4.5 kilometers, carries the water to the districts. From the division box on the main canal, a small concrete canal 10 kilometers long with a capacity of 700 liters per second conveys the water to one of the districts. Three earth dams have been built to store groundwater by winter flooding to increase ghanat supplies. The cost of the project was about 12,400,000 rials. A thirty to forty per cent water saving would easily cover the cost.

4. **Maragheh Project**

In the Maragheh area, located in the northwest of the country, a canal lining project has been partially executed and is scheduled to be finished in six months. As the temperature sometimes goes below 25°C, the canal is lined with reinforced concrete. The length of the canal is about 8 kilometers and its capacity is 4 cubic meters per second. Two chutes have been built to control the water and these produce 200 kilowatts of electric power. The cost of the project will be about 16,000,000 rials.

DRAINAGE AND LAND RECLAMATION

Large areas of flat lands in Iran have a high water table and a high content of soluble salts in the soil plant root zone during long periods of time. The large salt deserts named Kavir-i-Namak, Kavir-i-Markazi, and Kavir-i-Lut have covered thousands of square kilometers of the flat lands in the central part of the country. In addition to salt deserts, there are many small and large areas of different degrees of salted soils all over the country. In many villages with normal soils and a good quality of irrigation waters there are places of low productivity because of salt accumulations in the soil.

The Government is devoting considerable activity at the present time to raising the productivity of the soil or to reclaiming new lands. In previous seminars the Karkheh, Shabankarch, and Shavoor projects have been discussed.

In the future, in addition to continuing present projects, it is planned to concentrate drainage and land reclamation studies on three different experimental and demonstration farms. These farms are (a) Garmsar, which is located on the margin of a salt desert, because many people try to reclaim similar lands in different places; (b) Ghezelhessar, which is a typical sample of the low-lying areas which receive the surface and groundwater drainage of adjacent lands; and (c) Sistan, where the problem is insufficient slope of the land to permit the surface and groundwaters to flow off. Each of these stations has an area of 100 hectares. In Garmsar, a main open drain, two tile drains, and irrigation canals are already installed. In Ghezelhessar, main drains, four laterals and irrigation ditches are ready to be utilized. On both farms irrigation water is provided by means of ghanats. On each farm the following items are planned for study:

a. The best system of drainage to fit the economic and technical conditions of the country.
b. The best way to install and cover underground drains to meet local conditions.
c. The best spacing for the laterals.
d. Pumping out the water of the drainage system.
e. Leaching the soil with different waters.
f. The depth of water needed to leach different soils.
g. Treatment of alkali soils with chemical amendments.
h. The effect of different treatments on soil permeability.
i. The effect of planting on leaching.
j. The time necessary to reclaim different kinds of salted soils.
k. The cost per unit area for drainage and land reclamation.

IRRIGATION RESEARCH

To find the consumptive use of different plants, three stations have been established, in Karaj, Varamin, and Lahijan. Reports of these stations will be given in a separate paper. In the future it is planned to establish one station in each ostan to study the water needs of different plants and to use the results to save water and develop irrigated lands. Irrigation research on rice has already indicated that the farmers use much more water than is needed. The application of 9,000 cubic meters per hectares for rice has no advantages over the application of 4,000 cubic meters. The experiment is continuing in order to find the best amount of water to apply to rice. Research on sugar beets and cotton has given similar results.

DISCUSSION

Land levelling with crawler tractors and scrapers costs about 4 rials per cubic meter. Water rights were originally obtained as villages grew and

people appropriated water. While printed material is used to disseminate information to the farmer, this is done through extension people and others who can read and write. Much of the dissemination at the farmer level is by word-of-mouth. While there is much research information available, in order to get farmers to accept known principles, research demonstration farms are necessary. For example, it has been demonstrated that the amount of water used to raise rice might well be very drastically reduced. It was pointed out that the use of modern equipment in demonstration work is meaningless unless farmers can acquire such equipment or services, and an inquiry was made regarding the availability of credit. Mr. Mortezavi reported that credit is available, but not well-developed. Designs for land levelling are available to the farmers.

Sprinkler irrigation is not developed. There is a ten-acre sprinkler demonstration farm in operation. Lining experiments at Karaj College include clay, concrete, nylon and brick materials.

The U.S. Bureau of Reclamation standard of land classification is used. The cost of land levelling may be included in the project plan. Cotton and rice are grown on Class 4 land.

In reply to a question as to why plans are developed for land levelling when the country is not in a position to execute them, it was stated that some farmers can afford to go ahead with these plans. In other areas, the levelling has been done by hand over a long period of time. Where levelling is done by the Government, farmers pay 50 per cent of the cost to the Department of Agriculture Engineering Office.

In order that the use of high-quality leaching water on salty soils will not result in their dispersion, fairly salty water is used at first and a higher quality later for leaching.

A SUGGESTED PROGRAM FOR IMPROVED IRRIGATION PRODUCTION

by

Turkey

FOREWORD

The existing irrigation projects in Turkey do not provide the expected maximum benefits from the water and soil resources. The main causes of this are: Irrigation projects are not completely constructed, farming operation has not come up to the level required for intensive agriculture, farmers do not know the techniques of irrigated agriculture, there is lack of supplies and equipment, and there is a shortage of credits.

Upon consideration of all these factors integral plans are being prepared for the intended development of existing and new irrigation projects. The program herein discussed, for the Tarsus-Berdan area, is the first of these plans. While this reports a single project, it illustrates the responsibilities that governments must face if they are to improve irrigated agriculture. The application of the plan was started in 1961 and will end in 1968.

1. GENERAL

A. Introducing the Project Area

The Tarsus-Berdan Project is located in southern Turkey and includes 2,500 hectares on the left bank and 25,200 hectares on the right bank of the Berdan River. The total plan covers 27,700 hectares, and includes the watershed of the rivers flowing through the Berdan Plain.

This plain was formed by the alluvial deposits of the Berdan River and its tributaries. In this plain only the Berdan River is regular: the others are tributaries of irregular course. The slope of the area runs from north to south, the average slope being 0.5 per cent. Undulating lands are limited.

Population

The population of the project area is 144,000. Twenty-five thousand people are farmers and live in villages, 119,000 people live in urban centers (Mersin 68,000, Tarsus 51,000). The annual rate of population increase is 4.5 per cent, this being 1.8 per cent greater than the average rate of 2.7 per cent for Turkey.

Climate

The prevailing climate is Continental Mediterranean. Summers are warm and dry, winters are rainy and mild. The mean annual precipitation for 27 years has been 653 mm. according to the observations taken by the Tarsus Meteorological Station. Precipitation during the growing season is 103 mm., the mean annual temperature is 18.6°C., and the mean annual humidity is 64 per cent. The lowest temperature in January is 9°C. and the highest temperature in August is 28.1°C. The temperature falls below zero 9.7 days during a year, but never stays below zero more than 24 hours continuously. Precipitation is mostly in the form of rain, hail is rare; but snow never falls.

Transportation and Communication

The project area is connected with railway lines to the east and west and by highways to the east, west and north. Through Adana airport air transportation is possible with the interior and exterior of the country. The exports and imports of the region are handled through Mersin Harbor, which has a daily loading and unloading capacity of 5,000 tons. Telephone, telegraph and mail communications are possible in the cities of Mersin and Tarsus.

Economy

a. **Agriculture.** In the presently unirrigated area of the project, 65 per cent cotton and 35 per cent cereals are cultivated by dry farming. After the irrigation system entered into service, the growing of truck crops developed, especially around the cities of Mersin and Tarsus. Where the climate is suitable, great importance is given to citrus gardens. When the pumping system for irrigation is completed at «Yakakoy» there will be many citrus gardens

in this area. In recent years great attention has been given to irrigation of the cotton fields. Rice is the second most important crop in the area.

No feed crops are raised. In this area livestock raising has decreased due to the importance of industrial and commercial types of crops. In fixing the projected crop pattern in areas where water and soil resources development will be provided, it is necessary to take into consideration market conditions, prices, and the willingness of farmers, besides the factors of the water and soil resources available.

CROP PATTERN AFTER THE PROJECT IS COMPLETED

Cotton	30 per cent
Truck Crops	15 »
Citrus Fruits	15 »
Grain	10 »
Feed Crops	10 »
Rice	10 »
Fruits	5 »
Others Crops	5 »
Total :	100 per cent

b. **Trade and Industry.** The important trade and industrial centers are Mersin and Tarsus. Cotton textile, cotton-ginning, vegetable oil and rice decorticating industries have developed, especially the cotton textile industry. After meeting the needs of the textile factories, the remaining cotton production is exported at Mersin harbor. Mersin also has a modern packing house for citrus fruits.

c. **Mining.** There are many mines around Mersin and Tarsus. At present, chromium is the main exportable mineral and it is exported through Mersin Harbor.

B. THE BENEFIT-COST RATIO

The benefit-cost ratio and time-cost schedule for complete irrigation development for the Tarsus-Berdan project area are given in Table 1.

Table 1. Time — cost schedule and benefit — cost ratio.

		Turkish Liras
a)	Costs of Water Resources Development 1937—1938	
		4,500,000
	Yakakoy Pumping station (under construction)	6,300,000
	Left Bank Irrigation System (under construction)	5,650,000
		16,450,000
	Cost for Completing the Project	40,300,000
	Total State Investment	56,750,000
	Investment by Private Parties for Irrigation Pumping	10,000,000
	TOTAL	66,750,000
b)	Costs of Soil Resources Development	
	State Investment	19,665,000
	Private Investment	11,970,000
	TOTAL	31,635,000
c)	Tractors and Farm Equipment	15,411,000
d)	Training of Farmers	520,000
	Total Investment	114,316,000
	Annual Cost of the Existing Installations	8,000,000
	Annual Costs for Operation, Rent, Fertilizer, Seeds, Insecticides, Plant diseases, etc.	21,546,000

Total Annual Cost (8,000,000 + 21,546,000) = 29,546,000
Annual Gross Income Increase 580 TL/dec. X171,000=99,180,000
Benefit—Cost Ratio = 3.36

C. FACTORS IN DEVELOPMENT PLAN

Consideration of the problem of obtaining the maximum agricultural income from an irrigated area requires that all phases and stages of development be carefully planned, coordinated, and interwoven.

The factors involved are:

1. **Water,** considered from the standpoint of its source and quantity on to its ultimate use on crops and the removal by drainage of the surplus salty water.
2. **Land,** from its evaluation for irrigation purposes to its levelling and use for growing adapted crops.
3. **Crops,** from their seed selection to a final standardized package of quality product for market.
4. **Markets,** from local pricing to what is saleable in foreign trade.
5. **Farmers,** from what they think and how to do without irrigation to the development of highly skilled irrigation-farm operators.

   These factors in existing water-land resources development projects have not been considered to a degree paralleling their importance in production. This is attempted on the Tarsus-Berdan Project.

D. STEPS NECESSARY IN PROJECT DEVELOPMENT

Technically trained personnel from those agencies of the Government of Turkey most concerned have served as a team in preparing this plan. The team has created a program for projects development in the stages necessary for maximum income to the farmers concerned and to the nation. These steps are as follows:

1. **Construction of the water resource facilities**

   Completion of the water resource facilities will include necessary investigation, planning, and construction of primary and secondary distribution, pickup and drainage systems; and the operation and maintenance of the water supply system.

2. **Bringing the land and water resources together**

   This includes first of all the development of a subdivision or farm boundary plan according to the «lay of the land.» Secondly, the tertiary delivery, pickup and drainage systems must be constructed at the same time as necessary land grading and levelling are done.

3. **Bringing together the land-water resources and the people who are to use it so that the combination results in high crop yields**

   This is primarily a step in educating the farmer so he can make the most effective use of his carefully planned and developed land-water resource. This is a step which, of necessity, will start in the first meetings held to explain the advantages of changing landholders' boundaries.

4. **Providing a plan of financing and making accessible to farmers the supplies and equipment necessary for timely and effective operations**

   Nothing short of fully adequate supplies and equipment for production of high-yield crop-producing quality products will be considered.

5. **Providing satisfactory marketing facilities for a maximum of high value crops which can be produced from the area.**

   This means evaluation of potential markets and the development of necessary facilities for assembling and processing the crops to take advantage of the best markets at the right time. It is probable that additional packing and cooling facilities will be required to handle the big volume of crops which can be produced in the Tarsus-Berdan area. Implemention of the program plan requires that the various parts be considered and carried out in a well-coordinated manner. There are several agencies of the Turkish Government concerned which will be involved in carrying forward these operations.

E. WATER RESOURCES

The Berdan River is the main source of water supply for the project area. The Berdan River has a watershed of 2,000 sq. km. on the Taurus Mountains; its length is 83 kilometers. It reaches the Mediterranean Sea about 20 kilometers east of Mersin.

According to observations made over 22 years, the minimum discharges of the Berdan are as follows during the months indicated:

June	35.11 m^3/sec.	August	14.10 m^3/sec.
July	20.50 m^3/sec.	Sept.	12.20 m^3/sec.

After development of the project area, the natural discharge of the river will not be enough to provide the water needed to meet the discharges required according to the irrigation and industrial water rights of Tarsus. Because of this, surveys are continuing on the Berdan River of the possibility of providing storage.

WATER REQUIREMENTS

The duty of water at the diversion point for the existing and proposed crop pattern is given below:

Average water duty (liters/second/hectare)

MONTHS

	April	May	June	July	Aug.	Sept.	Oct.
Existing	0.36	1.10	1.22	1.20	0.85	0.76	0.50
Proposed	0.40	0.70	1.17	1.11	0.77	0.60	0.41

Water Distribution Scheme After Full Development
(for the month of July)
Right Bank

Municipality	1.50 m^3/sec.
Rehabilitation system	7.15 m^3/sec.
Pumping area	4.45 m^3/sec.
New Areas	4.90 m^3/sec.
	18.00 m^3/sec.
Left Bank	2.50 m^3/sec.
Total	20.50 m^3/sec.

F. SOILS

The soils of the project area can be grouped into three general divisions: (1) Alluvial, (2) colluvial, (3) residual. Alluvial soil can be divided into: (a) Alluvial, and (b) hydromorphic saline alluvial soils.

1. a. Alluvial soils are located at the central and east part of the project area. They are deep with no root restrictions in the profile generally characterized by heavy soils. They are formed by alluvial materials which were carried in and spread by the Berdan and Deliçay Rivers.

   b. Hydromorphic saline alluvial soils are located at the south and south-east parts of the project. They are also deep and characterized by heavy soils and are not suited to irrigation. These soils were formed over the marine alluvium, within the saline water table. Surface and subsoils tend to have strong concentrations of soluble salts and exchangeable sodium, with very low or no permeability.

   Soils of this group are heavily concentrated with lime and organic matter.

2. Coluvial soils are located north of the

Tarsus-Mersin highway, especially at the foothills. They are generally heavy in texture and calcareous, and both surface and subsoils are gravelly.

3. Residual soils are formed over the limestones and are located at the north-east and north-west edges of the project area. These soils are categorized as the terrarossa soils of the Mediterranean. They are heavy in texture and calcareous. A large proportion of these soils is very restricted in profile by limestone (30 cm. or less). Due to the climate and the high value of the crops growing, they are classified as irrigable.

The project land breakdown is as follows:

1. Right bank of the Berdan River

		decares
a.	Tarsus municipal service area	13,000
b.	Karabucal forest area	8,500
c.	Class 1, 2, 3, below main canal	103,000
d.	Refinery area	2,000
e.	Port area (full development)	4,000
f.	Class 5 land below main canal	53,000
g.	Class 6 land below main canal	24,500
h.	Class 1, 2 and 3 within pumping area	44,000
	Right bank total	252,000
2.	Left Bank	25,000
	Total	277,000

G. DRAINAGE

Surface and subsoil drainage is an important factor in the south and southeast parts of the project area. Because of the existence of permeable cobble and gravel material under all the northern part of the project area, satisfactory drainage is anticipated. The Berdan River and the Deliçay are the natural drainage ways, but they are not sufficient to drain the project area because of the very low gradient at the lower part of the project and the shallow depth. At the areas where restricted drainage occurs, the soils are of heavy texture and the permeability is very low or none.

A high water table exists in the southern part of the project area at depths of from 30 to 150 cm. According to laboratory results, the majority of these waters contain highly soluble salt and exchangeable sodium. The reasons for the high water table condition at the south part of the project area are:

(1) Insufficient natural drainage way,
(2) Excess waste water from the surrounding stream and irrigation canals and also periodic overflow from the Aynaz Swamp,
(3) Insufficient drains in the existing irrigation system,
(4) The heavy soil with an excessive amount of exchangeable sodium, which causes a very low permeability,
(5) Insufficient surface drainage,
(6) The poor knowledge on the part of farmers of irrigation

Correction requires

(1) Development of natural drainage ways,
(2) Lining the existing irrigation canals,
(3) Establishing a good artificial drainage system,
(4) Preventing the overflow from the Aynaz Swamp.

H. SALINITY AND ALKALINITY

Salinity and alkalinity are important problems in the project area. The saline and alkaline areas are located at the southern and south-eastern part of the Tarsus-Berdan Plain.

The causes of the salinity and alkalinity in the project area are:

(1) The saline marine deposits at the lower horizons,
(2) The high water table,
(3) Salt crystals carried by winds from the sea.

The problem area covers about 7,000 hectares of land.

At the central and northern section of the project area, the soils are free of salt and will not develop any salinity problems under extensive irrigation.

II. DEVELOPMENT OF WATER RESOURCES

With the water of the Berdan River, 182,000 decares of land will be irrigated. The

irrigation project contains a diversion dam, levees, left and right bank conveyance canals, and irrigation and main drainage systems for the right bank (64,500 Dec.); an irrigation system for the left bank (22,500 Dec.) and the right-bank Yakakoy pumping station (40,000 Dec.), which is under construction and will be completed in 1963.

New irrigation and drainage system construction for 40,000 Dec. and rehabilitation of the existing system on 64,500 Dec. on the right bank will start in 1963 and be completed in 1967.

BERDAN DIVERSION DAM

This was constructed in 1937-1940 at a cost of 903,000 TL at a site 5 kilometers north of Tarsus, on the Berdan River. The crest length is 150 m and the spill-way capacity 900 m^3/sec.

BERDAN LEVEES

The right-bank levee has a length of 18 kilometers, and starts south from the state highway bridge. The left-bank levee has a length of 19 kilometers. These continue as far as the dunes. The levee has an average height of 2.5 m and the floodway capacity is 750 m^3/sec. These were constructed during 1947-1948 with an expenditure of 989,000 TL.

RIGHT-BANK SYSTEM

The conveyance canal on the right bank is 30 kilometers long and its capacity is 7.9 m3/sec. It was built during 1939-1953 at a cost of 2,250,000 TL.

LEFT CONVEYANCE CANAL

This canal has a capacity of 2.5 m^3/sec., its length is 13 kilometers and it was constructed at the same time as the right-bank system at a cost of 300,000 TL. Rehabilitation of the existing canal and irrigation system of the service area is underway.

AREAS AFTER DEVELOPMENT (NET)

Right bank	Decares
Present gravity system	64,500
Pumping area	40,000
New area	44,000
	148,500
Left bank	22,500
Total net project area	171,000
Tarsus municipality	11,000
Area receiving water from the Berdan River	182,000

III. LAND DEVELOPMENT

A. Implementation

Land development carried out at the same time canals, drains and roads are built has not been fully attempted previously in Turkey. Procedures and standards must be developed and personnel trained before operations of this kind can be satisfactorily undertaken by contractors and properly supervised and directed by the Government. It is recommended, therefore, that the first block of land proposed herein for «tertiary development» be developed by the Government with its own forces.

Regardless of how the work is done, all development below secondary laterals should be carried out as a separate contract or item of work in the over-all project construction. Main project features such as main canals, drains, distribution laterals, and necessary control structures can be constructed under types of contracts well known and understood by engineers and contractors. This is not true of the work that will be performed under tertiary development. The embankment required for the tertiary canals and roads will be constructed with earth excavated during land leveling and drain construction. A roadway will generally be provided on every other tertiary canal bank. Often, the earth «borrowed» from the fields will be removed in extremely thin depths.Thus computations of earthwork volumes for light land levelling will be impracticable using generally accepted engineering me-

thods. Allocation of construction costs to the satisfaction of the contractor and farmer would be extremely difficult.

Until standard procedures understood and accepted by engineers, contractors and farmers have been established, it is recommended that all earth-moving work for land levelling and tertiary canal, drain and road construction be done under contract. Payment would be based on hourly rates for operating equipment.

B. Estimate Of Personnel and Equipment Needs

The work connected with land development and tertiary canal construction can be accomplished most efficiently with a balanced fleet of earth-moving equipment. The equipment described in this section is typical of that used in land development and minor and drain canal construction on large Government projects in the United States.

On an average, the equipment listed, working two eight-hour shifts a day for 150 days, will complete the road, levelling, ditch and surface drain construction for 30,000 Dec. of land (developed according to standard design) at the same time as tertiary canals are constructed.

In installing irrigation structures, prefabricated or precast types could most efficiently be used.

Table 2 Equipment needs to complete 30.000 decares annually.

Earth Moving Equipment		
No	**Description**	**Cost**
4	Crawler Tractor-Scraper Unit (120 hp with 10—ft. cutting blades)	$ 180 000
2	Crawler Tractor (120 hp) with bowl type dozer	64 000
1	Crawler Tractor (120 hp) with bottom-less scraper (18 ft)	35 000
1	Crawler Tractor (65 hp) with angle dozer	25 000
1	Crawler Tractor (65 hp) with angle dozer and tool bar attachment	28 000
1	Motor Grader (Heavy Duty)	23 000
1	Crane (rubber tired, self-propelled with 3/4 yard dragline attachment and bucket)	70 000
1	Weel Tractor (Heavy Duty)	5 000
1	Wheel Tractor (Heavy Duty) with tool bar attachment	5 000
1	Land Plane (BG Model No: 55 or equiv.)	15 000
1	Ditcher (large)	5 000
1	Land-Leveler-(Largest Eversman or equivalent)	10 000
2	Ditcher (small)	1 000
2	Disc Plow (Heavy Duty)	10 000
1	Fuel and Lubricating Machine (Truck mounted, 4-wheel drive)	11 000
	Spare parts (supply for five years)	93 000
		$ 580 000

	Transportation Equipment	
1	Trailer-Tractor (30 ton)	$ 35 000
3	Passenger Carryalls	12 000
4	Pickup 3/4 ton (4 wheel drive)	16 000
3	Pickup 3/4 ton	9 000
2	Trucks 1 1/2 ton flatbed (4 wheel drive)	10 000
2	Truck Dump (4 cubic motor)	12 000
	Spare parts (supply for five years)	6 000
	Total — Transportation equipment	$ 100 000
	Miscellaneous Equipment (Shop and Field)	
1	Electric welder (300 amperes) 4 wheel trailer mounted	5 000
1	Concrete Mixer (10 S)	4 000
1	Concrete Mixer (6 S)	2 500
1	Concrete Mixer (3 1/2 S)	1 500
2	Sets surveying instruments	2 000
1	Set drafting equipment	1 000
1	Reproduction Machine (Ozlid)	4 000
	Hand tools	5 000
	Office Supplies and equipment	5 000
	Office Supplies and equipment	5 000
	Total-Miscellaneaous Equipment	30 000
Estimated residual value at the end of five years is approximately 20 % of purchase price.		

Table 3. Personnel required to complete 30.000 decares annually

	Personnel Table 3	
No	**Title**	**Annual Salary**
1	Supervising Engineer	36 000 T.L.
1	Office Engineer	30 000
1	Draftsman	20 000
1	Computor	8 000
2	Survey Chief	30 000
2	Instrumentman	20 000
6	Rodman	24 000
1	Construction Engineer	30 000
2	Equipment Foreman	20 000
1	Labour Foreman	11 000
1	Field Mechanic	9 000
1	Field Mechanic Assistant	5 000
20	Equipment Operator	160 000
10	Skilled Workers (oilers, asst. operators)	50 000
20	Common Laborers	72 000
		525 000 T.L.

TABLE 4. COST OF LAND DEVELOPMENT PER DECARES

Private TL/Da.		Government TL/Da.	Total TL/Da.
Investigation for farm plan			
Land leveling		6.00	6.00
Engineering		8.00	8.00
Implementation	40.00		40.00
Farm irrigation and drainage system			
Engineering		6.00	6.00
Implementation	20.00		
Checks			
Engineering			
Construction	10.00		10.00
Irrigation canals from tertiary to farm ditch			
Engineering		5.00	5.00
Implementation		60.00	60.00
Roads between farms			
Engineering		3.00	3.00
Construction		25.00	25.00
TOTAL	70 TL/Da	115.00 TL/Da	185. TL/Da

IV. TRAINING FARMERS FOR HIGH CROP PRODUCTION UNDER IRRIGATION

Providing farmers with irrigation water is not enough if the full benefits of irrigated farming are to be realized. Farmers must be informed concerning the economic returns which can be realized by full use of irrigation water and by improved farming methods. Presenting this information in such a manner that they will be eager and willing to learn the techniques to realize maximum returns is necessary. Thus a training job, enlisting the cooperation of all agencies concerned, must be accomplished.

The types of training necessary may be broken down into several categories. First, however, it is helpful to have some idea of the size and complexity of the problem. In the total Mersin-Tarsus area (260,000 decares) there are approximately 2,640 farmers with holding ranging from 1 decare to over 1,000 decares. The model group ranges from 1 to 50 decares in the Mersin area (1,286 farmers out of a total of 1,671) and 11 to 250 decares in the Tarsus area (851 farmers out of 972). (See Table 5). It is expected that the larger farmers, i.e., those with 500 or more decares (61 farmers), will hire a manager who will actually operate the farm. Smaller farmers probably will either do all their own work or join together to hire a manager. The manager, as a larger operator, will benefit materially from high-level training.

TABLE 5 FARM SIZE DISTRIBUTION

Mersin									
Size Category	1-5 Dk.	6-10 Dk.	11-50 Dk.	51-100 Dk.	101-150 Dk.	151-300 Dk.	301-500 Dk.	501-1000 Dk.	Over 1000 Dk.
Number	599	271	416	148	99	78	30	22	8

Tarsus						
Size Category	5-10 Dk.	11-25 Dk.	26-50 Dk.	51-100 Dk.	101-250 Dk.	251-500 Dk.	Over 501 Dk.
Number	13	186	282	200	183	71	37

Obtaining the Farmer's Cooperation

The first phase of training will be to «sell» the benefits of full irrigation farming. It is extremely important to show the economic benefits which will accrue to the farmers from realignment of farm boundaries. This can probably best be done by utilizing a carefully-prepared set of visual aids showing the contrasts between the present situation and the production potential under full development. The entire process of irrigation development must be shown graphically in steps. Where

TIME - COST SCHEDULE FOR COMPLETE DEVELOPMENT
TARSUS - BERDAN PROJECT AREA TURKEY

	FIRST YEAR				SECOND YEAR				THIRD YEAR			
	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL
GEN INVESTIGATION & PLANNING ① 8.3 TL/DEK	69	25	651	–	67	25	623	–	46	10	226	
WATER RESOURCE DEVELOPMENT ②												
1 DESIGN & CONST SUPR 7.8 TL/DEK	28	10	150	–	335	16	250	–	435	20	300	–
2 REHABILITATION 112 TL/DEK	–	–	–	–	180	–	2200	–	235	–	2500	–
3 NEW CONST 299 TL/DEK	–	–	2000	–	100	–	2500	–	100	–	5000	–
4 OPERATION & MAINT ③ 65 TL/DEK	445	2	311	–	445	2	334	–	585	2	437	–
5 PRIVATE PUMP SYSTEMS 500 TL/DEK	3	–	–	1500	3	–	–	1500	3	–	–	1500
LAND DEVELOPMENT												
1 ENGINEERING 30 TL/DEK ④	12	12	360	–	20	20	600	–	30	30	900	–
2 CONSTRUCTION (GOVT) 85 TL/DEK ⑤	12	–	1020	–	20	–	1700	–	30	–	2550	–
3 CONSTRUCTION (PRIVATE) 70 TL/DEK ⑥	12	–	–	840	20	–	–	1400	30	–	–	2100
FARMER TRAINING	–	–	–	–	–	1	40	–	–	2	160	–
FARM SUPPLIES & EQUIP												
1 FERTILIZER (30 TL/DEK)	12	–	–	360	32	–	–	960	62	–	–	1860
2 TRACTORS (76 TL/DEK) ⑦	10	–	–	760	10	–	–	760	12	–	–	912
3 OTHER EQUIP (71 TL/DEK) ⑧	15	–	–	1065	15	–	–	1065	20	–	–	1420
4 SEED, PESTICIDES, etc (20 TL + 18 TL/DEK)	12	–	–	432	32	–	–	1152	62	–	–	2232
MARKETING AND TRANSPORTATION	–	–	–	3000	–	–	–	3000	–	–	–	3000
TOTAL TECHS & FUNDS	–	49	4492	7957	–	64	8247	9837	–	64	12073	13024
VALUE OF PROD INCREASE (580 TL/DEK) ⑨	NON				20	4 000 000 TL			40	12 000 000 TL		

	FOURTH YEAR				FIFTH YEAR				SIXTH YEAR			
	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL
GEN INVESTIGATION & PLANNING ① 8.3 TL/DEK												
WATER RESOURCE DEVELOPMENT ②												
1 DESIGN & CONST SUPR 7.8 TL/DEK	22	14	210	–	22	14	210	–	15	7	100	–
2 REHABILITATION 112 TL/DEK	23	–	2500	–	–	–	–	–	–	–	–	–
3 NEW CONST 299 TL/DEK	205	–	6700	–	22	–	6200	–	22	–	6400	–
4 OPERATION & MAINT ③ 65 TL/DEK	745	3	550	–	105	3	685	–	127	4	225	–
5 PRIVATE PUMP SYSTEMS 500 TL/DEK	3	–	–	1500	3	–	–	1500	3	–	–	1500
LAND DEVELOPMENT												
1 ENGINEERING 30 TL/DEK ④	30	30	900	–	30	30	900	–	30	30	900	–
2 CONSTRUCTION (GOVT) 85 TL/DEK ⑤	30	–	2550	–	30	–	2550	–	30		2550	–
3 CONSTRUCTION (PRIVATE) 70 TL/DEK ⑥	30	–	–	2100	30	–	–	2100	30	–	–	2100
FARMER TRAINING	–	2	160	–	–	2	160	–	–	–	–	–
FARM SUPPLIES & EQUIP												
1 FERTILIZER (30 TL/DEK)	92	–	–	2760	122	–	–	3660	152	–	–	4560
2 TRACTORS (76 TL/DEK) ⑦	12	–	–	912	12	–	–	912	15	–	–	1140
3 OTHER EQUIP (71 TL/DEK) ⑧	20	–	–	1420	20	–	–	1420	15	–	–	1065
4 SEED, PESTICIDES, etc (20 TL + 18 TL/DEK)	92	–	–	3312	122	–	–	4392	152	–	–	5472
MARKETING AND TRANSPORTATION	–	–	–	3000	–	–	–	3000	–	–	–	3000
TOTAL TECHS & FUNDS	–	49	13570	15004	–	49	10705	16984	–	41	10175	18837
VALUE OF PROD INCREASE (580 TL/DEK) ⑨	70	28 000 000 TL			100	50 000 000 TL			130	75 400 000 TL		

	SEVENTH YEAR				DEVELOPMENT TOTALS		
	DEK 1000	TECHNICIANS NUMBER	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL	DEK 1000	GOVT AGENCIES 1000 TL	PRIVATE 1000 TL
GEN INVESTIGATION & PLANNING ① 8.3 TL/DEK							
WATER RESOURCE DEVELOPMENT ②							
1 DESIGN & CONST SUPR 7.8 TL/DEK	7	5	80	–	171	1 500	
2 REHABILITATION 112 TL/DEK	–	–	–	–	643	7 200	
3 NEW CONST 299 TL/DEK	22	–	300	–	1065	31 800	
4 OPERATION & MAINT ③ 65 TL/DEK	149	4	970	–	–	–	
5 PRIVATE PUMP SYSTEMS 500 TL/DEK	2	–	–	1000	–	–	10 000
						40 300	10 000
LAND DEVELOPMENT							
1 ENGINEERING 30 TL/DEK ④	19	19	570	–	171	5 130	–
2 CONSTRUCTION (GOVT) 85 TL/DEK ⑤	19	–	1615	–	171	14 535	–
3 CONSTRUCTION (PRIVATE) 70 TL/DEK ⑥	19	–	–	1330	171	–	11 970
						19 665	11 970
FARMER TRAINING	–	–	–	–	–	520	–
FARM SUPPLIES & EQUIP							
1 FERTILIZER (30 TL/DEK)	171	–	–	5130			
2 TRACTORS (76 TL/DEK) ⑦	15	–	–	1140			
3 OTHER EQUIP (71 TL/DEK) ⑧	20	–	–	1420			
4 SEED, PESTICIDES, etc (20 TL + 18 TL/DEK)	171	–	–	6156			
MARKETING AND TRANSPORTATION	–	–	–	3000			
TOTAL TECHS & FUNDS	–	28	3535	19176			
VALUE OF PROD INCREASE (580 TL/DEK) ⑨	160	92 800 000 TL			8th YEAR AND AFTER 99 180 000 TL		

① Includes Cadastral Survey Ownership Map (3.0 TL/Dek) Detailed Topography (1.8 TL/Dek) Land Classification (1.5 TL/Dek) Drainage Studies (0.6 TL/Dek) Agro Economic Studies (0.35 TL/Dek) General Investigation & Negotiation (0.4 TL/Dek), System Layout & Planning (0.7 TL/Dek) Total area considered for Berdan River Water includes (1) Left Bank 22 500, (2) Right Bank 64,500, present system to be rehabilitated, plus 40,000 pump lift area, plus 64,000 added new area, Total 171,000 Net Dek (plus 11,000 Tarsus area, 182,000 Dek)

② Water Resource construction relates to unlinished, redesigned, and repair to primary and secondary distribution and drainage systems only on 171,000 net Dek

③ All O & M costs to be paid annually by water users, annual cost for 8th year and after, 1,110,000 TL

④ Cost for engineering activities (planning, design and supervision) will be borne by Govt

⑤ Canals from turbines to fields, drains from the pickup ditches to lateral and roads connecting farms be paid by Govt

⑥ Construction of farm ditches, pickup drains, checks, land leveling and farm roads be paid by farmers.

⑦ Area now has 297 tractors or about 1/2 enough therefor tractors are calculated for 86000 Dek

⑧ Area estimated to have about 1/4 enough other equipment, therefore equipment costs calculated for 125000 Dek

⑨ Calculated as average increase gross value of crop per decare 2nd year 200 TL, 3rd year 300 TL, 4th year 400 TL, 5th year 500 TL 6th year and after 580 TL

possible, examples of the following should be shown:

a. Realignment of land boundaries according to the lay of the land,
b. Land levelling and preparation,
c. Crop varieties and rotations,
d. Irrigation water management,
e. Fertilizer and pesticide use,
f. Harvesting methods and,
g. Marketing.

The necessity for realignment of farm boundaries must be understood and accepted by all farmers involved. Each landowner should be made to understand that he will receive the same amount of land as he previously owned except for the small percentage necessary for canals and access roads. Visual aids should be prepared showing the landholdings of an actual farmer in the area both before and after realignment. It should show his present setup with its limited income potential vs. the prospective setup showing water delivery, pickup, drainage facilities, access roads and increased income.

Costs and financing of the project (Table 1) must be pointed out to all farmers. This aspect of training can probably be covered in a series of meetings, field observations and demonstrations held in various villages by the present staffs of the Extension Service, Topraksu and DSI. It seems desirable to hold these meetings as soon as possible. However, probably not more than three teams should be used because the presentation should be as uniform as possible. Three teams each conducting 13 meetings should be able to cover the entire area in one month or less with four to six hours of orientation.

Short-Course Training

A second type of training will be necessary to teach farmers and operators improved methods of irrigation farming. This training may be broken into two phases, depending upon the amount of land owned.

1. In one group would be farmers who have holdings large enough to hire managers, either individually or cooperatively. These managers (estimated at one manager per 1,000 decares or a total of 120) could be given a series of intensive training session in all phases of good irrigation farm management. It is estimated that this training will require approximately three months.

2. The training of the second group, that is the owners who are small farmers, can be accomplished in a shorter training session of about 14 days. This short course should be designed to acquaint farmers with the same general principles of irrigation as are covered in the longer course for managers and large owners.

The training could be given by a team composed of an agricultural engineer, a soil technician, and a leading farm operator. The team would require transportation (probably a pickup truck) a driver, and training aids. One team working for three years would be sufficient to train all of the small farmers of the area. However, it seems desirable to train several teams (possibly five or ten) to give these short courses. Such a policy would upgrade the technical skills of a large portion of the extension staff of the area, both in knowledge and in teaching ability. This would also make the schedule for training the farmers more flexible. It also seems desirable to give irrigation training to all of the extension workers, even though they may not be involved in the actual training job; they will then be better able to assist farmers in implementing what they learn.

The short-course training for both the large and smaller landholders would be same except for duration and detail. It would cover the various inter-related aspects of irrigation, such as soil, water, crops, livestock, fertilizer, equipment, pesticides and seed.

The workshop method of instruction, making use of visits to demonstration areas, should be used insofar as possible. Each session should utilize illustrated lectures, slides and other visual aids. Each farmer should make a plan for his size of operation, utilizing the information given in the lectures and receiving the aid of the team members.

V. CREDIT

In any country, regardless of the stage of its development, a dependable source of credit for agriculture is one of the essential factors contributing to increased agricultural production and to a better living for farmers. Of the three economic elements of production-land, labor and capital, agriculture is usually in greatest need of capital. In Turkey there is an abundance of land and labor, but there is great need for capital to facilitate agricultural development.

It is slow and difficult, if not impossible for the agricultural sector of the economy of any country to generate within itself sufficient capital for its own development. This is particularly true during the early stages of economic development, when farmers are at a disadvantage in the market place, both for the sale of their products and for the purchase of their supplies. Thus the government of a country must take positive steps to set up the necessary institutions to open the channels of capital to agriculture.

Position of the Agricultural Bank and Recommendations

(1) The Agricultural Bank has the legal structure, organization and physical facilities throughout Turkey to provide credit service to farmers and to agricultural cooperatives if rehabilitated and reoriented toward agriculture.

(2) The financial resources of the Bank are very limited for future credit service, and ways and means need to be found to bolster these resources. This is primarily a problem that needs to be solved by the Government of Turkey.

(3) The Agricultural Bank needs to have its staff trained and oriented toward agriculture. The Bank is very anxious to improve this situation and has already taken steps, with the cooperation of A.I.D., to carry out an expanded participant training program.

(4) The objectives of any agricultural credit system should be:

(a) to extend credit to farmers for productive and helpful purposes, and (b) to help farmers improve their incomes and their financial position. If a loan is made to a farmer which will only prolong a hopeless debt situation, it will be contrary to the objectives of the system. Such loans are not helpful to the farmer. They drain the resources of the Bank and reduce the funds available for other credit-worthy farmers. They also have an inflationary influence on the general economy.

(5) It is important that there be a friendly relationship between the farmer and the credit institution, based on mutual confidence. To accomplish this, it is necessary that the far-farmer be given an opportunity to understand, when the loan is being negotiated, what he can expect from the Bank and what the Bank expects from him. Knowledge and complete understanding of all the important factors involved in this relationship are necessary to the establishment of mutual confidence. To accomplish this kind of relationship between the farmer on the one hand and the Agricultural Bank on the other necessitates an educational program in the villages.

(6) It is always desirable for the farmer to use his own money, to the extent possible, to accomplish his purpose, and to request a loan only to supplement his own money in order to complete the financing of his farm. This gives the farmer an equity in his farming operations which he will work harder to protect than if the Bank or the credit cooperative assumes the entire risk.

(7) In extending credit to a farmer, it is better to make him a loan large enough to pay off his other debts, if it is an amount that is within his repayment ability, rather than to make him a small loan and merely become another creditor. This involves a careful determination of the farmers's credit requirements, including enough money to pay other debts. For a farmer to owe a debt to more than one creditor is not considered good practice either for the creditor or the farmer.

Credit Needed for the Project

Credit needed for the project area of 182,000 decares is discussed in four parts, according to development phases.

(1) 100,000,000 TL. are needed to purchase pumps and equipment. These will be used for pump irrigation systems by private parties and organizations for the development of water resources.

(2) 11,970,000 TL. are needed for farming services such as land levelling, farm irrigation, and drainage and water control systems in connection with land resources development.

(3) 15,411,000 TL. are needed for tractors and farm equipment.

(4) 11,286,000 TL are needed for fertilizer, seed and insecticides. The cost of providing water outside the four items mentioned above and also of the installations for the distribution of water will be borne by DSI and Topraksu as a Government investment.

(5) It is estimated that 3,000,000 TL. are needed for marketing and transportation.

Procedure for Credit

Farmers in the Tarsus-Berdan Project area or other project areas concerned with soil and water resources development as is the Tarsus-Berdan project, can receive credit as outlined below:

1. The farmer applies to the local Soil and Water Organization (Topraksu). If this organization is not available, he applies to the Extension Service. Priority will be given to the requisitions of farmers who are in the project area, but requisitions outside of the project area shall also be taken into consideration.
2. The local Topraksu Organization will investigate the repayment capacity of farmers who request credit from the Agricultural Bank and, if this is satisfactory, prepare farm layout and credit plans. These plans shall also include repayment conditions. Farm credit plans thus prepared will be approved by the General Directorate of Topraksu.
3. Under the control of the Topraksu Organization, payments will be given to farmers according to approved credit plans in order to cover the expense of the work. Only 60 per cent of the necessary investment for full farm development can be given as a credit; the remainder of 40 per cent should be covered by the farmer.

Necessary funds for the farmer's credit can be obtained from two sources. The first is by agreement of Topraksu and the Agricultural Bank. The second is from released counterpart money by agreement of the Turkish Government and U.S. A.I.D. The protocol prepared between the Turkish Government and A.I.D. is not included in detail, but may be obtained from the authors.

VI. MARKETING AND TRANSPORTATION

It is suggested that 3,000,000 Turkish lira for the total project area per year be allocated to the project area as loan funds for the development of marketing, through such means as packing, grading, and cooling or storage facilities. In addition, both the Ministry of Agriculture and the Ministry of Commerce must continue and extend their efforts in developing stronger local and export markets for the winter vegetables and fruits of the area.

This would be for Turkey an ideal area in which to take active leadership in encouraging private or cooperative business enterprises to demonstrate the advantages of good marketing and transportation practices. To be successful, such demonstration must be carefully planned and activated from the planting of quality crop varieties through careful culture, harvesting, grading, packing, and quick transportation. Both air transport and refrigerated trailer trucks rolled onto ships should be part of the demonstration.

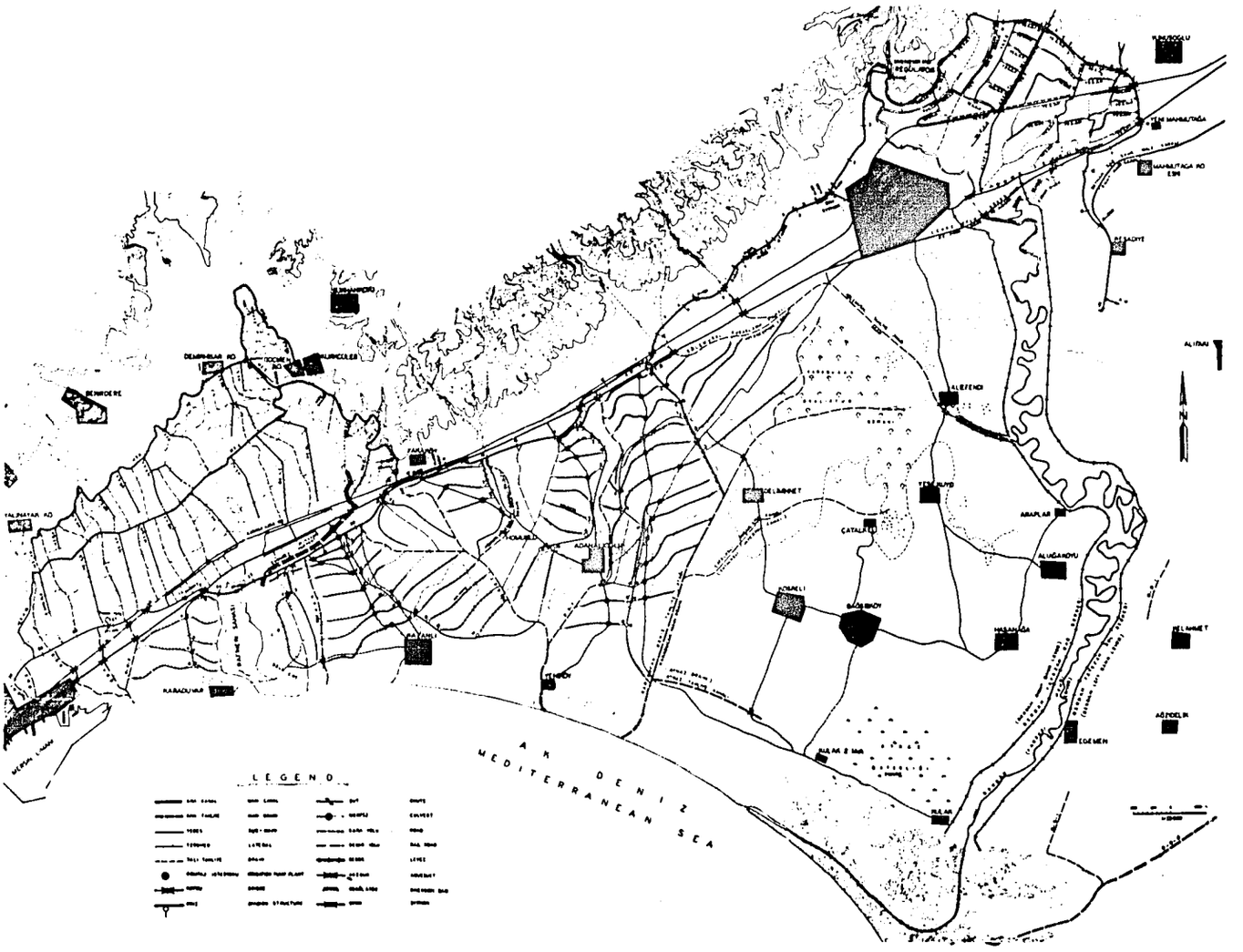
DISCUSSION

Labor costs for production have been included in calculating the benefit-cost ratios. Spare parts for equipment are based on estimates and this cost may be low. It is a relatively minor part of the total and increasing it would not greatly change the benefit-cost ratio.

In computing the water requirements, Blaney-Criddle and Penman's methods were used, plus experimental data from the Tarsus Research Institute. The values of k were those used for Arizona and California. The minimum flows given for the Berdan are indeed minimum flows, not means or averages. Repayment costs are based on 50 years. The pumping at Yakakoy is in two stages, with a total lift of 35 meters. Only part of the water is

lifted through the second stage, so that there are two delivery canals. Extensive studies of canal seepage have not been made.

A summary of remarks made by discussers follows: It is hoped that the pay scales of the technicians may compare favorably with those paid to the administrators. Cropping patterns should be expressed in terms of the land, not in terms of the owners, because land holdings may be too small to reflect the cropping patterns. Pakistan has been successful in discussing crop rotation plans with the farmers and working out plans with them. This is more desirable than imposing crop rotations by decree. The importance of training for those who are working with the farmers was stressed. The trainer should understand the social customs of the farmers also. There should not be too much elapsed time between the time that a farmer needs credit and the time that it is made available to him, especially as this applies to the meeting of emergency costs. Since all costs must eventually be recovered from the land, organizational costs should be kept as low as possible. Some of the activities, such as the construction or field ditches, may be left to the farmers themselves. In reply, Mr. Yegin felt that the farmer himself must be taken into account in planning the rotation. It may take approximately a year for farmers to realize their loan requests based on a complete farm plan. Organization costs should, of course, be kept as low as possible; however, not so low that the job cannot be done. With regard to construction of field drains and ditches by the farmer, the farmer is capable of doing this and no loan is contemplated for this purpose. While our Extension Service has been impossible for the farmers to carry out these recommendations because they did not have necessary tools or sources of capital.



CHAPTER VII

DRAINAGE AND SALINITY CONTROL

MANAVGAT PROJECT DRAINAGE AND RECLAMATION

by

Mr. Suha S. Eren

INTRODUCTION

The Manavgat Project is a relatively small project. Here, however, are encountered most phases of drainage engineering. The drainage problems include high water table, salinity, alkalinity artesion pressure, canal seepage, heavy-textured soils, and outlet by pumping.

The soil, drainage and economic studies for this area were made during 1961. They showed that the project area will be highly productive if proper irrigation and drainage installations are built and the necessary reclamation is made.

The project was approved by the General Directorate of State Hydraulic Works and the construction work commenced on April 1st, 1962.

This presentation is a brief summary of «The Detailed Land Clasification and Drainage Investigation Report of Manavgat Project.»

1 Civil Engineer, General Directorate of State Hydraulic Works, Ministry of Public Works, Turkey.

General Project Location

The Manavgat Plain is a small coastal plain located about 80 kilometers east of the town of Antalya. The project area is a portion of the Ma-

TABLE 7. MONTHLY AVERAGE VALUES — PRECIPITATION, TEMPERATURE, EVAPORATION AND HUMIDITY

Observation Stations	MONTHLY AVERAGES												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
Precipitation mm. Managat (inches)	407.3 (16.04)	222.6 (9.47)	179.2 (7.06)	44.1 (1.741)	24.1 (0.94)	11.3 (0.45)	0.4 (0.01)	0.4 (0.01)	22.8 (0.90)	91.0 (3.54)	161.6 (6.30)	430.3 (16.93)	1595.1 (62.80)
Temperature oC Antalya (of)	10.5 (50)	10.6 (51.1)	12.6 (54.7)	16.2 (61.2)	20.5 (68.9)	25.0 (77.0)	28.2 (82.7)	28.1 (82.6)	24.9 (76.8)	20.3 (68.5)	15.5 (59.9)	11.6 (52.8)	18.1 (64.6)
Pan Evaporation mm. Antalya (Class A pan) (inches)	31.5 (1.22)	49.8 (1.97)	63.0 (2.87)	91.4 (3.58)	133.9 (5.28)	243.8 (9.60)	299.2 (11.77)	283.5 (11.14)	213.4 (8.38)	102.4 (3.92)	61.0 (2.40)	31.5 (1.24)	1604.4 (63.15)
Humidity — % Antalya	69	68	65	68	68	63	58	60	58	62	67	70	65

navgat Plain and is bounded by the main irrigation canal on the north and east, by the Manavgat River on the west, and by sand dunes and the Mediterranean Sea on the south. It covers an area of 1441.0 hectares.

CLIMATIC CONDITIONS

The project area has a continental Mediterranean climate. Summers are dry and hot, winters are mild and rainy. The average annual rainfall is 1595 mm. (61.7 in.); 1400 mm. (55.1 in.) of this total falls between November and March. There is practically no rainfall during the summer months. The annual evaporation is 1604 mm. (64.6 in.). The average monthly temperature varies between 28.2°C (82.7°F) in July and 10.0°C (50°F) in December, with an average annual temperature of 18.1°C (64.6°F). The average humidity in the area is 65 per cent. The climatic conditions demand that irrigation be used to grow summer crops. Detailed information is presented in Table 1.

Soils Physical Characteristics

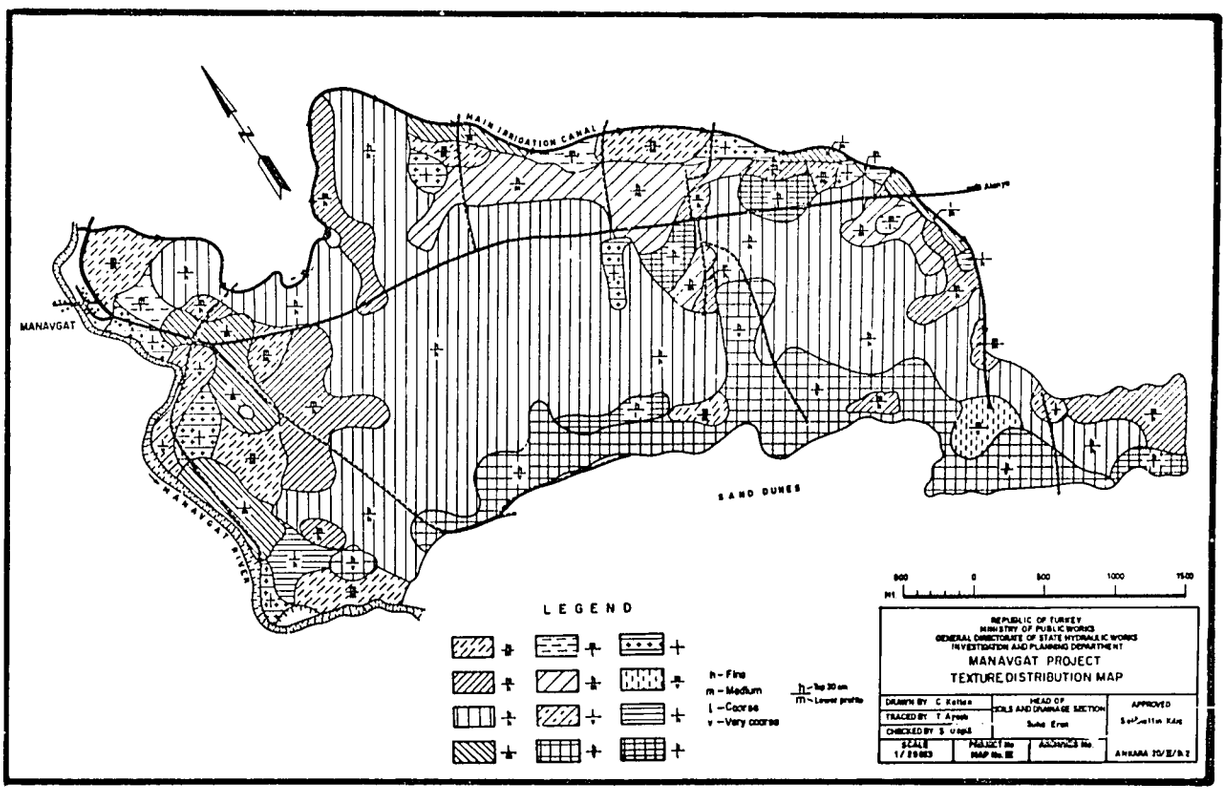
Soil Texture. The soils in the project area were formed from alluvial deposits of the Manavgat River and surounding creeks. The origins of the soils are limestone, sandstone and marl.

Soil texture varies over the plain from clay to sandy-loam. The soils at the slopes are clay-loam and loamy sand. At the center and the southern part of the plain, where the slopes are between zero and one per cent, the texture of the soil is heavy clay. The distribution of soil texture in the area is given in Fig. 1.

A sand layer about three to five meters thick (10 to 16 ft.) covers the whole area at about sea level. The sand layer is underlaid by an impermeable blue clay formation.

Soil Structure. The structure of the light textured soils is friable granular. There is no structure in the heavy clay soils.

Soil Depth. The soils in general are deep enough to permit good root development. Toward the south-



ern part of the area, the sand layer comes close to the surface.

Infiltration Rates. Soil infiltration rates are given in Table 2.

TABLE 2. INFILTRATION RATES

Texture of Soil	Average Infiltration
Fine (SiC, C)	3 mm/hr. (0.18 in/hr.)
Medium (SiCl, CL)	8 mm/hr. (0.32 in/hr.)
Coarse (L)	17 mm/hr. (0.67 in/hr.)

The infiltration rates of the medium and coarse textured soils are adequate for good irrigation practices and reclamation. The infiltration rate in the fine textured soils is somewhat low and measures to improve soil structure are needed.

Hydraulic Conductivity

The hydraulic conductivity of the soils, as measued by the auger-hole method and Kirkham permeameters in the field and by laboratory tests on disturbed soil samples, varies from very rapid to very slow. Hydraulic conductivity in alkaline areas is practically zero. The hydraulic conductivity of the sand layer is very rapid, Table 3.

Field Capacity. Field capacity studies show variation among the different soils. Readily available moisture values for the different soil textures are given in Table 4.

TABLE 4. READILY AVAILABLE MOISTURE

Soil Texture	R.A.M. cm/30 cm. of Soil
Clay, Silty-Clay	5.4 (2.12 in/ft)
Silty Clay-Loam	4.4 (1.73 in/ft)
Sandy-Clay-Loam	3.5 (1.38 in/ft)
Loam, Silty-Loam	2.9 (1.14 in/ft)
Sandy-Loam	2.5 (0.99 in/ft)

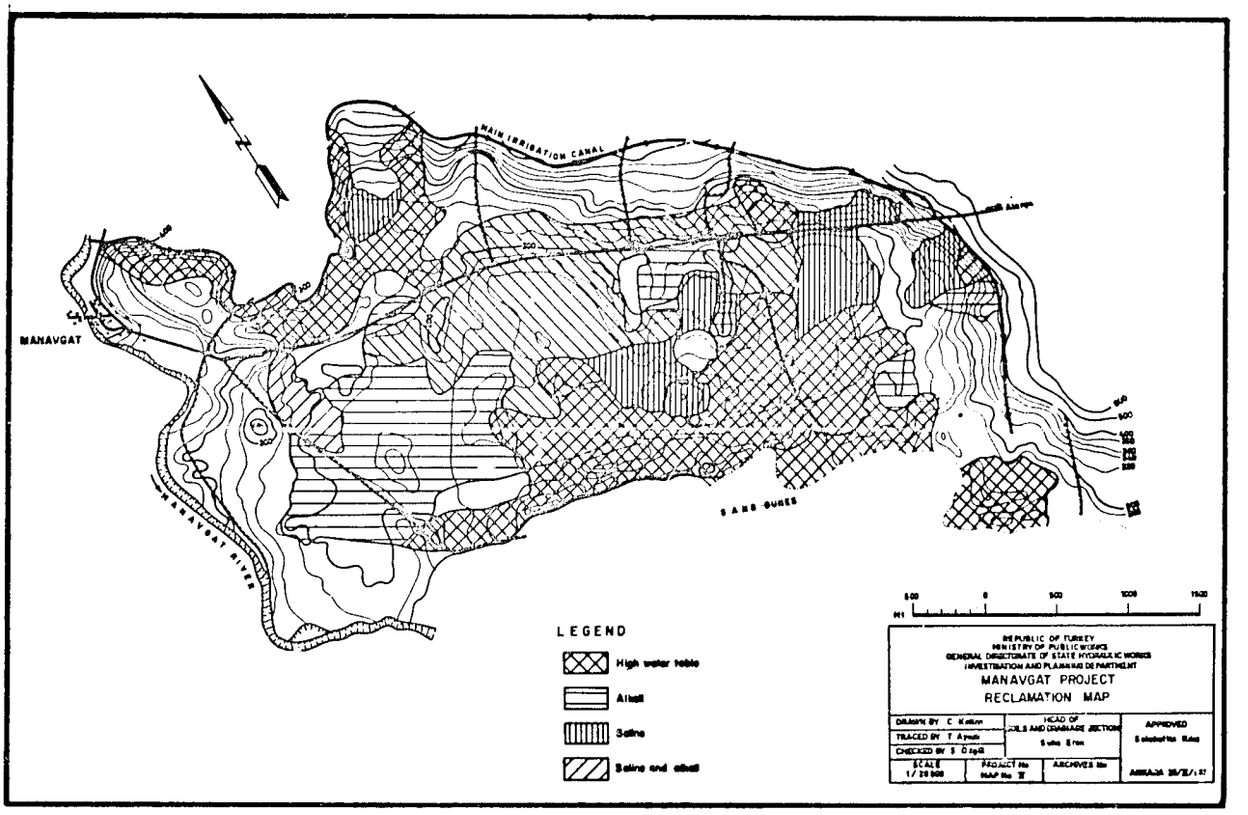
Chemical Characteristics

Lime Content. Since a major source of the soil parent material in the project area is limestone, the lime content of the soils is very high (average, 30 per cent). This will be a favorable factor in reclamation of the alkaline areas. In some profiles, the lime is leached and deposited at depths of 90 to 120 cm. (3 to 4 ft.).

Salinity. Salinity is one of the main problems in the project area. Over part of the area it is combined with alkalinity (Fig. 2).

TABLE 3. HYDRAULIC CONDUCTIVITY — M/DAY, (IN/HR.) (AUGER-HOLE METHOD)

Soil Texture	Number of tests	Minimum	Maximum	Average
Clay	65	0.05 (0.09)	4.40 (7.2)	0.67 (1.1)
Sandy-loam	1	—	—	4.2
Loamy-sand	3	4.50 (7.4)	12.60 (20.7)	7.6 (12.5)
Sand	50	1.00 (1.64)	27.20 (44.5)	5.2 (8.5)



There are several source of the salinity:

1. The soils originally contain salt.
2. The artesian water is saline.
3. Due to lack of surface drainage, the run-off collects in low areas and, through evaporation, the salts accumulate on the surface.

Salt accumulation is leached out by winter rains and accumulates again during the plant growing season. An example of this is given in Table 5.

TABLE 5. LEACHING BY WINTER RAINFALLS

Hole No.	Soil Layer	percent Total Salt	
		April 1961	October 1961
212	0-30 cm. (0-1 ft)	0.17	2.57
	30-60 cm. (1-2 ft)	0.06	0.55
	60-90 cm. (2-3 ft)	1.66	2.18
	90-120 cm. (3-4 ft)	1.66	2.57
215	0-30 cm. (0-1 ft)	0.36	0.75
	30-60 cm. (1-2 ft)	0.44	0.71
	60-90 cm. (2-3 ft)	0.21	2.18
	90-120 cm. (3-4 ft)	0.43	2.57
	120-150 cm. (4-5 ft)	0.03	2.57

Indications are that an efficient subsurface drainage system, aided by winter rainfall, can accomplish considerable salt removal.

Alkali. Alkali is also a problem in the area, 187 hectares of land in the project area being Alkali. There the exchangeable sodium is found in the complete profile and varies between 1.7 and 16.6 per cent. Generally, the top 30 cm. (1 ft.) of the soil are not alkaline. The highest concentration of exchangeable sodium is found between 60 ans 90 cms, (2 to 3 ft.).

Gypsum and Organic Matter. The soil in the project area contains no gypsum, and the organic matter content is very low.

AGRICULTURAL CONDITIONS

Crop Pattern. The main crop in this area is cotton. Citrus orchards and truck gardens are located near the Manavgat River banks, where adequate natural drainage exists.

Cotton is being grown continuously year after year and the yields are going down. Present yields average 150 to 200 kilograms per decare (1320 to 1960 lb./acre), where ten years ago the yield was 350 kilograms per decare (3080 lb/acre). Cotton yields on unirrigated fields are about 50 kilograms per decare (440 lb/acre).

Existing Irrigation. The main irrigation canal and a main surface drainage canal are completed. The secondary canals and tertiaries are not completed. Irrigation in the project area is accomplished by pumping from the river, the main irrigation canal and also from the drainage canal. The farmers irrigate by wild flooding only. In winter they keep the land under water in order to leach the salts. Since there is no effective farm drainage, conditions do not improve permanently.

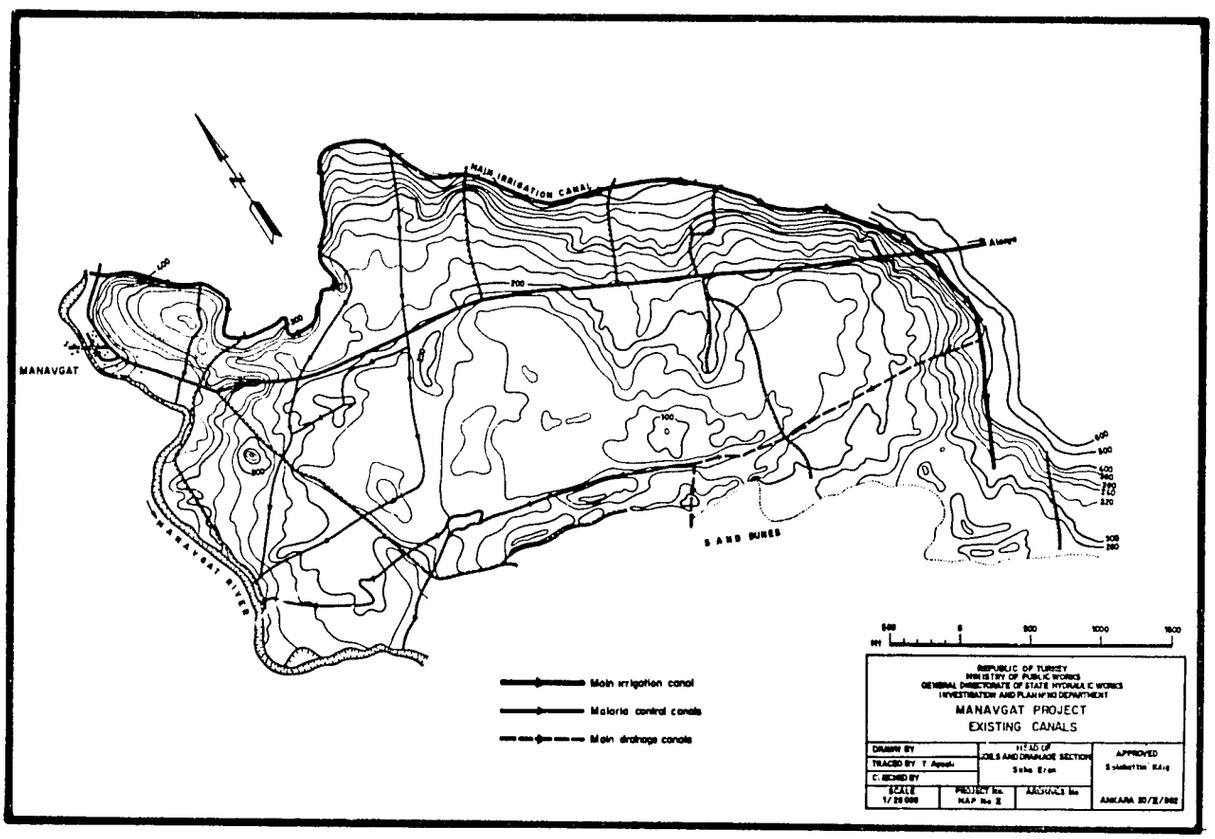


TABLE 6. RAINFALL CHARACTERISTICS

FREQUENCY	YEARS				
INTENSITY	5	10	25	50	100
24 hour rainfall mm.	131	155	185	207	230
(in.)	(5.20)	(6.10)	(7.30)	(8.15)	(9.06)
1 hour rainfall mm.	43	50	61	69	77
(in.)	(1.69)	(1.97)	(2.40)	(2.72)	(3.03)

Crop Adaptation. The ecological conditions indicate that any kind of crop can be grown in the project area. The major crops should be cotton, vegetables, citrus, sesame, corn and legumes. Cotton should be grown in rotation with sesame or soybean and vetch, sunflower or corn. A new crop that can be introduced to the area is peanuts.

DRAINAGE

The project area, bounded by hills at the north and east and by sand dunes at the south, is a closed basin without a natural outlet. Surface run-off collects in the central part of the plain. The factors contributing to drainage problems in the area are elaborated below.

Rainfall. The rains during winter and spring are very intensive and very quickly inundate the area. Surface ponding should be removed in 48 hours from the cultivated areas, and in two to four hours from the truck crop fields.

Rainfall characteristics for the project area are given in Table 6.

Rainfall records show that hourly rainfall intensities are approximately one-third of the 24-hour rainfall for a given frequency.

It has been found that water-table fluctuations are directly related to rainfall distribution over the year.

Creek Run-off. The main irrigation canal also acts as an interception ditch. Therefore, run-off from the creeks does not reach the project area.

Floods. The Manavgat River channel is deep and wide enough to confine large floods. Up to the present, there has not been a large flood that caused damage to the project area.

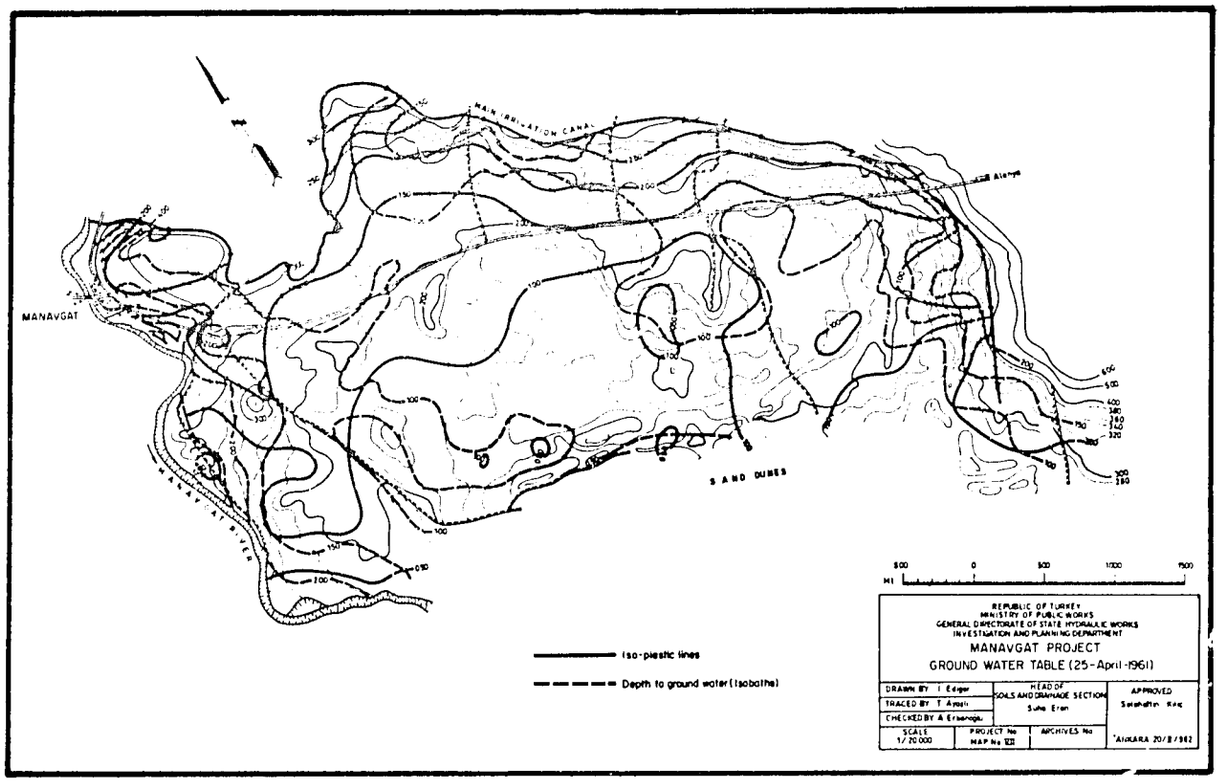
Canal Seepage. The main irrigation canal has not been lined. Piezometric studies made on the canal show that seepage is very high and is one of the factors contributing to the high water table. Measurements of flow in the canal also support this conclusion. The total seepage in a seven-kilometer (4.35 miles reach of the canal was found to be 200 liters/sec. (7 cfs).

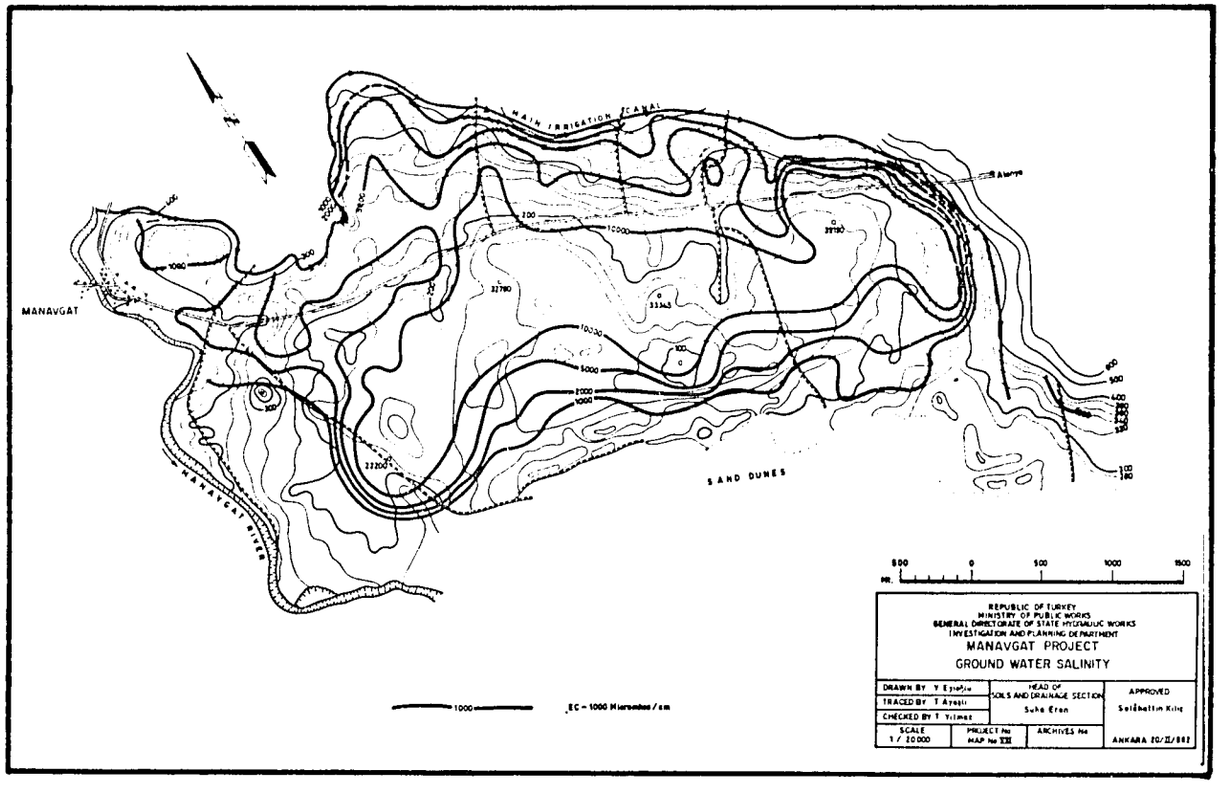
Irrigation. Irrigation of the cotton crop in the project area is by wild flooding. Basic preparations for irrigated agriculture are used. Winter flooding for leaching purposes also raises the watertable and delays early planting.

Artesian Pressure. The piezometric studies made in the project area show the existence of artesian pressure. The acquifer is 3 to 5 m thick (10 to 16 ft) and underlies the whole area. At the northern part of the plain, piezometers flowed at a depth of four meters.

Existing Water Table and Groundwater Quality. The iso-piestic lines and iso-baths for the water-table are given in Fig. 4.

The movement of the groundwater is generally toward the center of the plain. The water-table is very close to the surface. In


MAIN IRRIGATION CANAL
MANAVGAT
MANAVGAT RIVER
SAND DUNES
Alanya
Iso-piezetic lines
Depth to ground water (Isobaths)
REPUBLIC OF TURKEY
MINISTRY OF PUBLIC WORKS
GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS
INVESTIGATION AND PLANNING DEPARTMENT
MANAVGAT PROJECT
GROUND WATER TABLE (25-April-1961)
DRAWN BY I. Edger
TRACED BY T. Ayşeli
CHECKED BY A. Erbaroğlu
HEAD OF SOILS AND DRAINAGE SECTION
Suha Eren
APPROVED
SCALE 1/20000
PROJECT No
MAP No
ARCHIVES No
ANKARA 20/II/1962


MAIN IRRIGATION CANAL
MANAVGAT
MANAVGAT RIVER
SAND DUNES
Alanya
1000
EC = 1000 Micromhos / cm
REPUBLIC OF TURKEY
MINISTRY OF PUBLIC WORKS
GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS
INVESTIGATION AND PLANNING DEPARTMENT
MANAVGAT PROJECT
GROUND WATER SALINITY
DRAWN BY Y. Eşsoğlu
TRACED BY T. Ayşeli
CHECKED BY T. Yılmaz
HEAD OF SOILS AND DRAINAGE SECTION
Suha Eren
APPROVED
SCALE 1/20000
PROJECT No
MAP No
ARCHIVES No
ANKARA 20/II/1962

about 80 per cent of the area, the watertable is between the surface and 1.5 meters (5 ft). Along the Manavgat River, is below 2.0 meters (6.5 ft), as the river acts as a natural drain.

The groundwater is very saline, especially at the central part, (Fig. 5). Salinity is as high as 39,000 micromhos/cm.

Sea Intrusion. The Manavgat River runs almost parallel to the plain on the south side of the sand dunes before discharging into the sea. This prevents the salt water from intruding into the plain. The tide has been measured and found to be about 20 cm. (8 in). The tide also has no effect on the groundwater.

LAND CLASSIFICATION

A detailed land classification map (Fig No 6) has been prepared for the project area showing the different classes and subclasses. Tho land classes and their hectarages are given in Table 7 and 8.

Irrigation Water.

The source of irrigation water is the Manavgat River. The water quality is very good. The electrical conductivity is 235 to 400 micromhos/cm. The calcium and magnesium content is higher than the carbonates. There is no problem of residual carbonate or boron.

DESIGN CRITERIA

Reclamation Possibilities. At present 498 hectares (1,230 acres) of land in the project area need reclamation because of salinity, alkalinity and the high water-table. Reclamation possibilities and potential problems are given below:

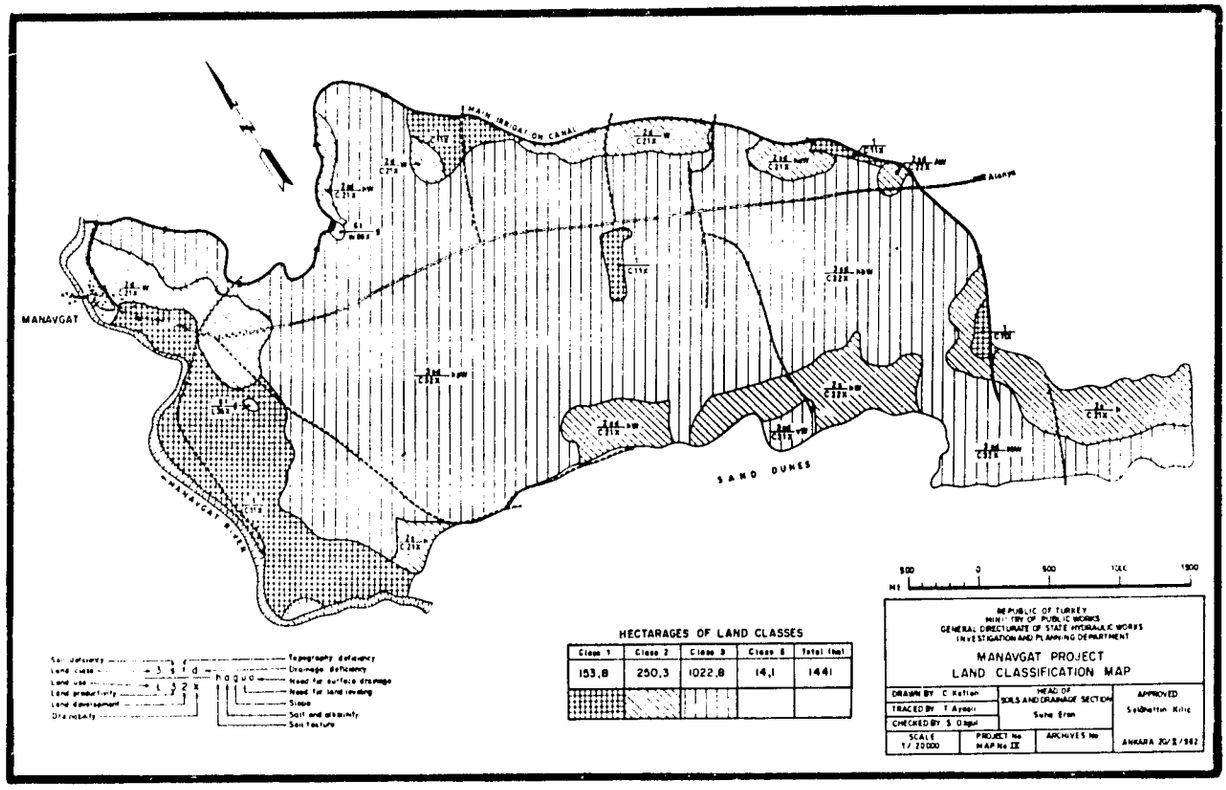
1. The drainability of the land is good. The high watertable can be lowered with out any difficulty.
2. Outlet conditions are poor. Pumping of drainage water is necessary.
3. The irrigation water is of good quality. However, it is not very desirable for lea-

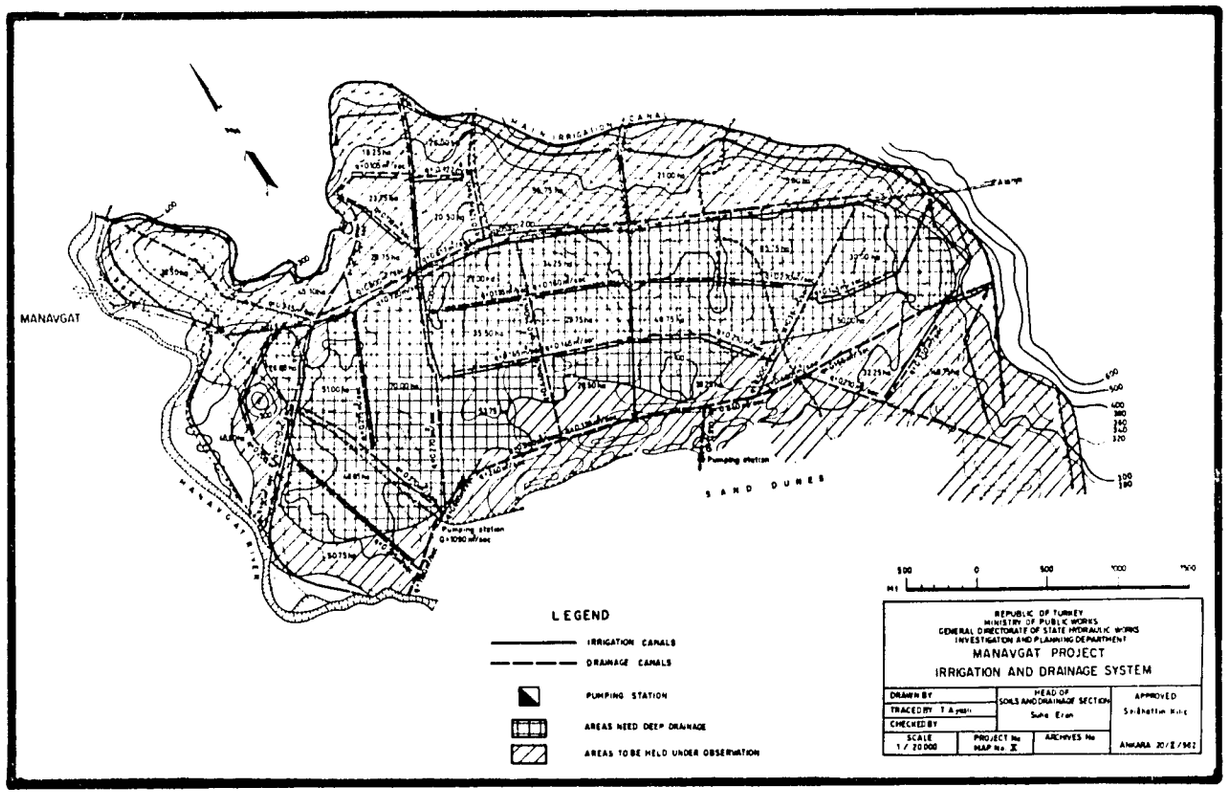
Table 7. Irrigable Land Classes

	Class 1	Class II					Class III					Total Irrigable area Ha.
		2S	2D	2sd	2std	Total	3S	3d	3sd	3std	Total	
Area Ha. (acre)	153.8 (379.9)	74.8 (184.8)	67.6 (167.0)	67.8 (167.5)	41.1 (101.5)	251.3 (620.8)	4.3 (10.6)	26.6 (65.7)	844.2 (2085.2)	146.7 (362.3)	1021.8 (2523.8)	1426.9 (3524.5)
Percent	10.7%	5.2	4.7	4.7	2.9	17.5	0.3	1.9	59.2	10.2	71.8	100 %

Table 8. Non-Irrigable Area

Hill	Roads	Canals
1.5 ha. (37 acres)	6.5 ha. (16.1 acres)	6.1 ha. (15.1 acres)


MAIN IRRIGATION CANAL
MANAVGAT
MANAVGAT RIVER
SAND DUNES
HECTARAGES OF LAND CLASSES
Class 1 | Class 2 | Class 3 | Class 6 | Total (ha)
153,8 | 250,3 | 1022,8 | 14,1 | 1441
Topography deficiency
Drainage deficiency
Need for surface drainage
Need for land levelling
Slope
Salt and alkalinity
Soil texture
REPUBLIC OF TURKEY
MINISTRY OF PUBLIC WORKS
GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS
INVESTIGATION AND PLANNING DEPARTMENT
MANAVGAT PROJECT
LAND CLASSIFICATION MAP
DRAWN BY C Kalion
TRACED BY T Ayeşin
CHECKED BY S Ozgul
HEAD OF SOILS AND DRAINAGE SECTION
Suha Eren
APPROVED
Sadettin Kilic
SCALE 1/20000
PROJECT No
MAP No IX
ARCHIVES No
ANKARA 20/II/1962


MAIN IRRIGATION CANAL
MANAVGAT
MANAVGAT RIVER
SAND DUNES
Pumping station
Pumping station
LEGEND
IRRIGATION CANALS
DRAINAGE CANALS
PUMPING STATION
AREAS NEED DEEP DRAINAGE
AREAS TO BE HELD UNDER OBSERVATION
REPUBLIC OF TURKEY
MINISTRY OF PUBLIC WORKS
GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS
INVESTIGATION AND PLANNING DEPARTMENT
MANAVGAT PROJECT
IRRIGATION AND DRAINAGE SYSTEM
DRAWN BY
TRACED BY T Ayeşin
CHECKED BY
HEAD OF SOILS AND DRAINAGE SECTION
Suha Eren
APPROVED
Sadettin Kilic
SCALE 1/20000
PROJECT No
MAP No. X
ARCHIVES No
ANKARA 20/II/1962

ching purposes. The water may cause deflocculation and reduce the permeability of the soils.

4. Approximately 80 to 100 cm. (30 to 40 inches) of water must pass through the root zone to provide adequate leaching.
5. One ton of gypsum for each decare is required to reclaim alkali and saline-alkali lands.
6. Cotton, rice and alfalfa can be grown during reclamation activities.

Irrigation and Drainage System. The irrigation and drainage system of the project area is given in Fig. 7. A total of 478 hectares (1,181 acres) of land will be drained by gravity. The rest of the area will be drained by pumping. A total of 1,400 hectares (3,458 acres) of land will be irrigated.

Pumping stations have been proposed. The capacities of these stations are 0.9 and 1.1 m^3/sec. (32 and 39 cfs). They are designed to take care of maximum rainfall with 10-year frequencies.

Deep Drainage. A total of 498 hectares (1,230 acres) of land in the project area requires deep drainage. The type of crop, the salinity of the groundwater and the climatic conditions require that the normal watertable should be kept at a depth of a least 150 cm (5 ft) from the surface. Deep drainage will be accomplished with closed tile drains. Tiles will be placed at a depth of approximately 180 to 200 m (6 to 7 ft). The drain spacings were calculated for different areas by the Houghoudt and Kirkham formulas and found to be between 50 m. and 150 meters (164 to 490 ft). A drainage coefficient of 7 mm/day (0.276 inches/day) has been accepted for the project area.

Drainage Canals. Proposed drainage canals are between 150 to 220 cm deep. The slopes vary between 0.0002 to 0.00078. The discharges are calculated by the McMath formula.

Artesian Water. Most of the drainage canals will intercept the sand layer and thus the artesian pressure will continuously be relieved by the canals. Since the pumping stations are designed for 10-year rainfall intensity, no additional pumping will be required for this additional discharge.

RECOMMENDATIONS

In order to have good crop production after the irrigation and drainage system is completed, the following practices are recommended:

1. The scientific use of water in very important for the project area.
2. The furrow irrigation system should be used in the area; wild flooding should be abandoned.
3. Crop rotation, especially where cotton is grown, should be encouraged.
4. The lands should be fortified by artificial fertilizers and/or farm manure.
5. The land should never remain idle during the first ten years of reclamation. Rice planting should not be encouraged except for reclamation purposes.
7. The farmers should be taught more efficient techniques of irrigated agriculture.
8. Extensive reclamation experiments should be made to establish economical methods before project reclamation is started.

DISCUSSION. The sand dunes are compact and set rather than alive. Water needs to be used economically because excess water has to be pumped. Furrow irrigation is used because of low infiltration. Crops are planted on the edge of the furrows in order to give some aeration to the root zone. The leaching will be taken care of by the winter rain.

An objection was made to having the drainage ditches transecting the canals. It was stated that the drainage system was designed with adjacent areas in mind. The irrigation designers changed some of the design and also made some overpasses for the drainages based on topographical considerations. The canal lies near the edge of the project in the sandy soils; therefore canal losses are high. The soils to be reclaimed are in the center of the area and are heavy. The clay fractions are not expandable clays, so extreme cracking is not anticipated. Preliminary leaching trials indicate the feasibility of leaching.

The discussion brought out that continued culture of cotton on a single plot often results in a disease. There are some cotton diseases in Turkey which those concerned with plant protection are working on.

TILE DRAINAGE FOR LAND RECLAMATION IN THE MENEMEN PLAIN

by

Mr. Kaya Bozkurt

INTRODUCTION

The tile drainage project described herein occupies an area along one of 29 tertiary canals installed by the State Hydraulic Works for the Izmir-Menemen irrigation system. Drainage problems in the area include a high water table which contributes to salinity and alkali development. Natural drainage has not been developed and deep artificial drainage depends on pumping for an outlet.

The drainage investigations, plans and cost estimates were made in 1961 by a Joint Drainage Group of the State Hydraulic Works (hereafter called DSI) and the Soil Conservation and Irrigation Service (hereafter called Topraksu). At the same time, a detailed soil study was made by the Ankara Land Classification Section of DSI. These studies indicated that production could be restored on abandoned lands and the general crop yields improved in the project area if drainage installations were built and necessary reclamation measures undertaken. These include land shaping and a better farm irrigation system, and improved soil and water management.

Drainage construction started in September 1961 and was completed at the end of December 1961. The system has been working successfully since its inception.

GENERAL PROJECT INFORMATION

Location. The Gediz River Delta, on the Aegean Coast, contains the Menemen irrigation system. The drainage project located within this system is the area served by one of the tertiary irrigation canals. It is bounded by the Sasalli P-2 and P-3 and the Seyrekkoy main drain. The distances from the project area to the cities of Menemen and Izmir are 25 and 30 kilometers, respectively. The distance from the project area to the Aegean Sea is six kilometers. The total drainage project area is 358 hectares. It is approximately rectangular, 2,500 meters in length and 1,400 in width. The road connecting Tuzcullu and Kaklic villages passes through the area.

Topography. The project area is nearly level, as can be seen on the map, Fig. 1. The general slope is from east to west and ranges between zero and 0.0005. The highest elevation in the area is 3.80 meters and the lowest is 2.90 meters above mean sea level.

Climatic Conditions. The project area is in the sub-humid region, the winters are mild and the summers are hot. The highest precipitation occurs in the winter, with lesser amounts in the spring and the fall. The 30-year averages for precipitation, temperature, and relative humidity are shown in Table 1.

Soils. Soil parent material has been developed from the alluvial deposition of the Gediz River. The texture becomes lighter with increasing soil depth. Generally speaking, from the surface to a depth of 90 cm. the texture is silty clay. Below 90 cm. in depth the texture becomes very fine sandy loam. This profile is dominant throughout the drainage project area.

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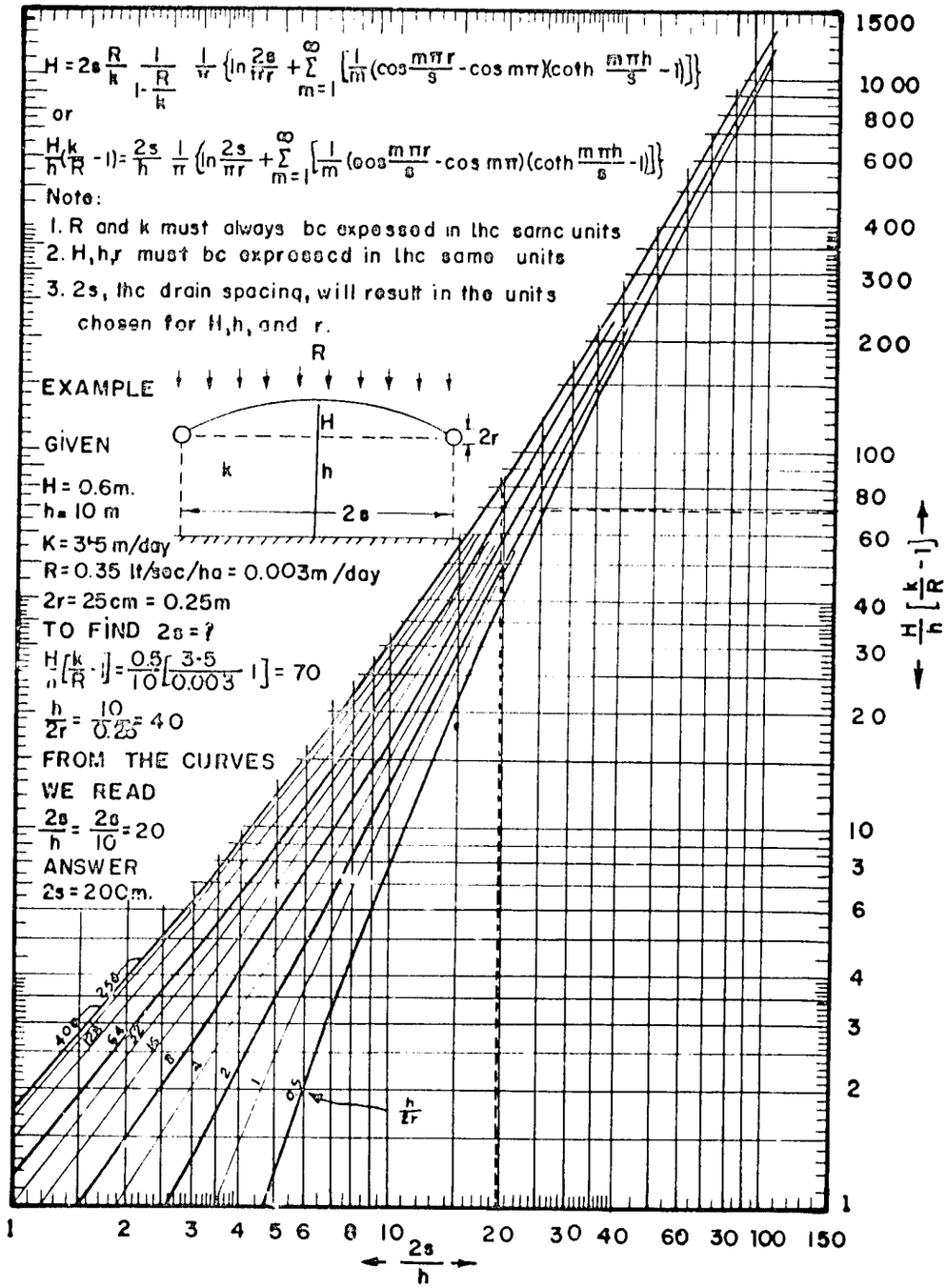
1 Agricultural Engineer and Project Leader: Topraksu General Directorate, Izmir, Turkey.

GRAPHICAL SOLUTION OF DRAIN SPACING FORMULA WHEN THE IMPERMEABLE LAYER IS AT A FINITE DEPTH h BELOW THE DRAIN CENTERS



FROM JOURNAL OF GEOPHYSICAL RESEARCH

Soils problems in the project area include saline, saline-alkali and nonsaline-alkali conditions. The sodium salts are dominent. The immediate origin of these salts has been through the rise of heighly saline groundwater (3 per cent saluble salt) that developed after the beginning of project irrigation. Roughly 90 per cent of the land in the project is designated Class 3, with salinity and drainage deficiencies predominating. The remaining 10 per cent of the area is Class 6.

Crop Pattern. The major crops in the area are those having high and medium salt tolerance. Cotton and barley predominate. Cotton production currently averages 100 kilograms per decare under irrigation and it is reported that it has yielded as high as 250 kilogram per decare. Barley averages 90 kilogram per decare under non-irrigated conditions and is restricted to a few small areas. Since the inception of irrigation in 1950, yields have been steadily decreasing; simultaneously salinity and alkalinity became a noticeable problem. Almost 20 per cent of the area is now abandoned and used for grazing because of the high salinity and alkalinity, which made farming unprofitable. In addition, a crop survey, completed in the spring of 1961, showed that on the average, 25 per cent of each cropped field had been salted out and was barren area.

Groundwater. The water table measured during the period of drainage investigations was continually high. The monthly readings are as follows:

Month	Jan.	Feb.	March	April	May	June	July
Depth to w.t. (cm.)	50	50	60	70	90	110	120

By late September, evaporation and transpiration had lowered the water table to 220 cm. Observed sources of groundwater replenishment are rainfall, irrigation and canal seepage. Limitations of time and the complexities of the system precluded quantitative measurements of either irrigation influence or canal seepage.

The groundwater near the surface is highly salinized with sodium sulfate and sodium chloride. Since the drainage by pumping began, the electrical conductivity of the drainage

Table 1. Climatic Data, Izmir, Turkey

STATION (Izmir)

Months	Monthly Procipitation (mm)	Relative Humidity %	Mean Temperature °C
Jan.	140.9	72	8.5
Feb.	102.1	69	9.2
Mar.	72.3	65	11.1
Apr.	40.9	62	15.4
May.	40.6	60	20.2
June	8.6	52	24.8
July	3.1	49	27.6
Aug.	2.6	49	27.3
Sept.	12.5	55	23.2
Oct.	53.5	64	18.4
Nov.	89.0	70	14.0
Dec.	135.4	72	10.2
Annual Average	701.5	61.5	17.5

discharge has averaged about 40,000 micromhos/cm. and the total soluble salts about 3 per cent.

In April, 1961, the average water level in the project was 70 cm. from ground level. On the basis of present information, the water table in April of this year was about 1.50 m. below ground surface. The water table outside the drainage area is at a depth of about of 1.00 m. The farmers inside the drainage area started spring work earlier than those outside the project area, in spite of heavy rains in late March.

Artesian Pressure. In the area, at two different locations, sets of piezometers were installed at depths of 2, 4 and 8 meters. Observations of the piezometers indicated no vertical flow. However, a well 78 meters deep, opened in the project area by DSI for the barrier survey, has continued artesian flow under a static head of about two meters above ground elevation.

The drillers' log explains the difference between deep and shallow observations. A barrier, composed largely of heavy sticky clay, begins at 12 meters and continues to a depth of 76 meters. The artesian acquifer is found below 76 meters. Unfortunately, the artesian water is of low quality (electrical conductivity, 2.5 millimhos; sodium absorption ratio, 21) and not suitable for irrigation. This is Class 4 water with a very high level of exchangeable sodium present.

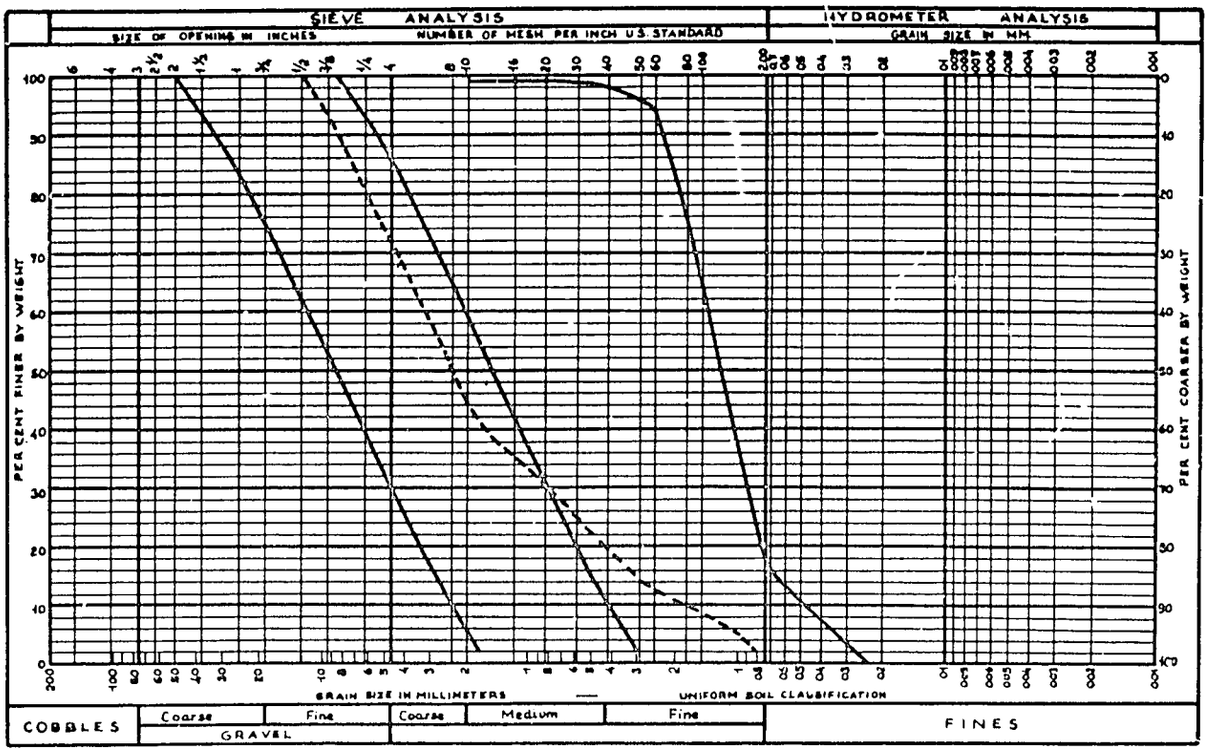
Outlet Conditions. The depth of the main drainage canals in the Menemen irrigation system is not sufficient for adequate deep drainage. Near the project area, present drainage canal depth averages 1.3 meters. Therefore, pumping is required for the outlet of deep tile and open drains. The drainage water is pumped from the main canal and discharged by means of a short surface canal to the Seyrekkoy Drainage Canal, which is one of the main drains of the original irrigation system. Two 50-liter-per-second pumps are installed to handle the deep drainage water. This coming summer the Regional DSI Office plans to deepen the Seyrekkoy Drain and thereby make gravity drainage possible for the Joint Drainage Project and the other tertiary canal areas that it serves.

Hydraulic Conductivities. Hydraulic conductivity measurements were made by the auger-hole method. In most of the areas, caving and poor stability of the fine sandy subsoil made it difficult to maintain an open auger-hole below the water table. To overcome this problem, a filter pipe was designed and used as a casing during the measurements.

Drainage Coefficient. In the absence of rainfall intensity records, the drainage coefficient was determined by taking 1 per cent of the average annual rainfall (a method mentioned in **Engineering for Agricultural Drainage,** by Roe and Ayres). This gives a drainage coefficient of 7 mm/day. Assuming that 45 per cent of the rain will pass through the soils to the tiles because of the combination of high infiltration capacity and nearly level land, this gives approximately 3 mm/day of 0.003 meters per day. This is equivalent to 0.35 lt/sec./ha. Total

TABLE 2. REPRESENTATIVE VALUES OF HYDRAULIC CONDUCTIVITY

Hole No.	Permeability (k) m/d	Value
1	1.7	Moderately rapid
2	3.3	Rapid
3	7.8	Very rapid
4	1.8	Moderately rapid
5	8.2	Very rapid
6	2.4	Moderately rapid
7	1.6	Moderate



expected discharge for the area is then 0.35 x 358 or 115.5 lt/second.

Barrier. The depth of the barrier from the ground surface ranges between 10 and 15 meters. An average depth of 12 meters was used for the drain spacing formulas.

Roughness Coefficient (n). Manning's roughness coefficient of n= 0.012 for the tiles and n= 0.030 for the open main drain was used.

Run-off. The drainage project area is surrounded by canals; therefore only the run-off originating from rainfall within the project area was considered. Surface drainage was not furnished for the first year. Where ponding of the surface water occurs, it should provide better leaching.

Floods. The Menemen irrigation system is protected from floods by the Gediz river through a large dike constructed on the north side of the Menemen plain paralled to the river. In addition the Seyrekkoy Drainage Canal immediately north of the project area carries the surface water from higher Elevations within the irrigation system.

Tile Depth and Spacing. Deep drainage is necessary because of the salinity and alkalinity in the area. The depth of all tiles ranges from 1,80 meters up to 2,00 meters. The spacing was checked by three formulas:

1. Donnan's formula

$$S = 2\sqrt{\frac{K}{R}(H_0^2 - h_0^2)} = 2\sqrt{\frac{3.5}{0.003}(10.6^2 - 10^2)} = 229$$

S = 229 meters spacing

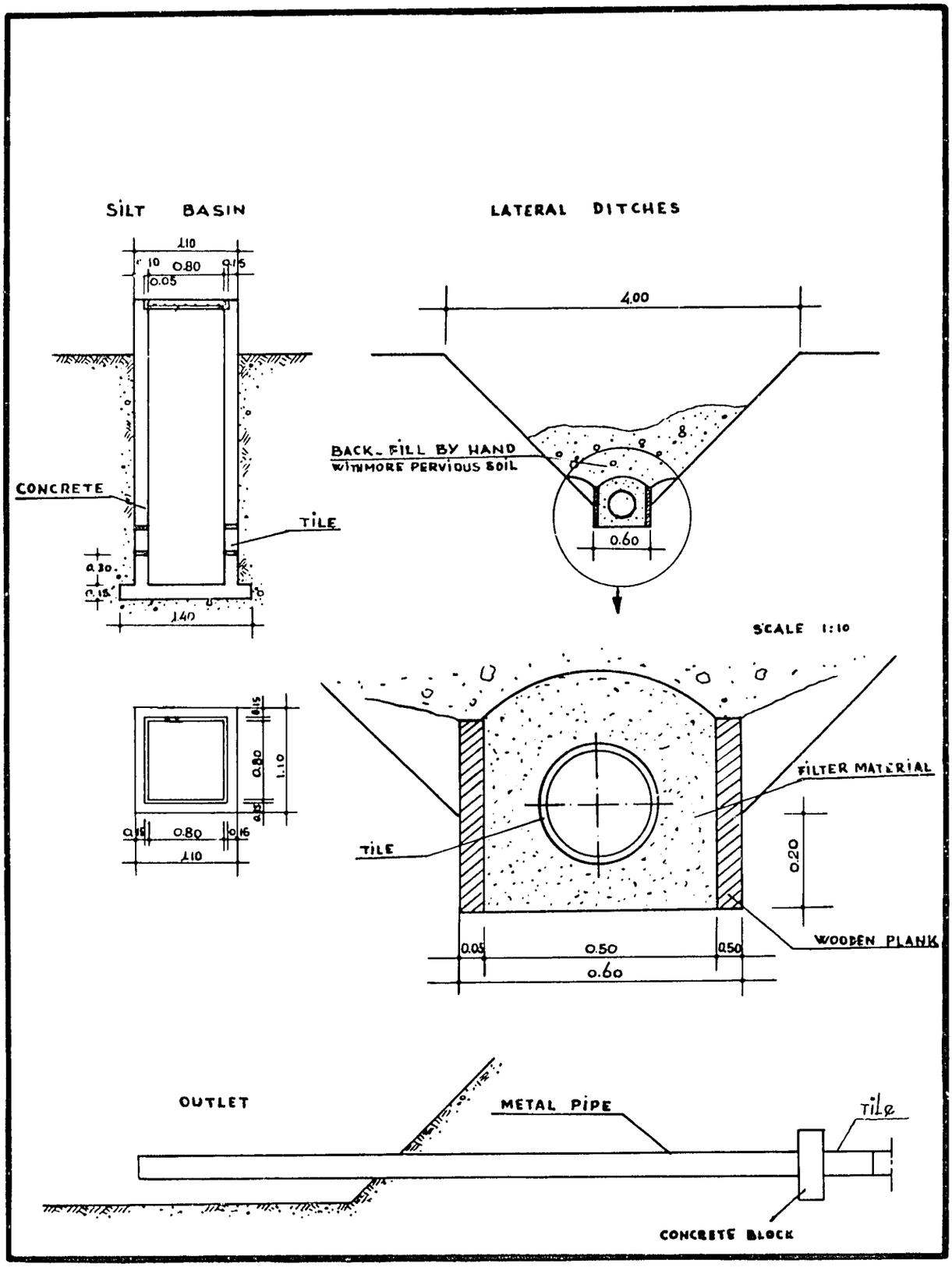
2. Houghout formula

$$H = \frac{R}{K}\,\frac{2.3}{\pi}\left[\text{Log}\ \frac{S}{2\ r_0} - 0.197\right]$$

$$0.60 = \frac{0.003}{3.5} \times \frac{2.3}{\pi} \times 330\left[\text{Log}\frac{330}{0.25} - 0.197\right] = 0.605$$

S = 330 meters spacing

3. The Sadik Teksoz and Don Kirkham formula as taken from the graphical solution; see Fig. 2:
   25 = 200 meters spacing.
   A 200-meter spacing was used for all the project area.


SILT BASIN
LATERAL DITCHES
1.10
0.10
0.80
0.15
0.05
CONCRETE
TILE
0.30
0.15
1.40
4.00
BACK-FILL BY HAND
WITHMORE PERVIOUS SOIL
0.60
SCALE 1:10
0.15
0.80
1.10
0.15
0.80
0.15
1.10
FILTER MATERIAL
TILE
0.20
WOODEN PLANK
0.05
0.50
0.50
0.60
OUTLET
METAL PIPE
Tile
CONCRETE BLOCK

Filter Material. The gradation curves of the base material, its limits, and the gradation curve of the filter material are shown in Fig. 3.

A 10-centimeter-thick filter of sandy material (which is not entirely within the limits of the curve for filter material) appears to be working fairly well. Even though the gradation curve of this filter material is finer than optimum, its conductivity is very rapid. Laboratory measurements gave a value of 13 cm/hr. hydrolic conductivity.

The drainage System. In the system the collector was designed and constructed as an open drain and the laterals as tile drains in parallel layout: see Fig. 1. general map.

Collector. The collector, open-type drain, is 1,905 meters long and has gradient of 0.0002; the side slopes are 1.2. The average depth is 2.50 meters; see Fig. 4.

Laterals There are are eleven laterals in the project. Their average length is 1,200 meters. The tile diameters are 25 cm. for 0+000 to 0+400 stations, 20 cm. for 0+400−0+800 and 16 cm. for 0+800 to 1+200. The tile slope is 0.0006 and silt basins were constructed on each tile line at 400-meter intervals. Design flow in the tiles is 0.6 full; average discharge is 10 lt/sec. for each lateral.

Cost Analysis. Table 3 shows the cost analysis for the tile drainage project. Excavation is the most expensive item compared to the other items of construction cost.

Table 3 shows that the cost of excavation plus back filling for lateral ditches is as much as twice as high as each of the other items. If trenching machines are employed, this cost should be lowered appreciably.

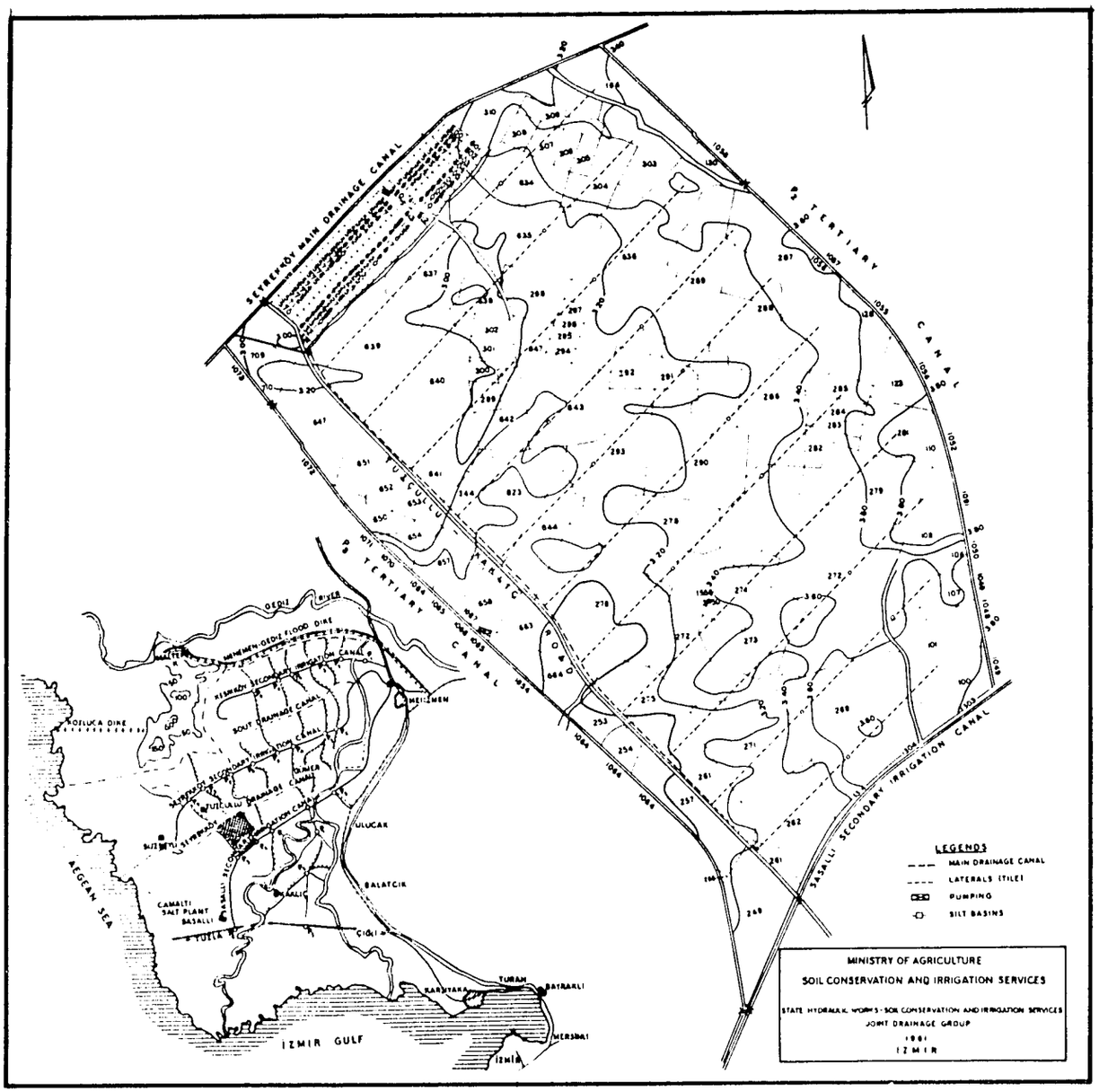
RESULTS

Salt Removed by Pumped Drainage. The amount of salt removed from the project area by pumping is shown in Fig. 5. Average pump discharge was measured at the time of installation, the time of pumping is continually recorded, and periodically samples are taken from the drainage water being discharged. These samples are analyzed for their total soluble salt contents. Volume of pump discharge, hours of operation and per cent of salt were used to compute the amount of salt removed. Up to March, 1962, 6,400 tons of salt had been removed. This is almost two tons per decare of area. Based on DSI Laboratory reports, this is about one-third of the quantity of salt that must be removed to reduce the salinity to 4 millimhos/cm throughout the 0-150 cm profile.

Reclamation. Detailed resampling of the soils in the area by the DSI Land Classification Group is scheduled for April, 1962. However, indications from four samples analyzed in March, 1962, although far from conclusive, are that the electrical conductivity has decreased without an appreciable increase in either readings of PH paste or 1:5 di-

TABLE 3. TILE DRAINAGE COST ANALYSIS

Work Item	Total cost Dollars	Engineer Estimate Per Decare Dollars	Engineer Estimate Per Meters Dollars	Contractors Bid Per Meters Length Dollars
Excavation and back filling by land and by machine	32,800.00	9.18	2.68	1.48
Filter material and its transportation	13,600.00	3.89	1.07	0.64
Cost of tiles and transportation	9,575.00	2.67	0.75	0.45
Labor and Construction	18,100.00	4.95	1.39	0.83
Total	74,075.00	19.79	5.89	3.40



lution. Disturbed permeability readings show a slight increase in rate of flow.

Control of the Water Table. The effectiveness of the drainage system in controlling the water table during winter rainfall is shown by the following:

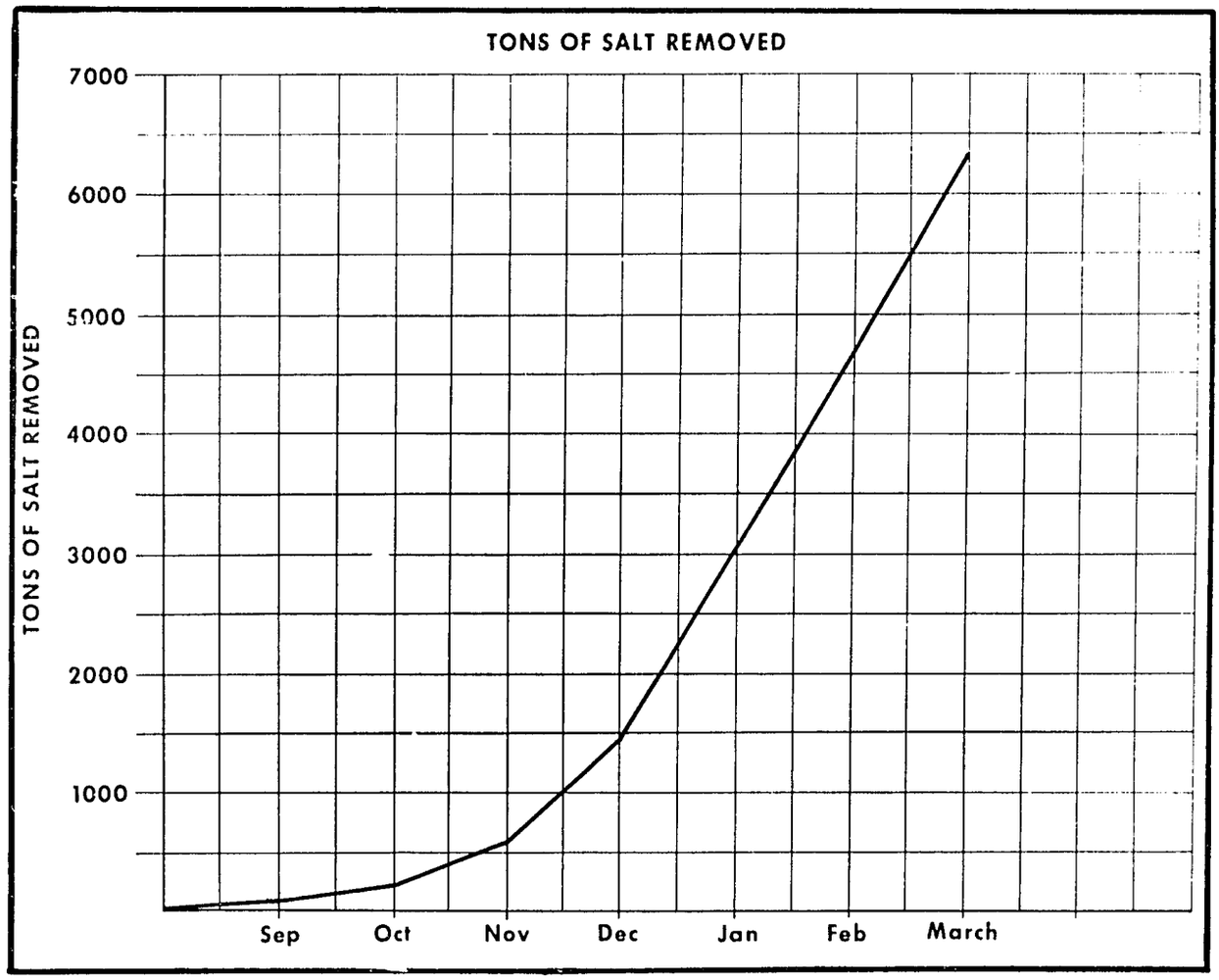
Depth to Water Table (cm)				
	January	February	March	April
1961	50	50	80	70
1962	128	134	128	128
Rainfall (mm)				
1961	127.2	87.6	12.2	100.5
1962	55.3	147.9	159.1	—

CONCLUSION

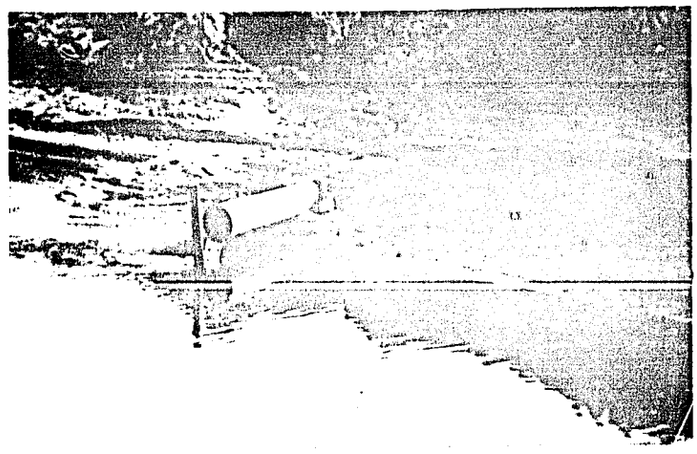
In conclusion, tile drainage for the irrigated lands in the Menemen irrigation system looks very promising. The cost is within the ability of the increase in crops to pay, and the results of the first year show that the system has been effective in removing salt.

Discussion. The tiles are of clay with square ends. The ends are simply butted together. Irregularities at the ends permit entrance of the water. There has been no experience regarding the penetration of drains by roots because of the short time since installation. The plank shown in the cross section in Fig. 4 temporarily holds the filter material in place during construction and is removed before back-filling. It is expected that at least four years will be required for the salt balance to come into equilibrium. The cost shown in the report of about $9.00 an acre is the contract cost and covers all construction except for design and supervision, which are computed at 20 per cent.

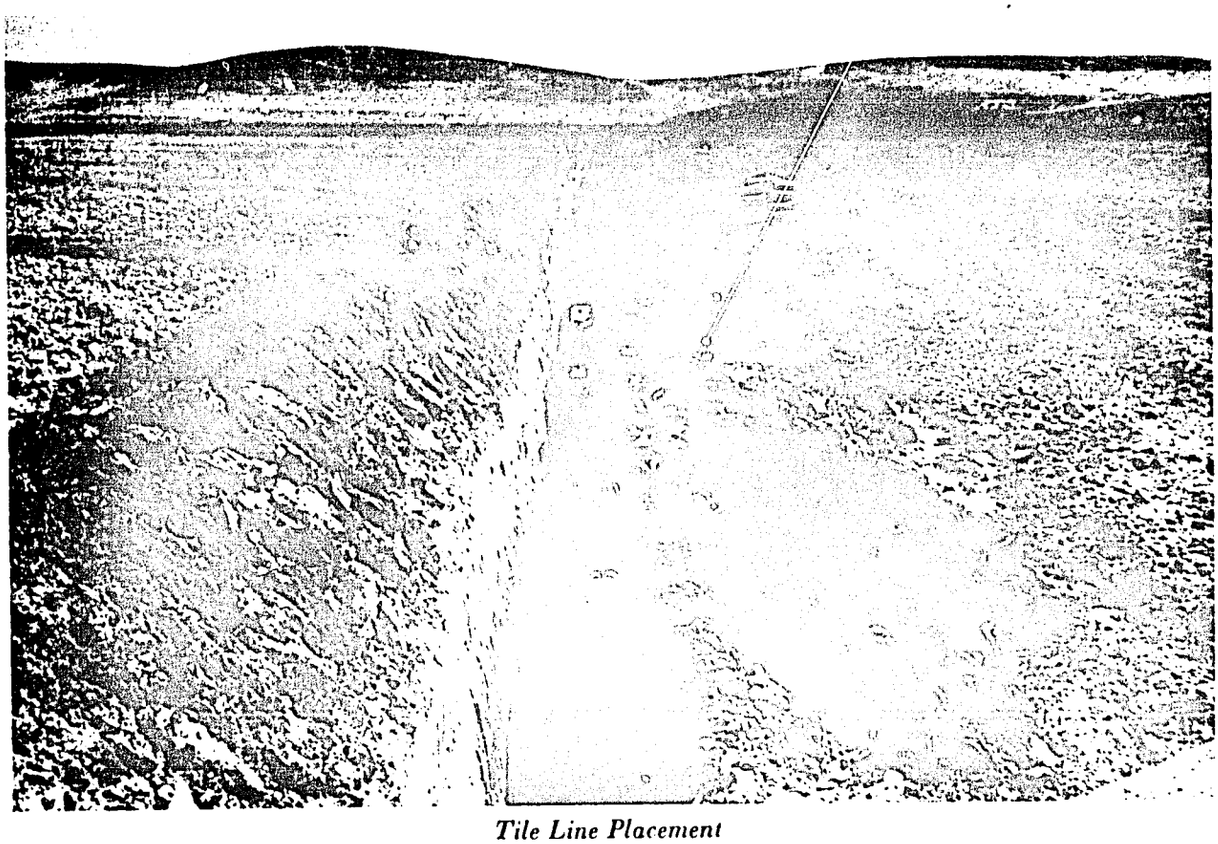
The depth to which tile could be placed was limited by the water table. Bell joints were not tried. Originally tiles were shipped from Adana, but because of the high cost of freight and breakage, arrangements were made with a roofing tile manufacturer in Izmir to make them locally. This was the first experience that this manufacturer had had with farm drain tiles. The tiles were made by extruding the clay through a die and the ends of



wire cut. The manufacturer could not make a bell tile. Considerable training of labor and a number of labor difficulties were encountered. This particular project is a pilot project in an attempt to solve a problem which is common in Turkey. Samples of the tile were tested at Incirclik Air Base and its crushing strength was found to be superior to that of American tiles, although there was considerable fault in the tiles, due to overburning and underburning especially.



The Outfall



Tile Line Placement

THE PROBLEM OF IRRIGATION

IN THE BLACK COTTON SOILS OR 'REGUS' OF INDIA

by

Dr. R. V. Tamhane

'Regur' or the black cotton soils of India cover an area of nearly 200,000 s.q miles. These soils are found throughout the southern half of the peninsula on the Deccan Plateau. Roughly, these soils are found between 73 degrees to 80 degrees of longitude and 15 degrees to 25 degrees of latitude. The Deccan plateau receives rainfall of between 20" and 25" during the monsoon period, namely between June and September, and has often been frequented by famine and the failure of crops. In order to relieve the situation and encourage intensive cultivation, the Government constructed a number of dams at suitable sites to provide an assured supply of water under the canal system and a storage reservoir. There are five major canal systems, viz.; Krishna Canal, Mutha Canal, Nira Right and Left Canals, Godavari Canal, and Pravara Right and Left Canals, with a commanded area of approximately 1.5 million acres. In addition to these, further south of the Deccan Plateau is the well-known canal of the Tungabhadra River.

SOILS OF THE REGION

Black soils occurring within the Deccan Plateau zone have a large number of physiographic regions, each having its own combination of soils. For example, the black soils found in river valleys like Narmada, Krishna and Godavari belong to a deeper member while those on the Deccan Plateau are invariably shallow members. Although the well-drained members of these two groups have much in common, there may be some distinctive differences due to the parent material. Black soil occurring on alluvial deposits in river valleys differ from the black soils developed on disintegrated rock or 'murum' of basalt. Thus, a wide range of variation results in the same zone.

Black soils occurring in India vary from a shallow depth of 12" to 18" to deeper soils 360" to 480" deep. These soils have been divided into three groups: (1) Black soils deep and heavy; (2) black soils medium and light and (3) black soils in the valleys of rivers flowing through the «regur» area. Irrespective of depth, black soils are invariably heavy in texture. The clay content varies from 30 to 60 per cent. Soils on ridges are shallow and contain about 30 to 35 per cent clay, while those in valley bottoms and low-lying areas are deep and contain nearly 40 to 55 per cent clay.

The clay content increases from 40 per cent in the surface to about 55 per cent in the lower depth. These soils have low permeability which decreases with depth. At about the second or fourth foot, there is generally an accumulation of salts, consisting largely of chlorides and sulphates of sodium, magnesium and calcium. These soils contain calcium carbonate. Under low rainfall, carbonates are found in small nodules distributed throughout the profile, but mostly in the surface horizon; while under high rainfall these lime nodules are found to have accumulated in the lower horizon either in the form of large nodules or in the form of a 'caliche' layer. Soils are invariably neutral to slightly alkaline in nature; pH varies between 7.5 to 8.5. The clay is mostly of the montmorillonite type with high cation exchange capacity

1 Dr. R. V. Tamhane, Soil Conservation Advisor, Ministry of Food and Agricilture, New Delhi (India).

and, with appreciable Na-saturation, is highly plastic. The organic matter content is very low. These soils swell considerably when wet and become highly plastic but when dry they shrink heavily, resulting in deep cracks and fissures, and become very hard. Fissures one foot wide and 3' deep are not uncommon. These have very high water-holding capacity. A water-holding capacity of 35 to 40 per cent is noted in many cases. However, they are quite productive and are reckoned to be among the fertile soils of India. Vast stretches of them cover the Deccan Plateau, but due to the scarcity of water, the maximum benefits have not been derived. However, with the introduction of a large-scale canal system, the demand for water supply has been met.

CANAL SYSTEM OF DECCAN

The canal system mentioned above was developed between 1870 and 1929. The table below gives the year and area undes the command of each individual canal:

Canal and date of opening	Krishna 1875	Mutha ·1880	Nira Left 1885	Godawari 1911-12	Pravara 1923	Nira Right 1929
			ACRES			
Gross commanded area	18,327	94,087	274,447	232,590	228,720	557,659
Culturable area	26,453	49,800	227,670	219,390	182,976	447,726
Approximate area commanded	25,000	35,000	150,000	150,000	160,000	350,000

During the last 40 years, quite extensive areas have been damaged due either to water-logging or salt development. Nearly 100,000 acres have been rendered unfit for cultivation. Of the total area, nearly one-third has been damaged by water-logging and the remaining area by the development of salt.

PROBLEMS OF CANAL IRRIGATION

The introduction of a canal system of irrigation, although it opens a new and bright to the farmers in a dry tract, always brings a potent danger of damaging lands by over-use of water.

New problems are introduced, especially in areas hitherto dry-farmed, where holdings are extensive and farming is poorly done. The only experience farmers in this type of tract have had with irrigation farming is in using the surface wells where is at command and supply is always limited. This experience is much too limited for large scale irrigation under a canal system.

PERCOLATION FOR CANAL DISTRIBUTORIES

Deccan rock is generally vertically imprevious but is fissured horizontally, and so transmits water under horizontal pressure. The canals are cut through the previous strata such as soft rock and 'murrum' and canal seepage is the most important source of percolation in the Deccan Plateau. The effect of such percolation is carried far into low-lying lands. Initial damage always occurs on lands in the vicinity of the canals, but diminishes later as a result of the reduction of percolation due to the formation of colloidal, vegetative and bacterial silt

film on the beds and sides to water's being imprisoned below non-porous soils.

PERCOLATION FROM IRRIGATED AREAS

As the agricultural development on a canal tract proceeds, a more important cause of damage to low-lying lands becomes apparent. This is due to seepage from the heavy irrigation to the lands situated on the ridges.

THE EFFECT OF IRRIGATION ON SOILS

When the canals were opened, water was available in excessive quantities and there was large wastage and loss by percolation. At later stages of development, when cultivators found that they could not get water as early as they wou'd like it because of the 10-to-12-day rotation in the canal system of distributing of water, they began to fill their fields to overflowing at every irrigation. A large amount of damage is also caused by the percolation of water from shallow fields on ridges.

PROBLEMS BEYOND THE OUTLET

Under the canal system innumerable problems confront the cultivator beyond the water outlet. These problems are not taken care of by the irrigation engineers or by the Agricultural Department in a coordinated manner. In the black cotton soil zone, the suitability of these heavy textured soils with low permeability for perennial irrigation is itself a problem. Under high temperature and low rainfall, they are always impregnated with salts which cause damage under heavy irrigation, and if proper subsoil drainage is not maintained, they are likely to be permanently damaged. When these soils are irrigated, water penetrates down to the 'murrum' layer but cannot pass through it. The drainage thereafter is lateral. The salt-laden water, moving laterally, emerges at the lower level of topography, depositing salt as the moisture evaporates. Capillary action takes place if free water is within four feet of the surface.

Of all the problems that confront an irrigation engineer and the Agricultural Department, the one least studied in a systematic manner is crop planning for a particular soil-climatic area. The water requirements of crops or the consumptive use of water by various crops have not yet been coordinated; thus, better and proper utilization of irrigation water has not resulted. The best method of irrigation suitable to the type of soil is also not studied in detail. The slowly permeable black cotton soils underlain with impervious material need to be provided with adequate surface drainage to prevent waterlogging and the accumulation of undesirable salts. A drainage way should be planned to carry away drained water from the end of every independent field.

These problems beyond the canal outlet need to be carefully studied and solutions demonstrated to the cultivator before he irrigates, so that not only the maximum benefit will be drived from canal irrigation but the damage caused to lands by over-irrigation and faulty methods will be minimized.

DISCUSSION: During the three-month wet season, the soil swells and closes the large cracks in it so that leaching from rains can occur. The Government has restricted canal irrigation for shallow-depth soils. Tile drains were not very useful in the black soils. Cotton, ground nuts and sugarcane are included in the rotation.

GENERAL DISCUSSION

Led by Pakistan

Mr. Hamid stressed the importance in reducing drainage problems of flood prevention measures. More information is needed on the cost of tile drains. In West Pakistan, tube-wells are receiving the highest priority, with deep open drains next. Tile drains have been assigned the third priority. Dr. Asgnar pointed out that drainage and reclamation programs involve soil programs as well, including the nature of the soil, the amount of water to be utilized, and the cropping pattern. The economics of the cropping pattern and the ability of the farmer to carry it out must be taken into account in solving the drainage problem. He stressed the importance of the capability of the cultivator and also the importance of experimental work, and mentioned that Pakistan must begin experimentation on tile drainage. He requested that more specific information on drainage be included in papers in the future.

Mr. Raza emphasized the importance of drainage work to Afghanistan, and mentioned that cost studies relating to alternate methods of drainage are very important. The cost of open drains 1.5 meters deep dug by hand was higher than for concrete tile placed by machine. However, open ditches were selected because of the problem of the clogging of tiles by camel-thorn roots. Clogged tiles were dug up and found to be completely choked with roots which could not be broken out even with a hammer. Afghanistan is interested in clay tiles, but has had no experience with them and would like to have information regarding them. Cost studies show that a 1.5-meter deep trench in clay loam soil can be dug by hand for 20 Afghanis per meter (approximately 50 cents), which is only about one-third the cost of machine excavation. For drains deeper than two meters, the advantage of human labor over the machine may not be so great. Mr. Mortezavi reported that Iran has only begun to lay some tile drains. Tiles are made by hand and are expensive. Iran badly needs information on how to manufacture tiles and how to install them in drainage systems.

Mr. Abou-Khalid mentioned that porous concrete tile is on the market. This tile solves the root problem. It has a porous area of about 80 per cent. These tiles are now manufactured in Lebanon. Mr. Abou-Khalid mentioned that he would be able to furnish information on them. It is planned to export the Lebanese-manufactured tile to Egypt. In calcium soils, the pores of the pipes may tend to clog after a period of ten years or so.

Dr. Asghar mentioned that Pakistan had experimented with these tiles, but found them quite easily clogged and quite expensive. Mr. Abou-Kalid stated that they were only testing these pipes. In reply to a request for more detail by Mr. Raza, Dr. Asghar stated that the pipe used in Pakistan was manufactured in the Indian Punjab, 80 miles east of Lahore, and was installed in a heavy soil 25 to 30 per cent clay with a water table at two feet during the summer and five feet during the winter. Drains worked well at first, but the discharge slowly decreased. Drains were spaced at 220 feet, field drains at 3½-foot depths, collector drains at 4-foot depths, secondary drains at 6 to 7-foot depths and main drains at 8 to 9-foot depths. The capital cost of the field drainage system was about 25 rupees per acre. The maintenance cost is 15 rupees annually. The cost of the main drainage system is 100 rupees per acre.

Dr. Tamhane pointed out that the manufacture of the porous concrete was an experiment and if the demand became sufficient so that the tile could be manufactured on a mass-produced basis, the cost would come down.

Mr. Rinnan pointed out that concrete tiles are useful for shallow drains in mature soils which do not produce much salt, but urged that their use in immature desert soils should include the use of a gravel envelope.

Mr. Asifi pointed out that the root problem may be avoided in tile drains if the growth of camel-thorns and trees is controlled near the drainage line. He also stated that roots may be cleaned from tiles by using certain types of machinery and mentioned that large open drains are quite difficult to maintain. Dr. Asghar mentioned that in their experiments about 10 per cent of the land was used up by the open drain ditches and that tile drainage systems can be afforded only when the value of the land is quite high. Mr. Eren mentioned that Type II cement should be used for concrete tiles where sulfates are present, and also stated that studies have showed that in Turkey clay tiles cost about one-third as much as concrete tiles. Mechanical excavation costs 1.0 to 1.2 TL per cubic meter. Hand excavation costs about 2.0 TL. There is also the cost of pumping for hand excavation. In the Adana area there has been no problem of clogging of tiles over a period of three years. There is no tile trenching machineary in Turkey at present. Trenches are first excavated by ditching machinery and the deeper excavation is then done by hand.

CHAPTER VIII

DEVELOPMENT AND MANAGEMENT OF SMALL IRRIGATION PROJECTS

IRRIGATION DEVELOPMENT BY THE CENTRAL WATER AUTHORITY

by

Jordan

The Hashemite Kingdom of Jordan is not simply a desert country of sand and rocks but is susceptible to considerable irrigation expansion in order to correct the agricultural imbalance now present in the country. Jordan has an area of 100,000 sq. km., of which 10,000 sq. km. are considered fit for agriculture and only 1,000 sq. km. are being irrigated at present. While Jordan actually ranks ahead of Egypt, Iraq, Lebanon and Saudi-Arabia in dunums of cultivation per inhabitant, it probably ranks below them on irrigated dunums per inhabitant. For this reason, extensive droughts or other agricultural calamities affect the agricultural economy of the country to a considerable degree.

Jordan has the Mediterranean climatic cycle, with dry summers and winter rains of considerable proportions. In the desert in the south and east the average rainfall is only 50 mm but in the hills of Karak-Shoubak it increases to 300 mm per year. It averages 400 mm in Amman and reaches 500 to 600 mm in the Salt-Ajloun mountains. As one moves west it decreases to 100 to 300 mm in the Jordan Valley and then increases to 600 mm in the Ramallah-Nablus Mountains of Palestine.

To build a broad agriculture base, it has been decided to effect as much irrigation in the Kingdom as can be accomplished with the water available. The biggest project under way at present is the East Ghor Canal Project, where ultimately it is hoped 400,000 dunums will be placed under Yarmouk River water. All other water resource development in the country is controlled by the Central Water Authority, which is an autonomous agency separate from the regular Government ministries and reports directly to the Prime Minister.

The mission of the Central Water Authority is well-stated in its enabling law, which says that the CWA was created for the purpose of investigating, planning, establishing, promoting, implementing, constructing, and, to the extent necessary, managing and operating a comprehensive program for the development, conservation, protection and control of the water resources of the Kingdom of Jordan for maximum feasible use for domestic, municipal, livestock, industrial, irrigation, hydroelectric power and other beneficial purposes. The Authority interprets this as a mandate to see that all possible water is used for the maximum benefit of the country. Domestic and stock water take first priority but irrigation water as high a priority as possible.

The irrigation facet of the Authority's work does not presently appear to be as large or as important as that of the East Ghor Canal Authority, but it is felt that its possibilities are considerably greater if present ideas can be worked out. The first attack on the problem has been to increase the water available to present irrigated lands and to make sure that what water there is actually gets to the land. This means rehabilitating present pro-

jects; some have been in use since ancient times and have largely fallen into disrepair. These utilize both spring and perennial stream flow. After springs are cleaned out, the maximum contact is exposed and quite often the outlet lowered to make sure no back pressure is exerted on the spring source. The spring is covered in such a manner that it cannot be contaminated or choked with debris and flood flows. The water is generally then led through a covered canal or pipe to a location with enough head room for a domestic fountain or faucets. After this, the water is led in an open channel to an animal through and then to a night storage pool large enough for 12 hours of spring flow and with sufficient head provided for efficient irrigation use. The last factor consists of small concrete-lined canals to assure that maximum water gets to the land. Six of these projects, serving a total of 600 dunums of land, are now completed; another 10 projects are under way affecting 6,000 dunums, with all 16 projects having an effective water flow of 1,500 m^3/hr. In one of the projects the spring flow was increased nine times by extensive development. The Authority will look at all 1,350 accessible springs in the Kingdom for complete exploitation along similar lines.

The use of perennial streams (often spring-fed) is also being started. Most of these locations are on the east shores of the Dead Sea and development will follow the pattern set by the predecessor agency when they constructed the nine wadi irrigation projects on the east side of the Jordan Valley. These consist of a diversion weir across the wadi and concrete-lined canals to command the irrigable land. In this manner all flow is intercepted and conveyed to the land with minimum loss. These systems are simple, operate completely by gravity and usually contain many drop structures and chutes as the water reaches the lower levels. Because of a basic lack of water, drainage has not been a problem, but as more water becomes available through the new works, the CWA will keep a close check to see that this difficulty does not occur. Work is now under way on two of these projects comprising 7,000 dunums and a flow of 1,700 m^3/hr.

The conservation and use of winter surface run-off in Jordan is quite a problem. There are few if any large reservoir sites, and the economics and hydrology of those which exist largely preclude their use. However, CWA has started one phase of such conservation and that is the building of low, earth-fill wadi dams. These are reliatively inexpensive, have natural spillways and stop the infrequent runoff from being wasted in the Dead Sea. One called Sultani, some 130 km. south of Amman, has just been completed. It filled to its 1,200,000 m^3 capacity as it was finished. The dam itself is 5 m high and one kilometer long. There are approximately 500 dunums downstream from that can use the water, and the large reservoir area can be used for grasses and similar crops as the water recedes. Two more of these are now under construction and sites for several more are being investigated.

No modern country can consider its water resources fully exploited without full use of the groundwater potential. CWA is strongly pursuing this phase of water development. Eleven percussion drill rigs are being used for exploratory holes as fast as the geologists can come up with their detailled surveys. In all of Jordan there are at present approximately 500 tubewells, with some 300 of these in the Jordan Valley. Explorations are starting to pay off, as has been found in two in the cases of two desert areas never before thought to have water. There appear to be some 50,000 dunums suitable for possible irrigation at Hassa, 160 km south of Amman, and at least 100,000 dunums at El-Jafer, some 230 km southeast of Amman.

There are good water and land in Jordan and the CWA is entering a development stage that may eventually mean the end of agricultural imports into the country. There are already cases of groundwater overdraft, and steps are being taken to prevent and correct them. We have established regulations which control drilling by requiring permits, set up licensing requirements for drilling contractors, and have on the books a law under which CWA can control actual water withdrawal when required.

With the accomplished fact of the East Ghor Canal, the full use of springs and wadi flow and the extensive discovery of underground waters, Jordan is entering into the stage of extensive irrigation agriculture. No matter how much water is found, real success now rests with the farmer. He must be aided with all the knowledge that has

been developed over the years. He must be shown that proper irrigation practices are necessary. There must be proper operational procedures in the projects, with water discipline enforced and proper operation and maintenance practices adhered to. An agricultural extension program must be set up to advise regarding these practices as well as on fertilizers, insecticides, crop rotation, drainage, credit, markets, etc. The Ministry of Agriculture has many competent and qualified people who can, and no doubt will, do the job, but at least the Central Water Authority knows that while finding and delivering water is the first thing to be done, unless the farmer is fully backed up bv knowledge of proper irrigation practices, such efforts are useless.

The plans attached to this report illustrate the Ghor Project, a typical small spring development project carried out by the Central Water Authority in the southern district of Jordan.

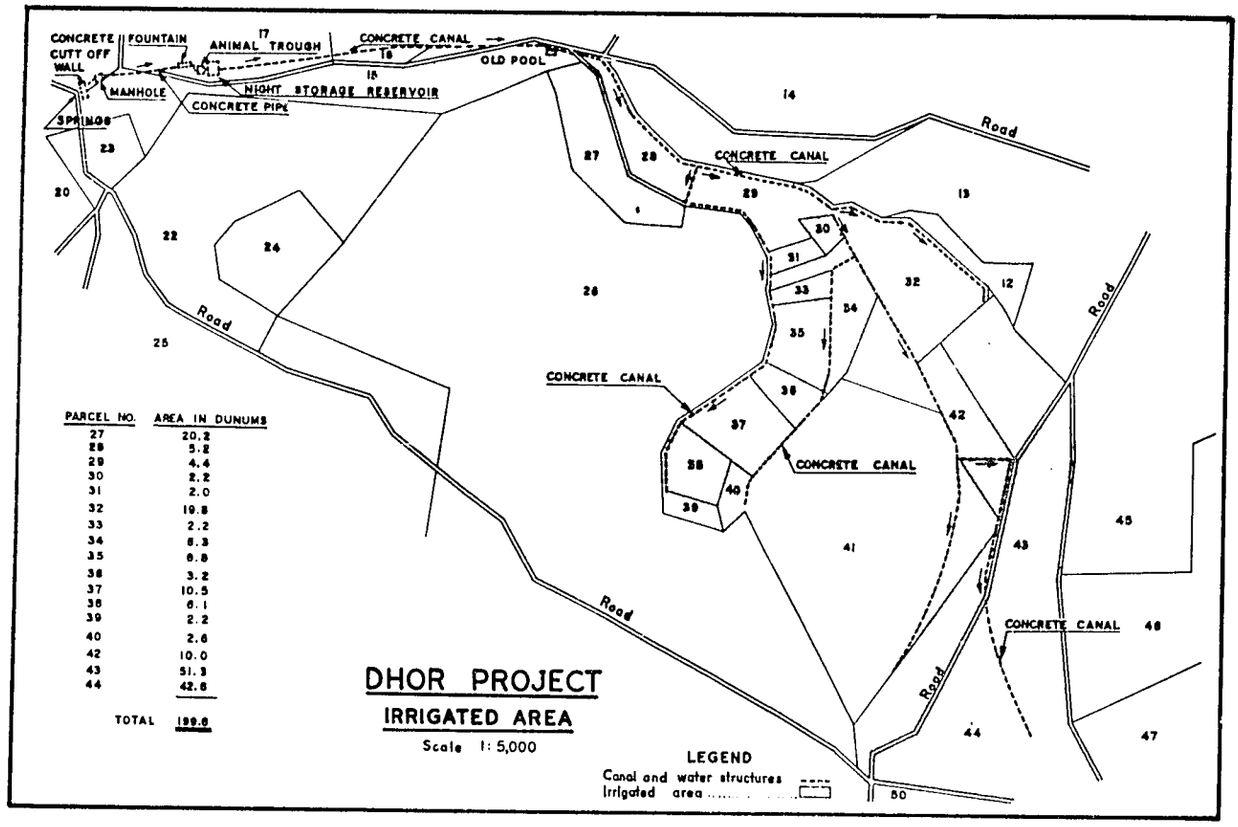
SPRING AND WADI DEVELOPMENT PROJECTS
UNDER CONSTRUCTION BY CENTRAL WATER AUTHORITY

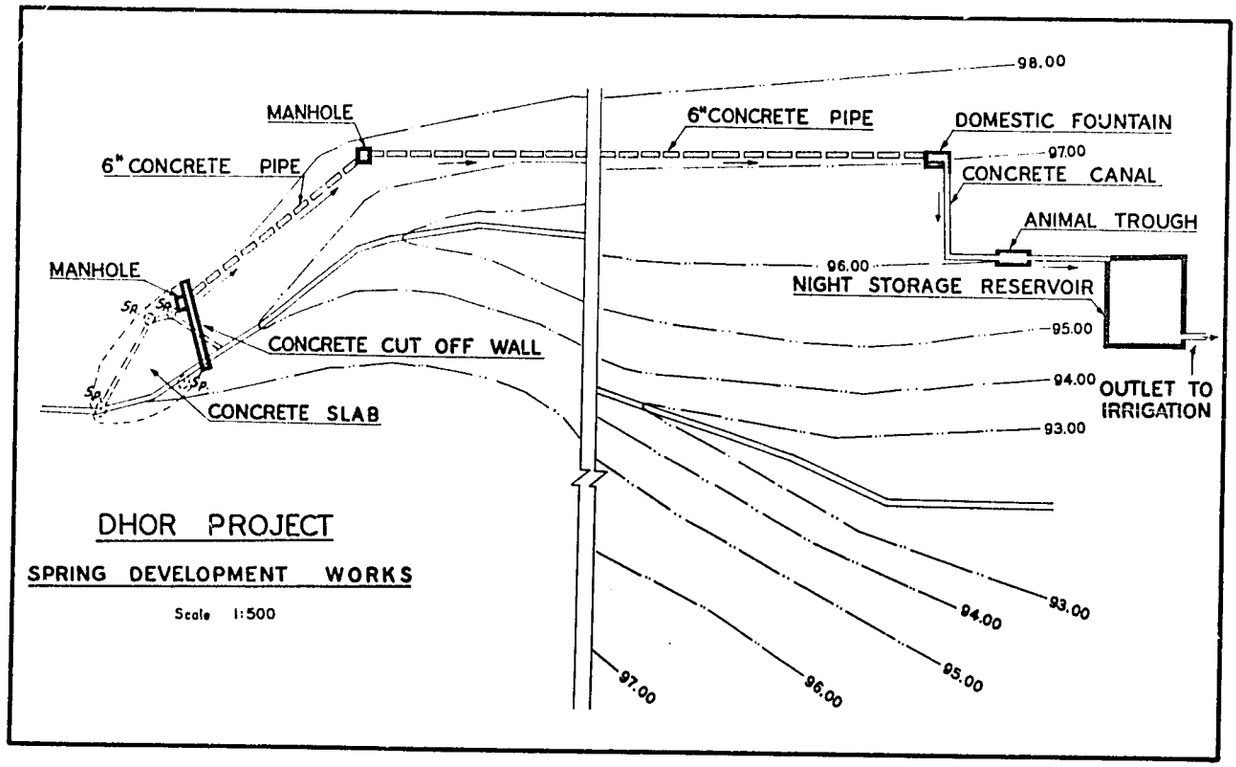
1 March 1962

Name of Project	Water flow before dev. m^3/hr.	Water flow after dev. m^3/hr.	Dunums served	Canal lined in m.	Cost JD.
1. Dirbas *	0.8	2.4	35	500	2300
2. Basta *	6.8	6.9	230	1800	6900
3. 'Uneiq *	2.6	5.3	40	600	3410
4. Sadaka *	0.8	1.3	70	550	3000
5. Um 'Ullieqa	8.6	—	90	500	650 ***
6. Ain Sidr	11.0	—	110	1400	2700 ***
7. Shammakh	3.0	—	50	750	1600 ***
8. Abu Makhtoub	6.4	—	100	1300	2500 ***
9. Ain El Onsor	8.6	—	100	900	1750 ***
10. El-Lajjoun	40.0	—	440	4750	6000 ***
11. Dana	19.6	—	500	1800	2000 ***
12. 'Ainah	85.0	—	3000	8200	11000 ***
13. Abu 'Idham *	1.4	2.2	80	1400	2500 ***
14. Fardhakh *	1.2	9.0	140	2300	3300 ***
15. Lhour	2.6	7.1	200	2800	3800 ***
16. Wadi Mousa	68.7	—	1560	12360	22000 ***
17. Dhira' **	184.0	—	4000	2700	3000 ***
18. Hadeethah	1530.0	—	3000	6000	17000 ***

* Completed ** Wadi works *** Estimated

DISCUSSION. The discussion brought out that while cleaning of springs results in increased flow immediately, the flow decreases over a period of time. There will not be high evaporation losses behind the small earth dams. This water will be stored as short a time as possible and used downstream to give only one irrigation. As the water recedes from the reservoir, the area in the reservoir will be cultivated. The normal maximum temperature is 38°C., with a normal minimum of 7° to 8° C. When hot desert winds blow, however, the maximum may go up to 47 to 48° C. The minimum temperature ever recorded was -21° C. The silt content of the streems is very heavy and silting will continue to be a problem in the future.


CONCRETE CUTT OFF WALL
FOUNTAIN
ANIMAL TROUGH
CONCRETE CANAL
OLD POOL
MANHOLE
NIGHT STORAGE RESERVOIR
CONCRETE PIPE
SPRINGS
CONCRETE CANAL
Road
CONCRETE CANAL
CONCRETE CANAL
CONCRETE CANAL
Road
Road
Road
PARCEL NO. AREA IN DUNUMS
27 20.2
28 5.2
29 4.4
30 2.2
31 2.0
32 19.8
33 2.2
34 8.3
35 8.8
36 3.2
37 10.5
38 6.1
39 2.2
40 2.6
42 10.0
43 51.3
44 42.6
TOTAL 199.0
DHOR PROJECT
IRRIGATED AREA
Scale 1: 5,000
LEGEND
Canal and water structures
Irrigated area


98.00
MANHOLE
6" CONCRETE PIPE
6" CONCRETE PIPE
DOMESTIC FOUNTAIN
97.00
CONCRETE CANAL
ANIMAL TROUGH
MANHOLE
96.00
NIGHT STORAGE RESERVOIR
95.00
CONCRETE CUT OFF WALL
94.00
OUTLET TO IRRIGATION
CONCRETE SLAB
93.00
DHOR PROJECT
SPRING DEVELOPMENT WORKS
Scale 1:500
93.00
94.00
95.00
96.00
97.00

REHABILITATION OF OLD IRRIGATION SYSTEMS IN AFGHANISTAN

by

Mr. M. Akbar Raza

Afghanistan, with a series of mountain ranges in the northern and central portions and deserts and flat areas in its southern part, is of a variable nature as far as topography, climate, water resources and other natural characteristics are concerned. It is predominately an agricultural country, where various methods of irrigation are in practice. In general, natural rainfall is inadequate; hence irrigation is an essential method of providing water for crop growth. Average annual rainfall ranges from 15 to 20 inches in the northern to 2 to 5 inches in the southern half of the country. Due to heat and high velocity wind in the southern parts, the rate of evaporation is generally high, which leads to greater loss of water. Loss of water by evaporation in the northern areas is not so great. In the southern regions, the maximum temperature during the months of May, June, July, and August ranges from 40° to 47° Centigrade, and the high winds of 20 to 30 miles per hour velocity during the same months aggravate the situation as far as the deficiency of water for irrigation is concerned.

The existence of varying types of geological and soil formations, the topography, the climate (with freezing and snow in a majority of the northern regions), the hot and dry nature of the south, with the varied timing of crop growth and types, precludes a single fixed method of irrigation. The most common methods of irrigation practiced by Afghan farmers are by flooding, furrows and borders, where the application of these methods is dependent on the factors stated above.

The flooding method is used extensively in the mountainous area where large volumes of water are available. The surface flooding of grain, hay and pasture land is accomplished from contour ditches. In order to level the land, terraces are usually built where a great deal of earth movement is performed on the rough, steep localities. Using this method, the flow of water is not controlled properly by the farmers, and as a result erosion and soil washing take place, with great loss of irrigation water.

Furrow irrigation is also generally practiced in Afghanistan for row crops such as potatoes, corn, fruit and vegetables. Wide, deep furrows are made by hand shovels. Due to lack of technical knowledge, a proper bottom slope is not given to the furrows and means for reduction of velocity and erosion do not exist. Irrigation water is turned into the furrows and the crop planted just above the water line along the berms of the furrows. Commonly the furrows are excavated in short lengths and water is turned into the head of each furrow until it is filled and then turned off. Most often this practice results in poor lateral penetration of water with deep percolation only in the furrows. Plant roots are therefore not able to grow beyond the moisture zones between furrows.

Border irrigation is practiced in areas which are well levelled for irrigation of field crops such as wheat, alfalfa, barley and legumes. Water turned into the upper end of each border moves down the slope in a thin sheet, guided by the borders. In some places this method is used inefficiently, where the irrigated land is of a steep or rolling nature. In such instances soil washing occurs; the high patches in the field remain dry and water does not penetrate to the roots of the crop.

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1 — Hydraulic Engineer, M.S.C.E., Ministry of Agriculture.

Sprinkler irrigation is not used in Afghanistan due to the great initial investment required for purchase of the system and the nonavailability of the needed power.

Excluding the land and water development projects undertaken recently, which are carried on according to modern standards of construction and development, most of the work needed for development is performed by technically unskilled labour, using primitive and customary methods which they have inherited. Construction of main canals, laterals, and field ditches, and soil moving, are accomplished in a crude and laborious manner by hand shovels and picks and available animal help. The use of mechanized equipment is scarcely known.

Diversion structures are built in a primitive way for lifting and diverting water into the main canals. These structures are mostly made of brush, logs, stones and mud, most often without any sort of foundation treatment, after the spring floods have passed each year. Due to their temporary nature, they are subject to frequent failures during the irrigation season. The diversion structures extend partly across the rivers, in order to turn part of the river flow, and occasionally extend fully across to raise the water level. Normally, no intake structure is built at the head of the canals and control of flow into the canals is not possible. The cost of maintenance and rebuilding the diversion structure up to two or three times a year is very high and large groups of laborers spend months to remedy the situation.

On most rivers of the country, erosion of stream bed is excessive and many channel shifts occur, leaving the intake of the canal high above the water surface in the river or dry due to the shift of stream channel. Proper bed stabilization practice is not common. In order to receive water in the canals, the intakes are usually moved upstream to join the river at points of high bed elevation and this way gain head, and year by year the canals become longer, which requires more expenditure and labor. Under the above-mentioned circumstances, supplying the firm and dependable amounts of water needed during critical periods is difficult. Practically every year the diversion structures are washed out, and canal intakes are eroded in many localities during the flood period, or the intake section becomes blocked and filled by an accumulation of silt carried by flood water or by the movement of the river bed material. Due to lack of silting basins and control structures, this occurrence and the resulting damages cannot be prevented. The existence of brush like salt cedar and reed grass close to the diversion sites somewhat facilitates construction, where this brush is used as reinforcement. But due to constant and extensive use and cutting of this brush, its availability becomes more limited each year. Obtaining brush in recent years has become very critical and as a result it has to be transported long distances; or use of other trees has been made, and losses due to cutting of productive trees have become great. In places typical cribs are made of wires, filled with rock and mud and placed in rows to form diversion structures.

Usually canals are not built with sufficient capacity and because of overloading the canal banks fail at many points. Proper slope is not given to the canal bed: excessive slope causes erosion of banks and canal bottom and not enough slope reduces the amount of flow in the canal. Location of alignment of canals is based on trial and error, but usually the contours are followed. This way many bends and curves exist along a majority of the canals. Loss of head in the canals due to sharp curves and friction is excessive and these improper curves also result in irregular irrigation systems, agricultural fields and block arrangements. In large canals excessive erosion and filling up on the outer bank and inside bank, respectively, take place. Lining of canals ordinarily is not practiced, except on new projects. Leakage and percolation losses of water are great. Weed growth along the banks of the canal is one of the major problems of maintenance and a cause of the restriction of canals and reduction in capacity. In comparison to other enormous losses, natural evaporation loss is not extraordinary, except in hot regions with high-velocity wind. Losses by leakage from canals is of a critical nature and large volumes of water are wasted in this manner.

It has been a practice and habit both past and present that landlords or farmers try to own a canal taking water from the rivers or karezes or

wells for irrigation of the plot of land belonging to them in order to reduce the problems with regard to distribution among them, and to obtain water for irrigation whenever they desire. Thus the number of canals exceeds the number required for efficient irrigation purposes. There are a great number of canals excavated parallel to one another with very close spacing; in some places the spacing is of the order of one or two meters. Looking at this condition from the point of view of the over-all efficiency of an irrigation system, there is an extreme misuse of water, loss of effort and expenditure in excavating the manifold unnecessary lengths of duplicating canal systems and in their maintenance, and also loss of a large acreage of agricultural land occupied by these extra canals, where one main canal could replace a series of canals and serve properly.

Generally, no proper structures such as drops, wasteways, checks, turnouts and intake gates, or storm drainage inlets are built. Canal banks are excavated with practically no side slope and sloughing occurs constantly. As explained before, sound engineering practice has not been applied in the construction of irrigation systems.

With the general idea existing among farmers that there will be more growth of crop with application of more water and small or non-existent charges for the use of water, waste is great on the one hand and on the other hand the groundwater level rises and waterlogging problems increase. The soil fertility becomes lower, the soil structure is spoiled and the soil aeration is reduced. The farmers located upstream usually receive the most water and a shortage of irrigation water in downstream regions is typical.

Generally in all the regions of the country a great deal of canal water is diverted, at numerous points along the canals where drops can be found, to operate water wheels for flour mills and rice hullers. In some places the waste water from the milles is channeled back to the river or original stream, but mostly the waste water is utilized for irrigation downstream of the mills, where there is less water available than upstream. In this way conflicts exist between agricultural demands and mill operations.

As a result of the factors stated above, irrigation efficiency is very low throughout the country and losses become as high as 70% of the volume diverted for irrigation. Water diversion for irrigation in most places in the country ranges as high as 7 to 14 acre feet per acre, where normally the application of 5 to 7 acre feet per acre could become a practical figure with some control and caution, accepting conveyance losses of 30 to 50%.

The high water table caused by excessive water application and retardation of groundwater movement through tight, heavy-textured soils and conglomerate substrata close to the land surface has often resulted in complete waterlogging and many communities have abandoned the land.

In an area where enough surface run-off is not available, use is made for irrigation of wells and karazes (guanats). Water is drawn from wells by means of buckets attached to large-diameter water wheels or to a series of buckets linked in a loop of chains or ropes. This operation is performed by the help of animals or by manual labor, depending on the depth of the wells and the amount of water available. Irrigation of large farms is not practicable by this method and the operation is time-consuming and expensive. Much use of karaze water for irrigation is made in the dry zones of Afghanistan. Karazes consist of a series of wells in a line tapping the groundwater, and connected to one another by underground galleries or tunnels. In this manner the discharge of a number of wells is accumulated and flows to the surface by gravity. The larger the number of wells, the greater is the discharge under constant hydrological conditions. Initial cost of excavation of the karazes is very high and all are excavated by hand labor. Filling of wells and caving in of the karaze tunnel occurs quite often because no reinforcement work is performed during the construction. Maintenance of the karazes is most expensive, with great expenditure of human labor and time. Selecting the site for karaze wells, the alignment and the slope of the tunnels and the surface channels is by trial and error and quite often duplication of effort and expense results. It is hoped and anticipated that in due course the application of pumps for use of underground water for irrigation will replace this tedious and difficult method.

It is obvious that the success of any irrigation system in a project is mainly dependent on the water-users of that project. The Government of Afghanistan, through its various agencies, has tried, by means of various programs, to raise the agricultural standards of the country, and the importance and application of technical and scientific methods are emphasized. Obtaining basic data for development and improvement of irrigation systems is necessary, and recently, with the help of A.I.D, FAO and a German hydrological mission, networks for hydrological investigations were developed for the purpose of measuring daily, monthly and annual discharges of the rivers and main streams. It is also anticipated that a more detailed and extensive study of the hydrological characteristics of the rivers, including sedimentation and silt transport analysis, will be performed. Within a period of about ten years some 50 stations for hydrological investigation of major rivers have been installed by the Ministry of Agriculture, the Ministry of Mines and Industries and the Helmand Valley Authority. On the recently-developed projects, discharge measurement on the canals is also practiced. Through the Ministry of Agriculture, various extension works, such as the training of farmers in better irrigation and cultivation practices, and in crop rotation methods and the obtaining of farm statistics are in operation and similar programs are undertaken by the Helmand Valley Authority, with the cooperation of A.I.D., FAO and other agencies.

Surveys for improvement of existing irrigation systems, made with the help of the United Nations Special Fund, are currently in operation in the Farah and Hari Rud valleys in the southwestern part of the country, where, naving considered the general irrigation deficiencies in those areas, a practical and technically sound irrigation layout will be superimposed. Aims for unification of many intakes and canals into one and developing an efficient secondary network with a regular pattern and proper alignment and capacity, as well as the introduction of modern controlled intake structures, are in mind. Present and future problems in regard to high water table, water logging and the drainage networks to be undertaken are also being considered.

In the northern parts of Afghanistan, cultivation of commercial crops such as cotton and sugar beets is of great importance and this area could be considered the major source of cotton products in the country. In order to increase production of cotton and other commercial crops, the Government has undertaken various development programs. Inefficiency of irrigation systems in this area, especially the water shortage during critical irrigation periods, causes severe crop losses. The inadequacies of two existing canals, the Archi and Adjmir in Kataghan Province in the north, require improvement schemes. The Archi Canal, in use for a long time, takes its water from the Kokcha River, extends westward for a distance of 18 kms. and bifurcates into two branches, one of 23 Km. and the other of 36 km. in length. The area to be irrigated under this canal is about 50,000 acres. The canal is, as is the general case, without permanent diversion, intake, spillway or any regulative or protective structures. At the intake the Kokcha River has several streams beds which are very liable to change during floods. The temporary intake of the Archi Canal consists mainly of a partial diversion made of willow branches and the gravel and cobles available in the Kokcha River bed. This temporary diversion structure is constantly subject to being washed out during floods, and it may be washed out several times a year. When this happens, it usually takes much effort and time to restore the diversion. With the help of FAO engineers, various plans were put forward to remedy the situation. Recommendations to construct a concrete diversion dam with ample spillway, and an alternate design using gabions filled with rocks, have been made. Considering the expense of the structure and future plans on the Kokcha River, it was thought better to combine the diversion and intake structure of the Archi Canal with the proposed Kokcha River project, where the construction of a dam in the upstream vicinity of the canal intake is also anticipated. Kokcha Canal, taking water from the dam, will supply the Archi Canal with enough water.

About two Kms. downstream from the intake, there is a stretch of 400 to 500 metres of canal which runs very close to the Kokcha. Due to the high velocity of flow in the river excessive erosion occurs and caving of the banks takes place, so

that at the narrowest place the river is only about five metres from the canal bed and about six metres above the river water. Any break in the canal bank would create a great shortage of irrigation water in the whole area. Protective measures are undertaken by means of strengthening the banks of the river at the critical sections with gabions filled with cobbles and with masonary walls. Proper foundation preparation is performed in order that undermining of the protective wall and gabions does not occur. The primitive canal crossing structures over the storm drainage channels, which were made of logs and lined with mud and were subject to washout, with great leakage and small capacity, were replaced by concrete siphons, proper wasteway structures and control gates.

The design and construction of a permanent bifurcation structure 18 kms. downstream of the Archi intake are being undertaken. Steel-fabricated gates and concrete structures for passing flood water under the canal, enlargement of sections of the canal, installation of turnout structures and other development works for the secondary irrigation network are performed continuously by the Ministry of Agriculture with the cooperation of FAO experts. At the completion of the improvement measures, the original capacity of the canal of about 300 cubic feet per second will be increased to about 700 cubic feet per second, and the supply of dependable water will be ensured.

The difficulties with the Adjmir Canal are somewhat similar. It takes its water from the Kunduz River, and with its length of 63 Kms. is subject to severe flood damages throughout. A stable intake structure is needed, but an arrangement was made that the tail water from the hydropower plant at Pul-i-Khumri be diverted to supply water to the canal. A stretch of 3 Km. of canal is proposed to connect the end of the power channel to the Adjmir Canal, which results in reduced expenses and saving of time. The irrigable area commanded by this canal is about 30,000 to 40,000 acres. In sections the canal had steep slopes and the high velocity of flow caused enormous erosion and at many points the banks were subject to cutting and washing out. By constructing concrete drop structures along the canal, the velocity was reduced. Bank stabilization and, in sections, realignment of the canal were performed. Flood water accumulated from the adjoining drainage basins in the upper reaches of the canal was channelized into one major wasteway crossing the canal by means of a concrete channel with a capacity of 150 cubic feet per second, and directed to the existing wasteway which is excavated for surplus power plant discharge. Because of the steep slope of the wasteway, a concrete drop is also being constructed. A second wasteway has been excavated and structures similar to the first wasterway will be built. Halfway from the intake, the primitive wooden channel lined with mud which was constructed to convey canal water across a deep wide flood channel and was subject to flood hazards two or three times a year, was replaced by a 74-metre, 60" circular concrete siphon with gated wasteway. In the meantime, the canal capacity at this section was increased from 40 to 140 cubic feet per second by constructing this siphon. A third siphon, a masonary structure at the downstream section of the canal with a capacity of 90 cfs., 90 metres in length, was constructed. A controlled wasteway is also attached to the structure. About 150 to 200 pipe turnouts are to be installed on various lateral intakes with control gates installed on them. Additional protective measures, wasteway structures and channels as needed will be completed as planned. With the completion of the recommended plans of improvement, the capacity of the Adjmir Canal will increase from the initial 300 cubic feet per second to about 500 cubic feet per second.

The major costs of these improvements are paid by the Government ; some charges will be borne by the farmer. Of course, the financial condition of the inhabitant farmers is considered. Repayment is accomplished in installments of long duration. The cost of local improvement of individual canals, performed by the farmers where the Government is not doing any work, is borne by the landowners themselves. The Agricultural Bank, in accordance with specific rules, makes development loans to the farmers with low interest charges on long duration installment plans.

Discussion. While the efficiency of old irrigation system is estimated at 30 per cent, it may be 40 to 50 per cent in the Helmand Valley. The effi-

ciency figures do not apply to irrigation from karazes, which are very efficient. Although sprinklers are not presently practical in places where they are needed, they would be used if they could be afforded and if power was available to operate them. Old systems are being improved as much as possible; on new projects, an attempt is made to meet Western standards, and U.S. standards are very commonly accepted.

Mr. Ozel of Turkey suggested that, in Turkey, some karazes are being lined, and inquired about this in Afghanistan. Mr. Raza replied that karazes are privately owned and the owners do not have the financial resources to line them. Mr. Asîfi pointed out that baked clay reinforcing lining rings are sometimes used. A question was raised regarding the interference of new water developments with karazes and it was stated that this is related to groundwater, which is not presently being developed. At the time groundwater is developed, consideration will have to be given to protecting or replacing the rights of karazes.

Pre-sowing irrigation is practiced in certain areas. The widths of borders vary locally, being from 8 to 10 meters around Kabul to 50 to 60 meters in the South. Rehabilitation programs are generally started at the request of the farmers themselves. That work which they can do is left to them, and the Government does the reminder. Costs are repaid over a 10-year period.

IRAN'S PROGRAM OF SMALL IRRIGATION PROJECT DEVELOPMENT

by

Mr. F. F. Raji

HISTORY

Iran is a land of low and ineffective precipitation with the exception of the Caspian region. It is a land, therefore, that has a tradition in irrigation. The ancient people realized the defficiency of irrigation water, so they established irrigation dams, ganats and other structures. The main purpose was to divert the water from the rivers for irrigation and to drain the groundwater for irrigation and domestic use. In this paper, it is unecessary to expain about the old dams and other irrigation structures, but it should be mentioned that many of them are not in use at present, because of poor maintenance.

During the past year the National Plan Organization of Iran (an organization for national planning in all sectors of the national economy) turned to a new irrigation policy of «small irrigation projects» as the key to agricultural development in preparing the Third Plan which begins this fall. A very high proportion of the water development expenditures in the two previous plans were spent for the construction of dams.

The irrigation program of the Government of Iran through the second period of the Plan Organization (started about seven years ago) had four parts:

1. Irrigation and dam construction
2. Irrigation surveys
3. Ganat and deep well program
4. Irrigation societies

The table below shows the distribution of expenditures for the above programs up to the end of 1337 (20th March 1959) and projected to the end of the second seven-year plan period. It is interesting to note that the dam construction program accounts for nearly 90 per cent of the Plan Organization allocation to irrigation for the plan period.

Three-fourths of all expenditures for «irriga-

1 — Engineer, Independent Irrigation Corporation, Iran.

Irrigation Expenditures for Second Plan
(Millions of Rials: 80 Rls. equals $ 1.00).

	Half period 1334-1337 (1955-1958)		Total period 1334-1341 (1955-1962)	
	Exp.:	per cent	Exp.:	per cent
Dam construction	4,557	83	12,237	89
Irrigation surveys	443	8	970	7
Ganat and deep well loans	352	6	352	3
Irrigation societies	130	3	150	1
TOTAL:	5,482	100	13.709	100

tion» have gone for the construction of two big dams — Karaj and Sefidrud. These are expected to use about 84 per cent of the Plan Organization allocation to «irrigation» by the end of the plan. This leaves only 16 per cent of the irrigation funds for all other small irrigation and dam construction projects, ganats, deep well loans, irrigation surveys and water societies.

The Karaj Dam, which will use about 38 per cent of the irrigation allotment, is not an irrigation project; it provides municipal water and electricity for Tehran. Expenditures on the Karaj Dam can be readily defended on the grounds of Tehran's needs for electricity and a more adequate supply of municipal water. From the standpoint of irrigation, large multipurpose projects should not be given a high priority without very careful consideration of alternate methods of achieving equal irrigation production through small projects. The Sefidrud Dam is a multipurpose project whose main purposes are power, irrigation and some flood control. Large projects should generally be undertaken at a later stage of the country's growth. This was first pointed out in the report submitted by Overseas Consultants, Incoorporated, in 1949, Their argument was mainly based on the following:

Large multipurpose projects are associated with the economics of scale and are most economical when they are large. Such projects require a close market for large blocks of power and a very substantial degree of industrial development. At present Tehran is the only place in Iran that has sufficient industry to demand large blocks of power. The large distances between the principal cities of Iran make electric power transmission costly.

Sefidrud Dam illustrates the difficulty. The closest market for its power is the Guilan area, which can use only 20,000 k.w. of the 90,000 k. w. of capacity at the plant. Although not accepted, a proposal was made that a transmission line, costing about 500 million rials, deliver the electricity to Tehran, 240 kilometers away.

The advisibility of large multipurpose projects in Iran is questionable not only because of the above points, but also because an examination of existing hydroelectric projects reveals other significant weaknesses:

1. Of the irrigation projects started in the first two plans, none made adequate provision for the management and sale of water, for water rights, for maintenance costs of the canal network, or for land use and tenure problems. There are some who believe that progress cannot wait for the completion of all the requisite details of planning, and that problems will be solved when they arise.
2. The estimated cost of large irrigation projects has increased enormously in Iran. The Karaj Dam cost estimates increased from 1.5 to over 6 billion Rls.

During the Second Plan period, the Government of Iran came to realize that big irrigation projects are not necessarily the most profitable projects, while small irrigation projects are more effective in solving Iran's irrigation problems. The people of Iran are most interested in small irrigation schemes. Some of these small projects can be done by the people themselves, with only technical assistance and loans from the Government. The Government, therefore, has allocated capital to the Agricultural Bank of Iran for groundwater development, such as the drilling of deep and shallow wells and ganat renovation. On the other hand, irrigated lands are more widely distributed in the various regions of the country when a number of small projects are built rather than one large one. This shows the social advantages of the small projects over the large projects. In the Third Plan, which will start in October, 1962, more stress is placed on small irrigation projects, as is outlined in the following.

SURFACE WATER DEVELOPMENT BY SMALL PROJECTS

It is estimated that during the Third Plan surface water development projects could be carried out on about 75,000 hectares, of which 45,000 hectares would be irrigated annualy for the first time and irrigation would be improved on 30,000 hectares.

A brief description of the proposed development by small surface projects during the Third Plan program follows:

(1) **Jahrom Project.** The building of several small dams in order to replenish underground water resources and prevent the drying up of the available wells used for the irrigation of 4,000 hectares of palm and citrus. The surveying is already finished; construction will start in the near future and will take about two years.

(2) **Shavour Project.** The construction of a network in the Shavour area to use the water of the Shavour diversion dam properly and to assist in land reclamation by establishing a drainage system. The surveying is almost finished and the network's construction will start in the near future and will take two years. It will add 5,000 hectares of irrigated land, which will be used for sugarcane and cotton.

(3) **Golpayegan Project.** Thic project is already approved and the job of constructing a network will be done during the next two years. The purpose is to use the water of the Akhtegan reservoir, which has already been constructed. This project will improve irrigation on a total of 5,000 hectares.

(4) **Parishan Lake Project.** The purpose of this project is to use the water of Parishan Lake for irrigation by pumping. The surveying is almost finished. The execution of the work will be started after the completion of the surveying, which will take two years. This project will improve irrigated lands totalling 5,000 hectares.

(5) **Bampour Network and Canal Lining.** The surveying will be finished after a few months and the construction will take two years. The purpose is to the water of the Bampour River by means of the diversion dam which is already built. This project will newly irrigate about 2,000 hectares and improve irrigation on an additional 2,000 hectares.

(6) **Garmsar Network Project.** This project is a network and canal construction job in order to prevent water losses and to change the old distribution system to a new one. The investigation and planning are already done. Construction will start after the design is completed and will take about three years. This project will improve irrigation on a total of about 12,000 hectares of land.

(7) **Jajerud Project.** This project is a network job in order to provide a better distribution system. The surveying will be finished during the next year, but construction will take about three years. The purpose is to use the additional water to be saved from loss and to improve irrigation on the available land by a new distribution system.

(8) **Abadeh Project,** including the use of Kaftar Lake water for irrigation, drainage of the Shadkam plain and effective use of Eglid springs water. Surveying and construction will be completed with the next three years.

(9) **Karkheh Project.** Within the last two years, drainage and land reclamation have been accomplished on about 5,000 hectares, and these lands improved from Class 5 to Class 3. The main purpose is to provide a water distribution system from the Karkheh diversion dam, has already been constructed. It is expected that 1,500 hectares of lands will be newly irrigated annually by establishing the irrigation and drainage distribution system.

(10) **Shabankareh Project.** This project involves an irrigation and drainage distribution system which is improving every year. About 4,000 hectares have been irrigated and improved up to now. It is expected that a total of 8,000 hectares of improved and irrigated lands will be obtained by continuation of this project in the future.

(11) **Nahavand Project.** This is a water loss prevention and water distribution development which will improve irrigation on 4,000 hectares of lands and will add 2,600 hectares of newly irrigated lands. Losses can be decreased by lining and repairing the canals and improving the distribution networks.

(12) **Kordan Project.** This project consists of the following stages:

a. Construction of a storage dam in order to control flood flow and use it for irrigation.
b. Construction of the inlets and canals for a new distribution system. The main result will be that 30 per cent more land will be irrigated.

GROUNDWATER DEVELOPMENT

Two major programs will be undertaken during the Plan period to develop groundwater resources:

1. **Deep and Shallow Wells.** A program for Government-sponsored loans administered by the

Agricultural Bank with the technical assistance of the Irrigation Bongah which will make it possible for landowners to drill up to 2,000 deep and shallow wells during the Plan period. On the assumption that each well will provide irrigation water for 25 hectares, this program would provide water for 50,000 hectares. It is estimated that some 30,000 hectares of this total will be irrigated annually for the first time, and the remaining 20,000 hectares will be land now regularly irrigated but for which water supplies will be improved.

In 1959 the Irrigation Bongah began developing a groundwater staff and making the investigations necessary to obtain scientific information on groundwater. The geologists of the Irrigation Bongah are investigating the groundwater conditions in several regions of Iran. These studies will form the basis for providing technical assistance to the Agricultural Bank and to farmers in drawing up groundwater development plans for the additional use of groundwater on small irrigation projects.

2. **Ganat Renovation.** Ganats represent a substantial national investment and provide irrigation water for perhaps as much as 80 per cent of the irrigated area south of the Elborz mountains bordering the Caspian Sea. During the Plan, the present program making credit available to ganat owners to enable them to undertake major renovations and thus increase water flow will be continued and expanded. To this end, a reserved credit fund of Rls. 500,000,000 (equivalent to $6,300,000) has been established, to be administered by the Agricultural Bank. This amount will be in addition to the capital already available for this purpose in the Bank. This program is expected to bring under annual irrigation for the first time 10,000 hectares and to improve irrigation on an additional 40,000 hectares.

During the Plan period, the Irrigation Bongah will have primary responsibility for small surface systems and the technical aspects of the well program. Responsibility for the loan programs will be vested in the Agricultural Bank. Educational activities to improve the use of irrigation water by cultivators will be the responsibility of the Agricultural Extension Service, with technical support provided by the Irrigation Bongah.

The Irrigation Bongah is now in the process of reorganizing in order to meet the increasing demands for technical services that will result from the emphasis on small irrigation projects in the Third Plan. The increased magnitude of irrigation activities will permit the Bongah to implement its work through more specialized branches, thus permitting Iranian technicians to achieve higher degrees of proficiency and to turn out a higher quality of work. Iran looking forward to doing more comprehensive planning and designing with Iranian engineers in the future.

Discussion. Irrigation societies are formed under their own boards of directors. However, the Government owns most of the capital used by the societies. Since Government funds revert each year, grants may be made to irrigation societies, which may impound the funds and spend them as they are needed without annual budgetary restrictions. The share of private funds in these societies as compared to Government funds is relatively minor.

The reasons for the great increase in construction costs over estimates for the Karaj Dam are not entirely clear, but it appears primarily that the work turned out to be much more difficult than was originally anticipated.

With regard to the lining of canals, Item No. 11, the canals were lined with concrete and the alignment was changed.

Iran feels that they were beginning to overobligate their resources for large multiple-purpose projects and that the effects of such projects are limited to localized areas. Smaller projects spread their benefits over a much wider area. Both Iran and U.S.A.I.D. favor shifting to small project development until the capital can be built up to continue large scale ones, Mr. Ozal felt that small project development might not be the best policy for all countries, because a large multiple-purpose development brings in new resources, which the countries need. Mr. Raji pointed out that the land to be brought under irrigation in five years under the small projects program in Iran totaled 50,000 hectares from surface irrigation, 50,000 hectares from deep well irrigation, and 10,000 hectares from ganats. The development of electricity from multiple purpose projects would be very useful for small pumping projects. Iran's small project plans apply to their Third Plan period. Mr. Blok thought

that the larger projects paid higher dividends in the long run. However, the smaller projects built in Ceylon are referred to the project agency and integrated with plans for the larger projects which will eventually be built. One of the advantages of the small projects is that they can be handled by Iranian engineers.

Mr. Hamid stated that while Pakistan has the potential for large projects and a dire need for food, they also are giving attention to their smaller projects. They have a small-dam organization which has the authority to build dams costing less than $200,000. Pakistan has a policy of emphasizing development of the west side of the Indus, so projects there, regardless of their small size, are initiated because the villagers in that area have no irrigation and providing even a few hundred acres for them is important. Even small projects lead to other developments in the area.

The Independent Irrigation Corporation has district offices only for hydrology and for river control. However, they plan to expand so that they will have general district offices. They are sending parties to the field and these parties can refer the problems they cannot handle to the central office.

DEVELOPMENT OF THE LAND AND WATER RESOURCES OF THE TAMANKADUWA DISTRICT OF CEYLON

by

Mr. M. A. Blok, A. M. I. C. E., M. I. E. C.[1]

INTRODUCTION

The Tamankaduwa District of Ceylon covers 1,250 square miles and forms part of the 4,034 square-mile drainage basin of the Mahaweli Ganga. It is situated in the north eastern part of the island and has a history dating back to the early Christian Era. The district, which was at one time the most flourishing area in Ceylon, fell into decay and ruin through various causes. This paper records the various stages by which the district was reclaimed from the jungle, making it today one of the foremost paddy producing areas of the island.

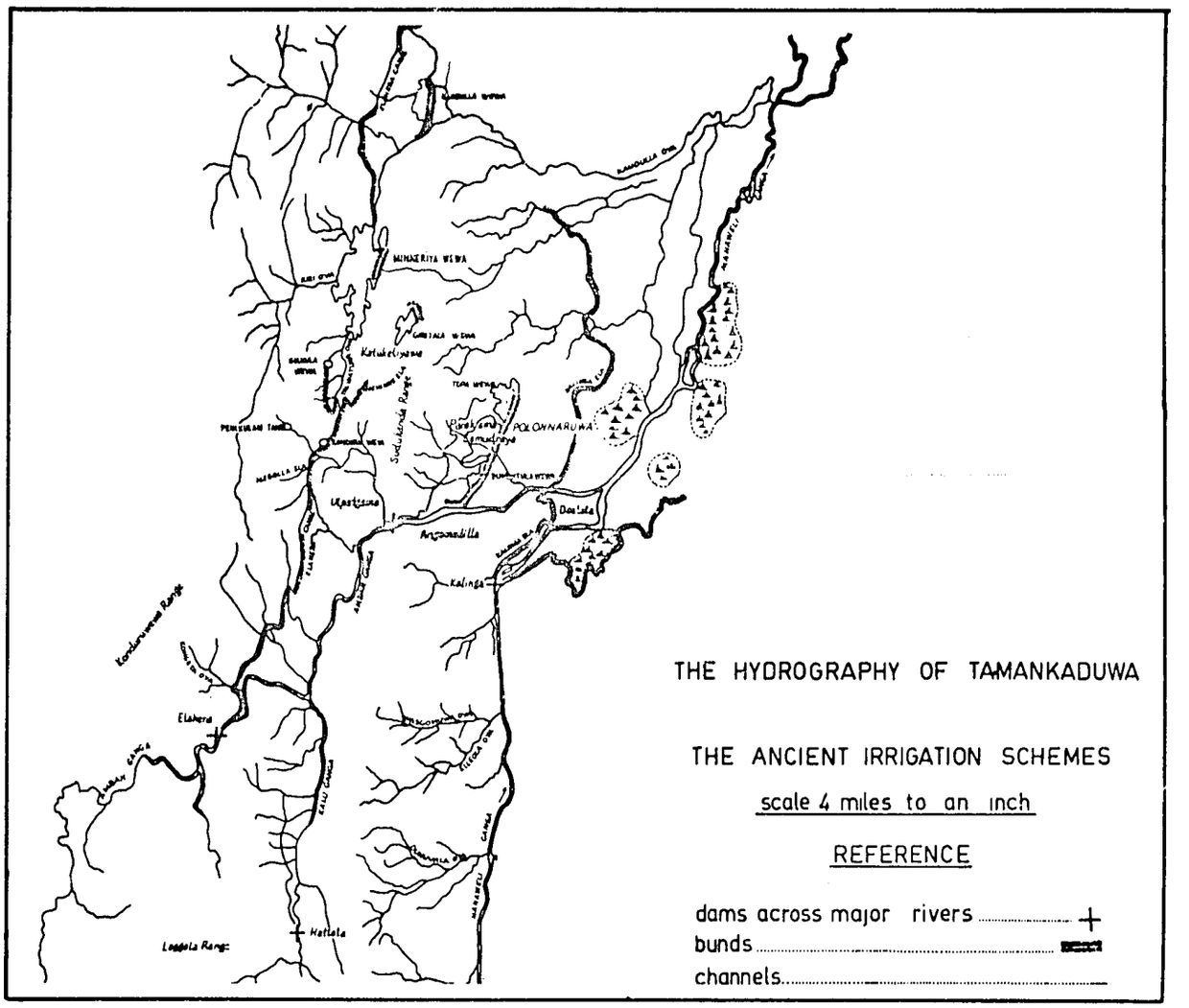
1 — Irrigation Department, Ceylon.

TOPOGRAPHY AND HYDROLOGY

The district consists largely of flat undulating land interspersed by isolated hillocks and is bisected by the Sudukanda range of hills. This range, which runs approximately north-south, was used by ancient irrigation engineers for dams and for storage reservoirs. The district receives between 50 to 75 inches of rainfall a year, of which the greater portion falls during the northeast monsoon, which lasts from October to February. The pattern of rainfall is best illustrated by the following table, which lists the mean monthly rainfall for the three stations of Minneriya, Polonnaruwa, and Elahera, which represent the western, eastern, and southern boundaries of the district.

TABLE 1. EXAMPLES OF RAINFALL.

Mean Rainfall in Inches			
Month	Minneriya	Topawewa (Polonnaruwa)	Naula
October	9.04	8.04	6.60
November	13.42	12.06	19.96
December	15.30	14.31	15.09
January	12.53	12.10	4.59
February	3.23	3.59	2.27
March	3.63	3.49	2.10
April	6.33	4.89	1.69
May	3.40	3.30	1.60
June	0.44	0.37	1.62
July	0.90	1.08	0.74
August	2.32	2.36	0.00
September	3.60	2.92	0.00
Total	74.14	68.51	56.26



The Mahaweli Ganga is the main drainage line of the district and its largest tributary, the Ambanganga, is the lifeblood of the people of Tamankaduwa, being one of the chief sources of irrigation water. The drainage basin of the Ambanganga is 520 square miles. The average annual runoff of the Mahaweli has been estimated to be 6,000,000 ac. ft., while that of the Ambanganga is nearly 1,000,000 ac. ft. The ancient engineers of Ceylon were quick to grasp the opportunities offered by these two perennial rivers, and executed magnificent feats of engineering in order to provide an assured supply of water for irrigated agriculture.

THE ANCIENT PATTERN OF IRRIGATION

The most striking feature of Tamankaduwa is the large number of major irrigation works left by the ancient kings of Ceylon. Probably the oldest major irrigation work in the Tamankaduwa District is the Minneriya Tank, which has a drainage area of 92.5 square miles. The construction of this great reservoir is attributed to King Mahasena and is believed to have been completed 17 centuries ago. The reservoir is formed by closing a gap in the Sudukanda range of hills with an artificial embankment one mile long. The irrigable area under this tank is 14,000 acres and consists of gently sloping undulating lands, well drained and ideal

for irrigation. A further work attributed to King Mahasena is the Kaudulla reservoir, which has a catchment area of 140 sq. miles. This tank was also formed by closing the gap in the same range of hills and commanded the some acreage as Minneriya, or even more. The supply to Kaudulla was augmented by the spill water of the Minneriya tank which flows directly into Kaudulla, while the spill water from the second spill of Minneriya was led along an artificial canal to the Kantalai tank, which lies outside the district, nearly 20 miles away.

The next tank to be constructed in ancient Tamankaduwa was Topawewa, which now forms a part of the great tank Parakrama Samudra or Sea of Paradrama, at Polonnaruwa. The construction of Topawewa was carried out by King Upatissa II in 368 A.D. It is believed that Topawewa at full supply level submerged an area of 1,000 acres or so, and irrigated a large extent of paddy lands.

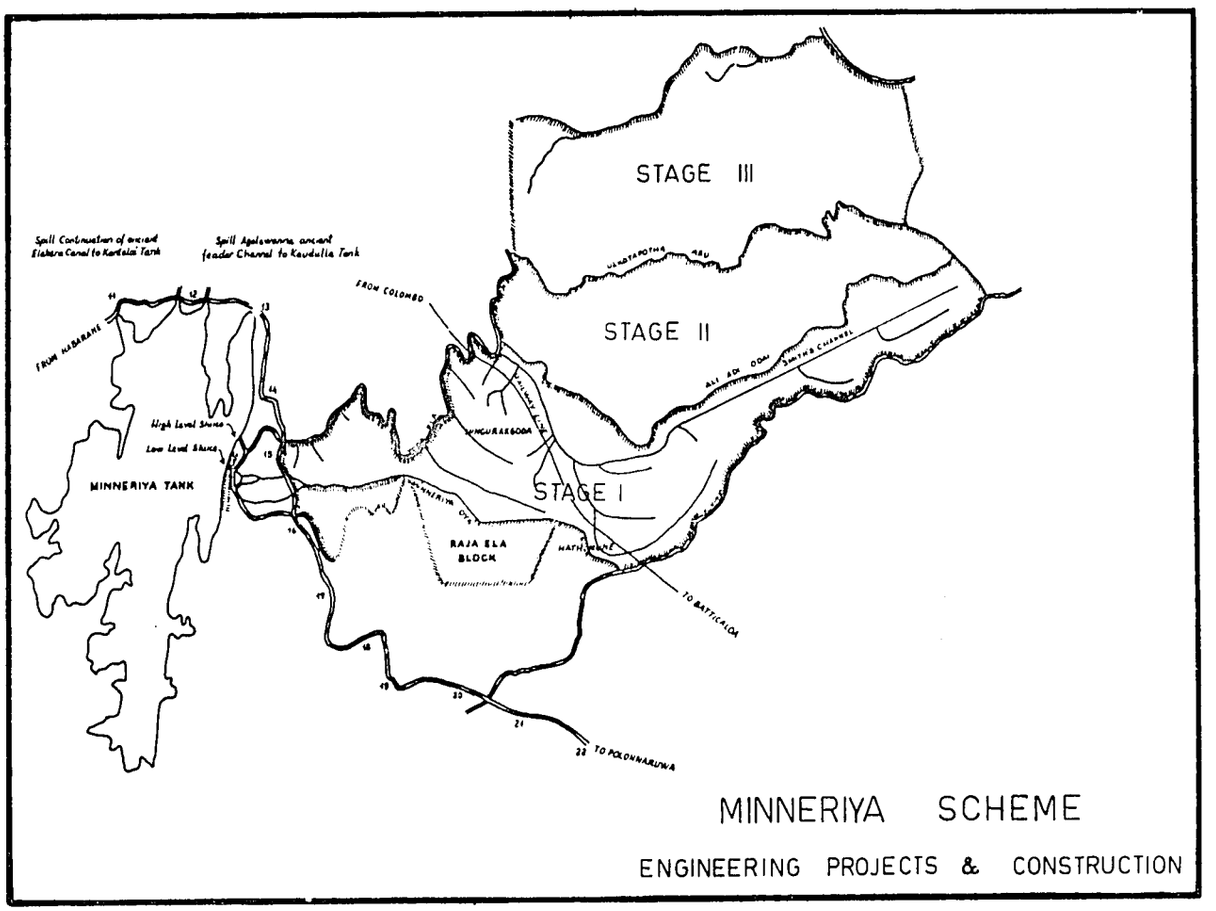
Up to this time the Mahaweliganga had not been exploited as a source of irrigation water, perhaps owing to lack of sufficient technical knowledge and construction know-how, but during the fifth century A.D., this task was accomplished by throwing a massive stone dam across this mighty river. This dam consisted of massive square and rectangular stone blocks, each of which weighed about two or three tons. The diversion of water from this dam was accomplished by means of left bank and right bank canals, the remains of which are visible today, and appear on the one-inch to a mile topographical maps. The origin of this work is obscure but the left bank canal is attributed to King Dhatusena, who ruled during the period A. D. 463-479. This left bank canal is today known as the Kalinga Ela.

It is presumed that about this time, and after the experience gained by the construction of the Kalinga Ela, a water shortage was experienced at Minneriya tank. This difficulty was resolved by the construction of a diversion dam across the Ambanganga at Elahera and a 23-mile-long conveyance canal to lead water into the Minneriya tank. This canal, known as the Elahera Minneriya canal, also provided irrigation to about 5,000 acres of paddy lands comprising what is known as the Elahera Schema of today.

At the point where the canal enters the feeder stream to Minneriya was constructed a bifurcation structure also consisting of large stone blocks by which a branch canal was led into Giritale wewa, a small storage reservoir lying to the East of Minneriya tank. The ingenuity of the ancient engineers is to be marvelled at because the 9 sp. mile catchment of Gritale wewa would have been quite inadequate to irrigate the 4,000 acres of paddy fields which are served by this tank without such an augmentation scheme. The Giritale tank is believed to have been constructed by King Agrabodi in 650 A.D.

The last and greatest work of the Tamankaduwa District was the Parakrama Samudra or Sea of Parakrama constructed by the greatest irrigation engineer in Ceylon history, King Parakrama Bahu (1153-1186 A. D.). This reservoir was formed by incorporating the earlier Topawewa of King Upatissa into a very much larger reservoir by extending the dam to take in the catchment of two large tributaries of the Ambanganga. The total length of the embankment is nearly nine miles and it is 40 to 50 ft. high in places. The total catchment area of Parakrama Samudra is only 28 sq. miles and in order to ensure a regular supply of water, the perennial Ambanganga was dammed by the familiar stone weir 600 ft. long and led into the tank by an artificial canal. The total area submerged by the reservoir is 5,500 acres and the irrigated extent is 18,200 acres. In addition to this masterpiece of irrigation engineering, history records that King Parakrama Bahu restored and improved 1,395 irrigation works which had fallen into disrepair and consequent disuse.

All these works gradually deteriorated after the twelfth century A.D. owing to various causes such as war, disease, drought, and floods, and it was not until the late 19th century that attention was focused on the possibility of restoring some of these works. From that time onwards no effort has been spared toward this end. The restoration of these works was taken up systematically, and the progress achieved on each of these works will now be outlined.



MINNERIYA SCHEME

(a) **Early Development**

Minneriya tank, the oldest of the major irrigation works in the Tamankaduwa District, and also one of the few surviving ancient works, was appropriately selected as the first improvement scheme to be undertaken in this area. Ever since the British occupation of Ceylon in 1815, periodic reports on improvements to Minneriya tank had been prepared, but in 1890 a definite scheme was drawn up.

The catchment area of the tank is 92.5 sq. miles and the average annual rainfall is 80 inches, providing a northeastern monsoon yield of some 78.000 ac. ft. The actual work of improvement commenced in 1897 and was completed in 1905; it was intended primarily to ensure a regular supply of water for 170 acres of ancient fields lying close to the tank and also to bring under cultivation at least 9000 acres of new land. The engineering work consisted of removing the sluice gate of the ancient sluice and the construction of two new sluices, one a low level sluice and the other a high level one. Improvements were also carried out on the two natural spills, one of which was connected to Kaudulla tank while the other discharged into the ancient Yoda Ela or channel linking Minneriya with Kantalai tank. In addition to this, a nine-mile conveyance canal was cut to irrigate the existing ancient fields and also to command 9,000 acres of land proposed for development.

Land utilization unfortunately did not keep pace with the engineering work, chiefly due to the high incidence of malaria which seriously hampered land development operations, and it is recorded that up to the year 1920 the only lands directly ir-

rigated by the tank were the 170 acres of ancient paddy fields.

In 1920, however, 9,000 acres of land were leased to a public company which proposed to colonize the area by the cultivation of paddy in blocks of 250 acres each. The concession offered by the Government at the time was a tax-free lease for the first 10 years, after which the land was to be taxed at Rs. 3.00 per acre.

The northeast monsoon rains of that year, however, brought with them an outbreak of malaria and by the end of the year the labor force had decamped. Thus ended the first attempt at large-scale colonization at Minneriya tank. This was followed by two further attempts which also ended in failure, and it was not until the year 1932 that the real colonization of Minnariya began.

(b) **Modern Development**

(i) **Plan of Development.** The Minneriya development scheme was formulated by the Ministry of Agriculture and Lands 1932. Conscious of the reasons for past failures,it was soon realized by the Ministry that colonization of vast tracts of inaccessible jungle had to be a joint venture among the Irrigation, Survey, Land Development, Agriculture and Medical Departments of the Government, and accordingly a committee composed of the heads of these departments was appointed to draw up a scheme of development. The main proposals drawn up by this committee were for the colonization of the area by three categories of cultivators; namely, peasants, middle class colonists and capitalists. The units of allotment recommended were 5 ac. for peasants, up to 50 ac. for middle class colonists, and larger areas for capitalists, after the needs of the other two categories had been met. Details were quickly worked out and preliminary work commenced the same year.

(ii) **Engineering Surveys.** The engineering surveys for this new venture were carried out by the Survey Department, which commenced work in 1932. At first 1800 acres were selected for survey, including the ancient lands already developed under the tank. The following year, the extent was increased to 10,000 acres and by the end of that year maps were made available to the Irrigation Department for the preparation of plans indicating the canal system, paddy allotments, highlands allotments, townships, etc. Five years later it was decided to take up the survey of a further 1,000 acres and also to survey the bed of Mineriya tank with a view of increasing its capacity. This work was completed in 1940.

(iii) **Constructed Work.** For the purposes of construction and development, this scheme was divided into three stages, each of which was taken up in a coordinated program of development. No major improvements were carried out to the Minneriya tank itself in the 1932 scheme, as the earlier work had already put the tank into working order. The length of embankment was 1,100 yards with a maximum height of 44 ft., and at full supply level the tank had a water spread of 4,670 acres and an impounding capacity of 65,700 ac. ft. The construction work included provision of irrigation, drainage and access facilities to the new development scheme. The main canal from the sluice which followed the trace of the ancient canal was reconditioned for a distance of 10 miles to carry a discharge of 183 cusecs of water. Branch and distributary canals were also constructed along with all appurtenant structures, access roads, and drainage channels. A right bank channel which took off from the main canal just downstreem of the sluice was also reconditioned to serve the 170 Ac. of ancient paddy fields, and this was later extended to serve 772 Ac. in all. About 900 acres were omitted due to poor soil conditions. These were later reclaimed by squatters using rainwater, after which the Government extended the irrigation channels to serve them. This brought the total area served by irrigation, drainage and access facilities to 10,000 Ac. of paddy.

About the time stage 3 was being completed, it was decided to increase the capacity of Minneriya tank to impound 110,000 ac. ft. by raising the spill level by 8 ft., the area inundated at full supply being 6,500 acres. Two new sluices were constructed, one to serve the left bank area and the other the right bank. The main canal was also improved up

to 10 miles to carry a discharge of 300 cusecs to serve total of 14,000 acres in all. Along with this, an additional area of 2,500 Ac. called Stage 4 was taken up for construction in 1959 and this is now in progress.

In 1961 it was proposed to develop about 600 K. W. of hydro power from the new low level sluice, to serve the towns and villages in and around Minneriya. Construction work has already begun on this scheme, which is planned for completion within two years.

(iv) **Soil Surveys and Land Development.** This scheme, being the first of its kind undertaken in modern Ceylon, was necessarily a training ground for the Government as well as its officials. Consequently, a soil survey was carried out only after preliminary work was well along. As a result certain areas originally earmarked for development had to be temporarily abandoned on the recommendation of the soil chemist. A direct consequence of this was a Government decision made in 1935 that soil surveys should precede engineering surveys.

Land development commenced on a plan drawn up by an official committee, which decided to alienate 5 ac. of paddy land and 3 ac. of highland and a house per peasant. Simultaneously, a township, highland roads, schools and medical facilities were provided. Colonists were settled in temporary huts until permanent buildings were constructed, and it is recorded with pride that in spite of the tremendous hardships they had to encounter, the first settlers who braved the vicissitudes of this virgin forest today comprise one of the most prosperous colonies in Ceylon.

While the early colonists were moving in, the used for marketing their produce at reasonable prices, for financial assistance, for initial cultivation, for provision of seed paddy, and for instruction in improved agricultural practices was keenly felt. As a result, cooperative agricultural sales societies were set up to ensure economic prices for agricultural produce, while credit societies provided loans for the purchase of implements, buffaloes, etc. In addition, a large Government farm was established to carry out demonstrations, and supply adequate planting materials to the farmers.

Many lessons were learned in this pioneer colonization scheme and the mistakes made at the outset have been corrected in the new development schemes now being undertaken.

Elahera Scheme

The Elahera scheme was devised in ancient times to divert the waters of the Ambanganga into the Minnariya and Giritale tanks by means of diversion weirs and a left-bank coveyance channel. This scheme too lay in ruins for several centuries, until the British occupation of Ceylon.

(a) **Early Development.**

The first scientific investigation of this scheme was undertaken about the year 1855 by three Englishmen. Having explored the area, which was completely overgrown by thick jungle, they recommended an engineering survey to assess the irrigation potential of what appeared to be a major diversion project. It was not until 30 years later, however, that an engineering survey was actually commenced; after a few years' work, with only a few improvements carried out to the head works, the scheme was abandoned.

(b) **Modern Development.**

(i) **Engineering surveys.** In 1935, engineering surveys of the Elahera scheme were commenced with a view to improving the diversion weir at the headworks and reconstructing the 23-mile conveyance channel to augment Minneriya and Giritale tanks. It was also proposed to contour survey the land that could be irrigated by direct issues from the canal. This was completed in 1940 and the plans were made available to the Irrigation Department for design and construction of the project.

(ii) **Construction works.** In 1937 proposals for the reconstruction of the Elahera scheme were made by the Director of Irrigation and accepted by the Government. The proposals envisaged improvements to the diversion weirs at the headworks and the construction of a new concrete head sluice. The scheme also provided for the construction of the channel

and road system required to serve an extent of 4,750 acres of paddy lands by direct irrigation. The total length of canal to be restored was 23 miles and the conveyance capacity was fixed at 250 cusecs. The engineering work was rendered extremely difficult because of the large number of cross drainages intercepting the channel trace. These were crossed by means of reinforced concrete flumes carried on piers. In addition, at the end of the conveyance channel, a modern concrete bifurcation structure was constructed to distribute the water between Minneriya and Giritale tanks and an ancient link channel three miles long restored to convey water from the bifurcation structure up to Giritale tank. The feeder stream to Minneriya tank begins just downstream of the bifurcation, hence no artificial channel was required.

With the increased development under Minneriya tank, and the augmentation of this capacity, steps were taken to increase the conveyance capacity of the Elahera canal so as to ensure two-season cultivation. This was further necessitated by a decision to augment the capacity of Giritale tank in order to step up its irrigable extent from 600 Ac. to 4,500 Ac. Proposals were framed for increasing the conveyance capacity to 1,000 cusecs. The crest level of the diversion weir was raised and a new concrete head sluice constructed. This proposal also did away with the concrete flumes at the cross drainage and provided for taking in a part of their catchment so that the tail end of the channel had a flood capacity of 3,500 cusecs. Thus flash floods were impounded to augment Minneriya tank. This work was completed in 1957 and its wisdom proved beyond doubt by the regular two-season cultivation enjoyed by the cultivators of Minneriya.

(iii) **Soil surveys and land development.** Soil surveys of the lands proposed to be irrigated by the canal were commenced in 1939 and investigations revealed that practically the entire extent consisted of good primary paddy soil. The area was found to be well-drained, with little or no evidence of hard pan below the surface.

After several attempts to colonize this area in the early 20th century had failed, the entire scheme was abandoned until 1934. In that year, the Government decided to take up the Elahera Scheme, both for large scale colonization and for augmenting the water supply to Minneriya tank.

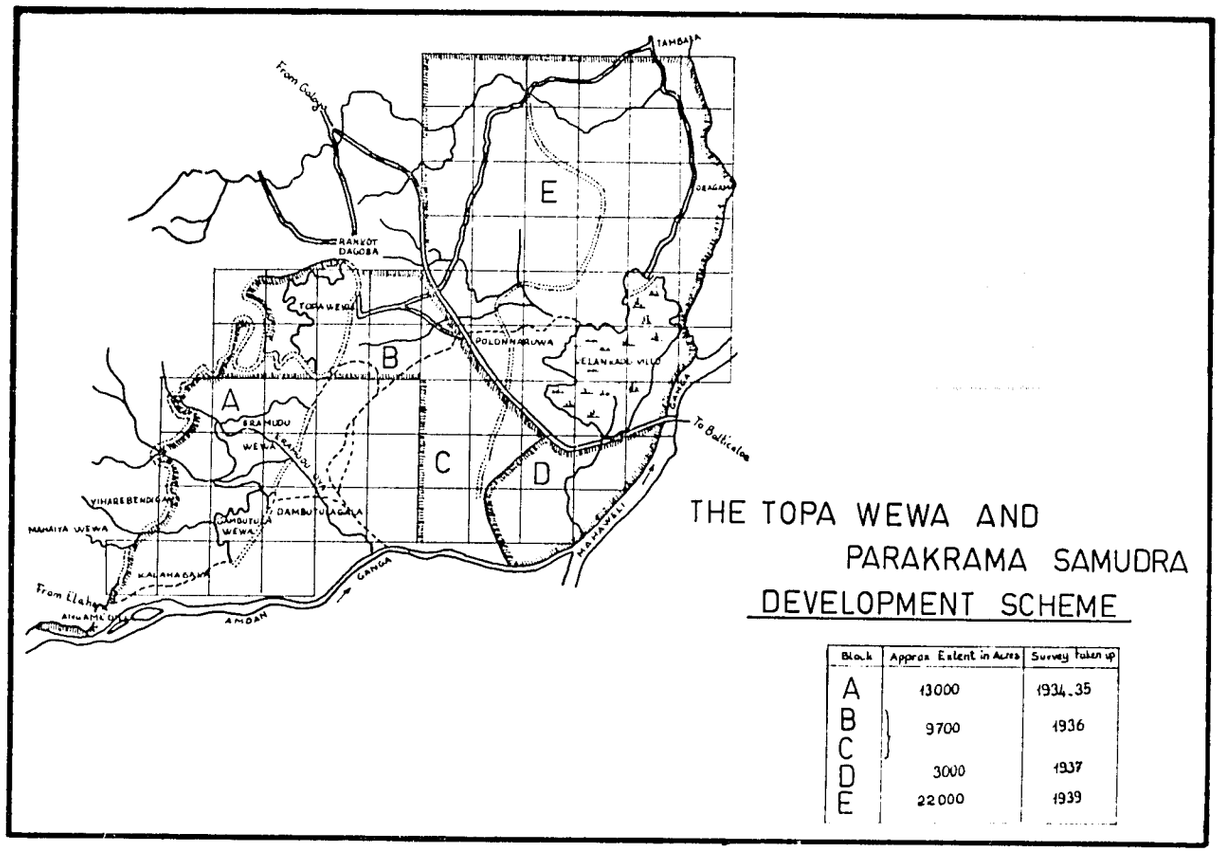
The blocking out plans prepared for Elahera provided for 5-Ac. paddy allotments and 3-Ac. highland allotments on the same pattern as for the Minneriya scheme, but the civic amenities such as schools, hospitals, and sites for civic centers were more carefully planned than for the earlier scheme. Here again the Government set up cooperative agricultural sales societies and credit societies for the benefit of the farmers, and the colony today has an air of great prosperity.

PARAKRAMA SAMUDRA SCHEME

The catchment area of Parakrama Samudra is 28 sq. miles and the catchment receives an annual rainfall of 72 inches, of which 57 inches are precipitated during the northeast monsoon. The yield from the catchment alone amounts to only 27,000 ac. ft., hence augmentation from river diversion is essential. This reservoir consists of three separate tanks — Topawewa, Eramuduwewa and Dumbutuluwewa — and these had been combined into one large reservoir called Parakrama Samudra or the Sea of Parakrama by King Parakrama Bahu the Great, as previously mentioned.

(i) **Engineering Survey.** Surveys began in 1934 and were at first intended for the restoration only of Topowewa and the inlet channel from the Ambanganga, but in 1937 it was decided to restore the entire scheme. This was found to be more feasible, as the closing of a single breach in the Eramudu wewa provided a very much larger storage capacity and also eliminated eight miles of the inlet channel of the 12 miles required to feed Topawewa only. The survey was completed in 1939.

(ii) **Construction work.** The restoration work involved the construction of two diversion weirs across the Ambanganga to replace the ancient stone weirs which had collapsed,



and the reconstruction of four miles of the ancient feeder channel. The single breach in Eramuduwewa, 600 ft. wide and 60 ft. deep, was also closed and a new 100-ft. concrete spillway constructed. For issues to the fields, three sluices were constructed; the left bank sluice to irrigate 16,000 acres, the center to irrigate 4,000 acres, and the right bank sluice to irrigate 1,500 acres. The capacity of the tank is 98,000 ac. ft. and the water spread inundates an area of 5,940 ac. at full supply level. The total length of embankment is 8 1/2 miles. The closing of this branch in this embankment was a landmark in the history of the Irrigation Department, in that crawler tractors were used for the first time for jungle clearing and earthwork.

The restoration of the tank was followed by the construction of channels, beginning with those under the right bank sluice. This work was spread out over several years and was completed in 1952.

(iii) Soil Surveys and Land Development. Soil surveys were carried out by the Agricultural Department and they revealed that the major portion of the area to be developed consisted of secondary paddy soil. They were followed by the preparation of blocking out plans and the construction of the channel system. To begin with, the Government started a large cattle farm within the scheme in order to popularize and develop animal husbandry, and also to supply cattle and buffaloes to colonists for plowing. While the farm itself was a success, it cannot be said that animal husbandry has developed to any great extent among the colonists.

With regard to the settlement of colonists, important decisions were made by the Government in 1939 to provide every assistance to the

new settlers. In the Minneriya scheme, the first colonists had to face a grave struggle for existence, and in order to avoid repetition of this, a special committee drew up proposals and programs for aiding colonization. The unit of paddy was kept at 5 Ac., while the highlander was to be provided with a house. The Government also undertook to clear the land and pay each family subsistence for the first six months until they established themselves. In the earlier scheme, the allottee was asked to clear the land and was paid for it afterwards but it was felt that this placed too great a strain on the resources of families who were almost destitute at the time of their selection as colonists. Arrangements were also made for marketing produce and for medical aid and schools, and development was considerably accelerated. Those who saw Polonnaruwa in the early 1930's cannot help being astounded by the rapid progress made by these settlers. Improved agricultural practices and the guaranteed price of paddy have placed many colonists economically far above the average white collar worker.

GIRITALE SCHEME

(i) **Early Development.** Giritale tank is a comparatively small reservoir with a catchment area of nine square miles. It was discovered during the British period and was found to be in working order except that the sluice was blocked. Early attempts made in 1897 and 1900 to clear the blocked sluice ended in failure, but in 1904 the tank was restored to working order.

(ii) **Modern Development.** The early work to restore this scheme was intended to benefit the 100 acres of ancient fields served by the tank at the time, and it was not until 1948 that proposals were framed for increasing the irrigable area to 600 Ac. by constructing a left-bank channel and distribution system. This scheme was one of the newer ones, so the construction proceeded with fewer problems. Here again the scheme was a colonization scheme with paddy and highland allotments for peasants.

About 1954, it was decided to alter radically the status of Giritale tank by increasing its capacity to 17,500 Ac. ft., with a water spread of 760 Ac. at full supply level. The maximum depth of water at the sill of the sluice was 40.69 ft. and the irrigable command was fixed at 4,500 Ac. Since the catchment area of the tank was only 9 sq. miles, augmentation was proposed from the Elahera canal, which was to bring in a maximum flood flow of 200 cusecs from the bifurcation structure. The improvements to the tank also involved the construction of a new right bank sluice to irrigate the new extent of 3700 Ac. of paddy, and the building of a new concrete fall spillway. These works were completed in 1956, and a program for development of the 3,800 Ac. of new lands was evolved.

The entire area proposed for development had been contour-surveyed a few years previously with the intention of setting up a sugarcane project, but by this time the legend of the prosperity of Tamankaduwa had spread far and wide, and the Government was faced with the prospect of settling hundreds of landless families who took up residence in the irrigable area earmarked for the scheme. These families felled jungle and started rain-fed crops to sustain themselves, and in view of the persistent demand for land, it was decided to make this too a colonization scheme for paddy cultivation. The construction of channels was accordingly undertaken in 1956 and it is of interest to observe that the main canal from the new right-bank sluice followed the trace of the ancient channel for almost its entire length.

The allotments at Giritale were made 3 Ac. for paddy and 2 Ac. for highland, as the demand for land was on the increase. This scheme was well planned and provision was made for schools, several dispensaries, and roads in the highland area. Community centers and townships were also planned and are gradually taking shape. The work on irrigation facilities was completed in 1961 and the entire 4.500 Ac. are now under cultivation.

In the past it had been observed that during the closed seasons for irrigation a number

of wells ran dry, causing severe hardship to the people. In the design of the canal system for Giritale, the alignments were adjusted to make use of the several abandoned village tanks which dot the area. The canals were made to flow into and out of these tanks so that during closed seasons, the dead storage of these small reservoirs provide adequate water for domestic needs. The system is working very well, and has been used in several of the newer colonizations schemes elsewhere in the country.

GAL AMUNA SCHEME

At the end of the Minneriya scheme the main drainage line Minneriya Oya wends its way to join the Kahambiliya Oya, which is a tributary of the Mahaweli Ganga. On the left bank of the Minneriya Oya is flat, gently sloping country covered by jungle. The astounding success of the Minneriya scheme attracted many people to the area and some of these families settled down on the left bank of Minneriya Oya and commenced cultivation of paddy by diverting the drainage water of the Minneriya fields. By 1956, practically the entire extent of some 3300 acres was under paddy cultivation, and in response to requests from these cultivators a proper scheme of irrigation and drainage was designed to meet their needs.

(i) **Construction.** To begin with, the entire area was contour-surveyed and a blocking out plan prepared demarcating the paddy and highlands and also the traces of the irrigation and drainage channels. A diversion weir radial gate control was constructed at the point where the ancient Kalinga Ela crosses the Minneriya Oya and a left bank canal four miles long was constructed, from which several branch channels took off to irrigate the paddy lands. The construction of the channel system is still in progress and up to the end of 1961 irrigation facilities had been provided to 1,500 acres of the 3,300 acres proposed. It is expected to complete all irrigation work by the end of the year. So far the scheme has proved successful except for sporadic flash floods in the irrigable area, and after observing the functioning of the scheme for a few years it is hoped to apply the principle of re-use of irrigation water to bring further areas under cultivation.

(ii) **Land development.** The land development aspect of this project was greatly facilitated by the fact that the settlers had cleared their paddy lands long before the scheme commenced. Nevertheless, considerable activity by the Government was required, for the construction of cottages and roads in the highland area. The unit of paddy was fixed at 4 Ac. while the unit of highland was 1 Ac. owing to the non-availability of sufficient highland. The usual assistance and amenities provided to colonists are being given to these cultivators also.

KAUDULLA SCHEME

Kaudulla tank was the last of the ancient irrigation works of the Tamankaduwa District to be taken up for restoration. The total catchment area of the land is 140 sq. miles and consists of steep, heavily wooded country. The tank itself was formed by closing the gaps in the Sudukande range of hills and the total length of embankment is seven miles, including the intervening high ground. Periodic inspections of this tank had been made for several years followed by reports, but it was not until 1956 that the restoration was decided upon and begun.

(i) **Engineering Survey.** The original engineering surveys of the tank bed were carried out by the Irrigation Department to ascertain the capacity of the tank, and were followed by an engineering survey 1,500 acres of paddy land proposed to be irrigated. Three years later, when the possibility of augmenting this tank by the Mahaweli Diversion scheme was found feasible, the Minister of Lands decided to alter radically the scope of the scheme to serve a very much larger area. Consequently, engineering surveys of 10,000 Ac. of paddy land were undertaken and this work is still proceeding.

(ii) **Construction Work.** The tank was breached at two points, through which two rivers, the Gal Oya and the Alut Oya, had pursued their courses. These rivers met just downstream of the bund to form the Kaudulu Oya, which is a tributary of the Mahaweli Ganga. The original proposals for this scheme envisaged restoration of the tank to impound 17,000 Ac. ft. of water with a full supply depth of 13 ft. and an irrigable command of 11,500 Ac., with the possible irrigation of a further 1,500 Ac. at a later stage. The low impounding capacity was decided upon after consideration of the fact that half the catchment was intercepted by the second half of the ancient Minneriya Kantalai channel, which had been restored some years ago to augment the Kantalai tank in the Trincomalee District. Soon after preliminary construction work commenced, however, Ceylon experienced unprecedented floods in December, 1957, as a result of which Kaudulla tank filled up and breached in spite of the two major breaches already existing.

At this stage a complete reappraisal of the scheme was made after which it was decided to restore the tank to have an eventual capacity of 170,000 Ac. ft. to irrigate 27,000 Ac. of paddy land. This decision was influenced by the fact that the Mahaweli diversion scheme would be able to supply sufficient water for such an ambitious project, and also by the fact that the greater portion of the seven mile embankment consisted of natural high ground well above the eventual embankment top level. It was further decided that the breach closures should be designed for the eventual bund top level but that the earthwork should stop at the level required for the present. The scheme was to be taken up in three stages. The first stage was the restoration of the tank to impound 49,000 Ac. ft. of water and the construction of canals for 4,000 Ac. of paddy, while the second stage contemplated was the extension of irrigation facilities to a further 6,000 Ac., making 10,000 Ac. in all. The final stage, which will be undertaken after the Mahaweli diversion project is completed, contemplates the increase of impounding capacity to 170,000 Ac. ft. to irrigate 27,000 Ac. of paddy in all.

Construction work on Stage 1 of the scheme commenced in 1959 and the tank restoration was completed in 1960. The spillway used was the ancient natural spill, widened and improved by the construction of the concrete causeway-type spill in accordance with hydrological calculations. The ancient sluices were removed and the gaps closed, and in their place a new reinforced concrete sluice was constructed to serve the 4,000 Ac. to be developed in Stage 1. An additional sluice to serve the balance of the area will be undertaken in Stage 2 of the project. The northeast monsoon rains of December 1960 were slightly above normal and as Kantalai tank was also full at the time, all the water from the catchment was permitted to enter Kaudulla tank through the control structures provided in the Minneriya Kantalai Yoda Ela. As a result, the tank filled up by the middle of February and began to spill.

In the ancient system of irrigation under this tank, the sluice discharged direct into the main drainage line and was picked up by a stone weir about two miles downstream. After examining engineering survey plans and working out alternative proposals, it was decided to follow the same practice and construct a concrete diversion weir with 10 radial gates 20ft. by 10 ft. high. The main canal takes off on the left bank of this weir and the ancient trace was adopted for a distance of nearly a mile, after which no ancient trace is visible.

Construction of the weir and canals for 4,000 Ac. of paddy is now in progress and is scheduled to be completed next year.

Conclusion:

Time does not permit a fuller account of all the details concerning the development of the land and water resources of the Tamankaduwa District, but it is hoped that this necessarily brief report conveys some indication of the problems arising and the results achieved so far.

It will be observed that 1932 marked the inauguration of several major irrigation sche-

mes. This was no coincidence but was a direct consequence of the grant of internal self-government to Ceylon in 1931. Up to 1932 the total extent of paddy land under major schemes in Tamankaduwa District was hardly 1,000 Ac., and it is recorded with pride that in spite of tremendous difficulties, there are at present nearly 40,000 Ac. of land under irrigated agriculture in the district.

Irrigation in Ceylon is as old as the recorded history of the island and restoration of its ancient irrigation works merely carries on the work. Completing the restoration of the ancient works of Tamankaduwa is by no means the end of development work in this district. Plans are now in hand for further exploitation of the land and water resources of the area and it is hoped that the application of modern scientific methods, combined with the knowledge gained from the ancient system of irrigation, will bring to Tamankaduwa a prosperity it has never experienced even in the magnificent era of Parakrama Bahu.

Discussion. The question of wind protection arose. Dr. Asghar stated that in the Thal Project the wind was sufficiently bad that the growing of cotton became almost impossible. To combat this, the Sesbania Aculete fields are laid out in strips with sugarcane and cotton. The crops are grown in such a rotation that when the cotton is coming up, the wind belts are ready for its protection. In one month there were 45 sand storms. The wind-break spacing in Ceylon is the same as the canals, 200 or 300 feet. Canals are not lined. No estimate has been made of the water losses to these plants. Actually, they are considered to be small, the canals silt up quite readily after a couple of years and canal losses are small. Mr. Ahmed reported that Saudi Arabia tamarix has been used to stabilize sand dunes. These are planted in rows 1,000 feet apart and are watered for the first two or three years, after which they grow without waterling.

Irrigation is Ceylon occurs only in the dry zone for the purpose of growing rice during the dry season. There is no rotation crop with the rice, which is grown every year in order to reduce the demands on foreign exchange. About 300,000,000 rupees a year are spent to import rice. The yields of rice in this district are about 40 bushels per acre per crop. In Pakistan, only heavy or medium soils are used to grow rice. Continued growing of rice over the years results in some stratification and deterioration of soils. Although no systematic measurements have been made of the water table in Ceylon, it is not particularly high in the rice-growing areas. Rice prices in Ceylon are guaranteed at 200 per cent of the world price. Two crops of rice are grown each year and chemical fertilizers are used. The average price for rice is 10 rupees per bushel. Leaching of nitrogen fertilizer to paddy soils in not a problem. However, it is very significant in upland soils.

DISTRIBUTION AND MANAGEMENT OF WATER BEYOND GOVERNMENT OUTLETS OF INDIA

by

Mr. J. P. Mital

Agriculture occupies a position of pivotal importance in the economy of India and provision of irrigation facilities is, perhaps, the most important single requirement for promoting agriculture. Large sums have, therefore, been spent on providing major, medium and minor irrigation works during the First and Second Plans. For the Third Plan also, of the total proposed outlay of Rs. 75 billion in the public sector, about Rs. 6.5 billion have been allocated for major and medium irrigation projects and about RS 2,5 billion for minor irrigation works, in the Agriculture and Community Development sectors.

Not all the irrigation facilities made available are, however, being utilized on the field. Only about half of the irrigation potential available at the channel outlets from major and medium irrigation projects was actually being utilized at the beginning of the Second Plan and although the percentage of utilization has been progressively increasing during the Second Plan period, the estimated percentage utilized at the end of the Plan was only 76. Even under minor irrigation there is some degree of delay or under-utilization, particularly for private tubewells, wells and pump sets. Thus, the need and scope for increased efforts that may ensure full utilization of the irrigation potential immediately after it is made available cannot be overemphasized. Even the quantity of water actually used is not being properly utilized and there is also ample scope for arranging more economic use or irrigation water by following improved practices of water distribution and application. It is, in fact, the context of this background that the problem of distribution and management of irrigation water beyond Government outlets needs careful examination.

The problem broadly resolves itself into two aspects: (i) conveyance of water from the Government outlets to the cultivators' fields, and (ii) application of the right quantity of water at the right type of field.

(i) **Conveyance.** The first requisite for conveyance of water from the Government outlet to the cultivators' fields is obviously a suitable channel. This is generally called the water-course or the field channel. Field channels are expected to be constructed and maintained by the beneficiaries of the area which the outlet serves, but this is not generally done. The main difficulties are agreement among all concerned on the alignment to be adopted and ability to obtain the land required. It is considered that the village panchayats would be in the best position to resolve these difficulties and thus ensure timely completion. The procedure suggested for construction of field channels on new projects by the Planning Commission, and also incorporated in their report on the Third Five Year Plan, is that «Their alignment should be marked out by the project authorities on village maps, and these maps should be supplied to the district and block authorities for getting the field channels excavated by the beneficiaries in good time. It is necessary to ensure that at the same time as the canal system is ready, the excavation of field channels by the beneficiaries is also completed. Acting as agents of Govern-

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1 — J.P. Mital Advisor on Irrigation, Ministry of Community Development and Cooperation, India.

ment, panchayats and panchayat samitis should be empowered to carry out the works and recover the costs in case of default.»

Timely clearance and proper maintenance of these channels are as important as their initial construction, and the obligation to carry out these operations at the correct time must also rest on the beneficiaries, to be enforced by the panchayat and panchayat samitis; the legislation proposed for construction should also include maintenance.

The field channels are mostly 'kacha' and there is considerable loss of water during transit; for instance as much as 22 per cent is estimated to be lost during transit in the field channels on the Ganga Canal system in Uttar Pradesh. The lining of these channels would be the proper answer to this problem, particularly in sandy areas. It is, however, difficult to persuade cultivators to invest in lining their channels by conventional methods. Research is therefore required on cheaper methods of lining using locally available materials. One such process uses what is known as 'water-proof mud plaster', which is made by mixing some bituminous compound with ordinary mud plaster. Experiments with this have recently been initiated and the results will be watched with interest.

The construction and proper maintenance of drainage and road crossing on field channels are equally important and are also the responsibility of the beneficiaries. This should, in fact, be treated as part of the construction and maintenance program for field channels and be included in the legislation referred to above. Absence or disrepair of these crossings results in considerable wastage of irrigation water. The canal acts in some states already provide for construction and maintenance of these crossings by the beneficiaries or, in case of default, by the State Irrigation Department at the cost of the beneficiaries.

In addition to providing necessary technical assistance to the beneficiary panchayats at all stages, credit on liberal terms will also have to be arranged for construction of field channels, and the possibilities of setting up a revolving fund for this purpose with the panchayats may be considered.

(ii) **Application.** The area which receives water from a Government outlet generally belongs to a number of cultivators and, as every cultivator is anxious to obtain the maximum quantity of water available at the earliest possible opportunity, it becomes necessary to fix a schedule for distribution of available supplies between the various share-holders, indicating their turn and the time. This turn system is called 'Osrabandi,' or 'warabandi' in Northern India, and is governed by rules framed under the canal acts. The turn system for each outlet may either be agreed to mutually among the shareholders themselves or the Divisional Canal Officer (Executive Engineer) may frame the schedule for them according to rules and procedures prescribed under the canal act. The turn generally begins with the first holding at the head of the water course and ends with the one at the tail end. The time of each farmer's turn is proportionate to his area in the command of the outlet. It becomes difficult in practice for the co-sharers to agree on the turn and quantity of water, and framing of formal 'osrahandi' thus becomes a necessity. It is felt, however, that with the establishment panchayati raj, the distribution and management of water from Government outlets should progressively be taken over by local institutions, e.g., panchayats or cooperatives of beneficiaries, as they should be in a much better position to resolve local difficulties and disputes amicably and expeditiously.

For the proper management of irrigation supplies, it is important that the cultivator should also know when to irrigate and how much to irrigate. Cultivators know very well that a shortage of water stunts plant growth and reduces crop yield. However, it needs to be effectively demonstrated to them that too much water is as harmful to a crop as too little. It leaches away plant food materials, impairs air supply to the plants through the roots and causes waterlogging of the land. It is therefore important to know when irrigation should be stopped.

From a purely theoretical angle, it is well known that the proper time for applying irrigation water comes when the moisture in the root zone of the soil has been depleted to a particular stage beyond the wilting point which stage varies from crop to crop and according to the soil composition. Any depletion beyond this stage would cause damage to plant growth. On the other hand, irrigation has to be stopped when water starts percolating below the bottom of the root zone. Any moisture in the soil below the root zone cannot be drawn by the roots and is lost to the plant. The amount of water required in each watering is, thus, determined by the moisture content of the soil between the two stages mentioned above. Large scale research-cum-demonstration farms are required to be set up, followed by actual demonstrations on the cultivators' fields for different areas and crops in order to educate and convince the farmer on this aspect of irrigation. In addition, he should be made conversant with simples methods of determining the moisture content, root zone and actual depth of water percolation on the field at the time of irrigation.

It is doubtful if enough data and information can yet be supplied to cultivators on these matters on the basis of actual experiments and other research work conducted by scientists and experts in the field. An extensive program of research and training on water use seems to be indicated to achieve this end. Two schemes, one of research on minor projects and water use and the other in training on the same subject, have been undertaken during the Third Five Year Plan. These schemes have a direct bearing on the subject, and its implementation in the Third Plan will go a long way toward providing the correct type of guidance to the cultivators.

Just as it is necessary to ensure the right quantity of water at the right time on the field, so preparation of the field to receive the water is required. If the field is uneven, the water will not be applied uniformly to full capacity in all parts of the field. In some portions the water will percolate below the root zones, while in others only a little depth may become saturated. The process of preparing the field involves not only proper levelling, but may also require terracing, 'mendhbundi' (even contour bunding in some areas), division of the field into small segments (kiaries), provision of drains, furrowing and corrugating, etc., depending upon the topography, local conditions and types of crops cultivated. While preparing the fields, it is also important to have a correct correlation among other factors, such as rate of flow of the water, size and grading of the field and infilteration rate of the soil. A slight maladjustment between these factors may lead to non-uniform wetting of the soil and wastage of water. Proper technical guidance has to be made available to the cultivators in all these matters in order to enable them to carry out these processes.

This work also entails considerable expenditure and it is, therefore, necessary to provide the cultivator with the requisite financing in the form of loans on liberal terms and at proper times in order to enable him to carry out the necessary operations. This point again has been discussed at various conferences and seminars, and the most satisfactory source for the purpose appears to be co-operative agencies. Providing the panchayats with some working capital in the form of a loan, to be used as a revolving fund, should also be very helpful.

The need for educating the farmer on proper water use and control cannot be over-emphasized, and it is considered that, in addition to the large scale research-cum-demonstration suggested above, the setting up of farmers' training schools and an Irrigation Extension Service is every state would be very helpful.

Discussion. It was brought out that a panchayat is assuming some of the powers formerly held by the irrigation officer. Mr. Mital felt that this accelerates the carrying out of decisions because it is more direct and because the villagers have more confidence in the panchayat. The whole new system is designed to decentralize authority and power. If the farmers do not assume this responsibility, field channels are constructed by the Government. About 1,600 miles of field channels have al-

ready been constructed in the Rajastan Project.

The rice land colonization in Ceylon opens a new period of social and land reform. Here, the village cultivation committee is empowered by law to enforce its decisions regarding the time of delivery of water, the maintenance of field channels, the maintenance of perimeter fences and all the incidentals connected with the cultivation of the land or the operation of the irrigation works. Mr. Mital stated that this authority exists in India. However, it varies among the states. Some of the states have passed laws granting this authority; others have not yet done so. This authority was first given in India in the Rajastan Project in 1958.

Dr. Tamhane stated so far no work has been done on the cultivators' fields outside of the work done by Mr. Knierim in Mysore. Mr. Mital stated that the cultivators show a real interest in saving water. Otherwise, utilization would not have been raised from 50 per cent to 76 per cent in a period of five years. Every state in India has one or more extension stations where crop requirements are worked out.

CHAPTER IX

RESEARCH

CONSUMPTIVE USE AND IRRIGATION EFFICIENCY IN IRAN

by

Mr. A. Inavani [1]

INTRODUCTION

Water is the main limiting factor in the expansion of irrigated agriculture in Iran. Thus, in irrigation planning, it is essential that consumptive use and irrigation water requirements be known. This is true for large irrigation projects or for individual farms.

New irrigation development is rapidly taking place throughout Iran. New lands are being brought under irrigation. Older irrigation lands are being revised to accommodate improved irrigation practices for better conserving soil, water and labor. So, in Iran there is urgent need for sound information on the amount of irrigation water required for profitable crop production.

Considering the above-mentioned points, the Agricultural Engineering Department of the Ministry of Agriculture has been establishing irrigation research stations since 1955. At the present time, experimental work is being conducted at Karadj for sugar beets; at Varamin, for cotton; and at Lahidjan, for rice. This research has the following objectives:

1. To determine the optimum amount of irrigation water required for the crops.
2. To determine the proper distribution of irrigation water during the growing season (time between irrigations).
3. To determine the amount of water needed for each irrigation.

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Reference to the data from experiments made in 1960 on cotton and sugar beets, which are similar, and the results obtained from experiments on rice, will indicate the nature of these experiments and the factors being investigated.

Definitions. Definitions of some of the terms used in this report are as follows:

1. **Consumptive Use (evaporation-transpiration**
   The sum of the volume of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from adjacent soil, snow or intercepted precipitation on the area in any specified time, divided by the given area.

2. **Irrigation Requirement**
   The quantity of water, exclusive of precipitation, that is required for crop production. This includes surface evaporation and other economically unavoidable wastes; Usually expressed in depth for a given time.

3. **Water Requirement**
   The quantity of water, regardless of its source, required by a crop in a given period of time for its normal growth under field conditions. It includes surface evaporation and other economically unavoidable wastes; usually expressed as depth for a given time.

4. **Field Capacity**
The amount of water held in a soil against the force of gravity under unrestricted drainage at a specified time after flooding.
5. **Permanent Wilting Percentage**
The moisture percentage in the soil at which plants wilt and do not recover unless water is added to the soil. It is expressed in percentage of moisture based on the over-dry weight of soil.
6. **Water Application Efficiency**
The ratio of the amount of water that is stored in the soil root zone to the amount of water delivered to the farm.

LOCATION OF EXPERIMENTAL PLOTS AND METHODS OF PROCEDURE FOR COTTON AND SUGAR BEETS

In starting the investigation reported herein, it was decided that more information of value could be obtained by an intensive study of the effects of variable irrigation treatments given to plots of limited area than by less complete studies in commercial fields The advantages of the smaller field plots are that they may be selected for uniformity in depth and type of soil; that they may be more evenly leveled; that water may be more evenly applied to them than to larger areas; and, finally, that they permit a more accurate record of seasonal soilmoisture conditions and fluctuations.

SIZE AND DESIGN OF PLOTS

Cotton. Recognized good practices such as plowing, disking, harrowing, distributing of fertilizers, etc., were used in preparing the seed bed and seeding. Selected seed was used. Seeding in all plots was in rows and distances were as follows:

To determine the available field capacity, a close estimation of field capacity and the permanent wilting point was used. The field capacity and wilting point of the soil at the location were not previously determined, and therefore it was necessary to make this estimation. By use of a soil moisture determination of samples taken with a king soil tube, the average moisture equivalent for the upper three feet at 60 to 72 hours after irrigation was determined. After several trials, the field capacity for the upper three feet was determined as 20.54 per cent for the cotton field and 18.95 per cent for the sugar beet field. Using the relation W.P. = F. C./1.84, for **cotton,** W. P. = 11.14 per cent, giving 9.36 per cent available field capacity ; for **sugar beets,** W.P. = 10.3 per cent, giving 8.65 per cent available field capacity. Two levels of irrigation were used: (1) the plots were irrigated when the test moisture showed 50 per cent of available field capacity (T_1); and (2) the plots were irrigated when the test moisture showed 25 per cent of available field capacity (T_2). For cotton, T_1 = 15.82 per cent and T_2 = 13.48 per cent; for rice, T_1 = 14.62 per cent and T_2 = 12.46 per cent. To study the effect of fertilizer on the consumption of water, fertilizer was used on half of the sugar beet plots, applied at the following levels:

Nitrogen	80 kg./hectare
Potash	100 kg./hectare
Phosphate	75 kg./hectare

Four replications were used for each phase. The land for cotton was divided into eight plots and for sugar beets into 16 plots.

	Length of plot in meters	Width of plot in meters	Spacing between two rows in meters	Spacing between plants in row, in meters
Cotton	24	5	0.8	·0.25
Sugar Beets	25	10	0.50	0.25

WATER MEASUREMENT

Throughout the experiment, irrigation water was obtainable on demand in any desired quantity. During the entire period of the experiment, the inflow and outflow water for each plot was carefully measured, using the mean of a number of measurements taken with partial flumes. The total amount of inflow and outflow to each plot and the amount of water infiltrated to the land were calculated. An attempt was made to make the interval between the consecutive measurements as short and precise as possible; on the other hand, uniform inflow was maintained as closely as was practical.

METHOD OF IRRIGATION

Shallow furrow irrigation was used and in order to distribute the amount of water equally among furrows, concrete pipes 20 centimeters long and 5 centimeters in inside diameter were placed at the same level in the entrance of furrows for each plot. Plot runoff was disposed of into a drainage system.

SOIL SAMPLING AND COMPUTATION

To determine accurately the moisture applied to the soil, samples were taken every day but sometimes beginning 48 hours after irrigation because of high moisture in the soil. Soil samples were taken on each plot to the depth of the root zone; say, the upper three feet. To determine the moisture from different depths, samples from each were dealt with separately. The samples were taken to the laboratory immediately. They were dried in an oven for 24 hours at 105° C. The amount of water to be applied for each irrigation was calculated from the formula $d = P_W A_S D/100$, where P_W is the field capacity minus the field moisture percentage. Water was applied when the field moisture percentage reached the value T_1 or T_2.

A soil moisture determination was made after each irrigation in order to check the soil moisture application.

YIELD

For the best determination of the yield and to eliminate the border effect of other plots, the middle rows were selected; the yield of one meter at the two ends of each row was discarded. The area thus left was measured carefully and used to compute the yield per hectare.

To determine the sugar content, 20 root samples were taken from each plot at the end of the irrigation season and at harvesting time, and immediately sent to the laboratory for sugar content determination.

Tables 1 and 2 show the results obtained from the experiments in 1960. In the cotton experiment, the best results were given by irrigation when the test moisture was reduced to 25% of available field moisture capacity. For sugar beets, the best crops were given by the plots which had fertilizer and irrigation when the moisture was reduced to 50% of available field moisture capacity.

TABLE 1. RESULTS OF EXPERIMENTS ON COTTON

Water Applied in Inches					
Plots	First Replic.	Second Replic.	Third Replic.	Fourth Replic.	Average
T_1	31.90	31.89	31.72	31.84	31.83
T_2	35.00	35.19	35.59	35.93	35.42
Yield of Cotton (Ton per Hectare)					
Plots	First Replic.	Second Replic.	Third Replic.	Fourth Replic.	Average
	1.855	2.309	2.508	2.664	2.334
	2.252	2.684	2.991	3.303	2.808

TABLE 2. RESULTS OF EXPERIMENTS ON SUGAR BEETS WATER AP..IED IN INCHES

Water applied in inches					
Plots	First Replic.	Second Replic.	Third Replic.	Fourth Replic.	Average
T_1 F	47.85	49.64	58.04	51.56	51.77
T_1 O	44.51	44.84	49.80	45.20	46.08,
T_2 F	41.50	43.05	41.19	42.90	42.16
T_2 O	41.11	40.95	44.04	40.14	41.56
Yield of Sugar Beets (Tons per Hectare)					
Plots	First Replic.	Second Replic.	Third Replic.	Fourth Replic.	Average.
T_1 F	35.884	36.405	39.391	33.608	36.322)
					)31
T_1 O	25.188	22.304	25.666	29.144	25.576)
T_2 F	30.797	27.724	28.217	38.130	31.217)
					)26.4
T_2 O	12.884	15.652	25.869	31.884	21.572)
Percentage of Sugar Content					
Plots	First Replic.	Second Replic.	Third Replic.	Fourth Replic.	Average
T_1 F	20.4	18	18	19	18.85)
					)18.7
T_1 O	17.2	18.4	19.6	19	18.55)
T_2 F	18.2	18.8	19	18.8	18.70)
					)18.5
T_2 O	16.2	18.2	19.4	19.6	18.35)

F = Fertilized Crops O = Unfertilized Crops

TABLE 3. NUMBER OF IRRIGATIONS.

Plots	Treatment	Number of Irrigations
Cotton	T_1	10
	T_2	8
Sugar Beets	T_1	25
	T_2	20

DESIGN OF IRRIGATION RESEARCH ON RICE IN LAHIDJAN

Design No. 1

Design:	Split plot
Number of repetitions:	4
Number of operations:	4
Varieties of rice:	early season, late season, average
Area of each kart:	35 square meters
Irrigation unit area:	105 meters
Total number of plots:	48 plots

Procedure. After transplanting, all the plots were flooded continuously for ten days; then the following schedule was adopted.

1. The plots were irrigated with an alternation of three days, two inches in the beginning and two inches after three days, and so on until the time of harvesting.
2. The plots were irrigated with an alternation of six days, two inches in the beginning and two inches after three days, and so on, until the time of harvesting.
3. The plots were irrigated with an alternation of nine days, two inches first, two inches after nine days and so on, until the time of harvesting.
4. The plots were irrigated with an alternation of 12 days, two inches at first, two inches after 12 days and so on, until the time of harvesting.

Design No. 2

Design:	Split Plot
Number of repetitions:	4
Number of operations:	5
Varieties of rice:	early season, late season, average
Area of each kart:	45 square meters
Irrigation unit area:	135 meters
Total number of plots:	60

Procedure. After transplanting, the plots were irrigated continuously for ten days. Then the water was cut off until the land started to crack, after which the following irrigation alternations were accomplished:

1. The plots were irrigated consecutively for three days. Then the water was cut off until the soil became dry. As soon as the first cracks appeared, the plots were irrigated frequently for three days.
2. The plots were irrigated consecutively for six days, the water was cut off until the soil dried and then the irrigation was repeated for six days.
3. The plots were irrigated for nine days, the water was cut off until the soil became dry and then it was irrigated constantly for nine days.
4. The plots were irrigated consecutively during the growing season but the water was cut off, once only, at the time of the appearance of the cluster.
5. Irrigation was done by the local method. The water was cut off in all plots five days before harvesting.

Design No. 3

Design:	Randomized block
Number of repititions:	4
Number of operations	3
Varieties of rice:	1 early season
Area of each kart:	30 square meters
Irrigation unit area:	3 square meters
Total number of plots:	12

Procedure. After transplanting, all plots were irrigated consecutively for ten days. After drying until the soil split, the following actions were taken until the cluster appeared:

1. The plots were irrigated consecutively for three days. The water was cut off until the land dried, then irrigated for three days constantly.
2. The plots were irrigated consecutively for six days, the water was cut until the land dried and then irrigated for six days constantly.
3. The plots were irrigated continuously for nine days, the water was cut off until the soil became dried and then irrigated continuously for nine days.

After the appearance of the cluster, until the grain began to become hard, the plots were irrigated once every three days; after that the irrigation was done as in the beginning.

RESULTS

The results obtained follow:

(a) **The Proper Time of Irrigation.** It is advisable to begin the irrigation when the previous water has been drained by evaporation, infiltration or use of the plant and the soil surface is moist, rather than when the plants are standing in it. In this manner the necessary air can reach the plant much easier and less water will be used.

By the above-mentioned method and taking into consideration the quality of the soil, climate and slope, the interval between two irrigations will be seven to ten days.

(b) **The Procedure of Irrigation.** In the Lahidjan area, the number of irrigations were between five and seven and if water losses and extra use were avoided, the amount of water needed for each hectare would be 4,000 cubic meters. At present the farmers are using more than 9,000 cubic meters per hectare and obtaining the same yields.

The following points should have a great effect in reducing the use of water and in raising the efficiency of irrigation and the yield:

(i) Leveled plots endure an alternation of 12 days in irrigation, whereas plots with a high slope do not endure even a six-day alternation.

(ii) Before the appearance of the cluster, the water must be cut from the field entirely. In this way the cluster will have more grains.

(iii) The rice needs plenty of water from the time it starts to floriate up to the time of sweetening.

In this period, which lasts 10 to 15 days, it is advisable to irrigate the plant so that the depth of water on the soil surface is constantly 3-6 centimeters. After that it needs less water, and 10-15 days before harvesting no water is needed at all, so it must be cut off to get a more satisfactory yield.

IRRIGATION EFFICIENCY

As water becomes more scarce and as the need becomes more pressing for maximum economic returns, proper handling of irrigation water and increasing irrigation efficiency become more important.

The Agricultural Engineering Department has established stations to study water application efficiency in different provinces of the country. The procedures for water measurement, soil sampling and computations are similar to those mentioned for determining consumptive use of water. The results obtained are as follows:

Location	Year	Water application efficiency, per cent
Seed Improvement Farm (Karaj)	1959	31.66
Djahan Chit Farm (Dardj)	1959	18.57
Isphahan	1960	38.7
Fars	1960	33.46
Garmsar	1960	39.13
Irrigation Research Farm (Karaj)	1957	64.25
» »	1958	68.00
» »	1959	63.00
» » (Varamin)	1958	58.40
» » »	1959	57.05
» » »	1960	48.20

RESEARCH ON WATER REQUIREMENTS DETERMINING THE WATER USE OF SUGARBEETS AND CORN IN THE BEKA'A, LEBANON

by

Mr. Nicholas Atallah

Summary

Evapotranspiration data for sugarbeets and corn were obtained intermittently in 1960 and 1961 by direct soil sampling. Soil moisture content determination was made after and before irrigation and moisture depletion was calculated.

Measured evapotranspiration was compared with estimated evapotranspiration as determined by two empirical methods, viz., the Blaney-Criddle method and the Penman method.

Results show that average total evapotranspiration during 1960 and 1961 for sugarbeets in the Beka'a, Lebanon, was 886 millimeters of water and for corn, 998 millimeters.

It was also shown that the use of empirical methods in determining the consumptive use of crops is justifiable if proper crop coefficients are known.

Introduction

As used in this paper, the terms «water requirement,» «irrigation requirement» and «consumptive use» correspond with A.S.A.E. definitions. The **water requirement** is the quantity of water, regardless of its source, required by a crop in a given period of time for its normal growth under field conditions. It includes surface evaporation and other economically unavoidable wastes. The **irrigation requirement** is the quantity of water, exclusive of precipitation, that is required for crop production. It includes surface evaporation and other economically unavoidable wastes. **Consumptive use** or **evapotranspiration** is the sum of the volume of water used by the vegetative growth of a given area in transpiration or the building of plant tissue and that evaporated from adjacent soil, snow or intercepted precipitation on the area in any specified time, divided by the given area.

Direct measurement of water use remains the most accurate procedure for determining evapotranspiration. However, direct measurement is a time-consuming procedure. This has led to the development of empirical and theoretical methods using climatic data and energy balance as bases for the estimation. When correlated with measured evapotranspiration, these empirical methods become useful in predicting water use by crops for planning and developing irrigation projects.

The purpose of this paper is to analyse water use data as measured during two growing seasons on the American University Farm in the Beka'a, Lebanon, to expose the problems involved in such determination and to discuss the applicability of two commonly used empirical equations.

In general, the Beka'a soil is an undeveloped alluvium. Climatic conditions vary from season to season, cold and humid in winter to warm and dry in summer. Rainfall, averaging 10 to 12 inches annually, occurs only between the months of November and April and is concentrated during December, January and February. Practically all summer crops depend on irrigation and consequently a knowledge of the water use of crops is useful in irrigation planning for the area.

The two empirical equations used in this paper to estimate evapotranspiration are the Blaney-Criddle formula and Penman's equation for evaporation from a free water surface.

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The Blaney-Criddle Formula. This formula, developed by H. F. Blaney and W. D. Criddle for the estimation of water requirements of crops, has been used in many parts of the world with considerable success.

Mathematically, the formula is expressed as

$$U = KF = \sum kf,$$

where U is the evapotranspiration of a crop in inches of water for any period; f is the monthly consuptive use factor and is equal to (txp)/100 where t is the mean monthly air temperature in degrees Fahrenheit, and p is the monthly per cent of daytime hours of the year; F is the sum of the monthly consumptive use factors for the period considered; and K is an empirical consumptive use coefficient generally assumed to be equal to k, the monthly coefficient, though there is some evidence that they may be different. k values for irrigated crops in the Western United States, as recommended by Blaney, Criddle and their co-workers are given below:

Crop	K
Alfalfa	0.85
Beans	0.65
Corn	0.75
Cotton	0.70
Citrus Orchard	0.55
Deciduous Orchard	0.65
Pasture, grass, hay	0.75
Potatoes	0.70
Rice	1.00
Small grains	0.75
Sorghum	0.70
Sugarbeets	0.70

Blaney-Criddle's formula has been used in many areas. Due to its simplicity, it enjoys wide recognition, although it does not take into consideration the effects of incident radiation, wind velocity and relative humidity on evapotranspiration.

Penman's Equation. H. L. Penman (1948) developed an equation for estimating evaporation from a free water surface. The method was developed on a theoretical basis by combining the theories of energy balance and diffusion of vapor. By introducing a crop factor to Penman's equation, evapotranspiration is readily estimated.

In a genarl form Penman's equation is expressed as

$$Eo = \frac{\Delta H + Ea\,\gamma}{\Delta + \gamma},$$

where Eo is the estimated evaporation from a free water surface, Δ is the slope of the saturation vapor pressure curve at any temperature Ta, H is the heat budget, γ is the constant in the west and dry bulb hygrometer equation and Ea, a derived parameter, is a function of wind velocily and the vapor pressure deficit at any temperature Ta. The psychrometer constant γ, for °F and mm of mercury = 0.27.

In the original work of Penman, the value of H is given as

$$H = Ra\,(1\text{-}r)\,(0.18 + 0.55\,n/N) - \sigma\,Ta^4\,(0.56\text{-}0.092\,V\,e_d)\,(0.1 + 0.9\,n/N)$$

where Ra is the mean monthly extraterrestrial radiation in mm/day[1], r is the radiation reflection coefficient, n/N is the ratio of actual to possible hours of sunshine, σ is the Stefan Boltzman constant (2.01 x 10-9 mm/day[1]), Ta is the mean monthly air temperature (degrees absolute) and e_d is the actual vapor pressure of the air in mm. of mercury.

Goss (1956) revised the expression for back radiation to suit conditions in the Sacramento Valley, California. These conditions are comparable to those existing in the Beka'a, Lebanon. The rivised expression is

$$H = Ra\,(1\text{-}r)\,(0.18 + 0.55\,n/N) - \sigma\,Ta^4\,(0.36\text{-}0.50\,V\,e_d)\,(0.1 + 0.9\,n/N).$$

The derived parameter Ea is expressed as,

$Ea = 0.35\,(0.5 + U_2/100)\,(e_a - e_d)$, where U_2 is the wind velocity at a height of two meters above ground in miles per day and e_a is the saturation vapor pressure at air temperature Ta.

Penman's Equation, though less known and used on a world-wide basis, has shown higher correlation with actual water use of crops in many experiments (Pruitt, 1960). This is partly due to

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1 — Assuming 590 cal/ml of water evaporated are required, all energy expressions have been converted into equivalent mm. of evaporation per day.

the fact that it recognizes, besides temperature, incident solar radiation, wind velocity and relative humidity as important factors in the evaporation process.

The term «potential evapotranspiration» as used in this paper refers to values of Eo or estimated evaporation from a free water surface in Penman's Equation and to values of (t x p) or the monthly consumptive use factor in Blaney-Criddle's formula.

INSTRUMENTATION AND EXPERIMENTAL PROCEDURE

Instrumentation. The climatic data for calculating estimates of evapotranspiration by the Blaney-Criddle and Penman methods were obtained at the weather station located on the University Farm.

Mean daily temperatures were obtained from maximum-minimum thermometers located in a standard shelter and read daily at 18:00 hours. Relative humidity was obtained by a whirl psychrometer, read daily at noon. Per cent of sunshine hours, n/N, and wind velocity, were measured by a sunshine recorder and a 3-cup anemometer respectively, both placed at a 2-meter height above ground surface. Salor radiation data Ra, for the location latitude[1], were calculated from «Physical and Dynamical Meteorology,» by Brunt (1944).

Experimental Procedure. During the summers of 1960 and 1961, gravimetric moisture measurement of soil samples taken at two different depths from the root zone of sugarbeets and corn was made. Samples were taken after and before irrigation with a 3-inch Soil Conservation bucket auger at 8-inch and 16-inch depths on the ridge between two adjacent plants. Samples were taken from three different sites in one-quarter of a dunom[2] plot, and placed immediately in weight-standardized tin boxes and weighed within an hour on a torsion balance. Soil samples were dried in an oven at 105°C. for 48 hours and then weighed. Moisture content on a dry weight basis was then computed and recorded in percentage. Moisture depletion during the time lapse was determined in millimeters of water by multiplying the depth of soil by the product of percentage depletion and bulk density.

Bulk density was determined for each of the plots by displacement of soil with a measured volume of water. A hole was made in the field with a scoop and all the soil thus removed was saved in a container. The bottom and sides of the hole were then covered closely with a thin polyethylene sheet and water was poured out of a 1000-ml. cylinder to fill the hole to the edge. The volume of the soil plus stones removed was thus determined by reading from the graduated cylinder the volume of water used. After stones had been removed, the soil was dried and weighed. The soil bulk density (less stones) was calculated by dividing the mass of dry soil by the total volume of soil plus included stones.

1 — The University Farm is located on 33°55.50' North Latitude.

2 — A dunom is 1,000 square meters.

TABLE 3. CORRECTED BULK DENSITIES[1] FROM SIX SITES IN TWO PLOTS. UNIVERSITY FARM, BEKA'A, LEBANON 1961.

Site	Weight of stone-free dry soil	Volume	Bulk Density
	gms.	(c.c.)	(gms/cc.)
1	527.8	455.0	1.16
2	471.2	462.0	1.02
3	485.4	468.5	1.04
4	522.7	458.5	1.14
5	484.0	457.0	1.06
6	539.1	453.0	1.17

1 — Bulk density of soil as calculated by mass of dry soil (without stones) divided by total volume of soil plus included stones.

From Table 1 it may be observed that moisture depletion did not vary to a great extent between the top and the lower 30 centimeters of soil. About 26 per cent more depletion occurred in the lower 30 centimeters. This reflects on the distribution of sugarbeet roots active in water uptake in the root zone. Table 2 shows, for corn, that moisture depletion occurred to a larger extent in the top 30 centimeters as compared with the lower 30 centimeters. Approximately 93 per cent more depletion occurred in the top 30 centimeters emphasizing the shallow distribution of corn roots. Though limited, the data indicate that peak water use occurred in July and August, diminishing in late August and September.

In order to assess the applicability of empirical equations based on climatic data, the latter were compiled for 1960 and 1961 from the first of April to the 13th of October and are presented in Tables 4 and 5 on a weekly mean basis. Tables 4 and 5 also show estimates of potential evapotranspiration calculated from Penman's Equation and the Blaney-Criddle formula, respectively. The estimates were expressed on a daily basis for each period.

Results in general show a greater value for estimates based on Penman's Equation than for the values obtained by the Blaney-Criddle formula. Little variation throughout the season is evident in the results obtained by the Blaney-Criddle method compared to the variation obtained by the Penman Equation.

The average coefficient of variation for two years calculated from the results of the former is 13 per cent, compared to 23 per cent for the latter. This may be explained by the fact that mean temperatures during summer in the Beka'a do not vary a great deal. Daytime temperatures increase toward midsummer and subsequently decrease toward its end. Night temperatures, however, stay on a rather constant low level. This results in mean temperatures of low fluctuation. Results obtained by using the Penman Equation vary to a larger extent because several climatic phenomena are involved in this method. The majority of these phenomena show a gradual increase toward the end in the season.

The last two columns of Table 4 and 5 show cumulative potential evapotranspiration figures as calculated by the Blaney-Criddle and Penman methods.

Ratios of measured evapotranspiration to calculated potential evapotranspiration, for the months during which field data were obtained, are shown in Table 6. These were determined by dividing the measured evapotranspiration shown in Tables 1 and 2 by the calculated potential evapotranspiration shown in Tables 4 and 5.

Discussion. Irrigation is applied every seven days. This is a common practice in the Beka'a Valley. The King soil tube cannot be used because of the rocky nature of the soil. The soil below 60 cm. is rocky and has little holding capacity. The possibility of using a calibrated sand to refill the hole and determine its volume was suggested. Since the weight of the stones is not included in the determination of bulk density, the bulk density reflects only the soil that has a water-holding capacity.

RESULTS AND DISCUSSION

Actual evapotranspiration data for sugarbeets and corn were obtained intermittently in 1960 and 1961 during the months of June, July, August and September; Tables 1 and 2.

Tables 1 and 2 show data obtained in both years for the two crops respectively.

TABLE 1. SOIL MOISTURE DEPLETION AND COMPUTED EVAPOTRANSPIRATION FOR SUGARBEETS DURING MEASURED PERIODS. UNIVERSITY FARM, BEKA'A, LEBANON, 1960, 1961.

Date of Irrigation	Date of Soil Sampling	Time of Depletion	Percentage Depletion in Top 30 cms. of Soil	Percentage Depletion in Lower 30 cms. of Soil	Average Percentage Depletion in 60 cm. Root Zone	Evapo-transpiration	
						Total	Rate
		(days)	(Average of 3 Samples)	(Average of 3 Samples)		(mm.)	(mm/day)
			1960				
June 28	June 30						
	July 5	5	3.7	5.4	4.55	30.0	6.0
July 5	July 7						
	July 12	5	2.7	3.6	3.15	20.6	4.1
July 26	July 28						
	Aug. 2	5	4.9	3.8	4.35	28.7	5.7
Aug. 23	Aug. 25						
	Aug. 30	5	5.6	3.3	4.45	29.4	5.9
Sept. 13	Sept. 15						
	Sept. 20	5	2.2	3.4	2.80	18.5	3.7
Sept. 27	Sept. 29						
	Oct. 4	5	1.5	2.9	2.20	14.5	2.9
			1961				
July 11	July 13						
	July 17	4	1.7	6.0	3.35	22.1	5.5
July 18	July 20						
	July 24	4	2.2	3.5	2.85	18.8	4.7
Aug. 1	Aug. 3						
	Aug. 7	4	2.4	3.7	3.05	20.1	5.0
Aug. 8	Aug. 10						
	Aug. 14	4	2.8	2.0	2.40	15.9	4.0
Aug. 15	Aug. 17						
	Aug. 21	4	2.3	2.0	2.15	14.2	3.5
Aug. 22	Aug. 24						
	Aug. 28	4	1.8	3.9	2.85	18.8	4.7
Aug. 29	Aug. 31						
	Sept. 4	4	2.4	1.8	2.10	13.9	3.5
Sept. 5	Sept. 7						
	Sept. 11	4	2.0	2.9	2.45	16.2	4.0

TABLE 2. SOIL MOISTURE DEPLETION AND COMPUTED EVAPOTRANSPIRATION FOR CORN DURING MEASURED PERIODS. UNIVERSITY FARM. BEKA'A, LEBANON. 1960, 1961.

Date of Irrigation	Date of Soil Sampling	Time of Depletion	Percentage Depletion in Top 30 cms. of Soil	Percentage Depletion in Lower 30 cms. of Soil	Average Percentage Depletion in 60 cm. Root Zone	Evapo-transpiration	
						Total	Rate
		(days)	(Average of 3 Samples)	(Average of 3 Samples)		(mm.)	(mm/day)
			1960				
June 24	June 28						
	June 30	2	1.7	2.2	1.95	12.9	6.4
July 1	July 5						
	July 7	2	1.2	2.3	1.75	11.6	5.8
July 29	Aug. 2						
	Aug. 4	2	1.8	1.0	1.40	9.1	4.5
Aug. 19	Aug. 23						
	Aug. 25	2	0.8	1.8	1.30	8.4	4.2
			1961				
July 11	July 13						
	July 17	4	5.3	2.3	3.80	25.0	6.3
July 18	July 20						
	July 24	4	7.5	3.2	5.35	35.3	8.8
July 25	July 27						
	July 31	4	3.4	3.4	3.40	22.4	5.6
Aug. 1	Aug. 3						
	Aug. 7	4	4.9	4.2	4.55	30.0	7.5
Aug. 8	Aug. 10						
	Aug. 14	4	7.3	2.2	4.75	31.3	7.8
Aug. 15	Aug. 17						
	Aug. 21	4	4.1	2.7	3.40	22.4	5.6
Aug. 22	Aug. 24						
	Aug. 28	4	4.6	4.8	4.70	31.0	7.7
Aug. 29	Aug. 31						
	Sept. 4	4	4.9	5.6	5.25	34.6	8.7
Sept. 5	Sept. 7						
	Sept. 11	4	3.6	3.6	3.60	23.7	5.9

TABLE 4. WEEKLY MEAN CLIMATIC DATA AND CORRESPONDING ESTIMATES OF POTENTIAL EVAPOTRANSPIRATION. UNIVERSITY FARM. BEKA'A, LEBANON. 1960

Weekly Period	Weekly Mean Temp. °F	Weekly Mean Relative Humidity	Weekly Mean n N*	Weekly Mean Ra** mm day	Weekly Mean Wind Velocity Miles day	Penman's Eo*** mm day	Blaney Criddle's (TXP) mm day	Cumulative Penman's Eo*** mm.	Blaney Criddle's mm.
April 1 — 7	52	48	.74	13.7	185	4.8	3.9	33.6	27.3
8 — 14	49	56	.63	14.3	124	3.9	3.6	60.9	52.5
15 — 21	59	41	.63	14.8	158	5.3	4.4	98.0	83.3
22 — 28	57	46	.59	15.0	188	5.3	4.3	135.1	113.4
April 29-May 5	62	28	.90	15.2	107	6.2	4.9	178.5	147.7
May 6 — 12	69	43	.62	15.4	131	5.5	5.5	217.0	186.2
13 — 19	58	32	.90	15.6	114	4.2	4.6	246.4	218.4
20 — 26	70	24	.83	15.9	109	6.9	5.6	294.7	257.6
May 27-June 2	66	39	.87	16.1	202	7.7	5.2	348.6	294.0
June 3 — 9	65	36	.88	16.4	149	7.2	5.3	399.0	331.1
10 — 16	68	34	.91	16.6	160	7.9	5.6	454.3	370.3
17 — 23	67	39	.88	16.6	181	7.8	5.5	508.9	408.8
24 — 30	71	30	.89	16.4	126	7.5	5.8	561.4	449.4
July 1 — 7	74	29	.87	16.2	134	7.7	6.0	615.3	491.4
8 — 14	74	30	.90	15.9	142	7.8	6.0	669.9	533.4
15 — 21	72	36	.90	15.6	168	8.0	5.8	725.9	574.0
22 — 28	75	35	.92	15.4	143	7.9	6.1	781.2	616.7
July 29-Aug. 4	73	34	.92	15.1	94	6.9	5.6	829.5	655.9
August 5 — 11	75	35	.93	14.8	159	7.6	5.7	882.7	695.8
12 — 18	78	33	.93	14.5	142	7.5	5.9	935.2	737.1
19 — 25	75	32	.91	14.2	162	7.3	5.7	986.3	777.0
Aug. 26-Sept. 1	71	35	.93	13.8	113	6.2	5.4	1029.7	814.8
Sept. 2 — 8	75	18	.85	13.5	107	6.1	5.3	1072.4	851.9
9 — 15	75	28	.94	13.1	130	6.6	5.3	1118.6	889.0
16 — 22	66	44	.92	12.5	121	4.3	4.7	1148.7	921.9
23 — 29	64	43	.91	11.8	137	4.9	4.5	1183.0	953.4
Sept. 30-Oct. 6	66	27	.94	11.2	96	4.0	4.3	1211.0	983.5
Oct. 7 — 13	64	31	.92	10.5	119	4.4	4.1	1241.8	1012.2

* n/N is the weekly mean ratio of actual to possible daily sunshine hours.

** Ra is the weekly mean extraterrestrial radiation.

*** Eo is the estimated evaporation from a free water surface per day, according to the Penman Equation.

**** K (TxP) is the weekly Blaney — Criddle's consumptive use factor (where K is 25.4 m.m./°F)

TABLE 5. WEEKLY MEAN CLIMATIC DATA AND CORRESPONDING ESTIMATES OF POTENTIAL EVAPOTRANSPIRATION. UNIVERSITY FARM, BEKA'A, LEBANON. 1961

Weekly Period	Weekly Mean Temp. °F	Weekly Mean Relative Humidity	Weekly Mean n/N	Weekly Mean Ra** mm/day	Weekly Mean Wind Velocity Miles/day	Penman's Eo mm/day	Blaney Criddle's (TxP) mm/day	Cumulative Penman's Eo mm.	Blaney Criddle's mm.
April 1 — 7	53	68	.55	13.7	119	3.4	3.9	23.8	27.3
8 — 14	54	68	.45	14.3	138	3.5	4.0	48.3	55.3
15 — 21	56	40	.86	14.8	92	3.9	4.2	75.6	84.7
22 — 28	59	38	.66	15.0	149	5.4	4.4	113.4	115.5
April 29-May 5	60	51	.74	15.2	147	5.5	4.8	151.9	149.1
May 6 — 12	59	55	.54	15.4	143	4.7	4.7	184.8	182.0
13 — 19	66	34	.75	15.6	122	6.3	5.2	228.9	218.4
20 — 26	67	30	.86	15.9	149	7.2	5.3	279.3	255.5
May 27-June 2	69	31	.79	16.1	201	7.8	5.5	333.9	294.0
June 3 — 9	73	28	.84	16.4	155	8.0	6.0	389.9	336.0
10 — 16	69	44	.85	16.6	164	7.5	5.7	442.4	375.9
17 — 23	70	30	87	16.6	148	7.8	5.7	497.0	415.8
24 — 30	71	44	.86	16.4	147	7.5	5.8	549.5	456.4
July 1 — 7	74	37	.87	16.2	151	7.8	6.0	604.1	498.4
8 — 14	72	39	.86	15.9	154	7.4	5.8	655.9	539.0
15 — 21	74	27	.87	15.6	133	7.5	6.0	708.4	581.0
22 — 28	76	2[illegible]	.89	15.4	144	7.7	6.2	762.3	624.4
July 29-Aug. 4	75	32	.88	15.1	138	7.3	5.7	813.4	664.3
Aug. 5 —11	75	41	.87	14.8	148	7.2	5.7	863.8	704.2
12 — 18	79	28	.87	14.5	141	7.5	6.0	916.3	746.2
19 — 25	73	35	.91	14.2	140	6.9	5.6	964.6	785.4
Aug. 26-Sept. 1	73	30	.92	13.8	131	6.7	5.6	1011.5	824.6
Sept. 2 — 8	67	37	.93	13.5	110	5.7	4.8	1051.4	858.2
9 — 15	68	42	.86	13.1	156	5.9	4.8	1092.7	891.8
16 — 22	66	64	.88	12.5	148	5.0	4.7	1127.7	924.7
23 — 29	62	64	.84	11.8	127	4.2	4.4	1157.1	955.5
Sept. 30-Oct. 6	65	60	.92	11.2	92	4.1	4.2	1185.8	984.9
Oct. 7 — 13	65	61	.92	10.5	100	2.7	4.2	1204.7	1014.3

TABLE 6. RATIOS OF MEASURED EVAPOTRANSPIRATION TO CALCULATED POTENTIAL EVAPOTRANSPIRATION. TWO YEAR AVERAGES. UNIVERSITY FARM, BEKA'A, LEBANON, 1960, 1961.

	Sugarbeets		Corn	
	E-T*	E-T**	E-T*	E-T**
July	0.68	0.87	0.82	0.98
August	0.72	0.88	0.80	0.98
September	0.66	0.73	—	—

* Ratio of measured evapotranspiration to estimated evaporation from a free water surface as determined by Penman's Equation.

** Ratio of measured evapotranspiration to monthly consumptive use factor as determined by the Blaney-Criddle formula.

The ratios shown above may be used to estimate consumptive use from the empirically determined potential evapotranspiration. Specific ratios for different crops should be determined for each month for which consumptive use data are required. When limited data are available, the maximum monthly ratio may be utilized to estimate total evapotranspiration. This procedure obviously overestimates total evapotranspiration but certainly provides safe requirement figures.

Table 7 gives estimated total evapotranspiration of sugarbeets and corn during 1960 and 1961 obtained by using the above mentioned ratios.

TABLE 7. ESTIMATED EVAPOTRANSPIRATION BY PENMAN'S AND BLANEY-CRIDDLE'S METHODS FOR CORN AND SUGARBEETS. UNIVERSITY FARM, BEKA'A, LEBANON, 1960, 1961.

Crop and Year		Penman's Method		
		Total potential evapotranspiration	E-T/Eo*	Total estimated evapotranspiration
		(mm.)		(mm.)
Sugarbeets	1960	1241.8	0.72	894.1
Corn	1960	1241.8	0.82	1018.3
Sugarbeets	1961	1204.7	0.72	867.4
Corn	1961	1204.7	0.82	987.8
		Blaney-Criddle's Method		
		E-T/B-C*		
		(mm.)		(mm.)
Sugarbeets	1960	1012.2	0.88	890.7
Corn	1960	1012.2	0.98	992.0
Sugarbeets	1961	1014.3	0.88	892.6
Corn	1961	1014.3	0.98	994.0

* Ratio of measured evapotranspiration to potential evapotranspiration as calculated by empirical method.

The above results obtained from data on the University Farm show that in the specific conditions of the location, small differences between either of the two methods were evident. Estimates of total evapotranspiration given in the above tables show differences ranging from 0.3 per cent to 2.6 per cent. This is an indication that either method could be used since they both yield similar results.

PROBLEMS INVOLVED IN THE STUDY

The problems encountered in this study were numerous and of different degrees of seriousness.

Soil sampling was difficult in most instances due to the common occurrence of rocks in the profile. The rocks in many cases interfered with the penetration of the auger to the desired sampling depth. This is believed to be a problem in any soil sampling by auger procedure in Lebanon, since the majority of arable lands have a high percentage of stones.

The smaller stones in the soil presented another problem. The bucket auger used in this study very often picked up stones with the soil. The stones had to be removed from the sample before the sample could be weighed. This procedure introduced a certain margin of error in the results.

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RESEARCH ON SOIL RECLAMATION AND CONSUMPTIVE USE IN TURKEY

by

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Part I

SOIL RECLAMATION RESEARCH

I. INTRODUCTION TO SALINITY AND ALKALINITY PROBLEMS IN TURKEY

A. Extent and Importance

According to the preliminary soils map of Turkey prepared by Mr. Harvey Oakes in 1954, hydromorphic saline alluvial (halomorphic) soils cover 650,200 hectares and solonchak soils 69,700 hectares. These figures refer only to lands that are basically accepted as non-arable. It is also recognized that 25 per cent, or 820,400 hectares, of the young alluvial soils in Turkey 681,280 hectares of the hydromorphic alluvial soils and 89,800 hectares of beach, sand dunes and marsh complex exhibit salinity and drainage problems. Their total area approximates 2,311,380 hectares, about 14 per cent of the arable land of Turkey.

Except for salty marshes and old salty lake beds, the saline and alkali soils of Turkey are mainly located on inland and coastal plains which are fertile and climatically favourable for good crop growth. TOPRAKSU data indicate an annual loss of 3,700,000,000 TL of agricultural production from 2,181,340 hectares of non-arable problem soils, plus a 1,150,000,000 TL annual loss from 1,151,960 hectares of land having problems but nevertheless being used for production. The total annual loss amounts from to 4,350,000,000 TL agricultural lands with problems.

It is also estimated that 6,500,000,000 TL would be required to convert these problem soils into arable lands.

B. CHARACTERISTICS

Available data indicate that the first survey of the saline and alkali soils of Turkey was made by Kerim Omer Caglar (later Professor in the Soils Department, Faculty of Agriculture, Ankara) in 1934. This survey was limited to extremely saline locations and did not designate the size of the problem areas. The second survey was made by Harvey Oakes in 1954 during the preparation of a soils map of Turkey. He classified the saline and alkali soils of Turkey as **hydromorphic saline alluvial** and **solonchak** soils, the former mainly located on azonal soils and the latter on intrazonal soils.

1. **Hydromorphic Saline Alluvial Soils** occur in all parts of Turkey; in stream valleys, deltas and basins in association with other alluvial soils. Many occur is small depressed or low-lying parts of flood plains, but many exist in large areas such as the Konya Basin. These soils are extremely variable in physical as well as chemical characteristics.

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2. **Solonchak Soils** are defined as soils that have high a **content of salts,** are receiving salts or have had at a previous time an excess of salts. The principal areas of these soils are fairly large tracts in old lake basins and in valleys where groundwater rises to or near the surface, temporarily or for long periods. The solonchaks, as recognized here, are of three general types:
   (a) Where the salts were introduced by flooding, as in old lake beds;
   (b) Where the salts came upward by capillary action from a shallow groundwater table;
   (c) A combination of the two types.

   On the other hand, hydromorphic saline alluvial soils as mapped occur mainly in situations subject to frequent overflow or in poorly drained areas that remain wet continuously or for long periods.

   As was also discussed by Harvey Oakes, the distinction between the two kinds of saline soils was based on practical reclamation potential rather than scientific significance. Thus, **hydromorphic saline alluvial soils** mainly refers to azonal alluvial soils that were salt affected by floods, seepage or uncontrolled irrigation; and **solonchaks** to intrazonal soils mainly formed on parent material or a base high in salts. The cause of accumulation for both is poor surface and subsurface drainage. Both may have saline, alkali and saline-alkali classes, as will be seen in the laboratory analysis of the soil samples from reclamation plots.

II. EXPERIMENTAL RESULTS CONCERNING RECLAIMABILITY AND CROP GROWTH

The first experiments on reclaimability and crop growth on saline and alkali soils in Turkey were initiated by the Tarsus Irrigation and Research Institute at Alifaki (later Alifaki Salinity Reclamation Station), in 1952.

In 1957, the Ankara Soil and Fertilizer Research Institute initiated field experiments in cooperation with a sugar company at Ankara; at Eskisehir with the Eskisehir Irrigation Experiment Station; at Izmir with the Menemen Irrigation Research Institute; at Konya with the Çumra Irrigation Experiment Station; and at Mersin with the Tarsus Irrigation Research Institute on laboratory and greenhouse experiments.

In this paper, the experimental results obtained by the Ankara Soil and Fertilizer Research Institute and the Tarsus Irrigation Research Institute will be summarized. The detailed information will be given in tables and figures.

The experiments made so far can be grouped as laboratory and greenhouse studies and field experiments.

A. LABORATORY AND GREENHOUSE STUDIES

These studies were conducted by the Ankara Soil and Fertilizer Research Institute from 1957 to 1961.

1. **pH Studies**
   (a) **Effect of soil-water ratio on pH readings of saline-alkali soils.** Readings with pH-meters equipped with glass and calomel electrodes were made on Tarsus and Menemen saline-alkali soils at 1/1, 1/5, 1/10 and 1/20. The statistical analysis of the readings showed significant increases in pH by dilution. Dilutions above 1/10 did not give significant increases and a 1/10 ratio is good enough for estimation of an alkaline condition provided the pH of the soil paste is about 8.00.
   (b) **Effect of varying absolute weights of soils and water at 1/10 ratio on the pH readings of saline-alkali soils.** Readings were made at a fixed 1/10 soil-water ratio varying the absolute weights as follows: 3 gr. soil: 30 cc water; 5 gr soil: 50 cc water; 10 gr soil: 100 cc water, 20 gr soil: 200 cc water. The results indicated that at least ten grams of soil were required.

(c) **Effect of length of standing time of soil paste on the pH readings of saline-alkali soils.** The soil pastes were allowed to stand two, four and 24 hours before the readings were made. There was an insignificant difference from two to four hours; significant, from four to 24 hours; highly significant, from two to 24 hours. The pH readings should be made by allowing the pastes to stand for 24 hours.

2. **A Study of the Water Quality of the Kizilirmak River.** The Kizilirmak is the longest river in Turkey with its course 1,100 kilometers, entirely within the national borders. In that distance throughout the year water quality is affected by a number of factors. The average salt content of the river is about 1,500 micromhos/cm during the year, but increases up to 3,534 micromhos/cm during May and June. A study of the river's course and a laboratory analysis lead to the conclusion that the following reasons explain the change in salt content:
   (a) Addition of drainage water at Çankiri.
   (b) Early spring runoffs carrying dissolved salt from the surrounding mountains.
   (c) Evaporation contributes to the concentration of salts within this long run.
3. **Growth and Yields of Various Crops Under Different Osmotic Pressures.** In the greenhouse, sand cultures with various osmotic pressures adjusted with sodium chloride were used to determine the growth and yield of various crops under varying salt concentrations. The treatments, crops and their relative growth or yields are summarized in Table 1.

B. FIELD EXPERIMENTS

The field experiments conducted in various parts of Turkey have been grouped according to whether they were conducted by the Ankara Soil and Fertilizer Research Institute (at Ankara, Eskisehir, Menemen, Çumra, Tarsus and Kayseri) or by the Tarsus Irrigation Research Institute (at the Alifaki Salinity Reclamation Station).

Those conducted by the Ankara Soil and Fertilizer Research Institute will be summarized first, followed by the results obtained by the Tarsus Irrigation Research Institute. The general physical and chemical characteristics of the experimental locations are given in Table 2.

1. **Field Experiments Conducted by the Ankara Soil and Fertilizer Research Instute.**
   (a) **Ankara**-Etimesgut: The experimental plots were located about 17 km. southwest of Ankara on flat, alluvial saline-alkali soils representative of 130 hectares. The sugar company which owned the land cooperated. The general character of the soils is given in Table 2. Briefly, this is: saturation percentage, 72.76-155.40, electrical conductivity, 2.71-14.99 millimhos/cm; ESP, 12.20-97.91 within 150 cm. of soil profile. The plots were located within open drains. The effect of leaching with 651 Kg/dk gypsum and rice crop on soil salinity and alkalinity is given in Table 3. Because of unfavorable conditions, about 80 per cent of the rice crop did not survive, but the leaching continued. This scarce vegetation had no beneficial effect on the soil; therefore these rice plots were only leaching treatments. Even then it was possible to lower EC_{ex} 10^4 to 2.81-6.00 and ESP to 33.07-78.61 in rice plots and to 1.98-4.59 and 42.79-77.02 in gypsum plots, respectively.
   (b) **Menemen:** the plots were located at Kesikkoy, 7 km. southwest of the Menemen Irrigation Research Institute, and were representative of 30,000 hectares. The general character of the soils is given in Table 2. Briefly,

TABLE 1. PER CENT OF GROWTH OR YIELD OF VARIOUS CROPS IN RELATION TO DIFFERENT OSMOTIC PRESSURES. (SOIL AND FERTILIZER RESEARCH INSTITUTE-ANKARA).

Year of the Experiment	Crop	Osmostic Pressures - Atmospheres											
		Per cent of Yield or Growth											
		Check	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	8.0
1958	Eggplant USA, early long purple	100	89.7		81.0		65.5		50.0		39.6		
1958	Tomatoes, native, pole	100	81.3		67.6		50.9		42.1		21.5		
1958	Pepper, native, long	100	67.3		65.2		63.0		43.4		43.4		
1958	Soybean, native	100	77.1		70.1		63.1		57.8		38.5		
1958	Radish, native, red	100	77.7		55.5		44.4		33.3		26.6		
1958	Cabbage, native, top	100	83.6		76.3		69.0		63.6		57.7		
1958	Rice, native, Misir	100	91.5		52.5		28.8		28.8		27.1		
1959	Soybean USA, Adams	100		89.8		82.9		72.4		59.6		56.1	46.5
1959	Beans	100		36.2		32.7				24.8		22.7	20.0
1959	Sugarbeets Klinwanzleben	100		61.0		66.0		64.0		52.0			19.0
1960	Rape seed, Hembkes Koolzood	100		81.0				61.5				59.6	44.9

TABLE 3. EFFETS OF LEACHING WITH GYPSUM AND RICE CROP ON THE SALINITY AND ALKALINITY OF ANKARA ETIMESGUT SOIL. (SOIL AND FERTILIZER RESEARCH INSTITUTE-ANKARA).

Treatments	Date of Sampling	ECex 10^4				ESP			
		Depth of Sampling (cm)				Depth of Sampling (cm)			
		0-30	30-60	60-90	90-120	0.30	30-60	60-90	90-120
Gypsum (651 Kg/Dk)	1	13.08	6.84	6.45	2.71	97.91	80.36	87.59	61.49
	2	4.59	2.87	2.59	1.98	45.03	77.02	76.39	42.79
Rice	1								
	2	2.81	3.08	6.00	5.87	67.56	78.61	70.41	33.07

Date of Sampling: (1) Before leaching ; (2) After leaching.

TABLE 2. PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS

LOCATION	Depth Of Sampling (Cm.)	Saturation Percentage	pH		EC x 10⁶	Soluble Cations m.e/lt.,				
			Paste	Extract		Ca	Mg	Na	K	Total
Ankara Etimesgut	0-30	72.76	9.97	923	13.08	1.51	0.20	134.00	0.25	135.96
	30-50	174.90	9.65	8.74	8.84	1.01	0.22	74.00	0.17	75.40
	50-70	93.64	9.55	8.35	6.45	2.02	1.11	62.50	0.15	65.78
	70-120	155.40	9.29	7.72	2.71	1.01	0.23	29.00	0.02	30.26
	120-150	57.07	8.60	8.05	14.99	1.52	2.56	13.75	0.27	18.10
Izmir - Menemen	0-30	46.4	7.69	7.47	82.11	45.58	144.60	821.51	4.10	416.09
	30-60	44.9	7.79	7.39	68.47	32.28	100.80	708.30	3.05	844.43
	60-90	45.4	7.77	7.36	75.49	33.25	119.89	768.00	3.80	864.94
Eskisehir-Kuzuld.	0-2	74.00	8.30	8.15	181.25	83.30		2412.5	10.00	2505.80
	2-30	52.50	8.40	7.30	51.04	154.84		605.0	10.50	770.34
	30-60	67.50	8.70	7.21	28.20	111.72		254.0	1.80	367.52
	60-90	69.00	8.38	8.12	8.72	12.74		79.0	0.40	92.14
	90-120	72.50	8.62	7.22	22.11	73.31		198.0	1.12	272.43
	120-150	69.00	8.37	7.93	8.47	12.15		76.5	0.40	89.05
	150-180	57.00	8.20	7.80	6.67	14.01		59.0	0.30	73.31
Çumra-Uçhoyük	0-30	45.13	8.01	8.09	5.52	11.00	6.54	12.70	2.93	33.17
	30-60	43.41	7.96	8.04	2.52	9.40	8.59	7.18	1.98	27.15
	60-90	46.69	8.01	8.05	1.40	2.90	3.01	5.76	3.67	15.34
Kayseri-Karasaz	0-30	77.43	8.05	8.05	30.15	11.22	24.31	260.00	13.00	308.52
	30-60	79.29	7.92	8.15	39.57	23.66	130.00	81.00	1.90	236.64
	60-80	94.75	8.12	8.30	9.24	3.57	15.35	74.00	1.83	94.74
	80-110	98.49	7.99	8.29	4.98	6.12	11.83	38.50	1.20	57.64
Tarsus-Alifaki	0-30	76.94	7.78	7.73	14.38	26.30	35.03	101.62	0.43	163.38
	30-60	88.47	7.72	7.48	28.37	62.98	91.59	174.71	0.64	329.92
	60-90	98.33	7.76	7.39	36.07	72.19	115.20	210.00	0.77	398.16
Tarsus-Alifaki	0-20	97	7.8		12.84	5.23		6.76		
	20-70	106	7.8		32.65	13.87		16.40		
	70-100	111	7.9		30.26	15.80		19.83		

WHERE FIELDS LEACHING EXPERIMENTS ARE CONDUCTED·

Soluble Anions m.e. lt.,					Exchangeable Cations							
CO^{3}	HCO^{3}	CL	SO^{4}	Total	CEC m.e 100 gr.	Na+ m.e 100 gr.	ESP	EPP	Ca SO^{4} 2H·O m.e 100 gr.	Ca CO^{3} m.e 100 gr.	PPM Boron	OM %
11.11	12.52	33.50	64.73	121.86	31.16		97.91	3.04				
1.01	5.15	19.50	38.20	63.86	32.50		80.36	1.47				
1.01	4.04	21.30	36.64	62.99	21.20		87.59	2.07				
—	3.63	15.50	10.38	29.51	28.49		61.49	3.05				
—	2.83	4.00	11.10	17.48	29.49		12.20	0.51				
—	2.28	1013.10	2.63	1018.01	14.38		64.64	4.46				
—	1.87	839.80	2.96	841.67	11.15		68.33	4.17				
—	2.27	913.20	7.05	922.52	12.52		59.74	3.96				
—	13.15	120.2	2421.0	2554.9								
—	3.15	225.8	521.0	750.0			49					
—	1.58	129.2	245.5	376.3			33					
—	2.34	43.8	—	46.8			31					
—	1.26	93.5	193.4	282.2			32					
—	3.15	43.5	—	46.7			31					
—	4.20	30.0	—	34.2			24					
—	3.45	19.6		23.05	21.3		13.8					
—	2.80	16.0		18.80	19.5		6.2					
—	3.20	10.5		13.70	21.8		3.4					
Tr.	1.65	325.0	—	326.65	32.62		48.69	8.61			7.80	11.14
Tr.	3.74	574.2	0.70	578.60	33.18		78.42	6.20			6.45	10.49
0.87	1.47	84.2	1.70	88.30	33.95		34.45	3.29			11.35	6.29
0.87	1.47	35.7	7.70	45.80	33.95		10.02	3.92			10.65	10.03
—	6.03	143.00	16.61	165.64	32.93		26.60	3.05				
—	9.71	283.25	56.05	349.01	32.39		30.46	2.39				
—	17.04	351.01	54.15	423.20	33.87		26.97	2.21				
050	0.321	10.287	1.26		40.84	8.16			0.66	57.3	1.00	
0.028	0.278	24.000	5.90		36.90	8.35			25.62	468.7	1.04	
0.000	0.340	28.746	4.42		35.40	12.23			72.90	485.8	1.00	

TABLE 4. EFFECT OF CHEMICAL AMENDMENTS, LEACHING WATER TREATMENTS AND (SOIL AND FERTILIZER

	Date of Sampling	HEAVY LEACHING (1000 mm.)								
		ECe X 10[1]				ESP				Alfalfa Yield Dry weight kg/dk
		0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120	
Check	1	71.84	74.23	83.52		59.42	78.34	55.70		
	2									
	3	1.03	1.21	1.18		7.19	19.52	28.26		
	4	2.06	4.56	3.45		11.04	23.18	30.67		418.2
	5	2.94	3.21	4.02	3.59	33.37	45.49	44.11	54.14	
	6	1.86	2.29	3.86	4.71	16.50		36.53	55.87	791.5
Gypsum 1500 Kg/Dk	1					60.15	28.80	55.70		
	2	2.19	2.82	2.82		27.98	45.03	51.49		
	3	1.09	1.62	1.35		15.52	33.31	42.21		
	4	2.78	3.15	1.87		18.75	15.86	28.82		827.8
	5	4.75	8.43	8.83	22.49	14.74	30.79	30.47		
	6	4.48	9.71	10.51		16.41	17.29	14.07		1125.1
Manure 4500 Kg/Dk	1					59.59	75.14	52.15		
	2	4.28	6.78	19.91		39.49	52.06	57.85		
	3	2.14	2.75	6.01		45.16	60.91	60.43		
	4	3.97	8.75	10.16		17.43	39.91	66.24		769.6
	5	2.93	4.89	6.01	5.22	22.06	59.77	62.97		
	6	1.69	3.78	5.39		20.15	49.37	56.21		925.1
Sulphur 150 Kg/Dk	1	72.61	49.12	72.62		59.63	48.25	51.89		
	2	5.53	3.64	2.80		21.07	36.84	52.01		
	3	1.66	1.95	2.07		33.60	50.23	56.94		
	4	3.84	3.81	3.21		18.26	44.16	48.27		602.8
	5	2.81	4.68	3.13	5.43	15.63	43.13	48.01		
	6	5.61	3.47	7.49	7.02	30.66	43.22	47.55	43.98	1007.8
Sulphuric Acid 150 Kg/Dk	1	92.79	66.81	63.03		70.66	75.94	57.07		
	2	2.82	4.37	3.14		10.03	19.60			
	3	6.11	17.76	30.06		35.21	46.41	37.96		
	4	7.41	11.85	22.36		34.92	46.90	21.18		424.5
	5	4.33	7.62	11.84	13.14	29.59		51.52	57.01	
	6	1.57	4.71	3.44	3.09	12.27	15.10	28.76		778.6

DATE OF SAMPLING: (1) 2/5/1958 (before leaching); (2) 2/12/1958 (after leaching with 1000 mm. in (4) 24/10/1959 (after alfalfa seeding in 12/5/1959 and applying 548 mm. irrigation water); (5) 5/8/1960

ALFALFA ON SOIL SALINITY AND ALKALINITY — MENEMEN, IZMIR INSTITUTE-ANKARA)

HEAVY LEACHING (600 mm.)								
ECe X 10'				ESP				Alfalfa Yield Dry weight kg/dk
0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120	
75.07	70.71	74.77		65.15	69.76	75.13		
4.79	23.33	59.26		52.30	53.29	67.82		
2.44	13.02	37.94			56.40	35.37		
8.30	11.40	31.24		40.82	53.62	55.33		30.9
3.86	5.37	21.21	38.61	35.58	50.79	16.61	11.85	
2.12	3.36	4.94	11.51	27.45	49.66	49.04	46.86	251.7
				69.12	70.14	72.12		
1.06	1.08	2.20		22.61	47.13	49.10		
3.22	3.64	4.42		25.96	46.41	55.97		513.0
3.27	11.97	17.03	22.49	12.81	44.48	45.94		
9.80	13.31	18.66		35.67	41.44	36.03		1030.4
				63.61	49.13	52.62		
4.22	10.54	4.55		33.99	54.56	33.56		514.2
3.02	4.23	10.22	18.82	14.79	21.13	18.70		
2.44	6.82	18.51		25.81	46.72	52.99		754.2
				57.11	63.13	72.12		
2.69	2.05	1.80		39.39	55.61	53.34		
3.44	10.88	10.16		33.16	57.75	23.25		248.3
2.84	4.13	4.76	4.93	32.83	57.75	62.26		
1.59	4.05	3.47		17.96	44.34	61.59		840.6
98.25	81.47	83.51		68.35	69.36	58.94		
2.83	13.85	45.31			57.13			
1.87	1.86	1.97		37.63	52.60	51.14		
3.56	3.48	12.82		22.99	23.58	32.40		189.4
4.33	7.62	11.84	13.40	13.32	38.65	48.34		
1.64	1.75	2.73		28.19	54.22	50.80		583.3

heavy leaching and 600 mm. in light leaching; (3) 12/4/1959 (after leaching with 453 mm. fter leaching with winter rainfall); (6) 8/11/1960 (after leaching with alfalfa).

this is: the saturation percentage, 44.9-46.4; electrical conductivity, 68.47-82.11 millimhos/cm; ESP 59.74-68.33 within a 90-cm. soil profile.

Experimental plots were located on a tract of land surrounded by open drains 1.5 m. deep. The size of the plots was 7x50 = 350 sq. m. The treatments and their effects on soil salinity and alkalinity are summarized in Table 4. In 1960, the foregoing values of 1957 were lowered to $EC_e x 10^3$, 1.57-18.51, ESP 12.27-61.59 within a 90-cm. soil profile.

The results are promising and encouraging. In almost every treatment, both the $EC_e x 10^3$ and ESP values, especially of the upper layers, were lowered to safe levels for the germination and growth of a wide range of plant species.

(c) **Eskisehir-Kizildiken:** Gypsum applications at 350, 400, 450 and 500 Kg/Dk. rates were given to experimental plots at Eskisehir-Kizildiken representative of 12,500 hectares.

The general character of these soils is given in Table 2: Saturation percentage, 52.50-74.00; $EC_e x 10^3$, 8.72-181.25 and ESP 31-49 within a 120-cm. coil profile. Following 400 mm of leaching, the $EC_e x 10^3$ and ESP values of the gypsum plots were significantly lowered compared to the control plots. Gypsum at the rate of 350 Kg/Dk gave satisfactory results and lowered salinity and alkalinity to safe levels, especially at the upper 60 cm. of the profile. The results are given in Table 5.

(d) **Çumra-Uçhoyuk:** Leaching plots were located at Uçhoyuk and were representative soil samples is given in Table 2. Briefly, the saturation percentages were 43.41-46.69; $EC_e x 10^3$, 1.40-5.52; and ESP 3.4-13.8. Though not highly saline or alkali at the present time, deep borings indicated the presence of an old lake bed rich in salts below; these are likely to rise with groundwater under impeded subsurface drainage.

The treatments were 410 Kg/Dk gypsum, 85 Kg/Dk sulphur, 134.5 and 124 Kg/Dk sulphuric acid and 2900 Kg/Dk manure under heavy leaching (750 mm) and light leaching (600 mm) conditions.

The effect of these treatments on ESP under heavy leaching is given in Figure 1. A second leaching experiment was started in 1959 on soils having higher $EC_e x 10^3$ and ESP values than the first ones. Leaching with rice crop was practiced in a land tract surrounded with open drains spaced at 62.5 m. and 1.5 m. deep. Native and maratelli rice varieties were used. An unexpected low temperature at the flowering stage caused the death of 80 per cent of the maratelli and 50 per cent of the native rice seedlings. The effect of one rice crop can be observed in Table 6. Both salinity and alkalinity were lowered to safe levels. (EC_e x 10^3 from 26.61-73.04 to 4.86-8.50; ESP from 18.00-33.60 to 0.20-5.50 within a 125-cm. soil profile).

(e) **Kayseri-Karasaz:** The experimental plots, representative of 3,000 hectares, were located on saline-alkali soils of organic origin near Kayseri. The general character of the soils is represented in Table 2. Briefly, this is: saturation percentage, 77.43-98.49; $EC_e \cdot x 10^3$, 4.98-39.57; ESP, 10.92-78.42; Boron 6.45-11.35 ppm within a 110-cm. soil profile. The experimental plots were surrounded with open drains 1.4 m. deep. Various rates of gypsum applications 80, 160, 240 and 320 Kg/Dk were made on September 26, 1959, and left to the leaching effect of the winter rains (average annual precipitation, 364.5

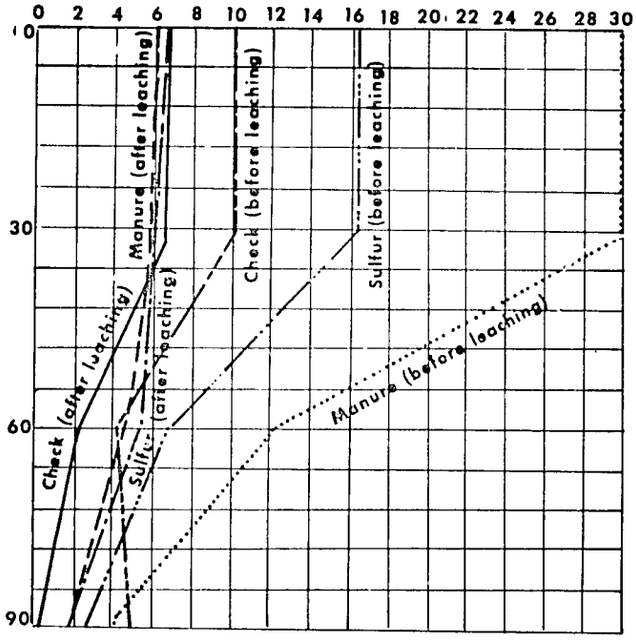

TABLE 5. EFFECT OF VARIOUS RATES OF GYPSUM APPLICATIONS AND 400 MM LEACHING ON SOIL SALINITY AND ALKALINITY, KIZILDIKEN-ESKISEHIR. (SOIL AND FERTILIZER RESEARCH INSTITUTE-ANKARA).

Treatment	Date of Sampling	ECex 10^4				ESP			
		Depth of Sampling (cm)				Depth of Sampling (cm)			
		0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120
A	1	38.50	46.20	41.74	37.37	75.56	46.10	51.83	69.82
(Check)	2	10.98	20.07	29.22	29.02	39.04	29.59	40.49	60.48
B									
(350 Kg/Dk)	1	12.23	19.08	26.40	30.90	30.50	27.82	20.25	58.12
(Gypsum)	2	4.25	4.86	7.34	11.75	6.05	9.64	14.35	29.10
C									
(400 Kg/Dk)	1	26.60	49.80	52.00	43.38	34.42	31.34	28.90	16.48
(Gypsum)	2	9.11	6.72	10.69	21.95	15.58	24.30	7.31	3.47
D									
(450 Kg/Dk)	1	38.50	46.20	41.74	37.37	75.56	46.10	51.83	69.82
(Gypsum)	2	10.73	20.92	38.84	40.75	25.24	35.65	24.52	30.35
E									
(500 Kg/Dk)	1	4.92	8.58	10.73	14.61	34.36	26.34	25.02	46.06
(Gypsum)	2	4.70	7.27	11.03	29.20	27.98	35.30	46.11	25.59

TABLE 6 EFFECT OF LEACHING WITH RICE ON SOIL SALINITY, ALKALINITY AND PROPERTIES AT ÇUMRA-UCHOYUK

Soil Character	Before Lleaching with Rice						After Leaching with Rice Crop				
	Sampling Depth (cm)						Sampling Depth (cm)				
	0-10	10-20	20-40	40-60	60-90	90-120	0-15	15-25	25-50	50-80	80-125
Saturation %	40.00	40.00	41.00	50.00	55.00	55.00	47.00	55.00	58.00	61.00	43.00
pH (Saturated paste)	8.05	7.95	8.06	8.15	8.12	8.03	7.55	7.60	7.95	7.70	7.60
pH (Saturation extract)	7.40	7.35	7.32	6.65	7.25	7.12	7.92	7.90	7.81	7.70	7.45
CFC							20.9	22.7	24.2	25.5	12.5
ESP	29.30	33.60	28.90	24.50	18.00	20.00	1.30	5.50	0.20	4.20	5.20
EPP							5.30	3.40	2.50	2.00	1.60
ECe x 10^3	56.00	73.04	51.69	38.11	26.61	27.00	4.86	6.80	8.50	6.54	6.30
Soluble cations (me/lt) Na	450	625	460	325	195	220	15.00	27.50	37.50	35.00	30.00
K	19.00	15.50	7.60	4.20	1.70	1.70	0.60	0.35	0.35	0.17	0.15
Ca	49.80	34.30	33.30	31.40	29.40	30.20	29.60	28.80	34.40	28.50	34.80
Mg	433.20	600.40	489.80	373.20	307.70	274.40	28.10	41.00	42.50	27.70	20.30
Soluble anions (melt) CO^3	—	—	—	—	—	—	—	—	—	—	—
HCO^3	25.00	15.00	12.50	12.50	12.50	12.50	2.80	3.70	4.00	2.70	2.30
CL	562.50	725.00	487.50	287.50	150.00	162.50	62.50	42.50	62.50	50.00	62.50
SO4	—	—	—	—	—	—	13.10	53.60	50.83	39.98	21.10

mm) for 45 to 60 days, followed by leaching. Salinity and exchangeable sodium status following the winter rains plus 200 mm of leaching are given in Table 7.

(f) **Tarsus-Alifaki:** Experimental plots were established at the Alifaki Salinity Reclamation Station in 1958 representative of 4,000 hectares in the Tarsus Plain and of about 85,000 hectares in the Çukurova Plain. The general character of the soils is given in Table 2: Saturation percentage, 76.94-98.33; $EC_e \times 10^4$ 14.38-36.07; ESP, 26.60-30.46 within a 90-cm soil profile. The effects of winter rains, light leaching (400 mm), heavy leaching (615 mm), and alfalfa along with 460 Kg/Dk sulfur and 2800 Kg/Dk manure on soil salinity and alkalinity are summarized in Table 8.

2. **Field Experiments Conducted by the Tarsus Irrigation Research Institute at the Alifaki Salinity Reclamation Station.** Field experiments at Alifaki were started in 1953. Various leaching, amendment and crop establishment treatments were tried. Lack of a laboratory at the time prevented the evaluation of these treatments from the standpoint of soil analysis. Therefore, the relative yields and growths of various crops were used as indicators to detect the degree of reclamation.

(a) **Leaching Trials:** Leaching trials were made on large-scale plots. On these artificially drained heavy soils, leaching with rice crop followed by irrigated pasture gave the best results (Table 9.)

In these trials, 0.36-0.55 per cent of salt was lowered to 0.13-0.25 per cent by two years of rice crop and to 0.09-0.16 per cent within a 120-cm soil profile by the following irrigated pasture. ESP values to indicate the changes of soil alkalinity are not available, but the appreciable lowering of soil paste pH, especially within the first foot of the soil under irrigated pasture (Table 10), may be an indication of the Na+ removal. The effects of rice and irrigated pas-

TABLE 7. EFFECT OF VARIOUS RATES OF GYPSUM APPLICATIONS AND 200 MM OF LEACHING WATER ON SALINEALKALI SOILS OF ORGANIC ORIGIN, KARASAZ-KAYSERI. (SOIL AND FERTILIZER RESEARCH INSTITUTE-ANKARA).

Treatment	Date of Sampling	$EC_e \times 10^4$				ESP			
		Depth of Sampling (cm)				Depth of Sampling (cm)			
		0-30	30-50	50-80	80-110	0-30	30-50	50-80	80-110
Check	1	8.31	21.06	21.06	4.99	16.65	8.95	8.90	4.62
	2	4.31	4.71	3.34	3.75	1.29	5.00	7.66	1.79
Gypsum (80 Kg/Dk)	1								
	2	7.74	9.46	8.11	7.01	1.79	4.57	1.62	3.59
Gypsum (320 Kg/Dk)	1								
	2	3.50	6.38	6.17	6.18	1.83	3.61	2.36	2.10

Date of Sampling: (1) 26/9/1959 (Before leaching);
(2) After the leaching of winter rainfall plus 200 mm. water).

TABLE 8. EFFECT OF CHEMICAL AMENDMENT, LEACHING WATER TREATMENTS AND ALFALFA ON HELVACI CLAY-ALIFAKA, TARSUS (SOIL AND FERTILIZER RESEARCH INSTITUTE-ANKARA).

Treatments	Date of Sampling	ECe X 10^3				ESP				Alfalfa yield dryweight kg/dk)
		Depth of sampling (Cm.)				Depth of sampling (Cm.)				
		0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120	
	Heavy Leaching (615 mm.)									
Check	1	23.97	36.66	35.02	—	23.23	28.27	43.17	—	
	2	2.61	18.66	29.32	23.89	24.21	24.81	28.49	28.59	
	3	4.46	26.04	27.11	25.34	13.14	14.44	25.65	24.77	21.80
Gypsum (460 kg/dk)	1	26.18	32.45	38.85	—	24.85	32.87	34.85	—	
	2	2.49	16.59	16.99	17.47	20.29	32.79	31.68	27.54	
	3	5.32	16.36	15.22	13.29	5.98	21.79	25.40	29.44	23.10
Manure (2800 kg/dk)	1	36.28	44.18	413.92	—	29.40	37.07	47.00	—	
	2	2.26	19.50	28.29	22.56	10.57	26.28	32.59	21.17	
	3	3.61	22.19	27.04	24.74	18.40	17.40	23.80	24.41	20.50
Sulphur (64 kg/dk)	1	51.83	38.59	32.35	—	23.50	34.25	33.50	—	
	2	2.68	17.77	18.41	18.32	18.42	23.29	22.85	16.02	
	3	4.68	19.79	18.04	21.64	11.22	19.40	21.05	25.34	20.00
	LIGHT LEACHING (400 mm.)									
Check	1	23.97	36.66	35.02	—	23.23	38.27	43.17	—	
	2	5.33	18.85	23.43	23.29	23.66	32.37	28.95	36.43	
	3	5.43	17.92	23.12	23.59	17.63	25.60	27.13	24.15	39.00
Gypsum (460 kg/dk)	1	26.18	38.45	38.85	—	24.85	32.87	34.85	—	
	2	3.29	25.56	27.01	22.01	11.10	31.69	34.76	24.42	
	3	5.79	25.40	27.68	27.04	19.01	26.73	34.56	31.46	25.00
Manure 2800 kg/dk)	1	36.28	44.18	43.92	—	29.40	37.07	47.00	—	
	2	5.08	24.49	28.95	27.49	25.51	34.87	42.68	34.41	
	3	4.39	23.64	26.59	25.92	12.79	23.22	33.86	26.93	25.00
Sulphur (64 kg/dk)	1	51.83	38.69	32.35	—	23.50	34.25	33.50	—	
	2	5.10	25.70	22.11	20.40	21.86	34.00	33.08	36.07	
	3	4.48	20.16	20.60	17.78	8.96	14.15	20.59	15.04	29.00

D. Date of Sampling : (1) 20/1/1959 (before leaching); (2) 6/11/1959 (After leaching with 333mm. rainfall plus 615 mm. water in heavy leaching and 400 mm. in light leaching); (3) 17/10/1960 (490.3.mm rainfall plus irrigation water for alfalfa that was seeded in 15/4/1960).

Leaching Water: Water used for heavy leaching contained 15% and light leaching 30% drainage water to maintain the soil permeability.

Figure 2. Distribution of soil salinity in a transverse field cross section through open drains 1.5 meters deep spaced at 150 meters following two years leaching with rice followed by two years irrigated pasture. Alifaki, Tarsus.
(Irrigation Research Institute, Tarsus).

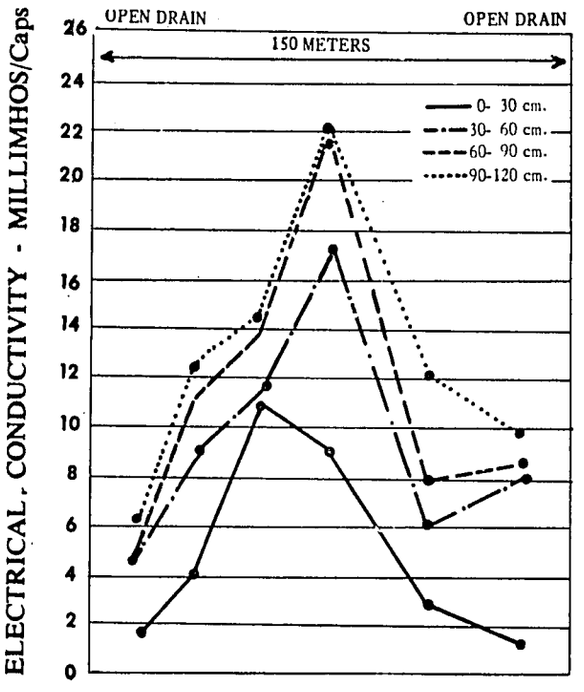

Figure 3. Distribution of soil salinity in a transverse field cross section through open drains 1.5 meters deep spaced at 60 meters following three years leaching of rice. Alafaki, Tarsus.
(Irrigation Research Institute. Tarsus)

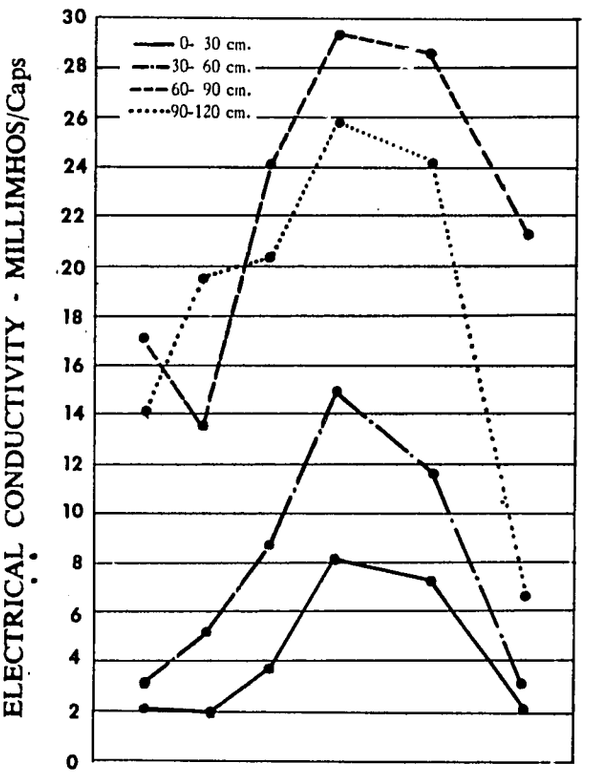

TABLE 9. EFFECT OF TWO YEARS OF LEACHING WITH RICE FOLLOWING IRRIGATED PASTURE ON SOIL SALINITY (HELVACI CLAY), ALIFAKI-TARSUS. (IRRIGATION RESEARCH INSTITUTE-TARSUS).

Treatment and Dates of Sampling	Total Soluble Salts - Per cent			
	0-30	30-60	60-90	90-120
Before leaching (April 12, 1957)	0.36	0.44	0.50	0.55
After first rice Crop (Nov. 11, 1957)	0.26	0.32	0.46	0.51
After second rice Crop (Nov. 5, 1958)	0.13	0.19	0.25	0.25
Before pasture (April 8, 1958)	0.16	0.23	0.26	0.28
After one year pasture (Nov. 5, 1958)	0.12	0.17	0.16	0.17
After two year pasture (Mar. 17, 1959)	0.09	0.14	0.16	0.15

TABLE 10. EFFECT OF IRRIGATED PASTURE EST ' ISHED ON NOVEMBER 6,1957, FOLLOWING TWO YEARS OF LEACHING WITH RICE ' N SOIL PH AS A CRITERIA OF ALKALINITY (HELVACI CLAY). (IRRIGATION RESEARCH INSTITUTE - TARSUS).

Depth of Sampling (cm.)	Dates of Sampling				
	Ap. 8, 1958	Nov. 5,1958	Mar. 7, 1959	Oct. 6,1959	Ap. 28, 1960
0-30	7.8	8.0	7.7	7.3	7.0
30-60	7.9	7.9	7.7	7.8	7.8
60-90	7.7	7.7	7.7	7.7	7.8
90-120	7.8	7.8	7.8	7.8	7.8

TABLE 11. GROUNDWATER AND SALINITY INDICATOR PLANTS IN THE ALIFAKI AREA (SALINE-ALKALI WET AND HEAVY SOILS - HELVACI CLAY - ALIFAKI) (IRRIGATION RESEARCH INSTITUTE - TARSUS).

Plant	Drainage and Salinity Characteristics		Relation of the Indicator Plants with Soil Salinity and Watertable
	Salinity EC x 10)	Depth to Water-table cm.	
Typha Latifolia (Cattail)	5-8	0-20	Waterlogging
Tamarix Gallical (Tamarisk)	30-35	50-60	High water table and wet profile
Prosopis Stephaniwna (Mesquito)	7-10	100-150	Low water table and salinity where it is vigorous
Statice Limonium (March Rosemary)	7-10	25-75	High water table or wet profile and low salt
Salicornia Herbacea (Samphires)	30-50	25-90	High water table or wet profile highly saline
Cressa Cretica (Cressa)	10-30	50-100	High salinity

TABLE 12. EFFECT OF WINTER RAINFALL ON SOIL SALINITY AT FIELDS LEACHED WITH RICE IN 1957 AND 1958, TARSUS-ALIFAKI (IRRIGATION RESERCH INSTITUTE-TARSUS)

Date of Sampling	Rainfall	Total Soluble Salts-Per cent			
	(mm)	0-30 cm.	30-60 cm	60-90 cm	90-120 cm
Nov. 11, 1957		0.26	0.32	0.46	0.51
May 12, 1958	502.9	0.08	0.16	0.30	0.22
Mar. 20, 1959	433.9	0.06	0.09	0.12	0.12

TABLE 13. EFFECT OF WINTER RAINFALL ON SOIL SALINITY UNDER VARIOUS AMEND MENT TREATMENTS, TARSUS-ALIFAKI. (IRRIGATION RESEARCH INSTITUTE-TARSUS).

Treatment	Before being leached with rain ECex 10^3			After being leached with 333 mm rainfall ECex 10^3		
	0-30	30-60	60-90	0-30	30-60	06-69
Check	23.97	36.66	35.02	2.61	18.66	29.32
Gypsum (460Kg/Dk)	26.18	32.45	38.85	2.49	16.59	18.99
Sulphur (64Kg/Dk)	51.83	38.59	32.35	2.68	17.77	18.41
Manure (2800Kg/Dk)	36.28	44.18	43.92	2.26	19.50	28.29

TABLE 14. EFFECT OF WINTER RAINFALL (522.6MM) ON SOIL SALINITY (ECex10³) UNDER ARTIFICIAL DRAINAGE WITHOUT ANY LEACHING AND AMENDMENT APPLICATION, TARSUS-ALIFAKI. (IRRIGATION RESEARCH INSTITUTE-TARSUS).

Depth of Sampling	Sampling Dates		
	Nov. 8, 1960	May 30, 1961	Nov. 19, 1961
0-30	16.85	6.36	7.66
30-60	20.29	19.13	15.56
60-90	23.37	24.34	18.95
90-120	22.19	23.43	18.60

TABLE 15. EFFECT OF WINTER RAINFALL ON EC X 10 OF THE AMENDMENT APPLIED AND LEACHED PILOTS, MENEMEN-KESIKKOY. (SOIL AND FERTILIZER RESEARCH INSTITUTE-ANKARA).

Treatments	After artificial leaching but before winter rainfall			After 453 mm winter rainfall		
	0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm
Light leaching check	4.79	23.33	59.26	2.44	13.02	37.94
Sulphur	4.30	7.26	2.41	2.69	2.05	1.79
H2SO4	2.83	13.85	45.31	1.87	1.86	1.96
Ca SO4	3.70	3.71	8.40	1.06	1.79	2.20
Heavy leaching check	2.50	2.51	1.54	1.03	1.21	1.18
Sulphur	5.53	3.64	2.80	1.66	1.93	2.07
Ca SO4	2.19	2.82	2.82	1.09	1.62	1.35
Manure	4.28	6.78	19.91	2.14	2.75	6.01

ture on soil salinity on large field plots encircled by open drains can also be observed in figures 2 and 3. The natural gypsum content of these heavy saline-alkali soils is of great advantage for reclamation procedures. Except for the first 20 cm, the soil profile down to one meter in depth indicates negative SCR values, according to SCR = Exc. Na+ —

$CaSO_4.2H_2O$, where all values are «m.e/100 gr. soil» units.

(b) **Groundwater and Salinity Indicator Plants:** The survey to determine the groundwater and salinity indicator plants in Alifaki was initiated by Prof. Hikmet Birand and Muzaffer Alap in 1952, and later extended and developed by Muzaffer Alap and Ozdemir Beyce in 1959; it was published in 1960. Table 11 lists the grounwater and salinity indicator plants of the Alifaki area.

III. CONCLUSIONS

A. Survey and experimental results indicate that the cause of salt accumulation in Turkey is the lack of sufficient surface and subsurface drainage rather than-with a few exceptions-parent material and climate. At all experimental plots, winter rains leached remarkable amounts of salts following artificial drainage, as is shown in Tables 12, 13, 14 and 15.

B. Application of chemical amendments hastens the removal of salt and alkali. Significant lowerings were also obtained in check plots and leaching with a crop treatment. At Tarsus, 250-300 Kg/Dk of rice crop could be obtained along with the leaching of salts in the first year. According to these reliable experimental results, the cures for Turkey's salt-affected soils may be listed as follows:

1. Artificial subsurface drainage is essential for reclamation.
2. Fortunately, Turkey's alkali soils are rich in Ca salts. Established rice, pasture or green manure crops or the application of organic matter will correct the undesirable physical and chemical properties through their effects on natural Ca salts.
3. To maintain soil permeability and increase the solubility of less-soluble Ca salts, drainage water or saline waters mixed with leaching water on artificially drained saline-alkali soils are beneficial during the initial phases of leaching.

C. The two research institutes mentioned here will direct their future studies to determination of the reclamation potentials of saline and alkali soils located in other parts of Turkey, along with plant-soil-and-climate relationships in problem areas.

D. The Topraksu General Directorate, relying on the results given have and on future studies, will undertake the reclamation of abandoned soils for the welfare of Turkish farm people in such a way as to provide them with better food and living standards.

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Part II

CONSUMPTIVE USE RESEARCH

I. INTRODUCTION

The consumptive use of water involves problems of water supply, both surface and underground, and watershed management as well as those relating to the management and economics of multiple-purpose water projects such as those for irrigation, power, flood control and municipal use.

The results of monthly determinations of evapotranspiration (consumptive-use) for irrigated crops may be employed to plan irrigation schedules and to estimate irrigation water requirements for each crop for maximum production. Data on the monthly use of water by vegetation are essential in planning irrigation systems in arid and semi-arid regions.

The term «consumptive use» or «evapotranspiration» includes all transpiration and evaporation losses from land on which there is vegetative growth of any kind, plus evaporation from free land and water surface.

Consumptive use is the best index of irrigation water requirements. The term «irrigation water requirements» refers to the amount of water, exclusive of precipitation, that is needed for the production of crops. It includes plant transpiration, evaporation, deep percolation, and other economically unavoidable wastes.

A large part of the irrigation water applied to farm land is consumed through evaporation and transpiration. In field measurements it is hard to separate evaporation from transpiration and the two processes are usually considered as one and called evapotranspiration or consumptive use.

Actual measurements of consumptive use for each of the physical and climatic conditions of any large area are expensive and time-consuming. The results of such research and measurements, along with meteorological observations, provide basic data for computing water requirements for irrigated lands where few or no data except climatological ones are available.

A number of formulas — namely, Blaney-Criddle, Hargreaves, Penman, Thorwaite, Turc, etc. have been developed to compute consumptive use values using meteorological data for similar areas. The one most widely used is the Blaney-Criddle formula.

In Turkey research work on this subject started with the establishment of irrigation research institutes or irrigation experiment stations in 1948. There are now two working research institutes (at Tarsus and Menemen) and two experiment stations (at Eskisehir and Çumra) and their substations. During their early years these experiment stations lacked necessary laboratories and equipment. Therefore their experiments were concentrated on the amount of irrigation water, needed irrigation frequency, irrigation time, and number of irrigations. The Tarsus Irrigation Research Institute initiated consumptive use studies in 1957, having completed the required laboratory.

II. STUDIES OF THE TARSUS IRRIGATION RESEARCH INSTITUTE

A. The Irrigation Water Requirement of Cotton Plants

1. **Purpose**
   a. To find the proper irrigation time and frequency for cotton.
   b. To determine the consumptive use and irrigation water requirement of cotton.

2. **Location.** 36°.55" north latitude, elevation 11 meters. Soils: deep alluvial clay-loam soils of medium permeability. Water table below two meters.
3. **Methods.** A 5 X 5 Latin square design is applied with 18.34 X 9.35 = 171.5 square-meter plots. Side effect is eliminated during the harvest by taking a 125-sq.m. plot size.
4. **Treatments.**
   a. Check (non-irrigated).
   b. Soil moisture near field capacity up to boll stage. From boll stage to boll-opening stage irrigated when soil moisture drops to wilting point.
   c. Irrigated when the available moisture of the 0 - 60 cm. soil depth drops to 50 per cent.
   d. Irrigated when available moisture drops to the wilting point up to boll stage. Following the boll stage, soil moisture near field capacity.
   e. Irrigated when the plant leaves show indications of wilting at 8 o'clock in the morning.
5. **Duration.** Three years (1957-1959).
6. **Seeding.** Cotton seeds are drilled with 85-cm row spacings. Tinned to 25-30 cm. on the rows
7. **Cotton Variety.** The variety seeded was Acala 130/292. It was the selection of the Adana Cotton Breeding Institute and was seeded widely in Çukurova. Now Coker 100 is taking its place.
8. **Soil Moisture Control and Irrigation.** Soil moisture samples were taken weekly from one plot of each treatment from the time of seeding to the time of harvest. Soil moisture samples are taken down to a 90cm soil depth with 30 cm intervals. Three samples representing each depth were taken to the laboratory for measurement of moisture content. Tensiometers were also installed in the plots. Time of irrigation was decided according to the moisture content at a 0-60 cm soil depth, where the plant roots are most dense.

   The amount of water applied was estimated as sufficient to bring a 0-90 cm soil depth to field capacity, and water was measured by using recording water gages while irrigating. Twelve faucets were installed on an iron pipe, with each faucet opening to a furrow. Water passing through the water gage and the pipe was delivered to the furrows, with these faucets using a portable motor-pump.

   Soil moisture before seeding and after harvest, and amount of precipitation during the growing period, were measured and recorded.
9. **Cultural Practices.** The experimental plots were handled with the farming methods usual in the region, such as listing, hoeing, furrowing, spraying and dusting. No fertilizer was used for three years.
10. **Conclusion.** Statistical analyses were made each year of seed cotton yields for each treatment. The highest yields were obtained from Treatment C for the three years, followed by Treatment B. The same results were true for all three years. Degrees of variation were even significant at the one per cent level. The conclusions reached are:
    a. There is a significant variation among the treatments.
    b. Cotton yields are increased by irrigation in Çukurova. The highest yields are obtained by maintining the available soil moisture above 50 per cent. From four to five irrigations are required to keep the moisture at this desired level.
    c. The consumptive use of cotton within a growing period under irrigated conditions varies from

480 to 692 mm, and is approximately 554 mm. The highest consumption is in July and August, this is the flowering and boll period of the cotton. Within that period daily consumptive use is about 8 mm.

Three-year results of the experiment are summarized in Table 16. The influence of the groundwater is probably for the first year.

11. **Monthly Consumptive Use.** The values for Treatment C, which provided the highest yields, are used to estimate the monthly consumptive use. The estimates are based on soil moisture contents, amount of irrigation water applied and precipitation within the seeding-harvest period.

The values obtained by using 1958 and 1959 records are given in Table 17.

12. **Monthly Consumptive Use Coefficients.** Monthly consumptive use coefficients for cotton are estimated by the Blaney-Criddle formula using meteorological records. This formula in metric units is:

U is k.f.

f is $\frac{P}{100}$ (1.8 t + 32) 25.4

U is seasonal consumptive use (mm)

u is monthly consumptive use (mm)

f is monthly consumptive use factor

t is monthly mean temperature (C°)

k is monthly consumptive use coefficient

p is the monthly per cent daytime hours of the year

TABLE 16. THE MEASURED MONTHLY CONSUMPTIVE USE OF CONTROL.

Treatments	Yields (Seed Cotton) kg/Decare	Seasonal Consumptive Use, mm.	Seasonal Irrigation Water, mm.	Number of Irrig.
A	87	166	—	—
B	141	443	295	3-4
C	153	585	432	5
D	109	434	304	3
E	90	164	—	—

TABLE 17. MONTHLY CONSUMPTIVE USE OF COTTON IN 1958-1959

Month	1958 mm	1959	Remarks
April	42	20	Consumptive use for 22 days
May	100	60	
June	136	78	
July	180	151	
August	188	149	
September	46	48	Consumptive use for 25 days
October	—	6	Consumptive use for 6 days
Total for growing period	692	511	Growing period 170 days in 1958, 180 days in 1959

TABLE 18. MONTHLY CONSUMPTIVE USE COEFFICIENTS, K. FOR COTTON IN 1958.

Months	t	p	f	u	$k \frac{u}{f}$	Remarks
April	16.9	8.85	100	42	0.40	22 days
May	21.4	9.81	176	100	0.60	
June	24.2	9.83	190	136	0.70	
July	26.5	9.99	229	180	0.80	
August	27.7	9.40	197	188	0.95	
September	23.7	8.36	135	46	0.35	25 days
Total Seasonal	—	—	1027	692	0.67	170 days

TABLE 19. MONTHLY CONSUMPTIVE USE COEFFICIENTS, K, FOR COTTON IN 1959.

Months	t	p	f	u	$k \frac{u}{f}$	Remarks
April	17.6	8.85	105	20	0.20	22 days
May	21.3	9.81	175	60	0.35	
June	23.9	9.83	187	78	0.45	
July	26.5	9.99	202	151	0.75	
August	26.7	9.40	191	149	0.80	
September	23.0	8.36	156	48	0.30	
October	18.2	7.85	25	6	0.25	6 days
Total Seasonal	—	—	1041	511	0.50	181 days

B. **Irrigation Water Requirement of Peanuts**

This experiment was conducted to terminate an experiment made in 1954-1956. This pre-testing indicated that highest yields are obtained with four 100-mm applications. The purpose of the following one-year experiment was to determine the irrigation frequency and consumptive use of peanut plants. The experimental plots were located on deep alluvial clay-loam soil with medium permeability and a water table below 120 cm. A 4 X 4 Latin square design was used. The treatments were:

1. Four 100-mm water applications.
2. Irrigated when the available moisture of the 0-60 cm. soil depth dropped to 50 per cent of field capacity.
3. Irrigated to keep the available moisture of the 0-60 cm. soil depth near field capacity up to the formation of gynophores. From the formation of gynophores to harvest, irrigated when available moisture drops to wilting point.
4. Irrigated when the available moisture of the 0-60 cm. soil depth dropped to wilting point up to the formation of gynophores. From the formation of gynophores to harvest, irrigated to keep the available moisture near field capacity.

Plot sizes were 7 X 18 = 126 sq.m. during the seeding and 5 X 16 = 80 sq.m. at harvest. Moisture controls, irrigations, records and sta-

tistical analyses were similar to those for cotton.

Statistical analysis indicated that Treatment B provided the highest yields and was significant at the 1-per cent level.

The experimental results are summarized in Table 20.

Soil moisture, irrigation, precipitation and meteorological records for Treatment B were used to estimate the monthly consumptive use and coefficients, using the Blaney-Criddle formula. The results are given in Table 21.

C. **Irrigation Water Requirement of Tomato Plants**

This experiment was conducted at the Tarsus Irrigation Research Institute in 1958-1960. The purpose was to determine the irrigation frequency and irrigation water requirements of tomato plants. Experimental plots were located on deep, alluvial clay-loam soils with medium permeability and a water table below 2 m. A 5 X 5 Latin square design was used. The treatments were as follows:

1. Irrigated when the available moisture of the 0-60 cm soil depth dropped to 50 per cent all through the growing period.
2. Irrigated when the available moisture of the 0-60 cm soil depth dropped to 50 per cent up to the formation of fruit. From the formation of fruit to harvest, irrigated at 25 per cent of the available moisture.
3. Irrigated when the available moisture of the 0-60 cm soil depth dropped to

TABLE 20. RESULTS OF CONSUMPTIVE USE EXPERIMENTS FOR PEANUTS.

Treatments	Yields Klg/Decare	Seasonal Consumptive Use, mm.	Seasonal Irrigation Water, mm.	Number of Irrigations
A	203	563	400	4
B	222	475	330	8
C	150	384	236	5
D	196	462	328	7

TABLE 21. MONTHLY CONSUMPTIVE USE COEFFICIENTS, K, FOR PEANUTS IN 1957.

Months	t	p	f	u	$k \frac{u}{f}$	Remarks
April	20.5	8.85	105	43	0.30	22 days
May	20.5	9.81	171	68	0.40	
June	25.6	9.83	195	79	0.40	
July	27.4	9.99	206	97	0.50	
August	27.6	9.40	195	100	0.50	
September	25.4	8.36	165	62	0.35	
October	22.1	7.85	72	26	0.35	15 days
Total Seasonal	—		1109	475	0.45	190 days

TABLE 22. CONSUMPTIVE USE COEFFICIENTS FOR TOMATOES.

Months	1958			1959			1960			Average for three years	
	u	f	$k = \frac{u}{f}$	u	f	$k = \frac{u}{f}$	u	f	$k = \frac{u}{f}$	u	k
April	30 (a)	42	0.70	–	–	–	–	–	–	90	0.70
May	207	176	1.20	135 (c)	141	0.95	75 (c)	120	0.65	139	0.95
June	255	190	1.34	178	187	0.95	180	190	0.95	204	1.10
July	228	229	1.00	203	202	1.00	195	206	0.95	209	1.00
August	85 (b)	96	0.90	113 (d)	146	0.80	–	–	–	141	0.85
Total Seasonal	805	733	1.10	629	677	0.95	450	516	0.87	783 (g) 628 (h)	0.95 1.00

(a) Consumptive use for 10 days in April – 1958
(b) Consumptive use for 15 days in August – 1958
(c) Consumptive use for 25 days in May – 1959
(d) Consumptive use for 24 days in August – 1959
(e) Consumptive use for 20 days in May – 1960
(g) Expected mean consumptive use maximum 5 mont growing period.
(h) Mean consumptive use for 103-day growing period.

25 per cent up to the formation of fruit. From the formation of fruit to harvest, irrigated at 50 per cent of the available moisture.

4. Irrigated when the available moisture of the 0-60 cm soil depth dropped to 25 per cent all through the growing period.
5. Check. Irrigated only once for transplanting. The Redcloud variety (origin U.S.A.) was used because it has given high yields and good quality in the region. Moisture control and irrigation records and statistical analyses were similar to those for cotton. The statistical analysis was based on yields. Highest yields were obtained from Treatment 2. The yields varied from 2.000-4.000 kg/dk. Six to eight irrigations were required for best results. The consumptive use for Treatment 2, from transplanting to harvest each year, the three year averages for monthly and seasonal consumptive use, and the consumptive use coefficients are given in Table 22.

D. Consumptive Use of Bean Plants

In 1960, the consumptive use of soybeans (origin: Germany) was determined by the soil moisture depletion method. Two irrigations were made within the two-month growing period. Bean plants used 204 mm water.

Monthly and seasonal consumptive use and consumptive use coefficients are summarized in Table 23.

E. Present and Future Studies

In addition to those experiments discussed above, the Tarsus Irrigation Research Institute is conducting the experiments listed below which will make some consumptive use data available:

1. Experiments with three factors: variety, fertilizer and water, in one single design on cotton and tomatoes.
2. Experiments with two factors, fertilizer and water, in one single design on beans and strawberries.
3. Determining the consumptive use of mandarines and oranges.
4. Determining the consumptive uses of the other crops of the region by the soil moisture depletion method.

Discussion: The average soil mosture in the upper 60 cm. was used as a criterion for determining time of irrigation. Where amendments are required, the cost of reclamation is difficult to estimate because gypsum is not now available on a mass-produced basis. One alkali area is in Western Turkey, as reported by Bozkurt, on the Menemen Plain. Further reclamation appears feasible by simple leaching by the winter rains. For the organic soils in Southern Turkey, successful reclamation resulted from using gypsum. As to time of reclamation at Menemen, they were successful in two years. A topographic map shows that all of the problem locations have poor drainage. Most involve surface and sub-surface drainage. It is difficult to find drainage outlets. High priority must be given to reclaiming and preventing salinity in fertile soils. The farmers

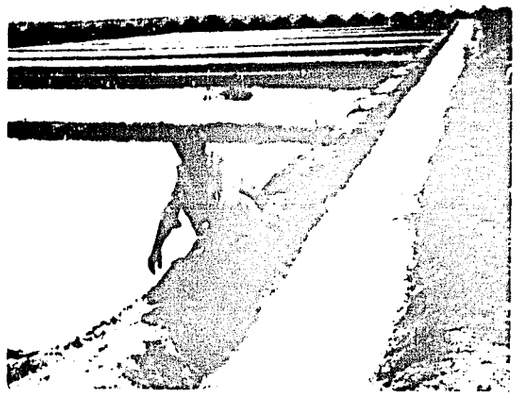
TABLE 23. CONSUMPTIVE USE OF SOYBEANS, 1960.

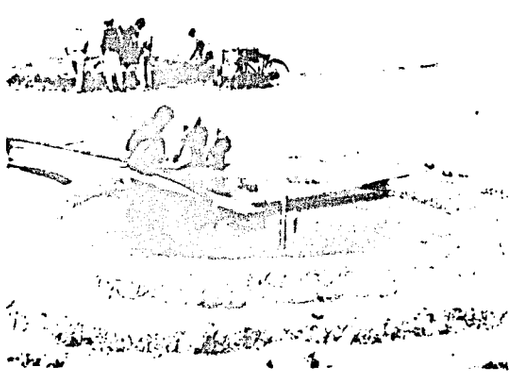
Months	u	f	$k = \frac{u}{f}$
May	108	184	0.60
June	98	190	0.50
Total Seasonal	206	374	0.55

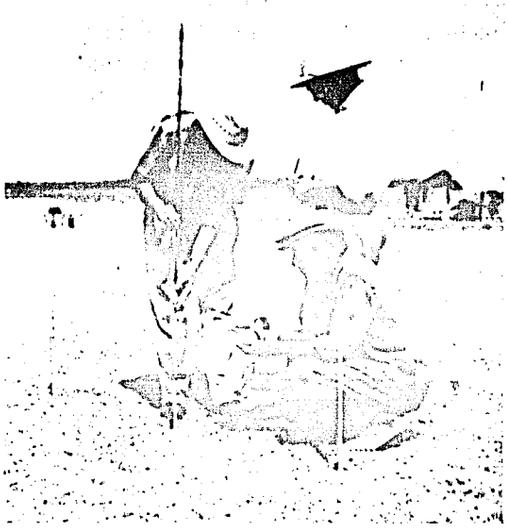
are very much interested in reclaiming their soils. However, the first step is to provide trunk drainage outlets so that this will be possible.

Boron is found in many places, especially near volcanic areas or areas of volcanic springs. The level to which boron must be lowered depends on the crop. For citrus it must be very low. The greenhouse is studying the boron tolerance of various crops and it is hoped that these results will be published this year. The literature shows that more water is required to lower boron than for salinity. Good results have been obtained in leaching boron. Dr. Asghar feels that green manure has no effect on lowering exchangeable sodium and it is also difficult to grow green manure on sodium soils.

Soil and Fertilizer Research Institute – ANKARA







Irrigation Research Activities

PROGRESS OF LAND RECLAMATION IN WEST PAKISTAN

by

Dr. A. G. Asghar

Land reclamation research in West Pakistan since the last Seminar continued on the following subjects:

(1) Water quality.
(2) Salt tolerance of crops.
(3) Consumptive use.
(4) Re-appearance of salts after reclamation.
(5) Lysimeter studies — crop planning for salinity control.
(6) Economics of land reclamation.
(7) Feasibility of cropping patterns.
(8) Agronomic practices.
(9) Salinity statistics—sample salinity survey.
(10) Drainage studies.

A brief statement of the results of these studies is given below. Detailed discussions on the subjects are given in the various research publications.

(1) Water Quality

(i) Saline characteristics of waters in old canal colonies of West Pakistan.[1]

Chemical quality of waters from surface sources, shallow and deeper aquifers in old canal colonies of West Pakistan has been described. The saline characteristics of waters in different areas manifesting distinct properties have also been traced and their geochemical origin studied. The river waters are of very good quality and the waters available in high water-table areas are such that these can either be used for irrigation directly or by mixing with canal water in 1:1 ratio. The areas near the rivers where over-spills often take place,, have good quality water. Seepage from canal also effects the water quality favourably. The saline characteristics of concentrated waters in Rechna Doab are different from those of Chaj Doab. In Chaj Doab the highly mineralised waters bear direct relation with sea waters while those in Rechna Doabs reveal that they are the result of solution of a saline residue and waters from surface sources.

(ii) An exhaustive note was submitted to the West Pakistan Flood Commission containing detail of the amount of soluble salts drained by the Indus and is tributaries during the snow melt period, during monsoon rain when land wash predominates into the river flow and during the six winter months when some contribution takes place from the valley storage and salts of the alluvium deposited in soils are also drained into the water. [2]

(iii) A brief note giving the salt content of the Indus and its tributaries up to Kurrum was published in the Indus.[3]

(iv) It is generally believed that working of deep tube-wells will deteriorate the aquifer and convert its water into saline. Data of the 1500 tube-wells of Rasul Project were collected. A comparison of conductivity of their waters observed in 1946 or 1954 with that existing in 1961 showed that except in areas with highly saline ground water, where the conductivity has increased by 30 to 60 per cent, in all other areas the increase in conductivity was within 10% and in some cases improvement in conductivity up to 30% was noted.[4]

The conception that generally the water quality of acquifer improves by pumping has been confirmed from tube-wells working in highly saline water of Gaja areas which has exhibited improvement in water quality after working for about 11 months.[5]

(2) Salt Tolerance of Crops

Information in respect of the salt tolerance of food and fibre crops of West Pakistan is meagre. Studies were carried out to get information on the salt tolerance of Egyptian clover (Berseem), gram and barley.[6]

Berseem, gram and barley were sown in non-

salinized plots at the usual sowing time. Salinization of the soil was achieved by applying saline water of 19 different qualities prepared by the addition of sodium chloride, sodium sulphate, sodium bicarbonate, calcium chloride and magnesium sulphate in different proportions. Three replications were provided for each treatment, including the control. In all, 60 plots were used for each crop. In the control plots groundwater was used.

Egyptian Clover (Berseem). The yield of the crop under different saline irrigations indicates that there is a decrease in yield with the increase in the conductivity of the irrigation water. At 1500 conductivity there is about 4% decrease. The yield decreases by 52% at a conductivity of 8000.

Berseem like sugarcane is a high delta crop. It is significant that in both these crops the yields fall by about 50% at 8000 conductivity.

Gram. The yield of the crop decreases with increase in the conductivity of the irrigation water. At 1500 conductivity a decrease of 5% has been observed and at the highest conductivity of 10.000 the yield is reduced by 55%.

Barley. The decrease in yield of the crop is similar to that of gram. Like gram this is also a low delta crop.

The curves of berseem, gram and barley interset each other at a conductivity of 8000. Before and beyond this point of intersection all the three curves follow an independent path. This is significant as it indicates that at 8000 conductivity the crops are effected to a similar degree. For the sake of comparison, the results for wheat, cotton and sugarcane are also reproduced.[7]

Accumulation of salines. The drainage provided in each case was 6.3%. 5.9% 19.35% and 26.37% in case of berseem, wheat, cotton and sugarcane respectively, of the consumptive use of water required for the growth of crops. Even with this excess delta the accumulation of salines has been observed, for the of different crops as under:

1. Berseem	=	.08%	at conductivity of	2000
2. Wheat	=	.01%	»	»
3. Cotton	=	.03%	»	»
4. Sugarcane	=	.02%	»	»
5. Barley	=	.075%	»	3500
6. Gram	=	.025%	»	3500

According to the formula for determining the leaching requirement given by U.S. Salinity Laboratory, assuming the permissible conductivity of drainage water as 8000 the leaching requirement with conductivity of 2000 works out to 25%. In the present study it has been observed that even up to a drainage of 26.37% for sugarcane water of conductivity of 2000 causes accumulation of salines in the soil. The computation does not take the salt content of the soil into consideration for which the leaching requirement would be additional.

(3) **Consumptive Use and Application**

(i) Knowledge of optimum water requirements for different crops under variable soil and meteorological conditions is essential to grow successful crops. In order to supply these requirements it is also essential to use efficient irrigation practices so that there may be minimum wastage of irrigation water. The water requirements for crop production are generally considered to consist only of the moisture requirements for growth of the plant. The soil problems that arise in arid regions have beyond doubt shown that for sustained crop production the water requirements consist also of the requirements of the soil. However, information on the first mentioned requirement which goes under the name of consumptive use has got to be obtained to supply the soil its full requirements.

Work to determine the consumptive use of water by different crops and the efficiency of different irrigation practices has been taken up at some of the experimental farms of the Land Reclamation Directorate. The results obtained for cotton crop at the Jagattan Farm in Lyallpur District are reported.[8]

Consumptive use of moisture by the crop was studied using three irrigation practices, viz, furrow with syphon, furrow without syphon and flooding with results of 19.93", 20.24" and 21.09" respectively. The consumptive use was 76, 80 and 77 per cent of the moisture supplied by irrigation and precipitation. This shows that the moisture holding capacity of the soil in the plots under different irrigation practices as well as the consumptive use was more or less equal.

The efficiency of irrigation by the different methods was 75 per cent, 67 per cent and 53 per

cent respectively for the three irrigation methods. The difference between moisture applied and moisture stored in the root-zone represents the conveyance losses at the farm, surface evaporation losses and deep percolation which is desired for leaching down salts in the soil profile. Basing calculations on the work of Blench, about 27 per cent of the water-course supply may be the absorption loss.[6] Another 10 per cent may be lost by evaporation. Deep percolation from the irrigation plot would, therefore, be nil in the first two methods and about 10% in the case of flooding. Even this 10%, may not serve the leaching objective if the application is not uniform and the moisture distribution even. The yields of seed cotton obtained were 1014 lbs., 979 lbs. and 868 lbs. per acre for furrow with syphon, furrow without syphon and flooding, respectively, and this indicates more uniform moisture distribution and intake of water with the first method.

Calculations of the consumptive use of water by crops have been made by application of the Blaney-Criddle formula.[10] The values of temperatures obtained from different stations are averages of the last ten years. The percentages of actual day time hours have been calculated from the data available for different stations.

In order to get the value of coefficient K., consumptive use figures of the last 15 years obtained from the lysimeter experiments of the Directorate of Land Reclamation, Lahore, were employed. Soil moisture studies were also conducted at Lahore, Lyallpur and Montgomery to get the values of K., As a result of these and lysimeter studies it was observed that there is a fairly consistent value for K for each crop. The coefficient values so developed have been used to estimate the consumptive use requirements in other areas of West Pakistan.

By the application of the values of **t, p** and **k** consumptive use of water has been calculated for the following crops and stations of West Pakistan.

Crops

Wheat, Cotton, Sugarcane, Maize, Toria, Gram and Lentil, Berseem, Senji, Shaftal, Chari and Guara.

Stations

Lahore, Lyallpur, Montgomery, Multan, Bahawalpur, Khanpur, Khushab, D. I. Khan, Peshawar, Rawalpindi and Sialkot.

Values of consumptive use, net irrigation requirements, irrigation requirements, water requirements have been obtained. The net irrigation requirement has been calculated by subtracting rainfall from the consumptive use. The net irrigation requirements divided by the irrigation efficiency gives the irrigation requirements of the crop. Asghar et al[7] have shown that irrigation water applied with different irrigation practices gives a mean farm irrigation efficiency of 65%. Accordingly calculations of irrigation requirements have been made on 65% irrigation efficiency. This amount of water is required at the outlet headgate. At least 15% more water must be applied to keep the salts depressed. In the crop and soil requirements this additional 15% of water has been included.

In order to arrive at the water requirements, total precipitation during the crop period has also been included. It has been assumed that all the precipitation during the crop period has been consumptively used. In these estimates it has also been assumed that the ground water is beyond the root-zone of the crop and does not make any contribution to the root-zone moisture. For high water-table areas, careful consideration should be given to the amount of moisture supplied to the crop by the ground water reservoir.

The crop and soil requirement data arrived at on the basis explained above for each crop for different stations range between the following values:

Wheat	. .	13.50" to 24.26"
Cotton	. .	30.37" to 49.21"
Sugarcane	. .	51.48" to 84.19"
Maize	. .	19.32" to 28.32"
Rice	. .	52.29" to 70.42"
Toria	. .	13.50" to 22.68"
Gram & Lentil	. .	15.20" to 26.48"
Berseem	. .	42.71" to 58.56"
Senji	. .	30.64" to 44.39"
Shaftal	. .	35.57" to 50.94"
Chari & Guara	. .	36.44" to 41.36"

(ii) Soil Evaporation. An estimation of the order of evaporation from different soils, when water-table is maintained at different depths, is important not only to know the quantity of water lost from soil, but to obtain information on the rise of moisture through a soil column and the accumulation of salts within the root-zones, close to the surface. About two years of experimental investigations conducted in nine tanks, each having 25 sq. ft. surface areas and depths of 5, 10 and 15 ft. and filled with three type of soils, Punjab typical soil, silty soil and fine sand, have shown that there is sharp decrease in soil evaporation with depths of water-table. [11] At a depth of ten feet below surface the rate of evaporation from soils or fine sand is hardly 2 to 5 per cent of the surface evaporation. A 50% reduction of evaporation as compared to that from a free surface takes place when the water-table is at 0.9, 1.2 and 2.0 ft. depths in the fine sand, silty and clay soils. The evaporation is reduced to 25% of the surface evaporation when the water-table is 2.3, 2.8 and 3.5 ft. below surface in the above stated three soils.

If soil or fine sand is saturated to top and then evaporation is allowed to take place, the water-table falls briskly within the capillary zone so that in case of fine sand a fall of 2.0 ft. was registered in 3 days, 2.4 ft. in silty soil and the the same order of fall was noted in clay soil. In case of fine sand, the brisk fall of water-table was soon reduced and it became steady. The brisk fall continued for about 3.5 ft. in silty soil after which it became steady. In case of clay soil the brisk fall continued to about 5 ft. followed by steady slow fall. This study gives an insight into the rate of fall and rise of water-table with seasons. It also proved that wherever, in waterlogged soils, water-table exists at a few feet below surface the pores contain considerable amount of moisture.

Along with these studies recording of soil temperature from surface down to a depth of six ft. was carried out under variation of season and position of water-table. The data on moisture content was also collected. Analysis of both these items is yet to be performed.

(4) Reappearance of Salts after Reclamation of Saline Soils by Leaching

Taylor[12] had come to the conclusion that under excessive irrigation or during rice cultivation if the salts are once washed down beyond 10', with water-table beyond 10', the salts would not move towards the surface and there is no chance of the area going saline afterwards. He thought that a field capacity zone exists between the capillary and pellicular zones which act as a buffer and moisture would not move from the water-table towards the surface. Any salt carrying moisture once having moved from top to the water-table has no chance to come back towards the surface. He based his views on the observations of Keen [13] that the pellicular zone in a soil column cannot go beyond 6' depth. Asghar[14] found that the pellicular zone can be formed to a depth of 11' from the natural surface indirect contact with the capillary zone and under the capillary forces acting at the surface under the Punjab conditions of temperature and humidity. On the basis of this work he had stated that the reclamation of saline areas may never be permanent. Recently Gardner and Fireman[15] have shown that movement and evaporation of water is possible with water-table as deep as 25, 30 feet or more and although the rate is slow accumulation of dissolved salts is possible. It is, therefore, clear that areas once reclaimed can not remain free of salts for a very long period. The salts which have once been washed down below 10' depth appear again near the surface under the action of evaporating forces.

To examine the validity of either of these two observations specific sites in various parts of ex-Punjab where land had been reclaimed from salinity by leaching were put under observation.[16] The results of these observations show that in the presence of a large number of soil variables affecting salt movement a precise correlation on a field scale is difficult to obtain but observations and results show that land once reclaimed can remain free of salts for 6 to 7 years or even for longer periods in some cases but thereafter salts must re-appear on the surface. Experiments on lysimeters have shown that rice, sugarcane and berseem add to the water-table while cotton, wheat, gram and maize

are exhaustive crops with respect to the removal of moisture from water-table during their growth.[17] From uncovered soil, at a mean temperature of 75°F, there is an average evaporation of 18.6" which can cause migration of 650 tons of salt per acre per year to the soil surface. If crops are included which provide some measure of drainage to the sub-soil it is possible to keep the salts depressed for all time and under all conditions. Depressing the salts beyond 10' may be considered just as a safe limit beyond which the salts should be washed down but it must not be regarded as the depth from where the salts cannot reappear at the surface. As a matter of fact to save the labour and money on reclamation it is very necessary to take proper care in soil management and take suitable measures to prevent re-deterioration of soil resulting from upward movement of salts. Only when the means and water resources for permanent reclamation are not available temporary relief may be considered necessary.

(5) **Studies in Lysimeters**

Crop planning for salinity control [18]. This study in lysimeters shows the influence of low cropping intensity and smaller irrigation delta employed for the principal cash crops on the rise of salts in the soil profils and the consequent deterioration of lands in the canal colonies of the former Punjab.

Observing that the exact quantitative amount of accretion or depletion in water-table during any crop cannot be accurately ascertained because the results are susceptible to interference by a number of factors, some estimations were made to arrive at the drainage under the commonly grown crops of the province. The estimations are based on the lysimeter data obtained with water-table at 10.5 feet depth.

The crops, when arranged in ascending order of magnitude of their drainages, occupy the following sequence:

Gram - Toria - Chari (Fodder) - Wheat - Cotton - Maize (matured) - Sugarcane - Rice (unpuddled).

On account of low available irrigation supply the crops falling in the end of above-mentioned series are raised on more extensive scale than those in the beginning with the result that more subsoil moisture is depleted than the additions made to water-table. This favours movement of salts towards the surface.

As a solution it is suggested that the irrigation delta should be enhanced at least to meet the water requirements of crops. The factors affecting the water requirements have been discussed.

Raising the depth of irrigation from 3" to 4" is recommended. The deltas proposed for various crops are given below:

TABLE 1. PROPOSED WATER DELTAS FOR VARIOUS CROPS.

Name of crop.	Growing season			Water delta in inches		Remark
	Sowing time	Harvest time	Average growth period	Practised	Proposed	
Toria	September	Mid January	4½ months	7"	8"	
Wheat	Mid October to Mid November	April-May	6 months	13"	16"	
Gram	September October	April	6 months	4"	8"	4" after rice.
Lentil	October November	April	6 months	4"	8"	-do-

Name of crop	Growing season		Water delta in inches			Remark
	Sowing time	Harvest time	Average growth period	Practised	Proposed	
Barleys	October November	April	6 months	13"	16"	
Oats	October December	April-May	6 months	13"	16"	
Senji	October	March	6 months	25"	32"	
Berseem	October	May	8 months	43"	56"	
Shaftal	October	April	7 months	37"	48"	
Turnips	September October	December	3 months	19"	24"	
Lucern	October November	April-May	8 months	49"	64"	
Maize	April July	July October	4 months	16"	20"	
Rice	June July	October November	3½ months	60"	60"	
Chari	June-July	September October	3 months	13"	16"	
Bajra	June-July	September October	3 months	10"	13"	
Guara	June-July	September October	3 months	13"	16"	
Cotton	May-June	December June	8 months	22"	26"	
Sugarcane	March	January	10 months	64"	84"	
Mong, Moth, Mash	June-July	October November	3 months	19"	24"	

Rotations are prescribed for high and low water-table areas to keep land covered for the maximum period in a year. The suggested rotations for high water-table areas contain Rice coming after three to five years. The possible drainage under various rotations and water duties needed to cater these are shown in the table below:

TABLE 2. WATER REQUIREMENTS FOR VARIOUS CROPPING PATTERNS.

Rotation	Cropping intensity.	Water-duty (acre per (cusec)	Water table Drainage for the rotation	Per year: Surface application	Per year: Total delta	Per year: Add: to water-table
1	2	3	4	5	6	7	8
			Inches	Inches	Ft.	Ft.	Ft.
1. Chari+Guara-Wheat-Maize-Gram	200	292.0	104.02	27	4.3	2.5	1.1
2. Maize-Guara (Green Manured) Wheat-Chari+Guara-Toria		302.1	58			2.4	
3. Chari+Guara-Guara (green manured) Wheat-Maize-Berseem-Cotton	200	177.6	148			4.1	
4. Chari+Guara-Wheat-Cotton/Berseem	200	156.4	156.0	44	6.5	4.7	1.8
5. Guara (green manured)-Wheat-Maize	166	164.3	226.0	81	6.3	4.4	2.3
6. Sugarcane-Sugarcane	100	104.3	212.0	101	8.8	7.0	4.2
7. Maize-Guara (green manured)-Wheat-Cotton/Berseem-Sugarcane	200	136.9	258.01	83	7.2	5.3	2.3
8. Maize-Wheat-Chari-Guara-Gram-Cotton Berseem	200	187.7	206.0	62	5.7	3.9	1.7
9. Cotton-Maize-Senji-Sugarcane	133	168.5	222.0	80	6.2	4.3	2.2
10. Maize-Toria-Cotton/Berseem	200	186.4	138.0	44	5.8	4.0	1.8
11. Chari-Guara-Toria-Cotton/Berseem	200	194.7	134.0	35	5.6	3.8	1.5
12. Mash or Moong-Wheat	200	219.0				3.3	
13. Chari+Guara-Gram-Cotton/Sugarcane	200	182.5	140.0	39	5.8	4.0	1.6
14. Chari+Guara-Gram-Cotton/Sugarcane	133	191.8	202.0	67	5.6	3.8	1.9
15. Rice-Berseem-Chari-Guara-Wheat-Maize-Senji	200	138.3	256.0	87	7.1	5.3	2.4
16. Rice-Lentils-Chari-Guara-Wheat-Wheat-Maize/Senji-Sugarcane	175	159.3	308.02	107	6.4	4.6	2.2
17. Rice/Shaftal-Chari-Moong-Oats-Guara-Wheat	200	164.3	227.03	61	6.3	4.5	1.7
18. Rice/Berseem-Sugarcane-Sugarcane	133	104.3	318.0	142	8.8	7.0	3.9
19. Rice/Gram-Chari+Guara-Toria-Sugarcane-Maize-Senji	175	155.0	314.01	117	6.6	4.7	2.4
20. Rice/Berseem-Chari+Guara-Wheat-Cotton	166	158.3	232.01	68	6.4	4.6	1.9
21. Rice-Wheat+Gram-Cotton/Berseem-Maise/Senji-Sugarcane	175	130.7	356.0	125	7.4	5.6	2.6

Crop patterns are proposed for a cultivator's holding of 12.5 acres in tracts having deep water-table and uneffected by salinity, as well as in high water-table regions. The average duty of water has been worked out to be 150 acres/cusec.

It is estimated that to increase the present water allowance from 3 cuses/1000 acres to the calculated duty of 150 acres/cusec, the quantum of water required will be about double of that supplied at present. This works to about 31 M.A.F. for the area already receiving irrigation in Rechna and Chaj Doabs and if C.C.A. of two doabs is also considered the figures would rise to 34 M.A.F.

Owing to adoption of high intensily rotations and increased irrigation delta, the nutritional stress on the land will be intensified. For sustained high yields, more fertilization of lands will be necessary. Also drainage facilities will have to be improved to cope with the rise in water-table due to greater percolation from the fields as a result of more water application.

(6) A Study in the Economics of Land and Water use in Land Reclamation

(i) A study in the economics of reclamation of deteriorated soils was undertaken at the Ballehwala and Chakanwali Reclamation Farms. It sets forth the methods of investigation and first statement of the results obtained at the Ballehwala Reclamation Farm which represents Bara type of soil in the Lower Bari Doab Colony. [19] The 'Bara' soil is highly compact and intractable alkali soil.

The study brings out data on the economics of crop growing on un-reclaimed, partially reclaimed and reclaimed land for the agricultural year 1957-58 and covers an area of 265.5 acres cultivated by 16 share cropping (Batai) tenants with an average holding of 16.5 acres.

About 2/3rd of the acreage under crops is on reclaimed while about 1/3rd is on partially reclaimed land. The un-reclaimed area under crop is only 5% of the total cropped area.

The basis of deriving the various items of land, labour and capital input have been laid down and the method of recording the data explained.

The gross yields obtained from reclaimed, partially reclaimed and un-reclaimed land show that un-reclaimed land is an impossible proposition. Partially reclaimed soils show much improvement but are still very low in productivity. The yields in reclaimed soils are considerably higher and are more than double in the two most important crops of wheat and cotton.

Costs and return per unit of output reveal that the cost per unit of output is several time higher than the return per unit from un-reclaimed and partially reclaimed soils. The picture is much better in case of reclaimed soil though commercial agriculture is not shown to be very profitable even on this land at the present levels of productivity. Even on lands unaffected by salinity, agriculture does not pay as a commercial proposition because of very low yields in the country. The most profitable crop is berseem in cotton followed by cotton, gram, rice, berseem and sugarcane. Wheat in spite of not being very profitable occupies a very large area as it is almost indispensable as the staple food crop. Of course profitability in agriculture depends upon the prevalent farm prices.

As irrigation water is the most serious limiting factor in agriculture in West Pakistan, the farmer adapts his cropping patterns to the availability of water. The returns per acre-inch of water were highest for gram which of course was due to its abnormally high prices, and low water requirements. At normal price level it would be comparable with wheat. Leaving gram apart wheat is the most economical user of water of all Rabi and Kharif crops which is one reason for the high acreage under wheat. Sugarcane, cotton and wheat-gram are other economical users of water. Rice, berseem, mash and kharif fodder are uneconomic users of water. On partially reclaimed soils and un-reclaimed soil (for wheat) the returns per unit of water are much lower than in case of reclaimed soils. Generally speaking the returns tend to be the lowest in heavy irrigated crops. This accounts for the tendency of the peasants to sow light irrigated crops on partially reclaimed and un-reclaimed soils. This is how the short term interests of the present clash with the requirements for soil improvement.

Detailed cost analysis of crop production reveals that in the reclaimed area the land input generally accounts for 30 to 50 per cent, labour input for 15 to 25 per cent and capital input for 28

to 47 per cent of the total input. This shows that agriculture is not labour intensive but land and capital intensive. For partially reclaimed area the pattern of land, labour and capital inputs is the same as for reclaimed land.

The details of cost of production of individual crops show that in all crops the most important single item of imput is rent. The rents cannot be lowered unless pressure of population on land is reduced by the transfer of population from agriculture to other sectors of economy. Expenditure on bullocks accounts for 1/4th to 2/5th of the total cost of growing a crop. A pair of bullocks on an average worked only for about 415 hours through the year which is a very low figure indicating a whole lot or wastage of bullock labour. Expenditure on manual labour ranges between 10 to 20% of the total cost of production which is low due to the low wages of labour on accounts of the high degree of unemployment and under-employment among the rural population.

An adult male worked for 675 hours during the year which is only 27% of the time considered necessary for full employment. It is here that the main scope lies for increasing the low wages of agricultural labour without raising cost of agricultural production.

The expenditure on fertilizer is negligible which explains to a great extent the low productivity of agriculture in Pakistan.

The analysis carried out is from the point of view of a businessman. Except for cash crops like cotton, sugarcane and a few other crops there are not not net returns per acre worth the name. However, farming pays for the peasant proprietor who does not have to pay exorbitant rents. He will save about 30 to 50% of the cost on rent and another 15 to 20% on the hiring of labour and looking after the bullocks. About 1/3 to 1/2 of the total cost would represent the actual expenditure and the rest would be his gross income. A tenant who has to pay rent only saves 15 to 20% of the total cost by supplying his own domestic labour. The peasant proprietor and the tenant are more interested in gross than in net returns.

(ii) The results of the study of the cost of production of crops during the year 1957-58 at the Chakanwali Reclamation Farm in high water-table area with non-perennial irrigation are reported.[20] Sixteen tenant holdings comprising an area of 205.60 acres were included in the study. The area represents an agricultural economy which depends on a single crop viz, rice. The depth of water-table is maintained below the crop root-zone by an open drainage system consisting of main drains, collector drains and field drains. While the provision and maintenance of main drains is the responsibility of government, the collector drains and field drains have to be provided and maintained by the landlord and the tenant.

A little more than 1/4 of the acreage cropped is on reclaimed, about 1/2 on partially reclaimed and about 1/5 on un-reclaimed land. The cost per unit of output is higher than the return per unit reclaimed, partially reclaimed as well as un-reclaimed land for almost all crops but the deficit is minimum in the case of the major crop of rice. For this crop land input is about 30% labour input about 34% and capital input 36% of the total input. For other Kharif crops and unirrigated Rabi crops, due to the low out-turns, the land input goes down to 10 to 15% capital input rises to 50 to 60% while labour input remains at 30 to 40%. This pattern of input is markedly different from that with perennial irrigation, but still agriculture is capital intensive and not land or labour intensive.

In the case of rice crop the over-all cost of maintenance of bullocks is the most important item which accounts for about 40% of the total cost. With non-perennial irrigation the intensity of cultivation is low while the bullocks have to be maintained the year round. In many cases the size of holding is smaller than a pair of bullocks can cultivate. A pair of bullocks on the average worked for about 500 hours during the year which shows high wastage of bullock labour. Manual labour accounts for about 20-25% of the total cost of production. An adult male worked for about 900 hours during the year which is about 36% of full employment, which indicates a high degree of under-employment and scope for raising the wages of agricultural labour without increasing the cost of production.

While the net income from all the crops including rice is negative from the business point of view,

a peasant proprietor and a tenant make their living on agriculture as the former does not make out of pocket investment on rent and manual labour and the latter on manual labour. The net income per acre depends on the action and interaction of a number of factors. The combinations of factors which resulted in high and low income are indicated.

(7) **Feasibility of Cropping Patterns for Permanent Reclamation and Soil Protection from Salinity in the Indus Valley[21].**

In the choice of cropping patterns for any area, the requirements of the soil for sustained crop production have to be considered. The type of soil and sub-soil, the depth of the sub-soil water-table and the salinity and alkalinity status of the soil determine these requirements.

Drainage should be considered the starting point of all development projects. Control of rising water-table and dewatering of waterlogged area is a basic requirement for sustained crop production. Surface drainage is necessary to cope with the precipitation which sometimes is very heavy. Lowering of the sub-soil water level can be achieved by deep seepage drains or tubewell pumping. The choice of the drainage system rests on the type profile, general slope and other hydrologic features of an area.

As salinity is the foremost problem of the Indus Valley soils the water requirements for cropping have to include the quantity of water required to check the concentration of harmful salts in the root-zone of the soil. In order to maintain an overall downward movement of moisture and dissolved salts, the cropping pattern should be such that it gives about 20% downward drainage of water delta applied in high sub-soil water-table areas and about 10% drainage in deep water-table areas. This makes it necessary to include high water delta crops like rice, sugarcane and berseem in rotations or to apply more than generally practised delta to the common low delta crops. It is also necessary to keep the intensity of cropping as near 200% as possible so that the land does not remain uncovered which promotes quick salt rise to the soil surface. These requirements cannot be met with the water allowance of 1 cusec for 300 acres or more existing on most of the Indus Valley canals. An over-all water allowance of 1 cusec for 150 acres has been suggested for a number of projects of the Soil Reclamation Board. Actually the duty per cusec under arid conditions in countries like the U.S.A. is only 100 acres per cusec or even less.

Economic and social factors have a great bearing on adoption of particular cropping patterns. Scientifically, a cropping pattern may be sound but it may not be feasible in one area due to limitations other than those of water, soil or fertilizer. It is essential that while making recommendations for crop rotations and cropping patterns these other factors should also be considered for their impact on the agricultural economy. This is true for all countries and more so far Pakistan.

For determining the cropping patterns an area can be divided into categories like the following:

(a) Heavy soils with less than 20% salt patches.

(b) Heavy soils with more than 20% salt patches.

(c) Light soils with less than 20% salt patches.

(d) Light soils with more than 20% salt patches.

The following cropping patterns are suggested for these main types of soil for a unit holding of 1.25 acres.

TABLE 3. CROPPING PATTERNS FOR VARIOUS SOIL CONDITIONS.

Cropping pattern for Type (a)			
Kharif		**Rabi**	
Rice	4.0 acres	Wheat	5.0 acres
Cotton	2.0 »	Gram	2.0 »
Sugarcane	1.0 »	Oil seed crop	1.0 »
Maize	1.0 »	Senji in cotton	2.0 »
Fodder	2.0 »	Berseem	1.0 »

Cropping pattern for Type (b)			
Kharif		**Rabi**	
Rice	6.0 acres	Wheat	4.0 acres
Fodder	1.5 »	Gram	2.0 »
Maize	1.0 »	Bersen	2.0 »
Sugarcane	1.0 »	Senji in cotton	1.0 »
Cotton	2.0 »	Oil seed crop	1.0 »
Cropping pattern for Type (c)			
Mash	4.0 acres	Wheat	6.0 acres
Cotton	2.0 »		
Bajra	3.0 »	Gram	3.0 »
Jowar	1.0 »	Berseem	2.0 »
Fodder	2.0 »	Oil seed crops	1.0 »
Cropping pattern for Type (d)			
Same as for Type (c) with preliminary leaching.			

The rotations and cropping patterns suggested are not the final word. Soil conditions differ greatly from field to field and it is for the agronomist to work out details and make changes where necessary.

The croppling patterns, however, must not only be based on the available knowledge of soil science but also be practicable with the labour and economic resources of the cultivator and with the water-supply available.

Labour requirements. The cultivator's family may be assumed to consist of two adult male members, one wife and two minor children. Although his wife and two minor children also give a helping land we will consider the labour hours of the two adult male members only. The available labour hours (at 8 hours per day) would be 480 or 496 in months of 30 days or 31 days.

For the cropping patterns type **(a)** the manual labour requirements (including the manual labour for maintenance of bullocks) range between 70 man-hours in December and 373 hours in the month of October. The labour intensive months are April (239 man-hours) May (260), June (349) and October (373). Although the actual man-hours of family labour available with the cultivator are more than the maximum man-hours required in any month, operations like harvesting of rabi crops and the sowing of cotton have to be completed within a limited number of days and there is pressure of work in April, May and June. Similarly at the time of harvest of paddy in October sowing of wheat and other rabi crops has also to be completed. Therefore, to complete the work within the limited number of days additional labour may be required in the labour intensive months. It is estimated that the labour that a cultivator of soil type **(a)** will have to hire in the months of April, June and October would not be more than:

April	40 man-hours.
June	80 man-hours.
October	80 man-hours.
Total	200 man-hours.

For the cropping pattern type **(b)** the labour intensive months are June (290 man-hours), July (385 man-hours) and October (371 man-hours). The labour that the cultivator will have to hire is:

June	40 man-hours.
July	80 man-hours.
October	80 man-hours.
Total	200 man-hours.

The cropping pattern type **(c)** has the highest labour requirement in May (281 man-hours), June (269 man-hours) and October (367 man-hours). The same are the labour intensive months for type **(d)** — June (306 man-hours), July (283 man-hours) and October (302 man-hours). Both these patterns

would require 56, 48 and 56, man-hours of hired labour in the months of June, July and October respectively.

The cost of the hire labour required for types **(a)** and **(b)** in a year will be Rs. 37.50 and for type **(c)** and **(d)** Rs. 30. The amount of the investment involved is moderate and probably within the cultivator's means in each case.

The bullock hours available with the cultivator per month are 240 or 248. The bullock-hour requirements of the four cropping patterns in each month range between the following:

Type **(a)** Between nil in December and January and 137 in May.
(b) Between 0.8 in December and 155 June.
(c) Between nil in January and 128 in June.
(d) Between 0.6 in February and March and 183 in June.

It is obvious that he will have to hire to bullock labour for any of the cropping patterns.

The working hours per adult male for the whole year for each pattern will be the following:

Type **(a)** 1115 hours.
Type **(b)** 1263 hours.
Type **(c)** 1183 hours.
Type **(d)** 1166 hours.

Taking 2500 man-hours in the year as full employment for an adult male he will be employed for not more than 50% of the time. Under-employment and waste of labour is about double this with the prevalent cropping patterns of low cropping intensity. It shows that even with the high cropping intensities of 168, 172, 176 and 176 under-employment would still be high which can only be put to productive use if the farming methods can be improved and industrial employment (including cottage industries) become available for the under-employed labour.

The bullock labour-hours for the year will be:
Type **(a)** 597 hours.
Type **(b)** 695 hours.
Type **(c)** 764 hours.
Type **(d)** 783 hours.

These again are very low figures which point to the backward farming methods in the country.

Farmer's Income. To see the economic feasibility of the changed cropping patterns one may work out the expenditure and income for each of these. The land, labour and capital input required in each month by a share-cropping tenant for the different cropping patterns as well as the gross income and net income in each case is shown. The gross income is based on the following crop outturns:

TABLE 4. ESTIMATED CROP YIELDS.

Name of crop	Yield per acre	
	Reclaimed	Partially Reclaimed
	In maunds	In maunds
Rice	25	16
Cotton	8	6
Sugarcane	40 (Gur)	32 (Gur)
Maize	20	15
Jowar	10	7
Bajra	10	7
Mash	12	9
Wheat	16	12
Gram	10	7
Kharif Fodder	Rs. 120 per acre	Rs. 100 per acre
Berseem	250 per acre	200 per acre

A net income of Rs. 1,975 can be obtained from an area of 12.5 acres put under cropping pattern type **(a)**. The net income in case of type **(b)** will be Rs, 1,163, for type **(c)** Rs. 644 and for type **(d)** Rs. 766.

However, as the cultivator does not consider the wages of his domestic labour as expenditure he is more interested in the gross rather than in the net income. The income including wages of domestic labour for the 4 cropping patterns would be:

	Rs.
Type **(a)**	2,415
(b)	1,620
(c)	1,070
(d)	1,185

For the peasant proprietor who will not have to pay rent on land the figure of income will be higher than this by the value of rent in kind and will be:

	Rs.
Type **(a)**	4,710
(b)	3,455
(c)	3,770
(d)	2,590

Cash Investment. As the figure for gross income and net income show, the financial resources of the cultivator are not likely to be the limiting factor for following these crop patterns. Water rates and land revenue, seed, manure and fertilizers and hired labour are the items which the farmer has to meet in cash. The expenditure for the year on each of these items for each of the patterns is given below:

TABLE 5. COST IN RUPEES OF VARIOUS FARM EXPENSES.

Crop Pattern	Land Revenue	Water rates	Seed	Manures & Fertilizer	Hired Labour	Total
(a)	79	146	253	168	37	683
(b)	81	159	254	168	37	699
(c)	83	108	135	72	30	428
(d)	83	108	135	72	30	428

As depreciation on bullocks and implements is accounted for, capital expenses on the purchase of a new bullock or implement cannot be included. Although the net income for each of the crop patterns is hand-some the cultivator's expenditure on maintenance of the family and incidental charges on ceremonies like marriage, births and deaths and on purchase of a new bullock or implements can exceed the net income. The necessity for easy credit facilities cannot, therefore, be overlooked. This needs the attention of Government.

Water Allowance. A water allowance of 1 cusec for 150 acres was suggested and has been adopted for the projects of the Soil Reclamation Board in the Rechna Doab. It is necessary to see whether the cropping patterns discussed here can be practised with this water allowance. The table below gives the irrigation delta required by different crops in each month.

TABLE 6. NUMBER OF IRRGATIONS IN EACH MONTH AND TOTAL DELTA REQUIRED FOR DIFFERENT CROPS.

Crop/Month	Jan.	Feb.	Mar.	Apr.	May.	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Depth of Irr.	Total
Rice						2	4	4	1	1			4"	60
CottonCotton					1		1	2	2	1			4"	28
Sugarcane			1	2	3	4	4	3	2	1	1		3"	63

Crop/Month	Jan.	Feb.	Mar.	Apr.	May.	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Depth of Irr.	Total
Maize						1	2	3	1				3"	21
Kh. Fodder crops*					1	2	2	2	2				3"	18
Mash						1	4	4	3	2	1		4"	66
Bajra							2	2	2				3"	18
Jowar							2	2	2				3"	18
Wheat		1	1							1		1	3"	12
Gram	1		1							1			3"	12
Oil seed crop									1	1		1	3"	9
Senji in cotton	2	3	2						1	2	2	2	3"	42
Berseem	3	3	3	1						1	2	3	3"	48
Preliminary Leaching						2	3						4"	20

*Sown at intervals.

The table below shows the total acre inches of water required for each of the 4 crop patterns in each month on the basis of the irrigation schedule given in the preceding table.

TABE 7. ACRE INCHES OF WATER REQUIRED IN EACH MONTH FOR DIFFERENT CROPPING PATTERN FOR A 12.5 ACRE HOLDING.

Crop pattern/ month	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
(a)	27	42	45	12	21	50	91	97	103	61	24	36
(b)	30	39	45	14	20	65	122	27	131	63	24	36
(c)	27	36	45	9	28	70	72	78	62	49	15	36
(d)	27	36	45	41	76	70	72	78	62	49	15	36

With a water allowance of 1 cusec/150 acres the quantity of water available for a 12.5 acres holding will be $\frac{12.5}{150} \times 2 \times 12 = 2$ acre inches a day, 60 or 62 acre inches in a month of 30 or 31 days.

In the months of October to April the total water requirements for any of the 4 cropping patterns are within the available quantum. But in the months of May to September the requirements of one or more of the crop patterns are more than this. However, these are different for the four different categories of soil catered.

The soil survey data for the area of the Soil Reclamation Board Projects in Rechna Doab included in the Salinity Control Project No. 1 of WAPDA shows the percentage of area falling in different soil series as follows:

Soil series	Area in acres	Percentage
Jhang	164,400	12.03
Farida	599,200	43.84
Buchiana	537,000	39.30
Chuharkana	64,800	4.75
Nokhar	1,100	.08

Jhang and Farida are the light soils, Chuharkana and Nokhar are the heavy soils, while Buchiana may be equally divided between the light and

heavy phases. This shows that 75% of the area will be in the light soil category and 25% in the heavy soil category. The proportion of area with more than 20% salt patches is in most cases 20 to 30% but to be on the safe side it may be assumed to be 33%. The proportion of area in each of the four categories will, therefore, be:

(a) Heavy soil with less than 20% salt patches . .	16.66
(b) Heavy soil with more than 20% salt patches . .	8.33
(c) Light soil with less than 20% salt patches . .	50.00
(d) Light soil with more than 20% salt patches . .	25.00

Taking the proportion of holdings in each category as above average water requirements for a 12.5 acres holding for the month of May to September come to the following:

May	=	38	Acre inches
June	=	66	»
July	=	79	»
August	=	90	»
September	=	75	»

In May the overall requirement will only be 38 acre inches against 62 acre inches available. The shortage in the months of June, July, August and September will be 6, 7, 8 and 15 acre inches — 66 acre inches in all. The average monsoon precipitation of 10 inches during the months of July, August and September will account for about 100 acre inches. The only shortage will be 6 acre inches in June before the monsoon season sets in. This means one irrigation to two acres which can be off-set against the surplus in the preceding month of May. This can also be left to a chance shower during the month.

It must be emphasized that the water allowance has to be determined according to the soil conditions which can vary from one holding to another and from one irrigation chak to another. It will also be different with any changes in the crop patterns that may have to be adopted in future. The over-all water allowance for a project may also have to be more or less than 1 cusec per 150 acres where necessary. It is evident, therefore, that the water allowance of 1 cusec/150 acres is by no means the last word on the subject but keeping the available resources in view is a sound recommendation for adoption in the initial stage of development and reclamation projects.

(8) **Agronomic Practices**

(i) Effect of pasture on crop yields[22] — In the United States high yields of crop are obtained after growing a leguminous crop for pasture. The addition of faecal matter by pasturing animals and also the nitrogen fixation by the leguminous crop enrich the soil and raise the crop yields. An experiment was carried out at Chakanwali Reclamation Farm to establish the benefit of this practice. Berseem was grown; cotton was used as index crop after pasture and no pasture. The yield of cotton obtained for the two treatments was as follows:

Treatment	**Yield of cotton.**
Berseem pastured	4 maunds per acre.
Berseem not pastured	3 maunds per acre.

The practice of pasture gave higher yield of the following crop.

(ii) Japanese Method vs. Local Method of rice cultivation[22]. — The yield of rice in Pakistan is very low as compared with other rice growing countries. The average yield is only 11 maunds per acre as compared with 40 maunds per acre obtained in Egypt and 33 maunds per acre in Japan. The method of sowing practised in Japan is reported to be different from the method practised in this country. There a number of seedling are transplanted in bunch at each point as against a single seedling usually transplanted at each point in Pakistan. Trials were, therefore, made at the Chakanwali Reclamation Farm with the Japanese method to see how far the crop outturn can be raised by the use of that method. These trials were made in 1951, 1956 and 1957. The 1955 crop was destroyed by rice borer attack and the results lost their experimental value.

The second experiment was in two sets. In set A there were two variables — the number of seedlings and the dose of ammonium sulphate.

The number of seedlings was 1 to 6. Manurial treatments were ammonium sulphate (100 lbs. per acre) and no ammonium sulphate.

With addition of ammonium sulphate 4 seedling in one year and 5 seedlings in the other gave the highest yield. Without addition of ammonium sulphate 5 seedlings in one year and 2 seedlings in the other gave the highest yield. In 1957 the crop was damaged to some extent by rice borer and therefore, the results obtained in 1956 are more reliable. Four and five seedlings per hole appear to get the maximum yield.

Set B. In this set four seedlings were planted in each hole. The variable were varieties, dates of sowing and manurial treatments.

Varieties—Jhona, Hansraj, Begmi.
Dates of sowing—Jhona—20th June, 1st of July.
Hansraj—1st July, 15 th July.
Begmi—1st July, 15th July.
Manurial —

1. Farm yard manure 12 cart loads per acre.
2. Farm yard manure 12 cart loads per acre plus ammonium sulphate and superphosphate 100 lbs per acre.
3. No manure.

These results obtained in 1956 showed:—

1. Higher yields for earlier sowing dates.
2. Yields increase with application of farm yard manure and increased further with addition of mixed nitrogen and phosphorus fertilizer.
3. The coarser Jhona variety gave higher outturn.

The results in 1957 were not so consistent due to damage by rice borer but the trends are generally in support of the above findings.

(ii) Skip over cultivation of cotton. To determine whether skip over cultivation of cotton increases the yield and if it is practicable a trial was made at the Bhallewala Reclamation Farm near Montgomery and Haveli Reclamation Farm Shorkot for three years.[24] The crop was grown on double row ridges. In 1958 there was 5 rows planted and 5 skipped and in the two years following it was 6 rows planted and 6 skipped. With five rows the increase in yield with skip over was 7% at Bhallewala and 7.4% at Haveli Farm. With six rows the increase was 5.8 and 5% in 1959 and 14.5 and 6.8% respectively in 1960. If more water can be spared for applying to the skipped over rows the increase in yield will be higher than this. The yield of wheat obtained in the skipped over strips at Bhallewala was 12 maunds, 16 maunds and 16.5 maunds per acre during the 3 years. At Haveli Farm it was sown only in 1960 and the yield was 18.44 maunds per acre. This shows that the practice of skip over cultivation of cotton can be recommended for raising the crop out-turn.

(9) Sample Salinity Survey on the Indus Valley Canals[24].

Soil salinity has been taking a rapidly increasing toll of the canal irrigated areas of the Indus Valley. The former Punjab Province served by the older canals was the first to be affected and therefore, the first to take notice of the menace. The need for assessing the extent of damage became pressing in the late thirties. An annual survey of damage caused by salinity and waterlogging in selected villages was initiated in 1927 by the Waterlogging Enquiry Committee through its revenue member, the Waterlogging Assistant to the Financial Commissioners. This survey carried out by the Civil Partwari has continued to date. It started with covering selected estates in selected districts but in time it was extended to the whole area of the canal irrigated districts of the former Punjab. The definition of affected area to be recorded has been modified from time to time.

When the Irrigation Department undertook relief work for affected areas by providing additional water supply for leaching down the salts, priority was given to land in the initial stages of appearance of salt as it could be treated more expeditiously and water resources could be used more economically. The information furnished by the Civil Thur and Sem Girdawari (Salinity and Waterlogging Survey) was not helpful as it did not record damage until it reached the stage when the field becomes unfit for crop production. The Irrigation Department therefore, undertook through its own

Revenue field staff an annual survey of affected area within the canal irrigation boundary, which records the area damaged to the extent of 20% and above per acre unit, into six different classes, three of which represent area gone out of cultivation due to salinity and three affected area under cultivation. The basis of this classification is a rough schedule of period which each class would require if subjected to leaching operations. This survey has been carried on since 1944 and although it has not achieved a high standard of accuracy for a number of reasons it has provided useful basic data on the extent and rate of increase in incidence of salinity.

This type of a province-wide survey involves labour and expense and difficulties of organization. The question, therefore, is very pertinent whether a sample survey could be a safe substitute for such a field to field survey and provide reasonably dependable data for gauging the extent and progressive increase of incidence of the menace. If such a procedure could produce information to a reasonably dependable extent it could be much more efficiently organized and managed than a complete field to field survey.

The annual salinity survey by the Irrigation Department on three randomly selected irrigation channels in each of three canal circles was subjected to per cent check. Statistical analysis of data for the total area affected, area gone out of cultivation, and affected area under cultivation shows that with one exception the population mean is within 99% confidence limits of the sample mean. It is, therefore, concluded that dependable information about the incidence of salinity in a canal can be obtained by a sample survey. For greater accuracy a sample survey can even be arranged by canal Divisions or Sub-Divisions rather than by canal circles.

(10) **Drainage Studies.**

(i) Control of waterlogging. All the ills of waterlogging and salinity are due to lack of drainage. The country has suffered considerably on this account. Of all the drainage measures, tubewell pumping seems to be most suitable for this country as these can give extra water to improve the crops yields and reclaim the land and reduce the high order of salinity of the top soil .A tubewell also quickly lowers the ground water which is filling all the pores of the soil. A large number of tubewells are installed in the country and several studies have been conducted on their hydraulics on design, reduction in cost of installation, durability and yield etc. In the recent CENTO[25] Symposium held at Lahore a Note on the Exploitation of Ground Water dealing with the rising cost of the tubewells and their short life was presented. Detailed results of performance of the existing 1500 tubewells are put forth in a recent reviews[26] on the tubewells. Earlier a similar note was submitted to the West Pakistan Engineering Congress.[27] Some suggestions to install an inexpensive tubewell are given in another contribution.[28]

It has been put forth that for conditions as occurring in the alluvium plains of the Punjab, a coir string type strainer is most lasting and cheap even when installed in highly saline water.[29] Another device is to use multiple strainers connected to the same pumping set, so as to increase the yield, quickly lower the water-table and have a durable long life tubewell.

It has been put forth that the recently developed tubewell technique is superior to even the presently proposed measure of having link canals as drainage channels[30] flowing in deep cuts in the land with full supply close to the natural surface. Such links will be a cause of quick rise in water-table around the land and will do more harm than serving as effective drain channels.

(ii) The major cause of rapid rise in the subsoil water-table in the Indus Basin is considered to be the canal system, one of the biggest in the world. However, no detailed experiments have been carried out to estimate seepage losses and accretion to water-table from the system. Various attempts made to estimate seepage losses were not based on direct scientific observations. The absorption losses can be very different from what is actually added to the sub-soil water reservoir, because a part of the loss will be due to evaporation, transpiration and leakage from the banks, which may never be added to the water-table. The need for measurement of seepage losses by more modern methods was felt to a great extent and it was de-

cided to use lysimeters for this study, where actually physical measurements of not only losses at surface could be made but also the actual addition to the sub-soil water measured with considerable accuracy.[11]

A group of three tanks (A.B & C) measuring 80' × 20' × 12', 60' × 20' × 12' and 20' × 20' 12' respectively was constructed. Tanks A was provided with a half section of a distributary and tank B with a water course. Tank C was kept as control.

To facilitate the filling of the distributary and the water course, a tubewell was installed and arrangements made to pump measured quantity of water in the distributary and the water course. Any rise in water-table, which was kept at first at 11.0' and then raised to 9.5' gradually, was noticed in the manometers provided in a manhole constructed in the middle for this purpose. An evaporation tank and Skelly's rain-gauge were also installed nearby. An air lock was also provided in the water course to study its effects on the rate of seepage.

From the data computed for 10 years (1950-60) the following observations were recorded.

(1) Seepage losses calculated from other methods, do not indicate the actual amount added to the water-table.

(2) Evaporations not only from water surface but also from soil surface plays an important role in determining the water added to the sub-soil reservoir.

(3) Seepage losses from a water course are higher on a percentage basis than those from a distributary.

(4) Introduction of an air locking layer in the canal bed has a reducing effect on the seepage showing that major portion is lost by downward movement through bed. However, this effect is only temporary.

(5) The atmospheric temperature has a direct effect on the seepage losses as well as accretion to the water-table.

(a) Lining of new canals. Canal lining can be a safe-guard against waterlogging and increase in salinity and at the same time effects a saving in the quantity of water. A note on the canal lining as practised in West Pakistan was published in 1960.[12]

The latest technique is that of double tile lining with a layer of bitumen as constructed in the lead race channel of Chichoki and Shadiwal Hydel. It was subjected to a field study and encouraging results were obtained.[13]

(b) Lining of existing earthen canals. The existing operating earthen canals have always been a problem as regards their lining. Their sandy beds are a source of considerable seepage. Besides many other reasons for the difficulty, a few are:

(i) High ground water table above the bed of the canal.

(ii) Difficulty of long closure.

(iii) Wide section.

It seems that a type of lining which may be semi-pervious such as 2 to 5 feet, chick soil, and could be laid while the canal is operating and can resist the scouring action of the canal, will be a suitable measure. Recent investigations have been conducted with these points in view by using bitumenous water emulsion called the cationic[14] asphalt emulsion. This material seems to have hopeful possibilities as it forms a sand mastic under running condition of the canal, penetrates a few inches into the sandy bed and reduces the percolation by 70 to 90 per cent.

Some other such materials under the trade names of S.S. 13 and Chevron are now also being brought into the field and perhaps one may prove suitable for lining existing earthen canals.

Discussion. Soil samples are taken in connection with the soil reclamation process, but not for gross classification. Dr. Asghar feels that salts kept below six to eight feet in depth do not affect crops. The intensity of ground cover by crops needs to be increased. Since field efficiency is such a large factor in determining the actual water used, more emphasis should be placed on this point. While field efficiencies of 65% are quoted, there are also cases of 35%. The data on water requirements in the paper give the total for each crop, regardless of the length of the growing season. Thus, one rice crop growing for five months may require approximately the same water as one sugarcane crop growing for ten months. Precipitation is taken into account. It averages about 15 inches; in the hills, 40 inches; lower down, four inches. The local precipitation must be added to the figures given in the paper.

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RESEARCH PROGRAM CARRIED OUT IN THE FIELD OF IRRIGATION, LEBANON

by

Mr. Antoine Abou-Khalid

INTRODUCTION

The justification for large expenditures by more wealthy countries like the United States in irrigation research is obvious. Why Lebanon should do such research may not be quite as obvious. However, because of efforts to double the irrigated acreage in 10 years (from 50,000 Ha to 110,000 Ha), the reason becomes apparent. The purpose of this introduction is to bring out the orientation of the research and to suggest what research can be conducted without being a charge on the national budget and with the means and persons available. The objective is to solve within a reasonable time the problems that arise with official organizations such as the Directorate of Waters, the Litani Bureau and the Ministry of Agriculture, and with the farmers themselves, in order to achieve the maximum benefit from this important factor in wealth, which is water. Perhaps such efforts can contribute also to science by verifying theories and formulas or adapting them to local conditions.

A. First Experiments

The Irrigation Section has recently been set up in the Institute. In 1957, the first irrigation experiments were conducted on a corn crop in the central Bekaa region at two different locations (Tel Amara and Torbol).

The purpose was to study the yield variation with respect to the rate and timing of irrigation. Experiments were on simple split plots of five blocks and five replicates, each block being subdivided into four sub-blocks. Seven different treatments were studied:

1. 300 m^3/ 7 days
2. 600 m^3/ 7 days
3. 300 m^3/15 days
4. 600 m^3/15 days
5. 900 m^3/15 days
6. 600 m^3/21 days
7. 900 m^3/21 days

The plots treated at the rate of 300 m^3/15 days and 600 m^3/21 days showed rolling of leaves and other symptoms of thirst due to distinct water deficiency. The evaluation of results, being based on the number of ears per plant, the average weight of ears and the weight per plot, indicated that weekly irrigation at the rate of 300 to 450 m^3/ha seemed to be the best.

The examination and statistical analysis of the results of these first experiments disclosed a lack of regularity in distribution, a factor given attention in recent experiments.

B. Scientific Basis of Extension of the Significance of Similar Experiments

These first experiments had practical significance and the extension of their results could roughly satisfy the farmers, but they have limited value because they treated particular cases. It would be interesting to bring out the parameters that allow the extrapolation and generalization of such results. A parallel study of soil moisture evolution in the root zone and the hydrodynamic characteristics of the soil (field capacity, wilting point) is now available.

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1 — **Head of Machinery and Irrigation Section, Agricultural Research Institute, Tel Amara, Lebanon.**

Moisture curves established during all the vegetative cycle of the plant will reflect the presence of the available water in the root zone and its importance or unimportance during the peak periods. These curves will be printed on a time graph showing expected soil moisture status and available water, with wilting zone and margin of security levels indicated. A comparison of these curves with the different yields obtained gives an idea of the best moment to apply water in relation to the available water left in the root zone, specially during the plant's peak requirement period.

Moreover, it is hoped to be able to continue the study on soil moisure even beyond the root activity zone and to establish two profiles, the first revealing the humidity of the soil before irrigation and the second the humidity 18 hours after irrigation, up to depths of 90 or 120 cms. Below the root zone the difference between the two curves is the loss by deep percolation. Information on this loss is necessary in calculating evapotranspiration and irrigation efficiencies.

Some studies are planned on evaporation, using pans of different heights filled with the same soil under known amounts of water and embedded in an irrigated perimeter. These boxes will be weighed soon after one irrigation and shortly before the following irrigation to measure the losses of water from the soil surface through evaporation which take place between irrigations. Climatological data will be recorded at meteorological parks close by and pitch Evaporometer indications will be used as reference. Knowing the water used, the evapotranspiration (Foliar plus soil evaporation) may be computed by the following equation: Water used = constitution water + Foliar evaporation + soil evaporation + losses through run-off and deep percolation.

By determining constituent moisture, all factors may be evaluated and it is believed a close approximation of transpiration can be calculated, as well as daily consumption and evapotranspiration. From both theoretical and practical points of view, it would be interesting to know these figures for different parts of the world. The use of large automatic lysimeters is not now contemplated, as their cost would surpass our material means.

C. Conception of Experiments and Actual Research

Plant water requirements, during the period of vegetative life, depend essentially on:

1. **The type of crop**
2. **The climatic conditions**

Thus, it is planned to determine the water requirements of one or several crops grown on a given site in a given climate through pertinent experimental tests, doing meanwhile the maximum number of analyses of the natural and experimental conditions affecting these experiments. Moreover, our experimentation is conducted according to well-defined standards, using statistical repetitions. Since water needs for the same crop depend on the density or population per hectare, a standard plot size is used, and for experimental purposes, normal plant spacing, plant population, and cropping procedure are adopted. Field experimental plots show, among other things, the best use of the water through irrigation to obtain maximum or optimum yield (because maximum yield is not necessarily always the best from the economic point of view). Maximum yield per unit of area and maximum yield per unit of volume of used water would be interesting to compare.

In a general manner, it is known that the yield of crops increases up to a certain point with increasing rates of water used; then it stays constant or increases very slowly, or even retrogrades. This «break in the curve» is to be determined for the most common irrigated crops. It is advisable to find out what amount of water and irrigation spacing give best results in every particular case. Being essentially a function of the hydrodynamic characteristics of soil, the irrigation dose is theoretically constant, while, on the other hand, the frequency of irrigation should vary in respect to the needs of crops. It should be remembered that plants grow by surges or pushes, and that at certain moments of their vegetative life during the (formation of new organs or the constitution of vegetable rereserves) their instantaneous water needs may greatly vary. This would mean that it is necessary to see that the plant does not lack available water at

one of these critical moments. A security margin having been planned, a concise study of the evolution of soil moisture status in the zone explored by the roots would permit farmers to be sure that such moisture exists.

Since the amount of real evapotranspiration is not known, reference is made to the potential evapotranspiration found, starting with the empiric formula of Blaney and Criddle. The reference dose represents a monthly dose equal to the highest monthly ETP (that of July, for example). Individual doses approach the maximum theoretic dose calculated from the soil characteristics and the depth of the soil root zone.

The point in question would be whether in practise rates that exceed theoretical evapotranspiration would permit increase of yield, and whether smaller doses would effectively cause important decreases of yield. Because of previous research in other countries, the series of irrigation rates and intervals to be tried is luckly limited. Already, the first experiments with irrigation on small plots carried out in 1957 at Tel Amara and Turbol have shown the uselessness of increasing the spread of treatments (the doses of 300 m^3/15 days and of 600 m^3/21 days will be eliminated, as well as the excessive doses that have not caused significant increases of yield). The experiments being carried out in 1962 cover rates between 300 to 600 m^3/ha., with periods of six to 12 days for potatoes, onions and sugar beets.

The results of the experiments will be referred to potential evapotranspiration so they can be compared during different years or in different regions.

D. Present Irrigation Experiments at the Various Stations of the Lebanese Agricultural Institute

1. Studies and experiments on potato water requirements under different conditions of soil and climate.

a. Comparative experiments on differential irrigation are being conducted at Torbol, the Kfardane Experimental Station in the Bekaa Valley, and at Abde Experimental Station. Three different rates of water are used:
300, 400, and 500 m^3/ha. with six days, eight days, and 12 days, respectively. Combinations would be 300 m^3/6 days, 300/8 days, 400/8 days, 500/8 days and 500/12 days. The number of replicates is six, experiments or randomized plots. The area of the parcel unit is:
5m x 4m.9 = 24 m^2. 50.

Of the seven rows of potatoes, only the three medium rows on the three-meter length will be considered, in order to avoid the border effect. Twenty physical and hydrodynamic analyses of the soil have been made previously by the Tel Amara Soils Laboratory up to a depth of 60 cms., as well as of two holes that go as far as 120 cms., with samples taken by layers and observations and notations on the profile recorded. The results of these analyses for the Torbol experimental field were:

Average moisture equivalent up to 60 cms: 28.5% (average of 20 samples by centrifugation for 30 minutes in a field of 1000 g).

Physical analyses: (20 — 60 cms. average of 20 specimens); coarse sand (0.2 to 2.0 mm), 2.43%; fine sand (0.02 to 0.2 mm), 18.77%; loam (0.002 to 0.02 mm), 18.66%; clay, 59.64%.

The maximum dose for 50 centimeters of soil is 45 x 0^m. 50 x 28.5 x 1.2 = 770 m^3/ha; and a practical dose is 770 x 2/3 = 513 m^3/ha (500 m^3/ha is the reference dose in the comparative experiments).

Using the Blaney-Criddle formula, the potential evaportranspiration has been calculated, using the average of the last ten years of records.

In addition, the corrected scale of evapotranspiration which considers the maximum dose and which has been established by the engineers of the Vergieres Station (France), has been used. In this manner a probable calendar of waterings has been set up.

With respect to the beginning of water application, study of the soil moisture in the root zone

is emphasized. Emphasis is given to a study of humidity variations, since it seems that the study of soil moisture reflects the qualities or defects of irrigation. Care should be taken that errors do not accumulate. These can arise anywhere, from the soil analyses and humidity determinations to the estimation of results, especially in using routine calculations. The precise application of required amounts of water, idential for the parcels, is important. Certain stations are using water meters or Parhsall flumes for this purpose; however, the Institute uses volumetric tanks which give exactly the correct volumes to the plots. These reservoirs are within one per cent of accuracy and will be helpful in exactly repeating the experiments or conducting similar ones at other locations.

The irrigation program of the Agricultural Research Institute for the year 1962 covers:

1. **Experimental fields for irrigation**

Three fields comprising 36 plots each are located in regions specializing in the production of potatoes, two in the Bekaa and one along the coast of North Lebanon. The total area is 2700 m^2.

2. **Investigation in cooperation with the most advanced potato producers with regard to the creation of local documentation on the traditional manner of irrigation.**

It is planned to mount water meters on the pumps that insure the irrigation of a given perimeter to collect water-use information which will be reported on a standard form we have developed.

These investigations and detailed records and observations of the traditional methods of irrigation will be compared with our various experiments with the intention of drawing from them the necessary conclusions.

3. **Sprinkler irrigation experiments (potatoes, onions and sugarbeets).**

Four different water applications with six replications will be used. These are:

400 m^3/ha/7 days
400 m^3/ha/9 days
500 m^3/ha/7 days
500 m^3/ha/9 days

This experiment includes a study of the sprinkler method, from both the technical point of view (efficiency, wind problem) and the economic point of view (investment, labor, supplemental power expenses).

4. **Mulch experiment**

Irrigation will be non-variable, 400 m^3/ha/8 days. A chemical cover (Esso mulch) was spread over six plots (six replicates) having a total area of 300 m^2.

This black by-product of oil is supposed to shorten the vegetable cycle by increased absorption of heat, reduce evaporation by the creation of a superficial film, and, finally, reduce the total amount of water to be given to the plant. These experiments are simultaneously carried out on the same homogeneous field of Torbol Station, thus permitting direct comparisons of water losses by evaporation and of irrigation efficiencies with those in a similar experiment not using mulch.

5. **Orchard irrigation study and control**

Research on the irrigation of orchards being long, and the estimation of results being often delicate if not difficult, Lebanon is satisfied with rationalizing the irrigation of two orchards of the Tel Amara Station. This is effected by planning to control the water application and follow the variations of soil moisture in the root zone, and by referring to the probable calendar of waterings which has been established and is based on analysis of climatological data, root depths and soil characteristics. Trenches have been dug at the foot of trees and the distribution of the roots carefully noted, and samples of the soil at different levels analyzed by the Tel Amara Soil Laboratory. Through the analysis of soil moisture in the root zone, it can be seen under which measure this calendar may be adopted and in which measure it approaches reality. This would mean finding out the difference between the calculated evapotranspiration balances and the real evapotranspiration.

All empirical methods have some weak points. No matter what the method of evaluating plant water requirements (lysimeters, cropping under experimental conditions or application of hydrodynamic equations), the results should be controlled by direct observations and experiments made under normal conditions.

CONCLUSIONS

In brief, the studies and experiments on irrigation carried out at the Lebanese Institute, without pretending to rival world research, possess the merit of having, on the one hand, a practical application for extension use and, on the other hand, an attachment to basic research, since they constitute direct verifications of theories and formulas. Moreover, this work is at a level appropriate to the country and the means and personnel available. Well-conducted, it will lead to establishing the evapotranspiration values approached for every large perimeter and the relative water requirements of various crops, with the ultimate aim of better use of irrigation water, canals, systems and projects. With this intent, the Ministry of Agriculture, together with the Institute, is actually studying three perimeters to be irrigated (total area: 6,000 ha).

Finally, problems corollary to irrigation such as the underground inrush of sea water at certain points on the coast of Lebanon (pumping of saline water), and the fertility decrease of certain irrigated lands, will probably necessitate parallel research and widen Lebanon's field of activity in the years to come.

In conclusion, the Lebanese Agricultural Research Institute Irrigation Section is carrying out this year:

1. Field experiments in different regions of Lebanon, mainly on potato crops (Torbol, Kfardane, Abde).
2. Soil moisture studies corollary to these experiments.
3. Measurements and analyses of climatological data in different regions and the establishment of various calculated evapotranspiration balances.
4. Measurements of evaporation by soil surface and losses by deep percolation beyond the root activity zone in order to estimate the real evaptranspiration and the irrigation efficiences.
5. Investigations with the most advanced potato producers on their traditional methods of irrigation and measurement of the given quantities of water.
6. Experiments on the use of the sprinkler irrigation method on potatoes, onions and sugarbeets.
7. An experiment on the rationalization of orchard irrigation for pear trees and cherry trees.
8. An experiment on underground irrigation of orchards, at the request of a German company that is providing porous concrete pipes.

It is hoped the results will compare with those obtained in other countries so that they can be extrapolated to give them a more than local or regional significance. This is one of the objectives of the Ankara Seminar, which provides an opportunity to meet, to exchange views and ideas and, finally, to collaborate in a common effort to promote the welfare of the developing countries.

Samples of the calendar for irrigating, the forms for recording the experimental data and the charts showing the experimental plot layout included in the original presentation may be obtained from the author.

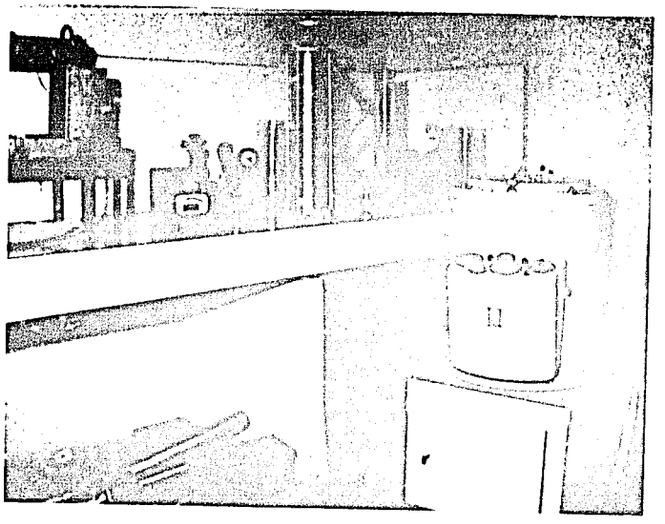
DISCUSSION

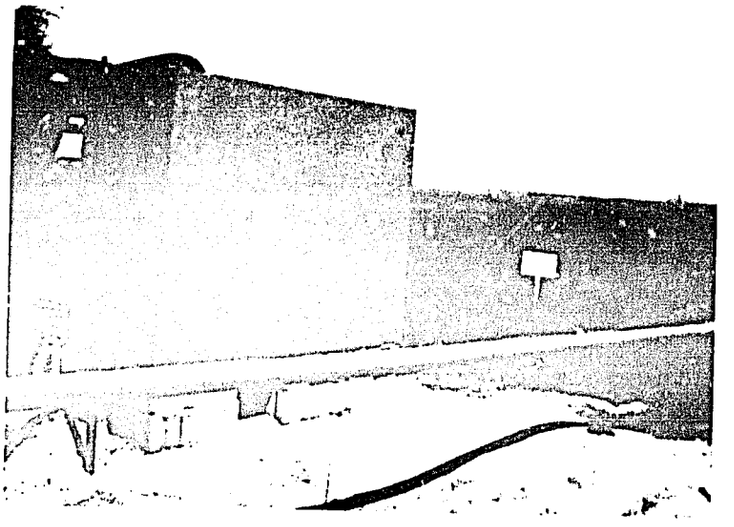
Although the International Conference of Soil Scientists recommends not more than four replications, the Institute uses six in order to obtain more statistical significance. Ordinary lead toothpaste tubes, used by Pakistan, are very good for bringing the moisture samples from the field to the laboratory. There is no loss of moisture even for periods as long as four weeks. The large tubes with a diameter of about 1 1/4 inches should be used.

Mr. Atallah stated that he thought it was more practical to have a definite time schedule on irrigation and deliver the proper amounts of water, rather than to wait until the moisture is at a certain predetermined level before irrigating. Mr. Natour pointed out that yield may not be a valid measure of irrigation effectiveness if there are other factors which influence production, such as fertility. Mr. Attalah stated that the research is carried out using normal conditions of fertilizer and other factors, and only the water is modified. Mr. Beyce mentioned that the nitrogen requirement would be different at different times of the irrigation rotation. Mr. Atallah stated that this is true, but they did not vary this because they are trying to place themselves in the position of the farmer. In the future, some correlations will be made between fertilizer and water.

GENERAL DISCUSSION

In his general discussion of the research work presented, Dr. Tamhane complimented the various countries presenting papers on the detailed papers given. He expressed the interest of the region in research on water requirements and on reclamation. He pointed out that while the results obtained in the various countries tend to substantiate each other, there are some differences — perhaps due largely to the varying techniques used. He suggested that more detailed information on techniques should be made available. It would be helpful if techniques could be worked out which could be commonly used. In water requirement studies, information on the weather is very important. There appears to be a great need for increased weather observations. The NESA Region should be classified into various soil and climatic zones. The actual conditions under which the research applies need to be stated, so that their applicability to other regions can be judged.





Irrigation Research – LEBANON

CHAPTER X

OPERATION AND MANAGEMENT

COORDINATION OF OPERATION AND MAINTENANCE WITH AGRICULTURAL PRACTICES, HELMAND VALLEY PROJECT, AFGHANISTAN

by

Mr. A. Tawab Asifi[1]

LOCATION AND TOPOGRAPHY

The Helmand Valley covers over 260,000 square kilometers in the southwest of Afghanistan, between 29° to 33° latitude and 61° to 69° longitude.

Spreading in the southern exposure of the Kohi Baba Parapamisus and the Hindu Kush mountains are the Helmand River basin and a few smaller watersheds. The lower extremity of the basin ends in the Chakhansur-Siestan sinks. Approximately one half of the watershed areas lie above 1,000 meters in altitude. The principal mountain ranges rise over 7,000 meters in the east and from 3,000 to 4,000 meters in the west. The foothills follow a westerly course and great outwash fans and plateaus extend in a southwesterly direction from the foothills. These vast outwashes are predominantly desert, with occasional flats and swales covered with more heavily vegetated silts of varying depths. The topography of these desert plains is gently rolling to hilly. It is broken near stream courses with occasional isolated uplifts of basalts, limestones, granites and schists breaking the vast sweep of the desert plains. The main rivers in this area are the Helmand, Arghandab, Farahrod, Khashrod, Musa Qala, Tarnak, Arghistan and Dori.

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1 Director General, Operations and Maintenance, Helmand Valley Authority, Lashkar Gau, Afghanistan.

CLIMATE

Temperature: The temperature is cooler in the higher mountain valleys and hotter in the lower deserts. The lowest recorded temperature is 12° F. and the highest, 121° F. The mean annual temperature is 69° F., the mean July temperature is 91° F., and 46° F. is the mean for the coldest month, January. These temperature ranges compare with continental desert climates in similar latitudes and situations in other countries.

Rainfall: The rainy season is from December to April, with occasional showers in November and May. Generally, 75 to 80 per cent of the rains fall in January through March and about 15 to 20 per cent in December and April. Rains producing high runoff have been observed. The range of mean annual rainfall varies from 2.8 inches for the areas lower than 490 meters in altitude to 13.4 inches for the areas higher than 1,790 meters in altitude. For the area under discussion, it is from 4.8 inches to 7.3 inches.

Evaporation: Average annual humidity ranges about 44 per cent. Mean monthly evaporation is three inches for January, the lowest month, and 18 inches for June. Mean annual evaporation is in the range of 111 inches.

SOILS

The soils of most of the potentially arable lands have developed from alluvial and aeolian

materials. The original bedrock sources are the uplifts of the Hindu Kush range and its westward extensions. Extreme tilting, folding and warping are evidence of great pressures exerted during the uplift. Glacial and post-glacial movement of materials from these uplifts covers a large area to the south and southwest of the mountains and foothills. Approximately 80 per cent of the presently irrigable lands in the Helmand River Valley is formed of river bottom soils and the remainder are shallow or bench type soils.

In general, **the river-bottom** or **valley-fill** soils represent the gradual accumulation of alluvial sediments together with the wind-laid materials at the lower extremities of long outwash slopes and fans, and above the more recent stream terraces. These soils are deep, moderately light brown to very pale brown silt loams and fine sandy loams, with silt loam to silty clay loam sub-soils. Where soils are stratified with lenses of compact, massive, silty clays, the permeability is low. The more uniform profiles are more permeable and better drained. Underlying materials vary from red desert soils and outwash gravels to more recent alluvial gravels and sands. The more recent series of terraces and benches along the various rivers are important agricultural areas. Dominantly, the soils are deep, light-colored silt loams, loams and very fine sandy loams. Along the Helmand River, considerable areas of uniformly sandy soils and sandy loams to loamy fine sands also occur. Some parts of the terrace benches along the Arghandab and Helmand are heavy silty clay loams and silty clays several feet in thickness, and do not drain well. Generally, however, the stream terraces are moderately to well drained and well-adapted to irrigation development.

Desert Plains Soils: Desert plains soils consist, for the most part, of very thin, reddish to gray, desert soils highly impregnated with lime over outwash gravels. Gypsum beds occur a few inches below the surface in many places. In some places in this vast desert, a thick mantle of soil that affords promise of agricultural use has accumulated. The deeper desert soils have in many places a very compact, reddish brown, sandy clay loam lower sub-soil which is slowly permeable. Over-irrigation of the more permeable upper horizons has resulted in perched water takes and salinization of these lands by capillary upward movement of saline waters to the surface. Compaction and cementation in all degrees are found in these desert soils. Cementing agents appear to be calcium carbonates, silicates and, in a few places, iron oxides. Cemented layers vary widely in thickness, texture and density. Caliches, lime-cemented sandstones, shales and a layer of conglomerate are common at depths of one to five meters under the surface. These relatively impervious rocks pose a serious drainage problem for most desert soils.

Considerable agricultural use is being made of these soils, with varying degrees of success. The Marja, Nad-i-Ali and parts of the Seraj, North Arghandab, and Tarnak projects are in areas of desert soils on outwash plain materials which are underlain at varying depths by hardpans or conglomerate. Most of the above soils are low in nitrogen and available phosphate.

HISTORY OF IRRIGATION

The earliest irrigation and agriculture of the Helmand Valley and Chakhansur-Siestan area undoubtedly preceded written history. Although archaeological research has given indication of this, only a fraction of this vast area has been examined. Some archaeological studies have revealed the earliest phases of the bronze age and ruins have been found dating back to about 3,000 B.C. Qala Bist is mentioned in ancient history, along with the ancient cities of Mineveh and Ur.

All along the Helmand River and its tributaries, the ruins of old cities and villages are scattered, reflecting a period which apparently had more prosperous and extensive irrigation and agriculture than now exist. Remains of large canals and ditches and extensive ruins indicate that the Helmand Valley once supported and fed large populations for centuries on irrigated farming. The extensive canal, irrigation and river diversion systems were undoubtedly hand-dug and maintained by the use of manpower . Extremely high floods in the spring months, and very low flows in the winter months must have required great numbers of men, with strong organization and leadership. But, alas, recurrent invasion of these agricultural lands by historic conquerors, the slaughter and extermina-

tion of large populations, and the destruction of cities and towns must have left a limited group of people who were unable to maintain and operate the vast diversion, canal and irrigation systems. A vicious circle ensued which was aggravated by inadequate drainage, poor land use methods and ever-rising problems of water logging and salinity, resulting in lower production, further chaos and abandonment.

HELMAND VALLEY DEVELOPMENT PROJECT

The Helmand Valley Projects were undertaken not only for the development of new lands but also for the rehabilitation of old lands. It is probable that only a small fraction of the total land watered by the various development schemes may be virgin soil. The vast acreage of barren or scantily vegetated lands which is affected to varying degrees by salts, alkali, ground water and erosion is a graphic record of past happenings and ways of land use. It also indicates that in order to farm and resettle these areas successfully, projects such as the Helmand Valley Development, designed and constructed by modern technological methods, operated and maintained under a sound program of proper irrigation and agricultural land-use methods, must be set up.

The present irrigation development program began in 1939. By 1950, the Boghra Diversion Dam, 60 kilometers of the Boghra Canal, canal structures and major inter-project roads were completed. From 1950 to 1954, the Boghra, Shamalan and Marja Canal systems, as well as the Kajakai and Arghandab storage dams and the Nad-i-Ali area irrigation system, were completed. Since 1954, the development has included the construction of the Marja irrigation system, the Arghandab Zahir Shahi Canal Diversion Dam, the Zahir Shahi Canal the South Arghandab and Tarnak Branches, Darweshan Diversion on the Helmand River and a portion of the Darweshan Canal, and certain other drainage outlet systems. The major works of the Helmand Valley Development Project are briefly summarized as follows:

Kajakai Storage Dam on the Helmand River. Earth dam, 94 meters high, 273 meters long; base width, 410 meters; 3,225,000 cubic meters of embankment; with a capacity of 1,495,000 acre feet and a possible increase in capacity by installation of gates of 800,000 acre feet.

Arghandab Storage Dam on the Arghandab River. Earth dam 50 meters high, 520 meters long; base width, 226 meters; 2,490,000 cubic meters of embankment; storage capacity about 388,000 acre feet.

Boghra Diversion Dam on the Helmand River. Rockfill, with concrete wier 180 meters long, 3.70 meters high.

Boghra Canal. Seventy-five kilometers long, 2,600 cfs. capacity.

Shamalan Canal. Sixty-six kilometers long, 750 cfs. capacity.

East Marja Canal. Twenty kilometers long, 450 cfs. capacity.

Darweshan Diversion. Helmand River.

Darweshan Canal. Fifty-one kilometers long, 1,000 cfs. capacity.

Zahir Shahi Diversion Dam on the Arghandab River. Rockfill, 800 meters long, 7 meters high; rock spillway.

Zahir Shahi Canal. Forty-three kilometers long, 1,500 cfs. capacity.

Nad-i-Ali Area. About 20,000 acres; Boghra Canal water; settlement, 1,200 families.

Marja Area. About 27,000 acres; Boghra Canal water; settlement, 605 families for the present time.

Shamalan Area. About 42,000 acres; Shamalan Canal water; settlement and old farms.

Darweshan Area. About 45,000 acres; Darweshan Canal water; old farms.

Central Arghandab. About 80,000 acres; Zahir Shahi Canal water; old farms.

North Arghandab. About 40,000 acres; North Arghandab intake structures; old farms.

Tarnak Area. About 64,000 acres; Zahir Shahi Canal water; old farms.

OPERATION, MAINTENANCE AND IRRIGATION

Since the Boghra Canal was not lined, leakage affecting the adjacent areas appeared in many places. Therefore, sections of heavy seepage were lined with compacted impervious earth linings; however, the necessary lining of the canals as a

whole is not yet completed.

For the purpose of proper and easy operation, wasteways and check and drop structures, some of which are gated, as well as gated branch canal and lateral structures and turnouts, were constructed. Since there are many washes crossing the alignment of the canals, protection from the damage of floods and heavy runoff is afforded by passing through concrete siphons and flumes. Inlets and underdrains are also provided at necessary stretches. The project lands are served from canals and branch canals through laterals, sub-laterals and farm ditches. All diversions and turnouts are controlled by gated concrete structures. The gates are either prefabricated metal, screw-type slide gates or wooden stop logs.

Mainly, canal operations are based on farm irrigation requirements. In order to reduce maintenance costs resulting from washouts, the erosion of banks and sloughing, excessive canal flows, high canal water velocities and sudden drops of canal water surface are avoided. The canals and ditches are patrolled by watermasters and ditchriders. A watermaster is responsible for a certain area, and sees to it that the canal delivery schedules are prepared and carried out He also supervises the regular maintenance of the irrigation system, and prepares a list of all the necessary repairs to the canals and structures before the end of a water year. The ditchriders are responsible for regulating laterals and sub-laterals to the farm-ditch level according to farm irrigation water requirements and prepared schedules.

Every year, during winter, from December 10 to January 20, the water is shut off 40 days. During this time all repairs and improvements, such as cleaning, desilting, demossing, and the laying of riprap and filter blankets at high-velocity or sloughing sections, are made. Where hand labor is impractical or costly, heavy machines like drag-chains, draglines, ditchers, etc., are used.

The farmer-developed lands of the Helmand and Arghandab Valley Projects are served from the main or branch canals through farmer-owned ditches. Main collector drains are dug by the Helmand Valley Authority (RVA).

In some other areas, such as Nad-i-Ali and Marja, the entire system of laterals, sub-laterals and farm-ditches is built by HVA before settlement. The land is leveled and put in blocks and sub-blocks, following the general topography of the area. Strips of about 50 acres are laid down, and these are served by farm ditches which are spaced 200 meters apart and are about 1,000 meters long.

Border irrigation, in most parts, is encouraged, although basin irrigation is widely used. Borders are usually about 20 meters wide by 200 meters long. Roads are constructed along the sides of all canals, main collector drains, laterals and most sub-laterals. Bridges are built at roads and necessary farm crossings. Because of low delivery efficiencies, about 30%, the Nad-i-Ali and Marja areas were designed on the basis of 40 acres per cfs., and 50 to 60 acres per cfs. were used for the tighter soils of the Tarnak Area.

DRAINAGE

It is generally accepted the world over that, to practice successful irrigated agriculture, drainage must be part of the program. Without drainage, irrigated agriculture can be practiced with some degree of success for only a limited period.

Prior to irrigation, the ground water table was about 22 feet below the surface in a Nad-i-Ali well. After irrigation started, the ground water rose to damaging levels and salinity concentrations became progressively more severe. After two years of irrigation, the ground water level in the same well was about five feet below the surface.

Following inspections and expert recommendations, intensive construction of sub-surface drains and improvement of the Boghra Canal were undertaken. These improved conditions to a certain degree; additional open farm drains were constructed later on.

The Nad-i-Ali drainage system presently is composed of about 163 kilometers of open, machine and hand-dug drains and 91 kilometers of tile drains. One proposed drainage system plan for Nad-i-Ali would require an additional 622 kilometers of tile drains and 205 kilometers of open drains. This system is based on a combination of three-foot and four-foot water-free, aerated root zones in the project area. Drain spacings are rela-

tively close because of low permeabilities and the shallow depth of the drainage barrier, comprised of compacted clays, caliche or conglomerate under the agricultural areas..

The special conditions and problems encountered when dealing with sub-soil water tables are innumerable, but they all follow the same basic laws. If the slowly permeable barrier is close to the surface, there will be relatively little storage for percolated waters. Unless the soils above are quite permeable, permitting free movement of water vertically, and unless the lands have an ample gradient to permit good lateral movement, the water table will encroach rapidly on the root zone. Water-logging, upward movement of water by capillarity and subsequent evaporation and accretion of salt deposits near the surface will occur.

Generally, it is desirable to keep the water at least four feet below the ground surface. In arid climates and in finer-textured soils, this may not be deep enough unless proper irrigation and drainage techniques are used. The important thing is to keep sufficient water moving down through the soils and out of the area to prevent accumulation of salines and to destroy the capillary effect in the soil profile.

Drainage cannot be economically justified under any condition unless adequate control of seepage losses from canals, laterals and irrigation ditches, and proper water application, can be exercised in conjunction with the drainage program. Studies of farm irrigation in the Nad-i-Ali area in the past have revealed an average efficiency of 20 to 30 per cent. Not much of this waste water ran off the surface, so that 60 to 70 per cent of all the water used by the farmers was entering the ground water. Since settlement and agricultural production are the primary goals of land development, the construction of dams, canals, irrigation systems and drains, and land leveling, do not have meaning unless the lands are put to full use and agricultural production. The facilities of a land development project should be maintained in the best operable condition. The excess waters stored underground that cause water-logging and choking of the lands and the toxic salts that prevent normal plant growth and kill plants, should regularly be removed through the drainage system.

Salts: Salts are common in gravelly desert soils, the concentration varying from 0.5 to 3.0 per cent in the first foot of the areas examined. They are chiefly chlorides, sulphates and bicarbonates.

Salt Balance: More salts must move out of an area than are added by surface irrigation in order to leach the land successfully. Measurements of Nad-i-Ali drain water show two to twelve tons of salts per acre foot, while the entering irrigation water carries about 0.39 tons per acre foot; this is favorable. For best leaching efficiencies, the drains that were built to remove surface and underground waters from agricultural lands should be cleaned and the gradient maintained for lower water surface and higher carrying capacities.

CONCLUSIONS:

As discussed in the previous paragraphs, coordination of operations, maintenance and irrigation with agricultural practices under the limited conditions of low irrigation and drainage tolerances is of utmost importance. Without it, agricultural production may be impossible.

1. **Leakage.** Leakage from canals and irrigation systems should be minimized by:
   (a) Lining of canals and the irrigation delivery system as much as is economically feasible.
   (b) Regulation and scheduling of water deliveries to the farms must be consistent with crop needs. Farmers have a tendency to have small heads of water running all the time in their farm ditches. The required amount of irrigation water should be applied in shorter periods by running high heads of water through the ditches and shutting off the water when it is not needed for irrigation. Rotation of water should be practiced and farm deliveries scheduled through farmer representatives (Mirabs) and ditchriders. The lateral and canal flows should be based on these requirements.
   (c) The canal and irrigation systems should be shut off for a period of 40

days to two months during the winter when farmers do not need any irrigation water.

(d) In order to prevent choking and ponding, canals and ditches should be maintained and cleaned by farmers in their free time and by maintenance crews and machinery during shut-off periods.

2. **Drainage.** Adequate drainage of the land requires open and closed collector and farm drains and regular maintenance of these drains to keep them in the best operating condition. Farm-labor maintenance crews and heavy machinery will be required to accomplish this.

3. **Proper Irrigation Practices.** Proper irrigation practices require the following steps:

   (a) The farmers must apply reasonable amounts of water at the right intervals, consistent with crop needs, the water-holding capacity of the soil and the requirements for removing and preventing salinity accretions in the soil profile.

   (b) Deeper plowing than is now practiced by the farmers is also necessary for more rapid infiltration of irrigation water.

   (c) Border irrigation is best suited to the area. The borders should not be checked in the middle. A full head of water for the required application should be used, starting from the upper end and filling to the lower end as quickly as possible. This will prevent over-irrigation of the upper reaches and under-irrigation of the lower reaches.

4. **Proper Land Use, Crop Rotation, Land Cover.** Even with adequate drainage, lands that are not irrigated and lie fallow after wheat and other grain irrigations for about four of the hottest months, with consequent high evaporations and a great upward movement of water and salines from the ground water table, will continue to deteriorate. This makes it imperative for the lands to be cropped with perennial plants such as grasses, clovers or alfalfa, or double-cropped with berseem, green manures, legumes, feed grains, cereals, melons or vegetables. These crops would shade the ground most of the time to reduce evaporation rates and would require irrigation often enough to reverse the upward movement of the salines. These practices not only help to reclaim and protect the lands, but are also more practical and economic from the standpoint of the project operations, and much more profitable for the farmer.

5. **Cultural Practices.** Proper farming and soil fertility practices should include the use of fertilizers if economically feasible.

6. **Research.** Research is needed in the above fields.

7. **Training of Operation, Maintenance and Irrigation Personnel and Crews.** Education of farmers in the above fields by the use of demonstration farms and other methods should be increased.

Through coordination of operations, maintenance and irrigation activities with agricultural practices, it is hoped that a higher degree of agricultural production, and a higher standards of living for the settlers and farmers can be achieved.

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DISCUSSION

Afghanistan cannot now afford concrete linings. The earth linings mentioned are about 80 cm. thick. The earth used for lining is tested and is quite impervious. Old sections are over-excavated, and the earth is placed at optimum moisture and

density. Sheepsfoot rollers are used for compacting it. The side slopes are 2:1 or 3:1 and are placed in layers with a width such that a tractor can work them. There is only a short period when existing canals are out of operation so that construction can be carried on. Such canals may be handled by using a bypass.

Where canals transect existing ditches based on old water rights, the required water is simply diverted from the canal to the existing ditches. Means for improving this situation are under study.

The Authority has completed construction at the expense of the Government with some help from A.I.D. It is hoped to recover these costs by taxation. Farmers are exempt from tax for the first five years, for development purposes. In addition to the property tax, a lump sum tax is levied on all water users. A payment based on the land under cultivation and the amount of water used would be preferable.

Tile spacing is one kilometer. It needs to be reduced by about one-third. The depths of drains are only one and one-half to two meters, due to the shallow soils.

Canal capacity design is based on 40 acres per cfs., except that in some places it may be 50 or 60 acres per cfs. where the soils are tighter. The system was originally designed as a rotation system. However, during the early settlement period there has been an excess of water, since all the land is not settled.

There are special crews for the operation and maintenance of large structures. These crews have heavy equipment and are trained for this type of heavy work. Operators, ditchriders and farmers are used for maintaining the sub-lateral drains, etc. If sub-laterals are sufficiently silted up, power ditchers may be used and the heavy maintenance crew may be called in to do the work. Irrigation crews prepare an inventory of the maintenance work needed each year and the responsibility for the various parts is assigned at a staff meeting. There is a systematic inspection of the whole system prior to closing the canals. Minor repairs are made currently by ditchriders and farmers.

The system was designed using borders, one factor in the decision being mechanical cultivation. Since the borders are about 200 meters long, converting to basins would require that the water pass through the upper basins in order to irrigate the lower basins. It was pointed out that handling surface drainage is not provided for in the small basin systems.

Water is not measured out to individual farmers but is measured at the turnouts to the laterals which serve a whole group of farmers. For new lands, it is possible to measure the water to each farmer. Usually, however, the sub-laterals are measured and there is installed a type of farm turnout that could be used for measuring.

A machine has recently been acquired to bore out the roots which clog the tiles. This machine is just now being placed in operation. Mr. Raza expressed pessimism about tile drains where manholes were not provided sufficiently close together so that inspection is adequate.

No information is available regarding the size of the stream used by on individual irrigator, although Mr. Asifi reported measuring 2.5 cfs. in a sublateral. No measurements of actual consumption on small plots have been made.

Mr. Hamid suggested that the papers dealing with projects shall include a chart showing mean temperature; rainfall; crop growth, maturing and harvesting; and canal demand for each month.

CHAPTER XI

SPECIAL PAPERS

IRRIGATION PROGRAM

UNDER THE LITANI PROJECT , LEBANON

by

Mr. Jamil H. Sawaya[1]

INTRODUCTION

The intention was to offer to this Seminar an accurate and detailed summary of the program for irrigation distribution and practice which the Litani River Authority plans to fulfill under the Litani project. Unfortunately, due to construction delays caused by unforseen technical difficulties in the construction of the Karaoun Dam and the Awali tunnel, and to lack of an adequate water law, the final decisions on the detailed irrigation program and the commencement of its execution have been delayed. At present, the technical difficulties related to the dam and tunnels have been resolved and a new water law, which is expected to be published and enforced by the end of this year, is presently under consideration by a special committee. Meanwhile, the Litani River Authority is considering expansion of the irrigation program far beyond that originally planned because of the great recent interest on the part of both the Government and the people in increasing the irrigable area in Lebanon.

Before discussing the irrigation program that is under consideration at present, a brief description of the general Litani project and the necessity for economical use of the water is necessary.

1 Chief Irrigation Engineer, Litani River Authority, Lebanon.

The Litani River basin covers an area of about 2,170 square kms. The upper six-tenths of the river course (80 kms) flows through the Bekaa Valley between the Lebanon and Anti-Lebanon mountains. The run-off from these mountain ranges collects in the Litani River basin an average annual flow of 640 million cubic meters of water. The runoff feeding the lower four-tenths of the river collects an average annual flow of 100 million cubic meters of water. Lacking reservoirs in the Litani watershed to store the runoff water for irrigation, all the run-off drained away to the sea. The need to conserve and store the waters for irrigation and generation of electric power led to the formation of the «Development Plan for the Litani Basin.» This plan called for retaining and utilizing the supply of water for irrigation and the generation of electric power and balancing these two uses to provide the greatest economic value to the country. The over-all program, briefly summarized, includes:

A. The Karaoun Dam at the end of the Bekaa Valley, where the mountains close in on the Litani to form a gorge. The storage capacity will be 200 million cubic meters of water at a surface elevation of 860 meters. (Height of dam, 60 m., and length, 1,050 m.).

B. The Markabi tunnel, (6.5 kms. long)

and Awali tunnel (18 kms. long), both 3.5 meters in dia. and having capacities of 23 and 25 cubic meters per second.

C. The Markabi and Awali power houses, generating an annual output of 1,050 million kilowatt hours.

D. The Khardale Dam, 15 kms. downstream from the Karaoun Dam, 60 meters high and 350 meters long. The reservoir capacity is 70 million cubic meters at a surface elevation of 295 meters.

E. The Zrariye tunnel and power house, generating an annual output of 75 million kilowatt hours.

F. The following irrigation schemes:
   1. South Bekaa Gravity
   2. South Bekaa Pumping
   3. Zone «A»
   4. Zone «B»
   5. Zone «C»

G. A supply of water for domestic use for villages within the perimeter of the irrigation schemes.

IRRIGATION PLAN

The irrigation plan that is presently under consideration by the Litani River Authority is as follows:

1. SOUTH BEKAA GRAVITY SCHEME

The source of water for this scheme is the Anjar, Chamsine, Beida and Faour springs situated at the foot of the Anti-Lebanon mountains. Three low diversion dams will be built, one below Anjar, one below Chamsine and one below Beida and Faour springs, to raise the level of the water slightly and to control the flow into the main canals. The three small reservoirs formed will be connected by means of 1.5 and 0.8 km. feeder canals. One main canal will start from the Anjar Reservoir, will extend in a southerly direction along the foot of the Anti-Lebanon mountains for about 25 kms., and will serve a maximum area of 3,500 hectares lying west of this canal. Another main canal will take off at Faour reservoir and will extend west and south for about 22 kms. to serve a maximum area of about 2,500 hectares lying to the east of the Litani River. This system is designed to furnish the full water requirement to a maximum area of 6,000 hectares. A proportionate share of the water is to be given to each village irrigation cooperative. The cooperative receives the water in its different distributaries and distributes it among its members according to a detailed schedule previously laid out and agreed upon between the villagers and the Irrigation Department of the Litani River Authority.

The discharge of the springs, 2.8 to 3.5 m^3 per second during the irrigation period from April to mid-September, was considered sufficient to irrigate the area if the main canals, secondary canals and laterals were properly constructed and concreted. This scheme was completely designed and prepared for execution. Unfortunately, previous water rights for irrigation by pumping outside the parimeter and the great drop in the discharge of these springs (1.5-2.5 m^3 per second) due to over-pumping from the water table, delayed execution of the plan and obliged the Litani Authority to reconsider it while awaiting the new water law. It is now planned to couple its execution, after modification, with the for pumping scheme from the Karaoun reservoir.

2. SOUTH BEKAA PUMPING SCHEME

Part of the water stored in the Karaoun Reservoir will be used to irrigate the part of South Bekaa, for which the natural summer flow and the pumping permitted from underground water resources are not sufficient. A pumping plant is to be installed on the left back of the Litani at Karaoun Dam. The water will be pumped to an elevation of 900 meters, a maximum lift of 95 meters from the minimum water elevation in the reservoir, and will be conveyed in a canal in a northerly direction for a length of 37 kms. along the lower slopes of the Anti-Lebanon mountains. At a distance of about 12 kms. from the pumping plant, a branch canal will cross through a 2-km. siphon to the right bank of the Litani and continue for about 18 kms. in a northerly direction. The two canals will supply water for the land on the east side of the Litani as far north as the Damascus-Beirut road, and on the west side as far north as the Ammik swamps.

The total irrigable area in the South Bekaa is 17,000 hectares, of which 6,000 hectares, lying mostly on the west bank of the Litani between the swamps of Ammik and the Damascus-Beirut road, are presently under irrigation. Water is funished by springs on the west bank that emerge from the foot of the Lebanon Mountains and by a few wells in the area. The irrigation distribution in this area is satisfactory for the present time, and future development is not yet considered. Of the remaining 12,000 hectures, only 5,000 hectares are under irrigation. Of this, only 800 hectares are irrigated by gravity and the rest by pumping from Anjar, Chamsine and Ghazayel. Irrigation in this area is in a deplorable condition. Cultivators fight for water and part of the cultivated area in summer receives limited water or none. The cultivators who are nearer to the springs get most of the water and those lower down receive little or nothing.

The condition in this area is a constant worry to the local Government. Consequently, the execution of the irrigation schemes in this area are of major importance. The Litani River Authority, having found that the gravity scheme will not improve conditions, intends to execute both the gravity and pumping schemes at the same time, as soon as the stored water in the Karaoun Reservoir is adequate for operation of the power plant and power house at Markabi during the summer. Most probably the execution of both schemes will commence in the early spring of 1963 and finish by the end of 1964.

3. ZONE «A»

This zone covers an era of 25,000 hectares between the Beirut-Damascus road (north), Nahr Awali (south), the Mediterranean Sea (west) and elevation 750 (east). This zone is newly considered for irrigation of part of its cultivable land by the Litani water due to the new Government policy of distributing the benefits of the use of this water to all districts lying south of the Beirut-Damascus road. The area is topographically divided into two sub-zones by the Nahr Damour, which cuts a deep gorge in the Lebanon Mountains. The northern sub-zone is called «Chouf» and the Southern «Iklim Kharoub.» This zone is characterized largely by hilly, dissected topography, and stony, comparatively shallow soils. Dry land cultivation is the dominant type of agriculture, with olives, figs, grapes, lentils and vetch as the principal crops. Very rocky, high, uncultivated lands comprise a sizable portion of the area. In general, this zone appears to be far less favorable from a land irrigability viewpoint than any of the other zones.

Irrigation in this zone is confined mainly to the lands adjacent to the tributaries Nahr Damour and Nahr Awali, which receive water from the river or from springs. The main irrigated crops are fruits, such as plums, applies and citrus, to a limited extent, and various kinds of vegetables. Terracing of hilly land is a customary practice on both dry and irrigated areas. Only relatively small areas appear to be suitable for irrigation, as summarized below:

Chouf Area	
300-600 m. elevation:	400 Hectares
600-750 m. elevation:	1600 Hectares
	2000 Hectares
Iklim Kharoub	
0-600 m. elevation:	2100 Hectares
600-750 m. elevation:	600 Hectares
	2700 Hectares

The main canal will take off from the Anan Reservoir at elevation 625 by a siphon across the Awali River to a principal distribution reservoir on the right bank at water elevation 610. From this distribution reservoir, two main gravity canals take off to irrigate 2,100 hectares by gravity in Iklim Kharoub between elevation 0 and 600 m. The first canal runs west a length of about 18 kms., and the second runs north about 23 kms. A pumping station will be installed to pump water from the principal distribution reservoir to a third main canal at elevation 760, a maximum lift of 150 meters. This main canal runs north for about 21 kms., and crosses Nahr Damour in a siphon about 800 meters in length to the Chouf area, where the canal again runs north another 11 kms. The area irrigated from this canal is to be about 2,600 hectares, of which 600 are in Iklim Kharoub and 2,000 in Chouf. The three main canals, as well as all secondary canals, will be constructed of steel or reinforced concrete pipes.

About 28 villages in this zone will be supplied with domestic water from the three main canals. The estimated water requirement for this zone is 2.6 cubic meters per second for irrigation and 400 liters per second for domestic supply.

Detailed investigations of a practical design for this scheme are not yet started, as there still remains the possibility of supplying this zone with the waters of Nahr Damour and Nahr Awali.

4. **ZONE «B»**

This zone includes plateau regions between Nahr Awali and Nahr Litani, near and above the coastal plain containing an area of 12,000 hectares of arable land suitable for irrigation of the total area of 60,000 hectares. This zone is sub-divided into two separate schemes: Upper Nabatiye (including tne Saida-Roum area) and Lower Nabatiye. These two schemes utilize water from different reservoirs and consequently will be considered separately.

(a) **The Upper Nabatiye Scheme.** This scheme includes the land lying between Nahr Awali and Nahr Zahrani between elevations 30 and 600, and the land lying between Nahr Zahrani and Nahr Litani between elevations 200 and 600. The irrigable land in this perimeter amounts to 8,300 hectares. The main canal will take off from the Anan Reservoir and run southward for about 44.5 kms. to the right bank of the Litani River at elevation 600 meters. From the main canal, eight or nine main branches will take off to irrigate the different scattered plateaus. The main canal will be an open reinforced concrete canal and the main branches will be of steel or reinforced concrete pipes. Domestic water will be supplied to about 32 villages in this area. The area. The water requirement of the area is estimated at 5.0 cubic meters per second, of which 300 liters per second will be for domestic supply and the rest for irrigation.

This scheme has priority over the other schemes in Zones A, B and C because the soil is more suitable for irrigation because of the strong demands of the villagers for development and, last but not least, because of the fact that this scheme is the most feasible from the Litani River Authority viewpoint. It is expected to have the water reach the Anan Reservoir by the end of 1963, and it is very probable that the execution of this scheme will commence in early 1964 after the detailed designs are completed.

(b) **The Lower Nabatiye Scheme.** This scheme includes the land lying between Nahr Zahrani and Nahr Litani, above the Kasmie main canal (elevation 30 m.) and below elevation 200 m. The irrigable land in this basin amounts to 3,500 hectares. The main canal will take off from the Khardali Reservoir and is dependent upon the construction of this dam, the Zaiye tunnel and canal, and the Zahrani tunnel and canal, before the water supply will be available. The water will be taken by the main canal of this area from the Zahrani canal and run northward for about 35 kms. to the left bank of the Zahrani River. At a point about 4.5 kms. from the beginning of the main canal, a smaller canal will branch off and run southwesterly for about 8 kms.

At present the irrigation in this area is limited to the land below elevation 30 m. that is irrigated by the present Kasmie canal.

The soil in this area is not very suitable for irrigation except for a small percentage of the total irrigable area. Consequently, this scheme will be executed only as part of the Zahrani power house and the Tyr irgation scheme after Khardali Dam is constructed. The execution of this

scheme will be in the second phase of the Litani project in the period 1966-1970.

5. ZONE «C»

Thise zone covers all the area south of the Litani up to the Palestinian boundary below elevation 750 meters. The total area of this zone is 42,000 hectares, of which only 5,000 hectares are recommended for irrigation. This zone is sub-divided into three separate schemes: Tyr, elevation 200 to 400 m.; Bent Jbail; and Tyr, elevation 30 to 200 m.

(a) **Tyr (elevation 200 to 400 meters).** The total area of this perimeter is about 12,000 hectares, of which 2,000 hectares are recommended as suitable for irrigation. Again, the area suitable for irrigation is located on small plateaus scattered among the 14 different villages in this region. The water for this scheme will be taken by a siphon across the Litani River from the Nabatiye main canal to elevation 550 meters. At this elevation, a small distribution reservoir will be built. From this reservoir the main canal will take off and run south for a length of about 22 kms. From the main canal, nine secondary canals branch off in a southwesterly direction to the different small plateaus. Domestic water supply will be distributed to all the villages, as there are no springs and they depend presently on small reservoirs holding water collected from rain runoff. The estimated water requirements for this scheme is about 1.4 cubic meters per second, of which 150 liters per second will be for domestic supply and the rest for irrigation. Irrigation at present (other than that provided by the Kasmie below elevation 30 m.) is limited to a few hectares irrigated from deep drilled wells by a few rich landowners. The underground water varies in depth between 250 to 400 meters, and thus the water pumped is not very economical except for citrus and banana groves.

The execution of this scheme will follow immediately after that of the Upper Nabatiye scheme.

(b) **Bent Jbail (elevation 400-750).** The total area of this perimeter is 22,000 hectares, of which only 2,000 hectares will be irrigated, though there are about 6,000 hectares of land suitable for irrigation. The reason for this is that this perimeter is irrigated by water pumped from the distribution reservoir on the left bank of the Litani to a maximum lift of 200 meters (elevation 550 to 750). Thus, it renders the water rate very high for irrigation on a large scale.

The major purpose of this scheme is the supplying of domestic water to the 35 villages in this perimeter and the irrigation of small areas of land in some villages where it is most required. The water pumped from the distribution reservoir will run south in a main canal about 32 kms. Eleven or twelve main branches, will take off from this canal to distribute the water to all the villages. The villagers now depend largely on winter-stored water in small reservoirs for their domestic supply. A few small natural springs are found in this area, which generally dry up during the summer months.

The execution of this scheme will commence, if finaly approved by the local authority, in conjunction with the Upper Nabatiye scheme. An alternative plan for supplying the area with water from the Hasbani River remains under consideration. The total requirement is estimated at 1.5 cubic meters per second, of which 400 liters per second will be for domestic supply and the rest for irrigation.

(c) **Tyr (elevation 30-200 m.).** This scheme includes the land lying south of the Litani below elevation 200 m. and above the Kasmie canal. The total area of this perimeter is about 7,000 hectares. The land suitable for irrigation is about 1,000 hectares of scattered small plateaus. The water will be taken by the main canal from the Zhariye canal and run southward about 18 kms. Five main branches will take off from the main canal and run in a southwesterly direction to irrigate the many small plateaus in the area.

The small area at present under irrigation in this region is served by water from drilled wells. The average depth of the water table is about 100 meters. Consequently, this lower Tyr scheme may be abandoned if future investigations of the underground water resources prove them satisfactory to supply the water requirements of about one cubic meter per second for domestic and irrigation supply. Well drilling is increasing rapidly in this perimeter, but to date the results have not been generally very encouraging, since no geological investigations are carried out before well locations are chosen.

IRRIGATION DISTRIBUTION

The efficient utilization of the water and the proper methods of applying are the main concerns of the Litani River Authority and the local Government. In the irrigation schemes, where the water head (the difference in level between the water in the canals and the land) is small, as in the Bekaa and pumping schemes, the distribution of water to the different landowners will be made by means of concrete lined canals. The distribution operation will be carried out using a previously agreed-upon system set up by the different cooperatives in the perimeter, under the direction and supervision of the Irrigation Department of the Litani River Authority. The administration and operation of the gravity irrigation schemes were subjects of a paper submitted in the last seminar.

In all the other schemes of the Litani project, the water head is ample for distribution by other methods than gravity. The method proposed by French experts as the best is the distribution of water by overhead sprinkler irrigation. This method is under serious consideration by the Litani River Authority because of the following advantages:

A. The saving of water by a proportion of 30 to 40 per cent ; no water losses in the canals or on the land and less misuse by cultivators.

B. Better control and measurement of the actual water application to each hectare because of the homogenous distribution over the area to which the water is applied.

C. The prevention of erosion. This is a very important consideration in view of the topography of the Lebanon Mountains.

D. The economy of land preparation and omission of the expensive procedure of terracing, as is the present custom. Little work in land preparation will be required.

E. The economy in labor, and the use of night irrigation when it is more favorable.

F. The economy to the individual cultivator on initial investment, which is very important to the poor cultivator who wishes to commence irrigation of his land.

G. Better and easier agricultural control of different crops, fruits and soils.

H. More equitable distribution, as it will be totally controlled by the Litani River Authority until distribution to the individual cultivator.

I. All the laterals being covered pipes, there will be no outside interference with the distribution system.

This method of irrigation is now practiced newly by a few rich private landowners in Lebanon and has not yet been properly utilized and appreciated by them.

BENEFITS FROM THE IRRIGATION SCHEMES:

The benefits from applying irrigation water to previously dry land are calculated as the difference between the gross income from irrigated land and the comparable income from dry land. Income data were obtained from a survey of 146 farms in the South Bekaa area:

TABLE 1. RETURNS FROM SELECTED DRY LAND CROPS.

Crop	Gross Value per Hectare	Crop	Gross Value per Hectare
Wheat	LL 340.5	Vetch (cattle feed)	LL 125.0
Barley	226.0	Chick peas	319.5
Vetch (edible)	190.0	Mixed Vegetables	117.5
Average - LL 253.0			

TABLE 2. RETURNS FROM SELECTED IRRIGATED CROPS.

Crop	Gross Value per Hectare	Crop	Gross Value per Hectare
Wheat	LL 480.5	Sugar Beets	LL 1,114.5
Potatoes	1,440.0	Mixed Vegetables	570.0
Onions	986.5		
Average — LL 948.6			

These comparative data suggest that with irrigation water the gross returns per hectare can be increased by nearly LL 700. However, not all of the increase in the value of the products can be attributed to the water, because applications of fertilizers are used with potatoes, onions and sugar beets. The average cost of the inputs (other than labor) per hectare of dry land was found to be LL 185,1 and that of irrigated land 781.5, including the customary rental charges for the use of the land. The returns to labor amounted to LL 67.9 per hectare of dry land and LL 167.1 per hectare of irrigated land. Consequently, with water for irrigation, the farmer increased his return by almost LL 100 for his labor. If water is supplied to their lands, farmers can earn more than double the labor income received from dry land crops. Dry land farming that was previously abandoned will be put under irrigation by the cultivators and their incomes will be sufficient to compensate for their labor. On this basis, the Litani River Authority, under the direction of the President of the Lebanese Republic, revised the plan to increase the quantity of water that will be provided for irrigation schemes from the Litani project.

DISCUSSION

Each village will have its own sprinkling system. The water will be delivered to a village reservoir. If there is still too much head on the pipe, a lower reservoir will control it. The relative efficiency of sprinkler and of border irrigation was discussed in detail; Mr. Sawaya took the position that the sprinkling system was the most efficient method in its uniformity of distribution. This was

not fully concurred in by Mr. Natur of Jordan. The sprinklers will be installed at Government expense. The Government may even irrigate for the farmers. Usually, pipe conveyance systems with basins around the trees will be used for citrus. The sprinkling systems usually purchased by farmers are quite uneconomical. Also, the pumping capacity purchased is usually too high. It is believed that Government designed sprinkling systems will save considerable cost. The cost will be about 500 Lebanese pounds per hectare. The spacing between sprinkler heads is usually 12 meters, although in some cases 18 meters may be used. The main distribution laterals will be steel pipe. Some of the main canals which are not under pressure may be of concrete pipe.

There will be no silting problem, as there will be a silt remover at the head of the main canal. There was considerable discussion about the life of the reservoir. Mr. Sawaya feels that it will be quite long. The siltation of the reservoir was discussed in detail. There is a tunnel which can be used to flush the silt out of the reservoir.

This project is not intended to be entirely economical from the point of view of irrigation development. Recent droughts have caused many displacements of farmers from the villages to the cities, and the Government is willing to subsidlize irrigation in order to maintain village stability. It is not intended to recover the full cost of the irrigation project from the cultivator. This may be subsidized in part by hydroelectric power. Also, the tax on irrigated land is about three times as high as on dry land. In addition, there will be water charges. The water tax will be $15 to $18 per hectare.

Mr. Hagen pointed out that in southern France there is a wine growing area. Since the depression of wine prices, it no longer pays to grow grapes. Therefore, France is subsidizing an irrigation project in order to stabilize the economic situation in this area. Mr. Hagen suggests that there may be increasingly more subsidy of irrigation works for the purpose of providing economic balance in a country or region.

CO-ORDINATED DEVELOPMENT OF GROUNDWATER IN RECHNA DOAB, WEST PAKISTAN

by

Mr. Sayyid Hamid

INTRODUCTION

The rise of the water table and the attendent salinization of the land is posing a serious problem to the agriculture of Rechna Doab, which is a vast canal-irrigated area in the semi-arid Indus Plains of West Pakistan. In this once very fertile area, agricultural production, which was already sub-normal for want of adequate irrigation applications, has been declining progressively as more and more lands have been going out of cultivation or loosing their productivity due to waterlogging and salinity. Surface floodings have also become severe and more frequent.

The consequences of a rising water table have been understood from the time irrigation development was started some 70 years ago and various approaches were tried at various times, such as frequent and extensive canal closures, lowering of canal water levels, conversion of perennial to non-perennial irrigation, tree plantations, lining of canal reaches, open surface drains and tubwells. But these were for the most part halfway measures and were neither as the nature and magnitude of the problem demanded.

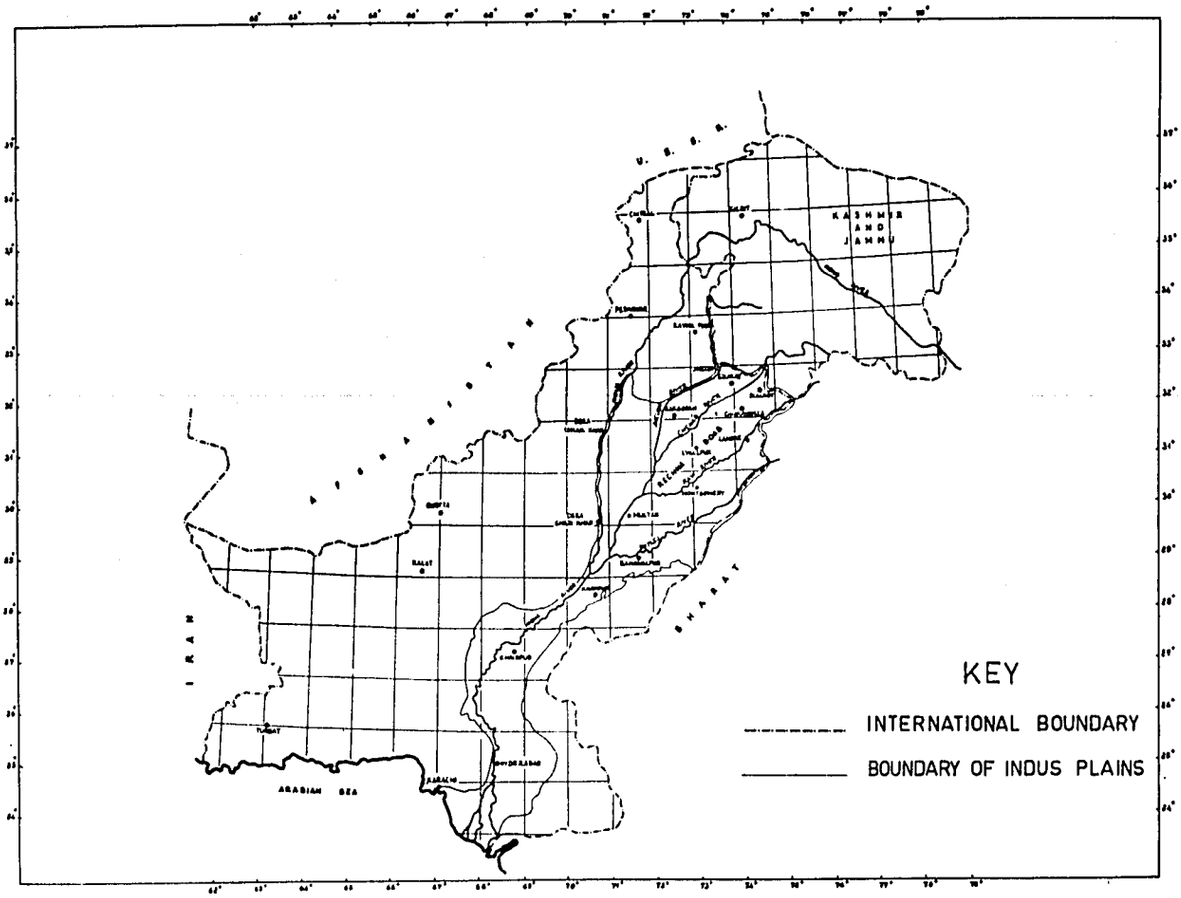
In 1954 a comprehensive program of groundwater and soil salinity investigations was started for the first time on scientific lines, to determine the geologic, hydrologic and all other related conditions which contribute or are related to the problems of waterlogging and salinity. These investigations established the existence of a vast interconnected groundwater aquifer underlying Rechna Doab, which had become virtually 'brimfull' from the additional recharge resulting since the irrigation systems were developed. The investigaions and studies further demonstrated that this aquifer could be developed to produce large quantities of useable groundwater supplies to supplement the existing surface supplies, and in turn lead to adequate subsurface drainage, which is vital for the control of waterlogging and salinity. As a result, a large Salinity Control and Reclamation Project has been undertaken in a part of the Rechna Doab, which represents the co-ordinated development of groundwater by installing 1,800 tubewells over a gross area of 1.2 million acres. The gross area of the Rechna Doab is 7.3 million acres.

This paper describes the approach which has been adopted for the co-ordinated development of groundwater in Rechna Doab in the light of prevailing conditions, and brings out the nature and extent of the investigations on which it was based.

GENERAL DESCRIPTION OF THE AREA LOCATION

Rechna Doab, a part of the Indus Valley, is bounded by two tributaries the Rivers Ravi and Chenab, from which it derives its name («Doab» meaning land between two rivers). The Rivers Ravi and Chenab originate in the Himalayan mountains and flow into West Pakistan from northeast to southwest. The Doab is bounded by the Pakistan-Kashmir boundary on the northeast and by the Rivers Chenab and Ravi, flowing roughly from northeast to southwest, down to their confluence. The width between the rivers is 50 to 60 miles and the length of the Doab from the foot of the mountains to the confluence is about 220 miles, with a gross area of 11,000 sq. miles. The location of Rechna Doab is shown in Fig. 1.

(1) Project Director and Deputy Chief Engineer, Groundwater and Reclamation Division. West Pakistan Water and Power Development Authority.



CLIMATE

Climately most of the Rechna Doab is **arid** to semi-arid. A small strip of the Doab along the Himalayan foothills is characterised by a semi-humid climate. The average rainfall progressively decreases, from 20-35 inches in the northeast to seven to eight inches in the southwest. The annual precipitation is concentrated in a three-and-a-half-month period, June to September; July and August are the months of heaviest rainfall. There is a secondary rainfall period from December to February. May and June are the hottest months; the average maximum temperature for these months is about 105°F. The daily maximum temperature may reach 115°F, or more for several days. In the rainy season. July to September, the average maximum temperature is 100°F. From December to February the day temperatures are in the 60's or 70's while the night temperatures are in the high 30's or low 40's. Freezing temperatures are recorded only rarely.

PHYSIOGRAPHY AND LAND FORMS

Rechna Doab has a relatively flat and even surface constituting a vast plain. In the north-eastern sub-mountain region, the height averages 850 ft. above sea level with a regular gradient of between two to three ft. per mile in the upper portion and just over one foot per mile in the lower portion. Across the Doab the land surface rises 25 to 30 ft. above the level of the rivers. The most conspicuous relief features in the Doab are three isolated hills which occur near the towns of Shahkot, Sangla and Chiniot, having elevations of 140, 160 and 360 ft. above the surrounding land surface.

The land forms in Rechna Doab are essentially alluvial in origin. Lying along the course of

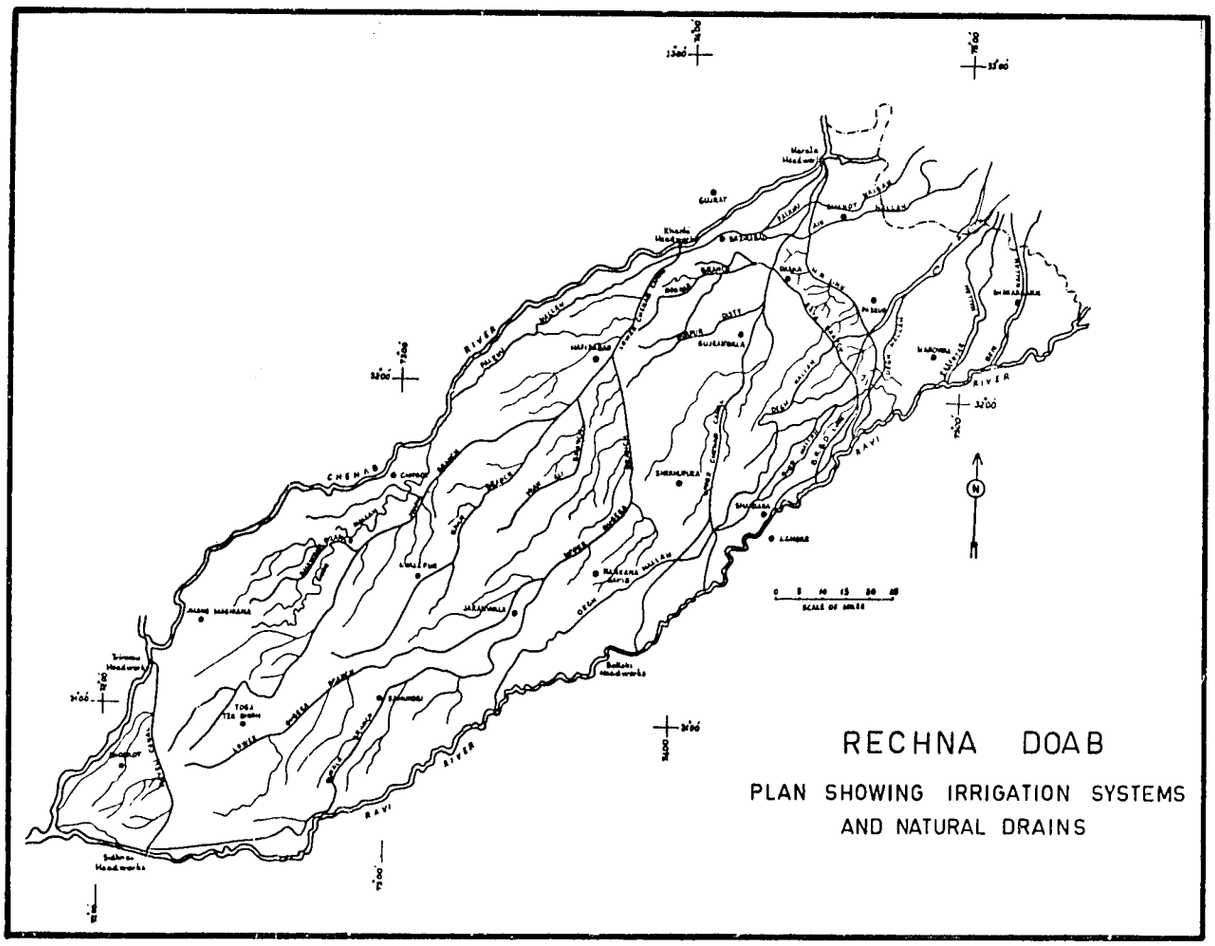
the Chenab and Ravi Rivers are narrow strips of active flood plains which are subject to inundation during summer flood flows, and in which the positions of the rivers channels are continuously changing. It is typical of the 'doabs' in West Pakistan that the lower central portion between the two rivers is occupied by an elevated plateau locally called the «Sandal Bar.» This land form, which has been termed «scalloped interfluve,» is a vast featureless plain bounded by conspicuous bluffs rangings in height from five to 30 feet. The meander flood plains occupy a position between the «bar» and the active flood plains of the rivers, and also extend over a wide area to the north and east of the «bar.» «These flood plains represent areas which have been abandoned by earlier river channels, but despite their low relief they still display a complex pattern of channel scars, levees, sand bars and slack water deposits. Most of the upper portion of the Doab is a cover flood pain, composed of sediments brought down by the rivers Chenab and Ravi and the streams flowing from the piedmont plain. Small areas of cover flood plain are also identified in the belts of the meander flood plains further south. The surface of the cover flood plains is much more level than in the meander flood plains, but there are many broad, ill-drained depressions. A small portion along the extreme eastern edge of the Doab, adjacent to the Himalayan foothills, is a piedmont plain. It has a slope of 100 feet in the first six miles and another 100 feet in the next 12 to 15 miles. The plain has been intricately dissected by a network of eroding streams on the higher slopes but along the lower edges the land between gullies is wider and more level.

GEOLOGY

The Indus alluvial plain is underlain by thick sediments which have been deposited by rivers flowing from the Himalayan Mountains. The basement floor of this plain is a part of the sunkenbelt, known as the Himalayan «fore deep.» «Bounded by the Himalayan Mountains to the north and the peninsular shield of Pre-Cambrian rocks to the south, the plain is a vast monotonous stretch of alluvium. In the Rechna Doab it is marked by a few outcrops of Pre-Cambrian rocks occurring at Shahkot, Sangla and Chiniot and forming the hills mentioned above, which are believed to be the eroded remants of a subterranean ridge, called the Delhi-Shahpur Ridge. Beyond the boundaries of Rechna Doab, similar outcrops occur to the northwest; and to the southeast the extension of the buried ridge has been established by deep borings. On either side of these outcrops the alluvium, which is of Quarternary age, is of great thickness and is believed to be from 1,000 ft. to more than 5,000 ft. deep.

IRRIGATION AND SURFACE DRAINAGE

As the natural precipitation in Rechna Doab is very scanty except in a small area to the northeast bordering the Himalayan foothills, agricultural production is not possible without irrigation. However, the climatic conditions are very favorable and cropping is otherwise possible throughout the year. Prior to the advent of largescale irrigation development, some 70 years ago, the whole area was a desert waste and only narrow strips of lands along the rivers were cultivated. Irrigation was initiated on a large scale in Rechna Doab in 1892 with the construction of a diversion weir on the Chenab River at Khanki and the Lower Chenab Canal, which was completed by the close of the century. Its authorised full supply is 11,500 cusecs and provides perennial irrigation supplies to a culturable commanded area of 2.84 million acres. During the summer cropping season when the river discharge is high, an additional culturable area of 150,000 acres is given irrigation supplies. The Lower Chenab Canal system, which is one of the largest in West Pakistan, irrigates most of the central and lower portion of the Doab. To irrigate the areas south of the River Ravi, a project was completed in 1915 under which a canal was constructed across the Rechna Doab to transfer the surplus water of the Chenab River to the Ravi. This canal, called the Upper Chenab Canal, takes off from a barrage or diversion weir at Marala and carries a discharge of 13,000 cusecs. In the Rechna Doab, part of the supplies of the Upper Chenab Canal are utilized to provide irrigation for a culturable commanded area of 1.44 million acres located east of the Lower Chenab Canal command. The southwest tip of the Doab is irrigated from the Haveli



Canal, opened in 1939 as a feeder link to carry 5,000 cusecs of surplus water from the Chenab at Trimmu to the Ravi above the Sidhnai headworks. The culturable area under the command of the Habeli Canal in Rechna Doab is 128,000 acres perennial and 78,000 acres non-perennial. With the partition of the Indian sub-continent in 1947, canals off-taking from the Rivers Ravi and Sutlej in Indian territory were threatened with shortage of supplies. This led to the construction of further feeder canals, the Marala Ravi Link and the B.R.B.D. Link. The Marala Ravi Link is the largest feeder canal across Rechna Doab and has a capacity of 22,000 cusecs. A small area of 160,000 acres in Rechna Doab is also commanded by this feeder. With the signing of the Indus Waters Treaty with India, a number of link canals must be constructed to transfer water from the western rivers to the canals dependent on the eastern rivers. One of these links will cut across Rechna Doab and carry a discharge of 18,600 cusecs. All the above canal systems in the Rechna Doab command a total culturable area of 4.8 million acres within a gross commanded area of 5.6 million acres, which is 80% of the entire area of the Doab.

Due to a flat topography, natural surface drainage is not well-defined in the Rechna Doab. The principal nullahs are the Dog and Basanter, which outfall into the Ravi, and the Aik, which joins the Chenab. These nullahs, which drain the upper portions of the Doab, do not have well-defined channels and in their lower reaches their beds become wide, low depressions. For the removal of surface run-off, these nullahs are not

very effective and after heavy rains, which are characteristic during the monsoon, they overflow their banks, inundating large areas. This condition is further aggravated when the river stages are high and the outlets of the nullahs are blocked.

To improve surface drainage conditions in Rechna Doab, a large number of surface drains have been constructed having a total length of 1,400 miles and a designed discharge capacity of 13,800 cusecs. These drains have not proved very effective and over an area of 1,500 square miles, where drainage conditions are particularly critical, their capacities are now being increased by 4,400 cusecs and additional branch drains are being provided. The irrigation systems and the natural drains described above are shown in Fig. 2.

PROBLEMS OF IRRIGATED AGRICULTURE

AGRICULTURAL PRODUCTIVITY

Typical of the irrigated lands in the rest of West Pakistan, agricultural productivity in Rechna Doab is very low in spite of the favourable climatic and soil conditions. A comparison of the average yields of the principal crops presently obtained in the irrigated lands, the yields obtained in other countries and the potential which can be achieved under a proper irrigated agriculture is given below:

Under existing economic conditions in West Pakistan, in which agriculture plays a prominent role and where the pressure on land is so great that there is only 0.7 acre of cultivated land per capita, the low agricultural productivity is a serious problem. It is in fact a problem of irrigated agriculture, as the major portion of the cultivated land is under irrigation and this is more so in Rechna Doab.

The low productivity is attributable to many factors. Farming methods for the most part are quite primitive. Individual farms are small in size and relatively little use is made of fertilizers and improved agricultural practices. The prime reasons for the low productivity, however, are connected with irrigation and drainage. The irrigation applications are spread too thinly. The irrigation supplies are far too short for the areas commanded by the irrigation systems, which results in very low cropping intensities and large portions of land remain fallow. These conditions, quite apart from having a depressing effect on the yields, tend to accentuate the salinization of the lands. The lack of adequate drainage, natural or artificial, on the other hand, has led to a great rise in the water table, large areas have become waterlogged and the attendant salinization has spread to a very large extent. These aspects are considered in greater detail below.

TABLE 1. COMPARISON OF CROP YIELDS.

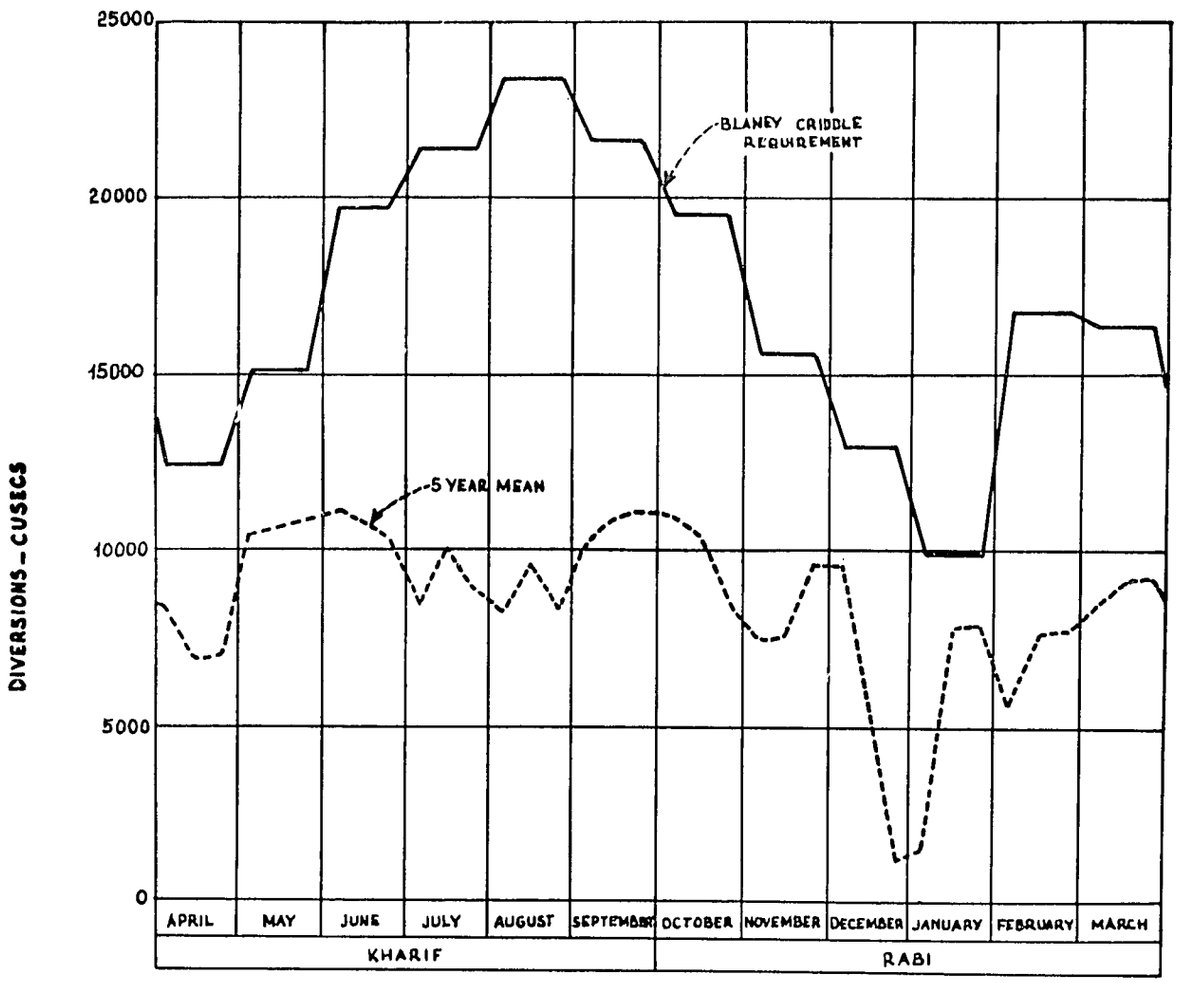
Crop	Crops yields — bls./acre				
	W. Pakistan irragated lands	U.S.A.*	Egypt	U.S.S.R.*	Estimated under improved conditions Rechna Doab
Wheat	970	1640	1600	830	1600-1800
Rice	1200	3300	3300	1900	2000
Sugarcane	2700	—	6200	—	4000
Cotton	490	500-1000	900	—	1000
Maize	960	2100	18	950	2000

* Principally from non-irrigated land.

IRRIGATION SUPPLIES

At the time when irrigation development was taken up in the Rechna Doab, one of the main considerations was to colonize large areas of virgin lands to provide settlement opportunities. This concept led to the layout of extensive irrigation systems and to the distribution of available supplies over large areas. The soil and water relationships and optimum crop water requirements were subjects which were not well understood, and distribution of irrigation supplies was determined more on the basis of experience. In relation to the culturable areas which could be supplied with irrigation water, water allowances were fixed in terms of the authorized discharge per 1000 acres, and intensities of cultivation were established for the two cropping seasons, the Kharif (April to September) and the Rabi (October to March). The water allowances and design intensities vary from one canal system to another. In the case of the Upper Chenab Canal, the water allowance for perennial areas is 2.73 cusecs and the designed Kharif and Rabi intensities are 24 ans 36 per cent, respectively. This means that 88 acres should be irrigated during Kharif and 132 acres during Rabi from a supply of one cusec. On the same canal, for the non-perennial areas the water allowance varies from 2.86 to 5.09 cusecs and with the designed intensities the duty is 70 acres per cusec. Considering the other canal systems, the water allowance on an average is equivalent to 1 cusecs per 350 acres of culturable commanded area and the annual design

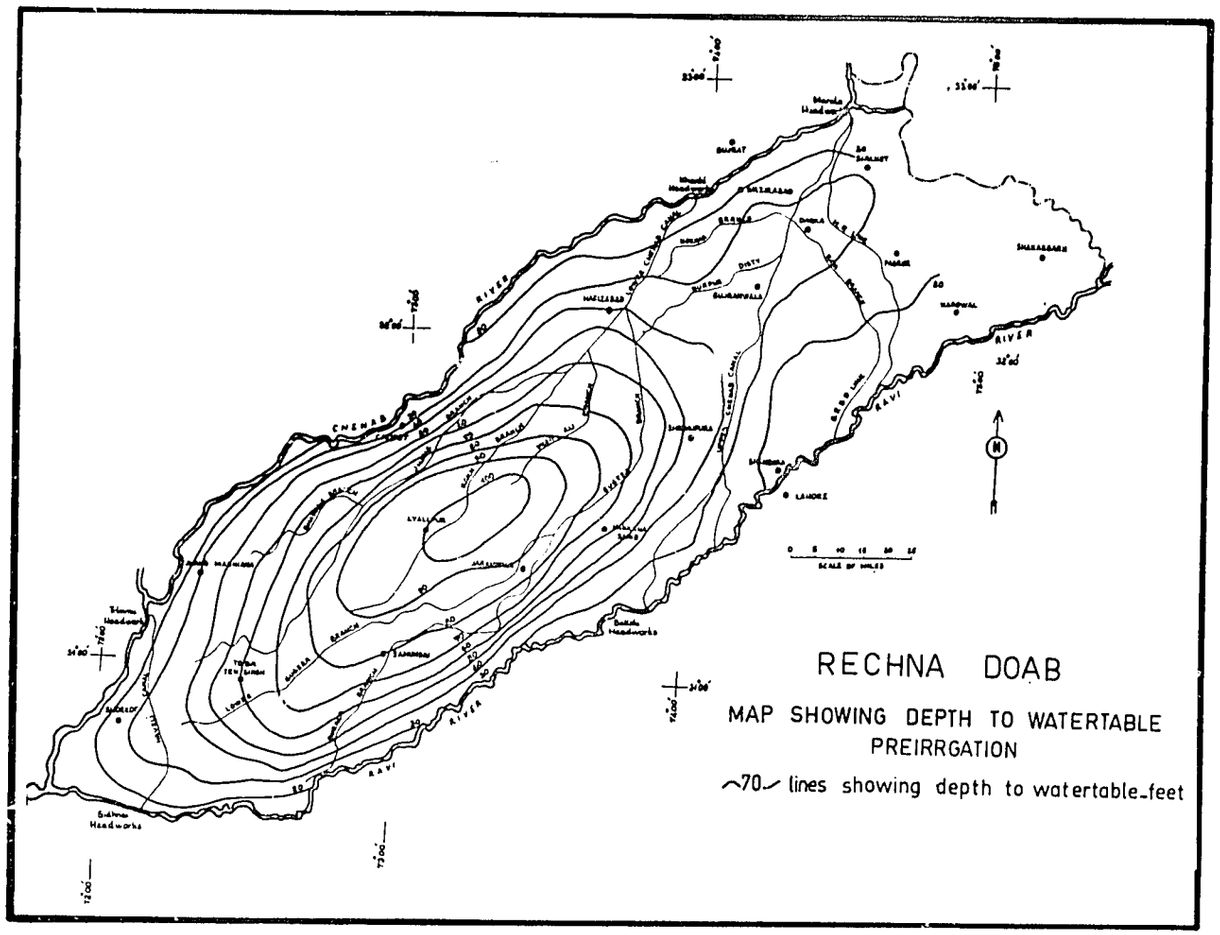
Lower Chenab Canal

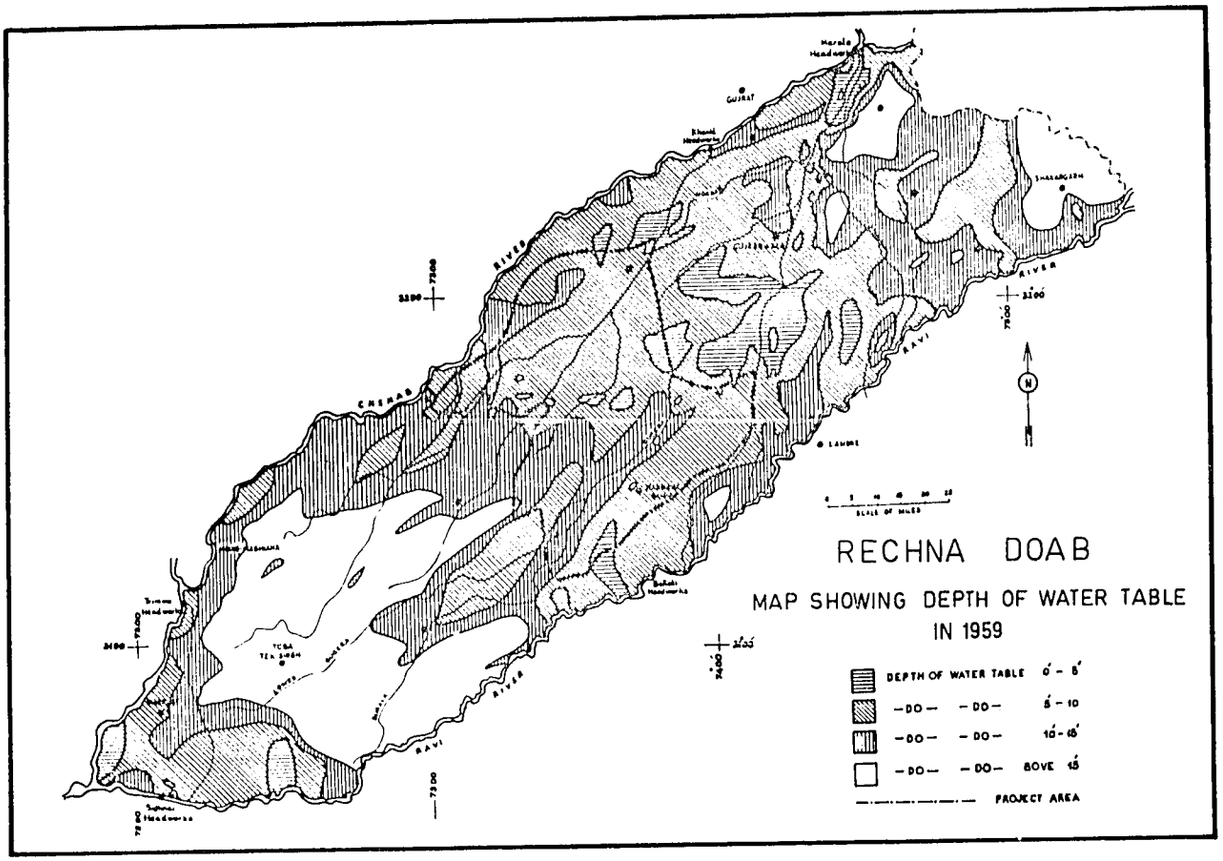


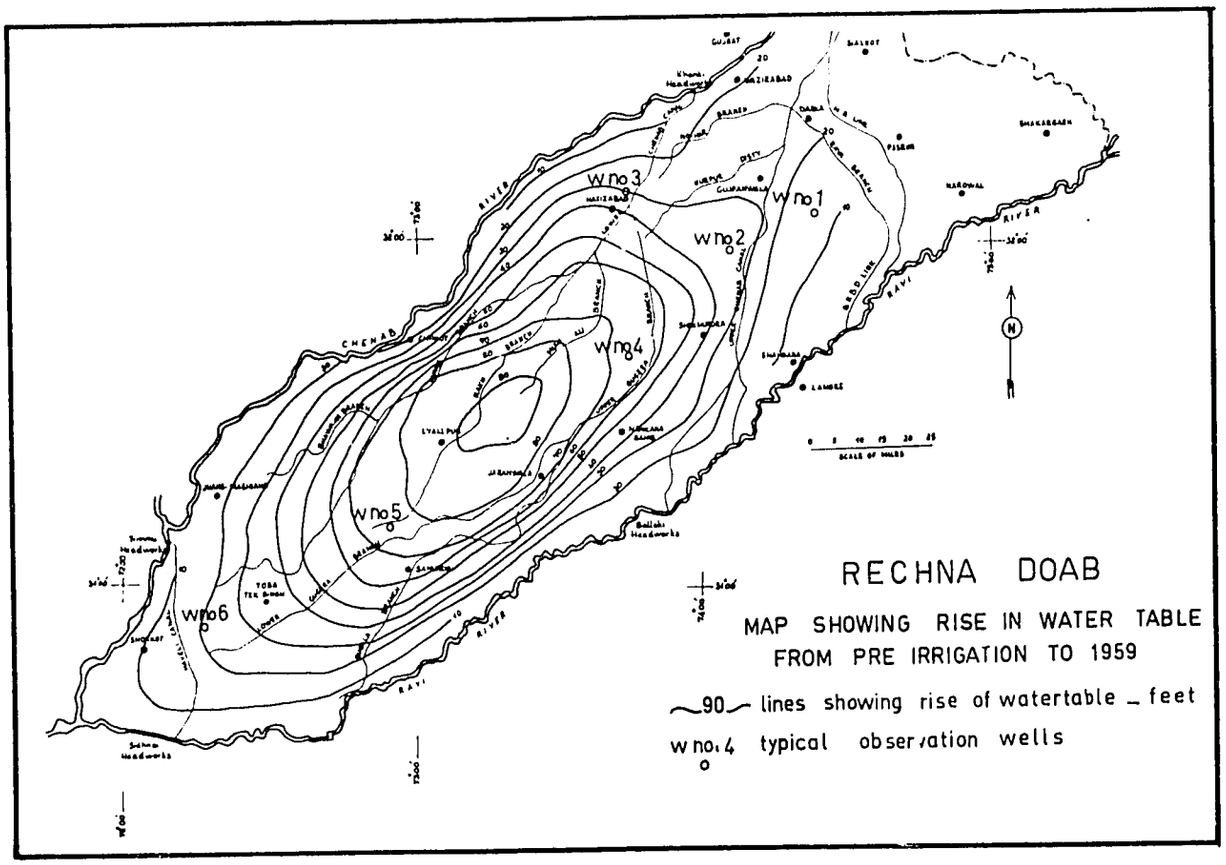
intensity is 75%; 25% in Kharif and 50% in Rabi. These water allowances and duties are among the lowest in the world. Moreover, in actual practice the intensities of irrigation have been far exceeded and range from 95 to 110 per cent. As a result, the irrigation supplies, already low, have been spread even more thinly. The inadequacy of the present irrigations is fully brought out when the consumptive use requirements are compared with the actual supplies. Fig. 3 shows the diversions necessary to meet the consumptive use requirements determined by the Blaney-Criddle method for the Lower Chenab Canal System for an intensity of 100% (44% in Kharif and 56% in Rabi). The actual mean supplies for a five-year period are also shown in this figure. Comparison of the two curves indicates that the available supplies are less than 50% of the requirements.

WATERLOGGING

Based on the experience of some of the earlier canal systems, it was apprehended that the opening of the Lower Chenab Canal might lead to waterlogging. In order to keep the trend of the water table under review, a series of observation wells was established as early as 1902 and regular observations were made in June and October each year, prior to and after the rains. These observations soon confirmed that the water table had been rising and it was not long before waterlogging developed in some areas. Similarly, within four years of the opening of the Upper Chenab Canal in 1915 waterlogging appeared along the canal and spread gradually. Prior to irrigation development, the water table lay at 20 to 30 feet along the rivers and in the upper and lower portions of the Doab, and in the centre the depth was over 100 ft.




RECHNA DOAB
MAP SHOWING DEPTH OF WATER TABLE IN 1959
DEPTH OF WATER TABLE 0' - 5'
-DO- -DO- 5' - 10'
-DO- -DO- 10' - 15'
-DO- -DO- ABOVE 15'
PROJECT AREA
CHENAB RIVER
RAVI RIVER
GUJRAT
LAHORE
SCALE OF MILES


RECHNA DOAB
MAP SHOWING RISE IN WATER TABLE FROM PRE IRRIGATION TO 1959
~90~ lines showing rise of watertable _ feet
w no. 4 typical observation wells
w no 1
w no 2
w no 3
w no 4
w no 5
w no 6
CHENAB RIVER
RAVI RIVER
GUJRAT
WAZIRABAD
LAHORE
NAROWAL
SCALE OF MILES

(Fig. 4 42-4). At present the water table lies within 10 feet of the surface in most of the upper half of the Doab and is more than 20 feet deep in only a small area (Fig. 5 42-5). The total rise in the water table from the pre-irrigation to the present time is shown in (Fig. 6 42-6), indicating that the water table has risen as much as 90 feet in the central portion of the Doab. The rise in the upper and lower portions and along the rivers has ranged from 10 to 20 feet. This extensive rise in the water table has resulted in saturating more than 180 million acre-feet of the subsurface formations. Typical hydrographs of wells along the Doab, whose locations are indicated in Fig. 6, show that the initial rate of rise in the water table was very steep in areas with a deep water table and considerably less in the upper and lower areas where the water table was at comparatively shallow depths. The rate of rise was also very large close to the main canals. As the water table assumed higher elevations, the rate of rise gradually declined and in most cases on reaching close to the ground surface, the water table became stablized at depths of three to five feet under the increased evapotranspiration.

Due to the rise in the water table, waterlogging has developed in sizeable areas in Rechna Doab. In 1959, the areas under different depth ranges were as follows:

TABLE 2. AREAS SHOWING DEGREE OF WATER-LOGGING, 1959.

Depth to Water Table Feet	Area in Acres	Percentage
0-5	440,000	6.3
5-10	3.050,000	43.3
10-15	1,950,000	27.6
Above 15	1,600,000	22.8
Total	7,040,000	100.0

SOIL SALINITY

With the rise of the water table, soil salinity started to increase in the irrigated areas in Rechna Doab. Although this problem came to the notice of the Government as early as 1908, its extent and the fact that it was on the increase did not come up for systematic study until 1927, when surveys of waterlogged and salinized soils were initiated in those where the water table had reached within 10 feet of the ground surface. These surveys were confined to selected districts and estates only, and these by no means represented the full extent of the problem. Since 1943, these surveys have been made for the irrigated areas as a whole and, based on visual inspections, have classified the salinized lands as, a) affected land that has never been cultivated; b) land which has gone out of cultivation; and c) land in which, salinity exists in 20% or more of the area.

These surveys indicated that by 1959 within the command of the canal systems in Rechna Doab a total area of 1.19 million acres of 25% of the survey area had been affected by salinity, and that during the previous 14 years there had been an increase in the affected area of 150,000 acres. The percentage of the culturable area which had gone out of cultivation, and been affected by salinity to the extent of 20% or more in 1945 is shown below:

TABLE 3. AREAS AFFECTED BY SALINITY.

Year	Per cent of culturable area		
	Gone out of cultivation.	Affected 20% or more	Total
1945	10.9	11.0	21.9
1959	11.9	13.1	25.0

Estimates of the land affected by salinity in Rechna Doab have also been made from interpretation of aerial photographs taken during 1954. These reveal that 1.14 million acres of land are predominently severely saline and that in another 2.3 million acres saline patches are common.

Recently a soil and salinity survey has also been carried out in Rechna Doab, from 1954 to 1957. The results, covering an area of 1.4 million acres where a reclamation project described later has been undertaken, indicate that 20% of the land is moderately saline (salt contents. 0.2 to 0.5%

15. % is strongly saline (salt content, 0.5 to 1.0%); and 2.5% is highly saline (salts more than 1%).

All the above estimates of salinity indicate that salinity is widespread in Rechna Doab and has assumed such large proportions as to constitute a major problem. Moreover, the spread of salinity is enlarging and every year it is estimated that more than 15,000 acres are going out of cultivation or being affected by salinity to such an extent that agricultural productivity is severely curtailed.

SURFACE FLOODING

The topographic conditions and the intensity of rainfall during the monsoon season in Rechna Doab have always been conductive of flood hazards, particularly in the upper portions where the precipitation is relatively large. The extent of the stream flows, however, depends largely on the condition of the land and its ability to absorb a portion of the rainfall and retard the runoff. During pre-irrigation times, when the water table was low, the soils had a great moisture-absorbing capacity. With the rise of the water table, as areas became waterlogged, the moisture-absorbing capacity was very much reduced. This has resulted in greater surface runoffs, which lead to widespread floodings of agricultural lands, making cultivation very difficult. The frequency and magnitude of the floodings in Rechna Doab have gone up quite considerably during recent years, and are attributable in great part to high water table conditions, — a consequence of irrigation development without adequate drainage.

EARLY MEASURES FOR WATERLOGGING AND SALINITY CONTROL

The debilitating effect of waterlogging and salinity on agriculture in Rechna Doab was realized not long after the irrigation systems were first introduced.

Various anti-waterlogging measures have been tried in the Rechna Doab during the last 50 years. These measures generally did not follow in a logical sequence and were mostly dictated by individual views on the causes of waterlogging. A great controversy prevailed as to the component of groundwater recharge which was most instrumental in the rise of the watertable and on the effect of seepage from canals on groundwater flow. To quote a few of the varying opinions; some of the earliest investigators concluded that, according to rainfall and intensity of irrigation, canal irrigation adds 200 to 600% (of the natural recharge) to the sub-soil water, of which the greater part is contributed in equal parts by the main canals and water courses. It was also postulated that «percolation cones» below the main canals obstruct groundwater flow, causing waterlogging. The efficacy of drains was discounted and the lining of canals and water courses was advocated (not distributaries and minors!). In early 1920, investigators, after analyzing the groundwater level data, concluded that the major cause of the rise in the water table was the recharge from precipitation, whereas the effect of canal irrigation was only secondary. As a result, great emphasis was placed on surface drainage. Still later a theory was propounded that waterlogging was to a large extent due to seepage from the canal system and only to a small extent due to the increased absorption of rainfall resulting from the breaking up of new areas for cultivation. The construction of drains was therefore suggested, and pumping from tubewells was held to have a local and temporary effect. In 1947 it was estimated that in the Lower Chenab Canal system the contribution to the water table from irrigation channels and rainfall was in the ratio of 2:1.5 whereas for the Upper Chenab Canal it was 1:2. Lining of distributaries and water-courses and adoption of tubewells as a method for sub-surface drainage were advocated at this stage. Seepage drains, however, were not favored on account of their purely local effect, and the use of surface drains on a very limited scale was suggested. In 1959, after analyzing water table data, a view was formulated by some research workers that clay lenses obstruct the sub-soil flow of water, which is insignificant and completely blocked at places, and this has caused the infiltered water to rise upward rather than establish a sub-surface gradient. The lack of sub-surface drainage was described as an impediment to the reclamation of saline soils by leaching, and the circulation of the stagnant water and redistribution of salts in thicker zones were suggested.

METHODS OF CONTROL

The various methods which were adopted for controlling waterlogging and salinity are briefly decribed below:

From 1908 to 1918 there was great emphasis on surface drains and a beginning was made on the lining of main irrigation channels; 12 miles, scattered over different channels, were lined. No substantial progress was made from 1918-26 due to World War I, but in the period 1926-33 a number of measures, such as provision of seepage drains along the main canals, lowering of full supply levels in canals by eliminating canal falls, and restricting of canal supplies, were tried. A few tubewells were also installed. However, all these measures resulted in doubtful benefits. From 1933 to 1941, surface drainage was given great emphasis and a large number of new drains were constructed. Subsequently a new approach was tried, which consisted of installing tubewells close to the main canals and putting the pumped water back into the canals, the object being to create an unsaturated zone below the canals so as to cut down the seepage.

It is significant to note that during all these years the problem was not tackled from a broad concept and with a proper appreciation of all the factors which control the behavior of groundwater.

INVESTIGATIONAL PROGRAMME

OBJECTIVES

The history of the earlier measures which were adopted in Rechna Doab to control waterlogging and salinity indicated that very little success had been achieved, and the problem continued to grow in magnitude. There were several reasons for this. Although the seriousness of the problem had been fully realized for a long time, a proper approach was not adopted for its solution whereby an engineering organization could devote full time to it. The most important reason was, however, the lack of proper appreciation of the need for complete hydrologic and geologic data on which proper solutions could be based. To remedy this situation, a program of investigation was started rather belatedly in 1954. The purpose of the investigation was to inventory the water and soil resources of selected areas and to describe the cause and effect relationships between irrigation activities and the incidence of waterlogging and salinity. The ultimate goal was to provide information that could be translated into development projects to help increase agricultural production through reclamation of affected lands, prevention of further deterioration, and improved agricultural practices on all lands. These investigations covering, all the related fields, have been completed in Rechna Doab and their nature and extent and the results achieved are briefly described below:

SOIL AND LAND CLASSIFICATION SURVEY

Although irrigation systems had been developed in Rechna Doab, no soil or land classification surveys had been carried out. Under the comprehensive investigations, therefore, these surveys were included as a first step, not only with the object of drainage and reclamation in mind but to provide a basis for efficient land and water use. The surveys were carried out on a semi-detailed basis. The soils were examined according to their characteristics, with special emphasis on the features that influence crop growth and reclamation and drainage planning. On the basis of these characteristics, the soils were grouped into classification units, the principal three of which are soil series, type and phase.

Soils series were established through a detailed study of the textural sequence of soil profile up to a depth of 72", together with other significant attributes — color, concretion and density. Soils reflecting similarity in all characteristics in the sub-soil up to the objective depth are grouped under one soil series. Variations within reasonable limits were compromised. Evaluation of texture was made in terms of five textural groups to avoid an unwieldy number of soil series.

The soil survey results indicate that the soil materials of the surveyed area in many respects show a high degree of similarity throughout the area. They are mostly reddish brown to greyish brown in color and contain high percentages of silt and fine-to-very-fine sand. The clay portion is largely of the non-swelling type, which to a considerable degree accounts for the generally favorable

permeability characteristic of the soil. They range from moderately permeable to highly permeable. Only a very small percentage have a relatively low cooefficient of permeability. The lime content of the soils is high, which is normal for areas of low rainfall.

The soils of the area in general are intrinsically fertile and have high potential productivity. Their organic matter content and other plant nutrients, such as nitrogen, phosphorous, have been depleted to a very low level through constant mismanagement. When adequate water supply and the requisite manures or chemical fertilizers are provided, they attain a high productivity level.

Topographically, the soils are located in extremely flat areas. With the exception of some small dune-like areas, topography poses few problems insofar as individual field development is concerned. Although this contributes to the complexity of planning irrigation and drainage facilities, it is probably one of the major reasons for the very low percentage of permanent waste lands in the area. Due to flat, relatively smooth surface features, the land is easily developed for irrigated forming. Favorable topographic features, coupled with the very high percentage of good soils, add up to a net condition wherein it is estimated that approximately 98% of the Doab lands are irrigable.

The systematic appraisal of lands and their designation by categories have been made by consideration of the relatively stable factors, of which soils, topography and drainage are of primary importance. These factors were considered individually and collectively from the standpoint of land classification for irrigation farming, and six classes were established.

SUB-SURFACE GEOLOGIC EXPLORATION

In the solution of drainage problems, a knowledge of the geologic conditions which govern the occurrence source, storage, yield and movement of ground water is essential. As very little was known of the subsurface geologic conditions, a program of investigations was undertaken in Rechna Doab under which a series of test holes was drilled to a depth of 600 feet on an average. These test holes were located along eight lines approximately 15 to 20 miles apart running transversely between the Rivers Chenab and Ravi. Another line of test holes was established running centrally along the length of the Doab. Along these test lines a total of 276 test holes was drilled at an average spacing of three miles. The total footage drilled amounted to 178,700 feet. The test holes were drilled by the rotary method and lithologic logs were made from the drill cuttings as drilling proceeded. Samples of the formation materials were also collected for laboratory analysis to determine the physical and chemical characteristics. An electrical resistivity and self-potential log was also run in each test well, to provide better correlation for the lithologic logs and to give an idea of the formation characteristics. Samples of water were also collected at varying depths from the test holes for determining the quality of the groundwater. In order to supplement the test drilling, electrical resistivity surveys were also carried out, so that the conditions revealed by the test holes could be projected in the intervening areas. These resistivity surveys were carried out along traverses on test lines, and between the test lines a series of probes were made on a grid pattern in an area where it was proposed to undertake the first drainage and reclamation project. The results of these resistivity surveys were interpreted to a depth of approximately 300 ft., as at greater depths reliable interpretation is not always possible.

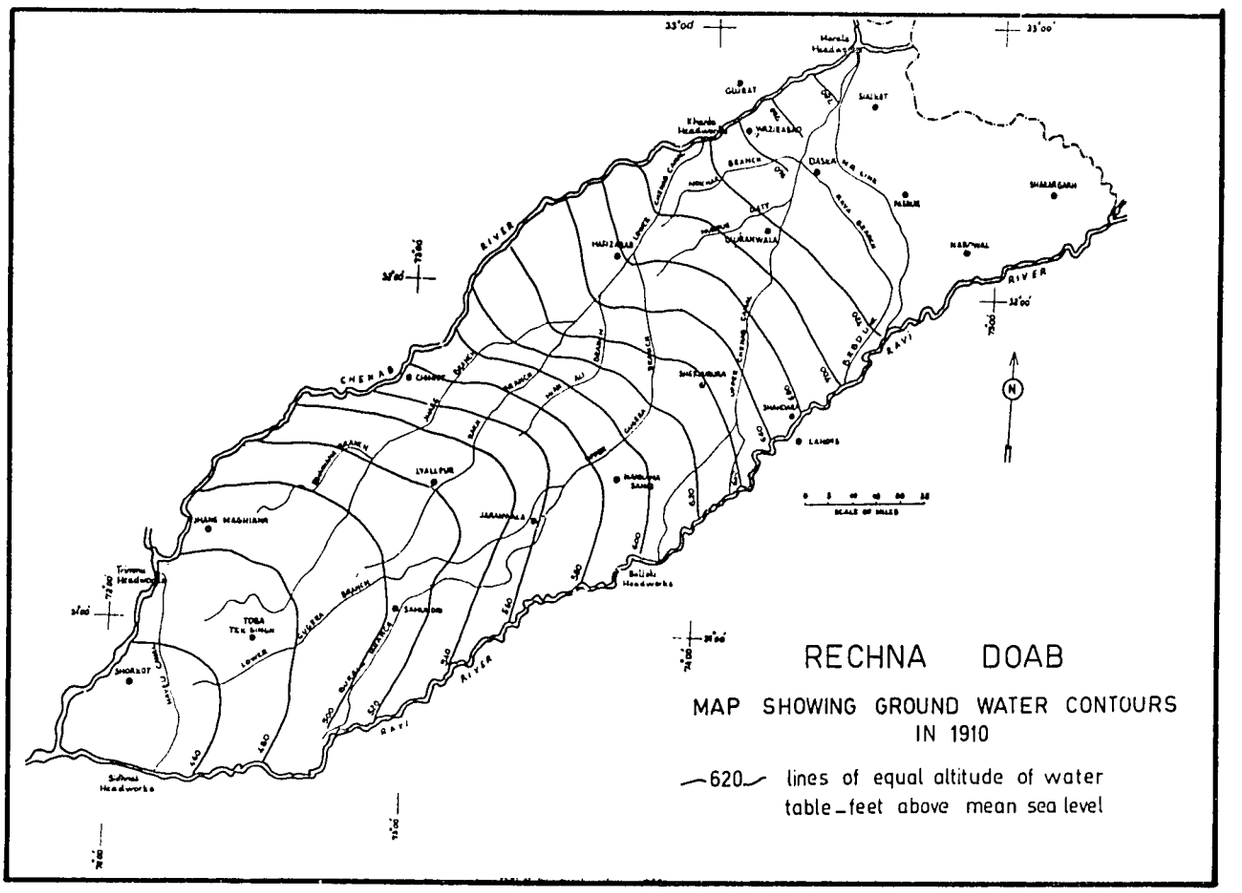
All these subsurface explorations have provided very useful information about the geologic conditions and the nature of the alluvium underlying the Doab. Except along the general trend of the Delhi-Shahpur Ridge, bedrock was not encountered in the upper and lower portions of the Doab and a few test holes drilled to depths of more than 1,000 feet were all in alluvium. These explorations also indicated that except in the immediate vicinity of the few outcrops, the buried ridge lay at depths of more than 600 feet. The alluvial deposits to the depths of exploration were found to consist of a wide variety of sediments, ranging between course sand and clays. The clays and silts usually occur in the form of lenses and there was no evidence to indicate that the less permeable formations form any barriers to restrict or confine grounwater flow throught the sands. The thickness of the aquifers in the 400-ft. depth zone

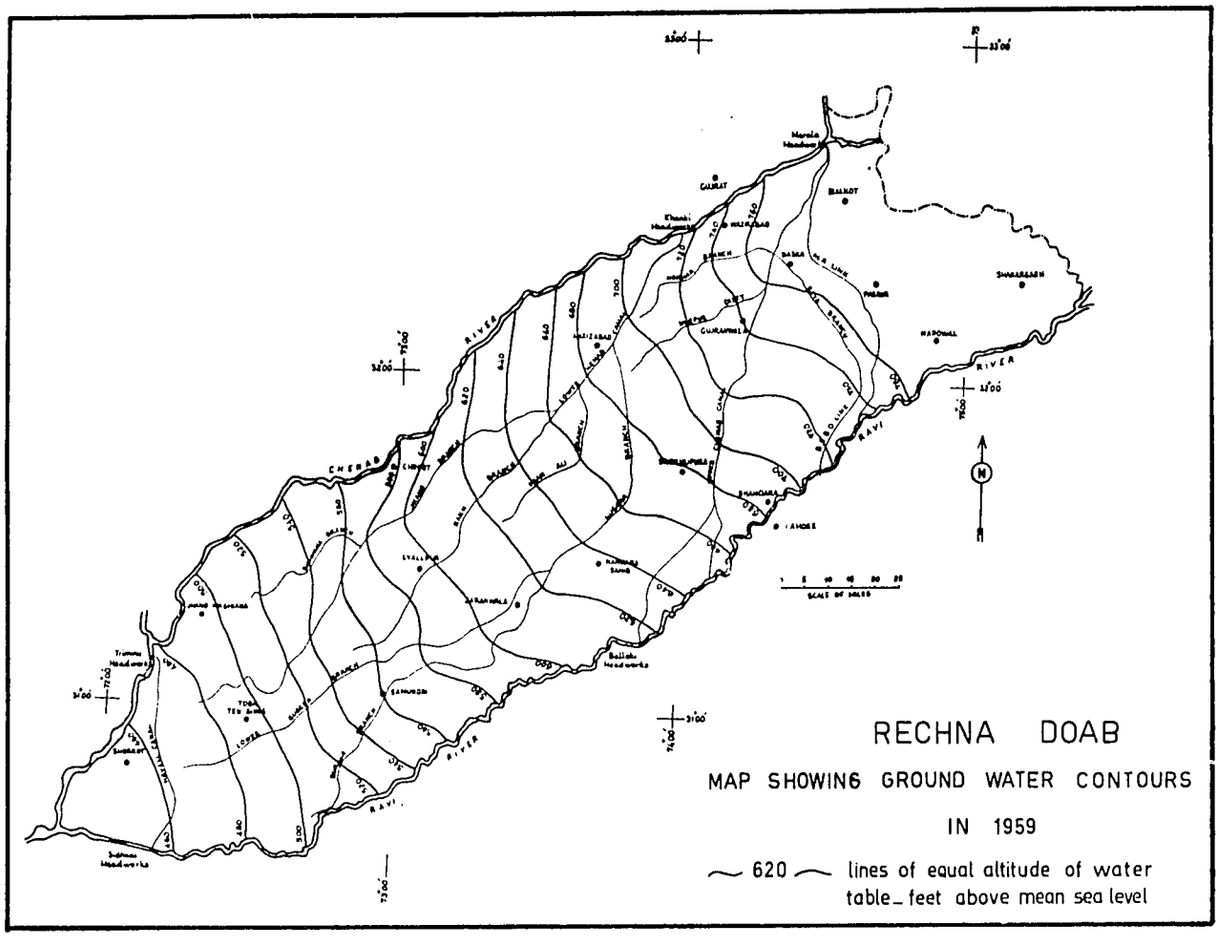
was found to vary from 350 ft. in the lower portions of the Doab to less than 100 ft. in the upper reaches. The thickness of the aquifers was also noted to decreases in the vicinity of the Pre-Cambrian outcrops near Chiniot and Sangle, where the finer sediments predominate.

AQUIFER CHARACTERISTICS

Apart from the exploratory drilling, which provided useful information on the nature and extent of groundwater aquifers and the physical properties of the water-bearing formations, a number of aquifer tests were carried out by the pumping well method. These tests were carried out on 62 wells 150 to 300 feet deep and the specific capacities of the wells and the co-efficient of transmissibility and storage were determined. These tests indicated that the aquifer underlying Rechna Doab had a co-efficient of transmissibility ranging from 0.5 to more than 1.0 cfs/ft. and wells could be expected to have specific capacities of 0.2 to 0.33 cfs per ft. of draw-down.

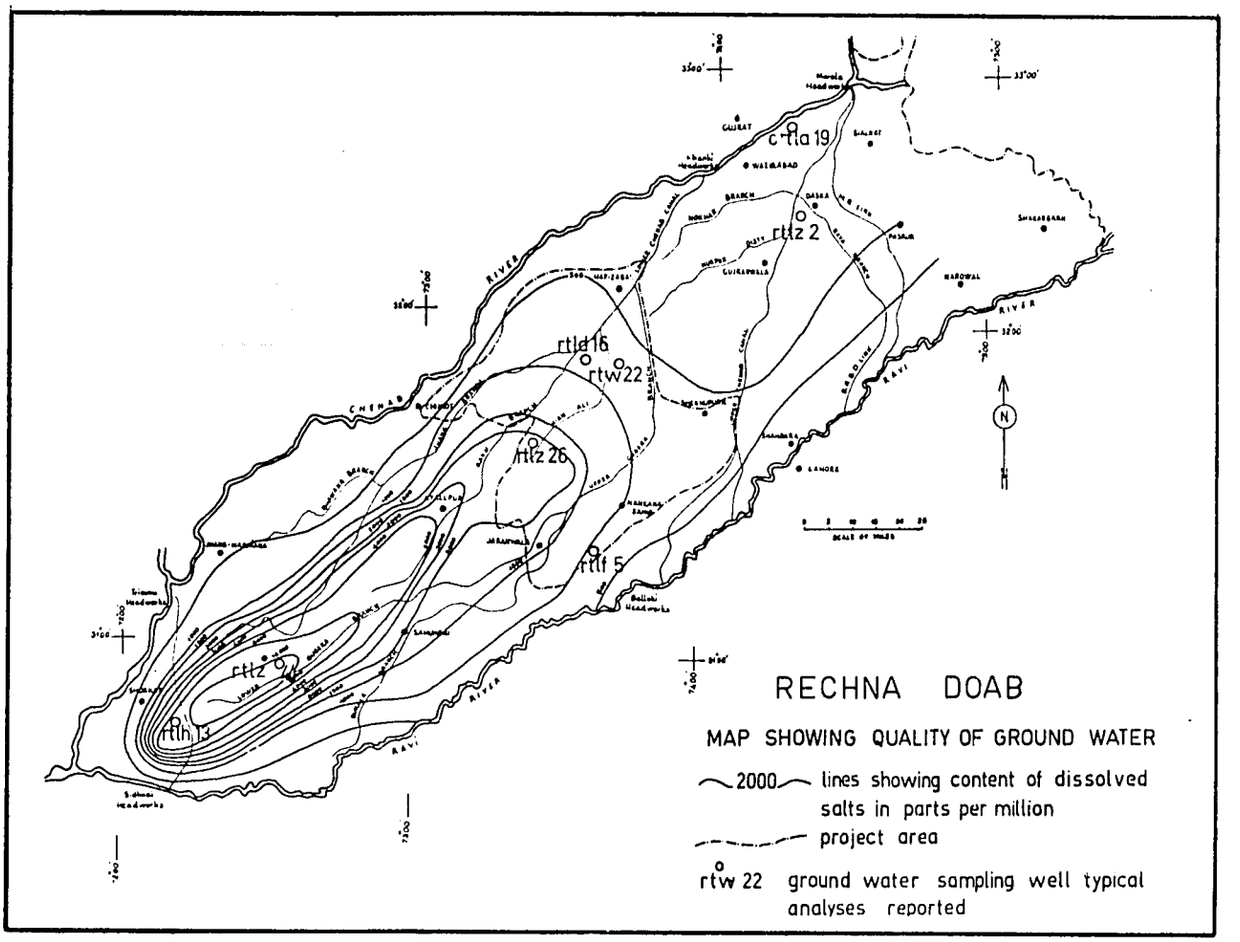
Watertable Fluctuations. Records of groundwater level data in Rechna Doab have been kept from 1894, when certain wells were selected for measurement of groundwater elevations. These were supplemented by local wells in 1907 and additional wells were later established in 1920 and 1940. Under the comprehensive investigation program, 21 automatic water depth recorders have been installed to record groundwater level fluctuations continuously. The total number of these observation wells is now about 700. From the water level record of these wells, which has been observed twice every year in June and October, prior to and after the rains, it has been possible to determine the manner in which the water table has risen from the time irrigation was introduced and to evaluate the groundwater recharge. Fig. 7 shows grounwater contours in the Rechna Doab





in June, 1910, which have been constructed on the basis of the groundwater level record. These contours indicate that soon after the Lower Chenab Canal was opened, the Rivers Ravi and Chenab were influent and the general movement of groundwater was toward the centre of the Doab and down to the confluence, there being a groundwater trough between the two rivers. The water table conditions in 1959 are depicted by the groundwater contours in Fig., 8 which indicate that the upper reaches of the rivers have changed from influent to effluent and in place of a trough there is now a groundwater mound in the centre of the Doab. Detailed studies of the water level record have brought out how hydrological conditions have changed or are changing in various parts of the Doab. In the upper portions, the rise in water table has become negligible as recharge and discharge have equalized, but in the lower portions where the water table is still 15 to 20 feet there is still gradual rise and equilibrium has not yet been achieved. The rise in the water table has, however, built up groundwater storage and offers great potentialities for development.

Quality of Groundwater. For the utilization of groundwater, knowledge of its quality is essential. This subject has been thoroughly examined for Rechna Doab as part of the overall investigations. Water samples have been collected from existing shallow wells and from deep exploratory bore holes and complete chemical analyses have been carried out. Nearly 90,000 existing shallow wells were inventoried, of which 28,372 were sampled for complete analysis. Water samples at varying depths of up to 450 feet were also obtained from 185 exploratory bore holes and test wells and analyzed simularly.



The results of these analyses indicate that the quality of groundwater varies between wide limits in different areas of the Doab. The quality of the shallow groundwater, which reflects the effect of recharge, is generally superior to the quality of deep groundwater, and the variations over the Doab are not very significant, although locally the differences in quality make it difficult to depict gradual changes. The total dissolved solids in the shallow groundwater generally range from 500 to 1,000 parts per million. The deep groundwater however, shows great variation, both in the concentration of the total dissolved solids and their composition. Fig. 9 (42-9) shows lines of equal total dissolved solids in parts per million, which depict the general pattern of variation of the dissolved mineral content of the deep groundwater under Rechna Doab. In the lower central part of the Doab there is a zone of highly brakish water having more than 10,000 ppm. of dissolved solids. This zone is surrounded by waters which improve in quality outwards toward the rivers and in the upper parts.

Considering the Doab as a whole, about 75% of the area is underlain with groundwater having less than 1,000 ppm. of dissolved solids; about 10% is in the range 1,000 to 2,000 ppm.; about 5% in the range 2,000-3,000 ppm. and about 10% more than 3,000 ppm. Thus a major portion of the Doab has groundwater which can be used for irrigation and the usefulness of this can be extended further if it is used after being with canal waters which have very low concentrations of salts. The results of a few typical analyses of river and groundwater in Rechna Doab are shown in Table 4.

TABLE 1. CHEMICAL ANALYSIS OF WATER SAMPLES IN RECHNA DOAB

Sl. No.	Source and Location	Sampled in	Milliequivalent per litre							Dissolved Solid P.P.M.	Condvy. Microm-hos at 25 c	pH	SAR
			Ca	Mg	Na + k	Co 3	Hco 3	Cl	So 4				
	Rivers Ravi and Chenab												
I. 1.	Ravi of Jassar	Dec. 1959	2.04	0.72	1.04	—	3.18	0.15	0.47	236	360	7.3	1.0
2.	Chenab at Marala	—do—	1.73	0.74	1.05	—	2.43	0.10	0.44	224	333	7.6	0.9
Subtile	Typical groundwater samples from various areas of Rechna Doab												
II. (a)	Adjoining river & upper part of the Doab.												
1.	RTLA 19	1956	2.54	1.37	1.91	—	4.67	0.40	0.75	308	500	7.8	1.3
2.	RTLZ 2	—do—	2.91	1.69	1.47	—	4.40	0.24	1.43	348	560	7.3	0.9
(b)	In the South Centl. part.												
1.	RTLH 13	1957	10.78	16.23	163.63	0.53	3.201	136.40	52.21	13266	18666	8.2	56.3
2.	RTLZ 44	—do—	33.62	38.37	107.14	—	2.74	120.26	56.12	10106	16266	7.7	17.3
(c)	In the Proj. Areas												
1.	RTWF 22	1954	1.16	0.80	6.81	0.37	5.60	0.81	1.98	510	827	6.0	7.4
2.	RTLF 5	—do—	1.89	2.71	3.16	—	5.52	0.97	1.27	450	650	7.6	2
3.	RTLD 16	—do—	1.49	2.16	7.24	—	6.26	1.07	3.49	640	950	8.1	5.4
4.	RTLZ 26	—do—	2.37	3.85	32.70	1.63	12.64	9.72	12.89	2322	3527	8.3	19.4
	(Shahkot Area)												

(Location of water sampling wells shown on Fig. 9).

OTHER INVESTIGATIONS

Besides the above main investigations, studies have been carried out to determine canal seepage losses in Rechna Doab in order to determine quantitatively this element of groundwater recharge. Climatological and precipitation data have also been collected and analyzed. The distribution of canal supplies and the agronomical aspects of determining water requirements and cropping patterns have likewise been taken into account.

GROUNDWATER DEVELOPMENT PROGRAM

IRRIGATION AND DRAINAGE REQUIREMENTS

Waterlogging in the Rechna Doab and the attendant salinity, as indicated previously, have assumed such large proportions that the economic life dependent on agricultural productivity is threatened. The average crop yields in the area, are among the lowest in the world.

The cause of the low yields and the low level of productivity is not entirely the waterlogging and salinity of the soils. As was brought out previously, the irrigation applications are far below the optimum crop requirements. The situation is further aggravated by improper irrigation and agricultural practices, lack of adequate pest control and the declining fertility of soil for want of fertilizers. Agricultural production is also limited by the recuring floods which damage standing crops and render the sowing of winter crops impracticable in the affected areas.

A fundamental requirement to remedy the above problems of agricultural productivity is the urgent need for controlling groundwater levels and removing the salts from the soils. Unless this is done, efforts in all other directions cannot be expected to achieve any lasting benefits.

In order to control groundwater levels, it is necessary to depress the water table, and the salts can then be flushed down by excess applications of water for leaching. These objectives can only be achieved by adequate drainage and supplementary supplies of water over and above the optimum crop requirements.

USE OF GROUND WATER FOR IRRIGATION AND DRAINAGE

Whereas various approaches could be considered for providing proper drainage conditions, the provision of additional irrigation supplies poses many problems. The surface sources of supply are presently dependent on river flows which are fully committed. The only way surface sources can be supplemented is by the construction of storage reservoirs which can conserve the flood discharges. Such surface storage will be required to meet the demands of new developments and the deficiencies in irrigation supplies in areas where the groundwater is too saline for use. Moreover, if surface sources had a developable potential, it would involve the enlargement of existing irrigation systems to an extent comparable to the layout of new systems of almost double the capacity. Then again, these large systems would result in greater seepage losses and in turn much larger drainage works would have to be provided. The lining of canals in this connection could be considered, but this subject has received considerable attention and with available methods it has been found to be difficult to justify on economic grounds. The only other way to supplement the present surface supplies is by developing groundwater, and it is in this context that its use achieves a dual purpose — providing subsurface drainage and making usable water supplies available for irrigation. This approach has been adopted in Rechna Doab, where an area of 1.2 million acres in the command of the Lower Chenab Canal system has been taken up for a drainage and reclamation project by the installing of 1,800 tubewells.

AQUIFER YIELD AND QUALITY OF GROUNDWATER

The effectiveness of groundwater exploitation for irrigation and drainage is intimately related to the yield of the groundwater aquifer. Whereas it may be possible initially to withdraw sufficient water from the groundwater storage to lower the water table to such a depth that proper drainage conditions are established, and thereafter to limit the rate of withdrawal to the safe yield of the aquifer, the mining of groundwater would not take place. In

such a case, the yield of the groundwater would be limited to the average rate of net recharge. However, if mining of groundwater storage is resorted to, then a much larger yield can be realized, but this in turn leads to a progressive decline in the water table and greater pumping lifts. The decline in the water table, however, is not linear with time but diminishes gradually and in time conditions of near-equilibrium can be achieved as groundwater inflow increases and outflow decreases and other losses are also curtailed. The behavior of the ground water aquifer can be analyzed under different conditions of groundwater withdrawal if sufficient data are available, and it is therefore possible to determine an optimum groundwater yield which is best related to local economic conditions. In the groundwater development and drainage project in Rechna Doab it has been estimated that a groundwater withdrawal of 1,25 ft. per year over the gross project area would lead to a lowering of the water table so that at the end of 40 years the water levels would descend to the levels which existed before the introduction of irrigation. These levels do not represent a very high pumping lift and, considering the life of the project, are fully justified.

The quality of groundwater varies considerably within Rechna Doab but in the project area the groundwater can be characterized as being in general of medium to high salt content (500 to 1500 ppm.), with low to medium residual sodium (SARs of 5 to 15). Such waters can be successfully utilized for irrigation if good drainage is provided and sufficient water is applied to maintain a downward movement of the salts through the root zone. The groundwater, however, is not intended to be utilized as such for irrigation except for small areas which are at present un-commanded by the canals. The bulk of the groundwater will be mixed in the farmer's irrigation water courses with the canal supplies having a concentration of salts of less than 250 ppm., and therefore the quality of the combined supplies is not likely to present any problems. However, the use of groundwater for irrigation in the area where it is pumped does not afford an opportunity for removal of the salts from that area. Essentially, all salts now contained in the groundwater and these accumulated in the soils and leached downwards in the reclamation process, as well as the salts contained in the canal waters applied to the lands and which ultimately reach the groundwater reservoir from canal leakage, will in effect be continuously re-circulated by pumping and will lead to slow deterioration in the quality of groundwater. With the available data, however, it has been estimated that such a process will be so slow that it will not present any problem, at least during the life of the project.

PLAN OF GROUND WATER DEVELOPMENT

For the first drainage and reclamation project in Rechna Doab based on the exploitation of groundwater, a compact area has been selected within the command of the Lower Chenab Canal. The execution of this project is in the hands of the West Pakistan Water and Power Development Authority, a semi-autonomous Government body. The location of the project area is shown in Fig. 9. The prime considerations which led to the choice of this area were:

(1) Prior to deterioration, the land in the area had a very high level of productivity.
(2) The area is among the worst of those affected by waterlogging and salinity.
(3) From the point of view of geological condition and soil types, the area is best suited for drainage by tubewells.
(4) Soil types respond readily to reclamation by leaching operations.
(5) The quality of the groundwater is good to excellent.
(6) The area is well-developed. Communications, marketing and electric power facilities are available.
(7) The area is a compact contiguous block where pumping operations can achieve their objective most efficiently.

As the project aims at the utilization of groundwater for supplementing the existing canal supplies for irrigation, the crop water requirements and means for mixing and distribution had to be kept in view. These considerations led to the de-

termination of the number, capacities, design and locations of the tubewells to be used for groundwater withdrawal. The pattern of existing canal supplies follows the river flows and is unrelated to the crop water requirements. When the consumptive use requirements are maximum, in July and August, the tubewells should be capable of producing the required supplies to meet the full crop water requirements, and at the same time should have sufficient extra capacity to make up for any deficiencies that may occur in the natural precipitation. Taking into account the yield of the aquifer and the existing supplies, and fixing a pattern of cropping and cropping intensity such that the consumptive use requirements can be met, criteria can be fixed for determining the capacity of tubewells. However, it is realized that any estimates of groundwater yield based on assumptions cannot be relied upon the rigidly and in projects of this nature a true idea of yield can be obtained only after the tubewells have been operated for a sufficient length of time. As the operational yield for this project has been calculated to be on the conservative side, the capacities of the tubewells have been determined on the higher side, and are such as would make it possible to achieve cropping intensities of up to 150% in years of normal precipitation. The criteria adopted for determining the capacity of tubewells was to allow for tubewells plus actual canal supplies measured at the outlet heads at the rate of 1 cusec per 150 acres of culturable commanded land. Against this water allowance, the existing water allowance is 1 cusec of authorised supply for 350 acres. Even if the operational yield of the groundwater were restricted to 1.25 ft. per gross acre, the quantity of groundwater developed will be of the order of 1.5 million acre feet per year, as against existing canal supplies of 1.25 million acre feet, and will therefore make the total supply available more than double that existing.

Under the existing irrigation system, water is supplied to sizeable units of areas called «chaks» from outlets in the distributaries and minors. These «chaks» vary in size from a few hundred acres to over 1,000 acres and are provided by a system of water courses with the delivery of water to the individual fields under a system of rotation. The tubewells have been so designed that they can command one, two, or three adjacent «chaks,» and their locations have been fixed close to the outlets so that after mixing with canal supplies the water can be distributed most effectively, without the necessity of costly conveyance channels and without disturbing the existing farmers' distribution systems. The tubewell capacities have been fixed within a range of from two to five cusecs with increments of half a cusec, and in order to command all the «chaks,» their necessary number has been found to be 1,800 and the total installed pumping comes to 5,500 cusecs.

The tubewells have been drilled with 18- and 22-inch diameters, depending on the use of percussion or reverse rotary drilling rigs. The depths have been specified as 250 ft. 300 ft. according to the thickness of the acquifers encoutered. Instead of screen, 10-inch dia. slotted pipes having 1/16-inch opening to provide 30 square inches of entry area per foot of pipe have been adopted, with gravel shrouding. The length of slotted casing varies from 130 to 180 ft., resulting in theoretical maximum water velocities through the slot openings of from 0.10 to 0.15 feet per second.

The tubewells have been equipped with multistage deepwell turbine-type pumps operated by electric motors Electric energy for operating the tubewells is available in the area and the electrification of the tubewells involves only the laying of 11 kw. distribution lines and the installation of step-down transformers.

The project has been under construction since 1959 and is nearing completion. Of the total number of 1,800 tubewells, 1,200 have been put in operation and the balance will be ready progressively by the middle of 1962.

FINANCIAL AND ECONOMIC ASPECTS

No engineering enterprise can be justified on its merits alone unless the benefits derived therefrom are economically and financially acceptable. The Salinity Control and Reclamation Project in this respect has a high order of justification.

If drainage is not provided, at the present rate of deterioration virtually all the lands involved would ultimately become unproductive. In such a case the only alternative would be abandonment of

extensive irrigation works and other improvements, relocation of the population now resident in the area to new areas, and construction of new works to serve an area capable of producing the amount of food and fibre which this area has produced in the past. Obviously, the cost of this alternative would be many times the cost of drainage works.

The initial cost of tubewells under the project works out to Rs. 88 per irrigated acre without the cost of electrification and the annual operational expenses at Rs. 15.5 per acre. If the tubewell water were charged at the rates existing for canal water, then the annual cost of tubewells to be debited to drainage would work out to Rs. 10 per acre. If adequate water supplies were available, as an alternative to tubewells, a system of tile and/or open drains would be a fundamental requirement. It is estimated that such a system would cost about Rs. 225 per irrigated acre in initial cost, and the annual cost would be of the order of Rs. 10 to 12 per acre. It is therefore evident that as a means for drainage alone, pumpage by tubewells is financially more attractive than a system of drains.

Aside from their justification for drainage, the tubewells are economically an attractive source of supplementary water for irrigation. In the project area the tubewells will supplement the canal supplies by more than 100% and, in addition, will provide optimum crop requirements to new areas to the extent of 16% of the existing irrigated areas. If the entire annual cost of operating the tubewells is realized by the sale of the water produced, the rate per acre foot will amount to Rs. 11.4 against the canal water rate of Rs. 4 per acre foot. That this water rate for tubewell water is not excessive has been brought out by studies carried out to determine the increase in productivity. It is estimated that with adequat drainage and additional irrigation supplies, and with improved irrigation and cultural practices, the gross annual value of crop production would increase from the present level of Rs. 120 Rs. 210 per acre. The increase in cost of production other than water charges is estimated at Rs. 40 per acre (from Rs. 80 to Rs. 120). There would thus be an increase in farm incomes of Rs. 50 per acre before payment of water charges. The present canal water charges are Rs. 5 per acre, whereas the tubewell-cum-canal supplies would amount to about Rs. 20.0 per acre, so that even after payment of all water charges there would be a net increase in farm incomes of Rs. 30.0 per acre annually.

With a substantial rise in yields, the gross value of crop production is estimated to increase from Rs. 111 million to Rs. 226 million annually. This annual increase, amounting to Rs. 115 million, is more than the capital cost of the projet of Rs. 95.3 million.

The above financial estimate is based on the average annual operating expenses, which include fixed charges for the repayment of capital in a 20-year period at 3.5% interest and a sinking fund reserve to replace the pumps and motors in a 20-year period at 2% interest. The useful life of the tubewells is estimated to be 40 years, so that the benefits over the life of the project will be even more favorable.

ANCILLIARY BENEFITS OF THE TUBEWELLS PROJECT

With operation of the tubewells it would be possible to draw the water table down to depths much greater than is practical with a system of drains. This will be of direct benefit in reducing evaporation losses and conserving water which would otherwise have been lost with an open drainage system. By lowering the water table, the tubewell system will tend to minimize the threat of floods, as the absorptive capacity will improve and a greater component of recharge from rainfall and overland flows will be available for re-use. Also a much larger storage space will be created for possible recharge by overland flows during occasional periods of heavy precipitation.

The elimination of waterlogging will help in improving the sanitary conditions and in controlling malaria, which is widespread in the area. This will lead to a better standard of health.

The network of distribution lines to energize the tubewells will make electric power available to remote villages, where it will foster small-scale industry and remove to some extent the pressure on the land.

OPERATION AND MANAGEMENT

The completion of any drainage and reclamation project does not mean the solution of all pro-

blems. It is only after the facilities provided for drainage are properly handled, the additional water supplies are effectively utilized and improved agricultural practices are introduced. that full benefits can accrue to the agriculture of the area. These aspects have been fully realized in the Drainage and Reclamation Project of Rechna Doab and an organisation has been set up for the operation and management of this Project. The primary functions of this organization are given below:

1) **Maintenance of Works:** The maintenance functions to be performed in the project area will consist of the regular servicing of tubewell pumping and electrification equipment and will include the maintenance of tubewells as well, which may involve such treatments as acidizing to clear incrustations which may take place.

2) **Water Control.** For the Drainage and Reclamation Project this function is of vital importance, as the use of the groundwater has to be co-ordinated with canal supplies and adjusted for crop water and drainage requirements. Moreover, supplies must be properly utilized and wastage eliminated. At the same time, the operation of the project has to be kept constantly under review and records have to be maintained of the quantity and quality of groundwater pumped and the effect of the pumping on the water levels. Data will also have to be maintained on the canal supplies delivered and the precipitation apart from those on the cropping patterns, cropping intensities and crop yields. The soil conditions for desalinization and fertility status due to leaching will also have to be watched and evaluated to determine the results achieved. The analysis of all these data will have to be carried out simultaneously to determine more accurately the operational yield of the aquifer and to bring about any adjustments that may have to be made in the plan for groundwater use.

3) **Land and Water Use.** Functions under this field will cover all related agricultural aspects based on proper land and water use, and will consist of extension work with the object of instruction the farmers and demonstrating better agricultural practices. These functions will be carried out through a large staff qualified in soil fertility, agronomy, agriculture and irrigation.

4) **Research.** It is also proposed to have a research cell in the organisation to carry out research on agricultural problems local to the project area. These will consist of cropping patterns, crop rotations, crop water requirements and other related subjects.

Discussion. Turkey's discussion was led by Ali Orhan. It was presented in the form of questions, which are restated here together with the answers given by the Pakistan delegation.

1. It is understood that, along with irrigation water being scarce, the area has been subject to frequent floods. Investigations carried out during the last few years have shown that lowering of the water table by pumpage and compensating for irrigation water deficiency from the groundwater, thus making use of the vast groundwater storage that is replenished by precipitation and floods, provide the most suitable solution to the problem. There is no question that this procedure will greatly contribute to the solution; however, this will not eliminate flood hazards and whether it will be a solution to salinity seems doubtfull. Have any investigations been made of the possibilities of checking flood hazards by creating dams in the upstream sections and supplying deficient irrigation water from the reservoirs thus created?

Answer. The headwaters of the two rivers are in India and there are no suitable dam sites. Even if suitable reservoir sites were discovered, it would take a long time to develop them. The floods inundate the lands near the rivers, but not the centers of the Doabs. Local rains may be as much as 15 inches in two days, which greatly exceeds the capicity of the existing drainage. Levees are being constructed to confine the river floods and floodways are being built to remove the local floods. Flood intensity apparently has increased since partition, but no definite reason for this can be assigned scientifically.

2. Has effective field drainage been established within the chaks along with the main drainage

system for the purpose of lowering the water table to the optimum depth in the irrigation area? If not, is it thought that such a system will be effective built?

Answer. Drains have been built which will take care of the areas within the chaks. They are designed to handle floods and control the water table rather than lower it.

3. Is it not possible to protect the project area by building levees at suitable locations parallel to the rivers?

Answer. This possibility is limited and if carried out too extensively restricts the capacity of the flood channel and also causes a higher intensity downstream, which means that the downstream must be protected too. We are doing this where absolutely necessary, however. In some causes the drains are blocked during the flood stage to avoid the flood waters backing up into them and filling them up. In other cases, where the outfall is particularly bad, pumping stations are installed, but these are only to handle surface waters. This is where the outfall is particularly bad. For small drains acting as seepage drains in the winter, no pumping is required at that time.

4. Actually, groundwater seems to be effluent toward the rivers on the edges, and flowing parallel to the rivers in the central part of the project area. Is it not possible to make use of this fact in the development of the drainage system?

Answer. An open drain is being considered down the middle of the area. However, there is no gravity outfall available and a pumping station would be required. These details must be considered project by project and we are not ready yet with our final plans. Flood peaks may last from three to four hours during the 2½ month summer. This may happen perhaps four times during the period. Drains are being enlarged to take care of the water impounded behind levees.

5. Out of the whole project area, which has a spread of 7,040,000 acres the groundwater table in only 6.3% stands within five feet below the ground surface, and more than five feet in the rest.

a. What are the other reasons for lowering the groundwater table more than five feet, beside that of irrigation water supply?

b. What are the reasons for lowering the groundwater table to its pre-irrigation level?

Answer. A lot of water is needed to accomplish leaching and to establish a much more intense agriculture than at present. The intensity of cropping is to be increased from 75 to 90% to a minimum of 180%. The water allowance is now only enough to meet the consumptive requirements of the crops. Once the salts are leached down, the amount of water required may be reduced. It has been shown that salinization occurs from water tables as deep as 22 feet. We want to depress them well below the minimum depth of 15 feet.

6. It is understood that the water table will be gradually lowered by pumping at the rate of 1.25 ft. per year and the water will be used for irrigation;and that within 40 years the groundwater table will be finally lowered to where it was before irrigation was initiated in the area. Since the water level in the vast neighboring area will automatically drop during the time pumpage continues in the project area, is the projected pumping capacity sufficient to handle the situation?

Answer. It is not considered that the water table in the adjoining areas will effect the drawdown appreciably in the pumped area, due to the low permeability. Moreover, the entire program for West Pakistan must be carried out within ten years, so no problem is anticipated on this point.

7. Since the depth of the tube-wells drilled in the area varies between 250 and 500 feet, and the length of the perforated screens used varies between 130 ans 180 feet, and since salinity of the groundwater will increase as the wells are drilled deeper, and considering that water of low salt content is preferred in irrigation, is it not harmful to pump water from such depths?

Answer. In general, the qualtiy of the deeper waters is quite good and may even be better than

that of the shallower waters.

8. Are there any other reasons or advantages, outside those cited on page 17 of the report, for choosing as the project area the part of the Doab upstream from the Lower Chenab Canal?

Answer. The groundwater study for this area was the first to be completed. In practically the entire area, the deep aquifers were sweet. To the east, the soils are such that groundwater supplies might be problematic. To the west, the groundwater supplies are more saline.

9. What kind of precautionary measures are being considered for the reclamation of the highly salinized area south of the project area, which is threatened by approaching danger as the groundwater level keeps on dropping?

Answer. Remedying the inadequate water supply and lack of proper drainage.

10. What precaution is taken to insure satisfactory mixing of the groundwater discharged into irrigation canals with the canal waters? What is the distance necessary for a satisfactory mixing of the two kinds of water? Will there be no harm in establishing head-works and diverting water for irrigation within the mixing distance?

Answer. The required distance is quite small; 100 feet is adequate. Precautions have been taken so that this distance is provided between the pump and the diversion.

11. What is the basis for estimating 40 years as the useful life of the tube-well- Forty years seem to be a highly optimistic figure for the life of a tube-well.

Answer. These conclusions have been reached on the basis of a very extensive study by Pakistan engineers and A.I.D.experts.The design of the tube-wells is based on experience in the U.S.A. and on tube-wells installed in other areas under U.S.A. supervision and on the advice of the constructors. It is estimated that the moving parts will have to be replaced in 20 years.

12. Have investigations revealed any captive groundwater zones in the area?

Answer. No captive zones are known. Geological investigations prove a connection between the tube-well aquifers and upper waters.

13. Are there any hydrologic inventories worked out for the same area for different time periods?

Answer. There have been wells in the area for more 60 years, as long as 100 years in some cases.

14. What is the system adopted for the operation of the wells in the project and what is the type of organization necessary for a satisfactory operation?

Answer. There is a supervising engineer in charge of the wells and he has a number of divisions under him. There are sub-divisional officers, overseers and well operators under the divisional officer. Tube-well operators are trained in the central office and sent out to work with people who have had actual experience. Operators present information on discharge, hours of operation, power used. A new organization may be set up following a report by U.S. experts which is now pending. The wells are constructed by the Government and the water is put into the channels. The rest is the cultivator's business.

15. What kind of supervision is undertaken by the Government in irrigation operations?

Answer. All types of supervision for use of the water on the land are given, including such things as cropping patterns, manuring, etc.

16. Since the water table is near the surface, why not use centrifugal pumps, at least in the initial phases?

Answer. Since these would have to be replaced in the very near future, it was thought much better to have the turbines to start with.

17. Is the present industrial development in Pakistan favorable for local pump manufacture, or are the pumps imported from abroad?

Answer. They are manufactured in Pakistan.

18. What is the procedure employed in perforating the pipes to be used as screens? What special method has been used to provide screen opening 1/16-inch wide?

Answer. This is done with machinery by the contractor at the site.

19. The initial cost of the tube-wells, which is calculated to be Rs 88 per irrigated acre, seems to be too low. Taking Rs 7 = $1.00 and using the figure for the area irrigated by one well as 350 acres, the initial cost of a well is calculated to be only $4,400. Under existing conditions in Turkey, it is impossible to complete a well 300 feet deep and equip it with a deep well pump having a capacity of 2.5 Cu secs. at such a cost.

Answer. The official exchange rate on rupees is 4.75 to the dollar and one tube-well irrigates much more than 350 acres. The cost of one tube-well, with electrification and pumping equipment and operators' quarters, comes to 70,000 pupees or roughly $14,000. The cost of the tube-well and the pump and motor is about 50,000 rupees or $10,000.

20. Tube-wells have been drilled with percussion type drills and reverse circulation type rotary drills. Since the latter have greater performance capacity and higher efficiency than the percussion type rigs in drilling through alluvium, what are the reasons that have led toward using percussion rigs and drilling through alluvium? Has, by any chance, the use of percussion rigs been limited to groundwater investigation as a consequence of local subsurface geologic conditions?

Answer. The percussion rigs were already owned by the Department. The contractor brought in the rotary rigs, so we are using both.

Open Discussion. Mr. Ozel asked whether, if groundwater were lowered, this would increase the seepage from the main canals. Mr. Hamid stated that when the water table is within five feet, the heavy draft of vegetation increases the losses from the canal. If however, the water table is lowered to 15 feet, for example, the head is greater and the seepage theoretically should be increased. Experimentation with a means to line the canals is being conducted. Mr. Hamid thinks little will be gained by stopping the canal seepage maintained during the reclamation period. This will help keep the pumped water sweet. Some of the surface drainages may be blocked so that the flood waters may also be used for leaching.

Regarding electrification of the tube-well project, 400,000 to 500,000 kw are needed and will be produced with hydroelectrical installations or natural gas.

SMALL PUMP IRRIGATION DEVELOPMENT

IN EAST PAKISTAN

by

Mr. B. Karim[1]

INTRODUCTION

East Pakistan lies between latitude 20° — 45' and longitude 88° and 92 — 30' E. The climate is tropical. The mean summer temperature is 90° F.; the mean winter temperature, 64° F.

The normal annual precipitation is 80". The rainfall is not distributed evenly throughout the year. About 85% of the rainfall occurs during the months April to September.

TABLE 1. PROVINCIAL NORMAL RAINFALL

Month	Rainfall (Inches)	Month	Rainfall (Inches)
January	0.33"	July	15.81"
February	0.89	August	14.53
March	1.13	September	11.34
April	4.13	October	5.86
May	7.81	November	0.96
June	15.25	December	0.21

Area and Population. The total population of the province is 50.8 million, with a density of 940 per square mile. The area of the province is 54,100 square miles.

Soil and Topography. East Pakistan may rightly be called the land of rivers. Big rivers with their innumerable tributaries form a network throughout the province, particularly in the eastern area. Most of these rivers are perennial and carry sufficient water for irrigation even in the driest period of the year. These rivers with their tributaries occupy about 10% of the surface area.

Most of these rivers carry heavy silt and during the period of monsoons they overflow their banks, depositing heavy silt on the flooded area. The soil is of alluvial origin.

The entire province is more or less of Deltaic formation and of flat surface, except some portions in the border regions on the north, east and south, which are moderately hilly.

Occupation of the People. Agriculture is the main occupation of the people and 85% of the population are so engaged, directly or indirectly. The heavy pressure of population has resulted in very uneconomic holdings by individual farmers, the average being 2.5 acres. This condition is further aggravated by the fact that these small holdings are fragmented and scattered.

Crops. Rice is the staple food crop of the province. Aus, Aman and Boro are the three main types grown. The first two types are rainfed, and the third is grown exclusively under irrigation.

Jute and sugarcane are the most important cash crops, of which jute is grown on natural rainfall. Acreage under major crops and respective production are indicated in Table 2.

TABLE 2. AREAS AND PRODUCTION OF MAJOR CROPS

Crop	Area in Million Acres	Production in Million Tons/Bale
Aus	5.95	2.1
Aman	14.29	6.0
Boro	.92	.40
Wheat	.14	.03
Sugarcane	.28	3.6
Jute	1.37	5.36(m.bales)
Potatoes	.12	.34

1 Deputy Manager, East Pakistan Agricultural Development Corporation.

Food Production. There are at present 22.2 million acres of land under cultivation. About 1.5 million acres are culturable waste which can be brought under crop through deep tillage and extension of irrigation facilities. The tabulation below indicates broadly the present use of land:

Under cultivation:	22.2	million	acres
Culturable waste:	1.5	»	»
Forest:	5.5	»	»
Not available:	5.0	»	»

About 8.5 million tons of foodgrains are now produced in the province, which represents deficit of about half a million tons. Various development projects, both long-term and short-term, have been initiated by the Government to boost food production—not only to cover the deficit but also to meet the increasing demands of the rapidly-growing population. Small irrigation projects are to play a significant part in this development.

DESCRIPTION OF PROJECT

Power Pump. Irrigation by power pumps is one of the short term projects which aims at an immediate increase in production by bringing more land under crop through the provision of irrigation from available surface water sources. These power pumps are also used for supplementary irrigation to rainfed crops in periods of drought.

Power pump settings consist of a centrifugal pump directly coupled with a Diesel engine and generally mounted on a steel-wheeled trolley for easy transportation.

The engines are all Diesel and mostly aircooled. Diesel engines have been found to be dependable and economical. The local cost of Diesel fuel is about one-third that of gasoline. Aircooling is preferred because of the uncertainly of the clean water supply at work sites. General specifications for such a pump set are given in Appendix A.

Different sizes of sets are used, with capacities ranging from 1 to 5 cusec. All one- and two-cusec pumps are fitted on trolleys and are easily portable. The four- and five-cusec pumps are mounted on steel pontoons for easy movement from place to place along the river courses.

Project Areas: The low-lying tract of the province floods and remains under water from May to September. About 40% of the lands of the province are affected by this seasonal flood. On recession of the flood waters in October, the land is available for cultivation and crops can not be grown without irrigation, as rainfall during the months from October to March is uncertain and also inadequate.

These low-lying areas are intersected by a large number of rivers and their tributaries. After the recession of the floods, when land becomes available, power pumps are installed on the banks of the rivers and water is raised to channels and laterals conveying it to the fields. The sizes of the pumping units are determinal by the sizes available, the approachable area to be irrigated, and the water requirement of the crops to be grown. Generally, the water source is adequate.

Pump Installation. In setting up the pumps, care is taken to keep the suction lift within 15'. The sets in most cases are installed along the slopes of the banks as near the water source as possible. The wheels are removed from the trolley and the base plate is solidly anchored on the ground. No concrete foundation is necessary. The suction length generally does not exceed 20'. On the delivery side, 20 to 30' of pipes are usually required to carry the water over the banks. Where hose pipes are used, no bends are necessary. In the case of steel pipes, two to three bends are sufficient.

Irrigation Practices. Boro is the main food crop grown in the low-lying areas and, with power pump irrigation, it has been possible to get additional acreage under this crop. Boro paddy requires heavy irrigation. Seedlings are grown in the month of November, transplantation takes places, in the middle of December, and harvesting is done in April. The crop grows well in standing water and the irrigation practice is to provide about one inch of standing water on the crop land. This helps in controlling weeds. Six irrigations of six inches in depth each have been found adequate. It is possible to grow 40 acres of boro paddy per cusec of discharge. In the early stages of growth of the plant, a power pump is required to work about ten hours a day and at later stages, during February and March, 18 hours a day. A total of 100 such irrigation days is available in one crop season.

A great many power pumps are now used for

production of this crop. The sets are installed at sites in the first part of December and remain there throughout the growing season of the crop, i.e., up to the middle of April, after which they are removed for servicing and repair. Permanent installation of sets is not possible, as the boro-growing areas are lowlands and become flooded. This flood water also restricts the number of crops that can be raised from such areas to one in most cases, and that in the winter season. Since these areas have ample surface water sources within easy reach, no initial layout for digging canals or distributaries is required, and with a power pump, water can be supplied directly to the fields. As short-term measures, power pumps have therefore definite advantages in these areas.

So far there has not been any demand for power pumps in the highlands which have approachable surface water sources for growing irrigated crops.

The main crop rotations in these areas are:

A. Aus followed by transplanted aman;

B. Jute followed by transplanted aman.

All the above crops are rainfed. When a drought situation prevails, cultivators ask for power pumps for supplementary irrigation, but in normal years they are not inclined to use them. From an examination of the above crop rotation. it will appear that if boro, which is the main food crop of winter, is grown in these areas through irrigation, the sowing of aus or jute will be delayed. The cultivators are hesitant to sacrifice any of these rainfed crops for an irrigated boro crop. Similarly, production of a minor crop in the winter does not pay for the cost of the power pumps. Considering the over-all availability of pumps in the province, it is also not possible to tie up a power pump for production of a minor crop in the winter in place of a boro crop which can be produced easily in low land with the aid of the pump.

Power pumps will be more economical in the highlands in comparison to the low lands; they are now used for production of boro paddy when only a major crop in the winter can be grown without dislocating the existing rainfed crops. In such circumstances, the pump will not only produce an additional crop but also will provide supplementary irrigation to the other crop in periods of drought and will help in assuring timely sowing of these crops.

A suitable cropping pattern must therefore be developed for these areas before large-scale introduction of power pumps. A few pilot projects are accordingly being carried out.

OPERATION OF PUMPING UNITS

Working Procedure. A decentralized working pattern has been found most effective. According to the scope of the work and future expansion, the province has been divided into a number of work zones and each zone has further been divided into units of operation. One unit consists of roughly 50 pumps. Each such unit is provided with adequate operational and maintenance personnel. Roughly, a unit has the following staff:

A. **One Unit Officer.** This officer is a technically-qualified person and is in over-all charge of both operational and maintenance work under the unit.

B. **Four Assistant Supervisors.** These officers are responsible for contacting cultivators and encouraging them to form cooperative pump societies. When requests for power pumps are received from such societies, the assistant superiors visit the area and examine the feasibility of pump use. If the proposals are accepted, they execute the conract between the Government and the cooperative society. When the pump is installed at the site, they arrange for equitable distribution of irrigation water to members of the society in consultation with its secretaries. They also draw up the layout of the channels and distributaries which the cooperative societies are required to provide at their own expense. After irrigation, they survey the irrigated areas and collect the water tax from the beneficiaries.

C. **Four Mechanics.** These technicians go around the fields during the irrigation season and carry out regular servicing and maintenance of the machines. Minor repairs and replacements are also carried out by them in the fields. When the irri-

gation work is over and the power pumps are removed to the storage shed in the headquarters of the unit, they take up regular repair and replacement work and keep the sets ready for the next irrigation season.

D. **One Store-Keeper.** The storekeeper's resposibility is keeping proper records of oil, fuel, spare parts and the other equipment of the unit.

Generally, seven to ten such units form a zone. The officer in charge of a zone is given adequate administrative and financial power to carry out his duties and responsibilities properly and promptly on the spot and is not required to make refer frequently to higher authorities. These zonal headquarters are, therefore, the central stations for all field activities.

The sets are hired out by the Government to the cultivators at a subsidized rate. The subsidy is intended to encourage irrigation on a large scale, and and also to make the people irrigation minded. All expenditures for operation and maintenance are met by the Government and a flat rate per acre per season is levied on the farmers. For example, in the case of boro paddy, for which about 95% of the total number of sets are engaged in the winter season, sets are installed at sites in the first part of December and kept operating through the growing season of the crop. After the harvest, the cultivators are required to pay Rs. 31.00 per acre. The actual cost of operation comes to Rs. 45.00 per acres. This subsidy is, however, being reduced progressively each year, until in 1964-65 it will disappear.

An hourly rate imposed for crops other than boro and in cases of supplementary irrigation. This rate varies according to the size of the irrigation unit.

Since the average holdings are very small, it is not possible for the cultivators to take power pumps individually. They therefore form into cooperatives and request pumps collectively from the Government. As soon as such petitions are received, officers of the department visit and examine the areas. These officers (assistant supervisors) also help cultivators to form new cooperatives. If, after examination, the proposal for a pump is found acceptable, contracts are executed. Power pumps are then allotted according to the size of the project, and the parties are required to take the sets from unit headquarters at their cost. The sets are then installed at sites by agencies of the Government. The entire operational and maintenance cost is borne by the Government. The societies, at their expense, build huts near the power pump for accommodation of the operators and also construct channels and their distributaries, as instructed by the assistant supervisors.

The secretaries of the societies, who are elected by the members from among themselves, maintain liaison between the societies and the department, and also help in realizing the water tax from the member cultivators. The record shows that collection of the hire charge from the beneficiaries has never been difficult. Almost 85% of the dues can be realized immediately after harvest, and the rest of the amount later.

The cooperative movement in its province has been a great success in the field of power pump irrigation. The people of the province, who were generally skeptical about irrigation farming, are gradually becoming irrigation minded.

Transport and Movement. The project areas are mostly located in inaccessible areas and are not generally connected with roads. Rivers are the main sources of communication. At present, speedboats fitted with outboard engines are used for supervision and maintenance work, but by and large communication and transport depend on wooden country craft.

Where road communications are available, jeeps and jeep pick-ups are used. Heavy equipment is carried by railway to the point nearest the project area.

Repair and Maintenance. To carry out on-the-spot repairs in fields and to undertake major repairs and overhauling, a number of workshops have been established throughout the province. There is one central workshop located in the provincial headquarters. This is equipped with all necessary machines and tools and provided with experienced technicians to carry out major repairs and overhauling. A full line of spare parts is also carried in this workshop. The requirements of the

zonal workshops for spare parts are met from this central station. Under the central workshop there are branch workshops which are located in the headquarters of the operational zones and are known as zonal workshops. There are four such workshops now in existence which are being expanded to cope with the increased volume of work. Two more zonal workshops are in the process of being built. These workshops are equipped with the necessary tools and equipment to carry out general repair and replacement work. Elementary spares parts are also manufactured in these workshops. Under each zonal worshop there are a number of maintenance depots. These are supplied with mechanics, hand tools and the necessary spare parts to carry out normal servicing and replacement work. Each maintenance depot will soon be equipped with one mobile workshop to do spot repairs in the fields during the working season.

Field repairs are now the responsibility of the maintenance depots. During the season, mechanics attached to the depots constantly tour around the worksites and carry out regular servicing and adjustments. Minor repairs and replacements are carried out in the fields and, where spot repairs are not possible, the sets are sent to the zonal workshops. In case the services of the central workshop are required, the machine is diverted to that workshop.

Locally-produced power pumps as well as imported ones are in operation at present. However, the imported pumps far exceed the locally produced ones in number. To keep this machinery in condition and to minimize breakdowns in fields, it is necessary to carry a full line of spare parts in sufficient quantities. The normal practice is to purchase 20% of the value of the machine as spare parts when the machine is bought, subsequently replenishing the stock each year.

For every 50 pumps, four touring mechanics are generally employed. For quick movement, they are provided with speed-boats fitted with outboard engines.

TRAINING

The requirement for technical personel is large. A regular training program is carried out for both operational and maintenance staffs. About 1,000 pump operators are required to be trained annually. In addition, technical personnel in large numbers are needed for supervisory work. Regular training courses are conducted in collaboration with the power pump companies in various workshops under the project.

Physical fitness is given great importance in selecting trainees because of the arduous nature of the work in the fields. Maintenance personnel are selected from technicians graduated from various technical institutions. Experienced and efficient operators are also promoted to mechanics. Refresher courses are arranged for the supervisory staffs of various workshops under the guidance of A.I.D. advisors.

ECONOMIC ADVANTAGE

Besides making possible an additional crop of paddy in the winter season, the pumps also provide supplementary irrigation to rainfed crops in periods of drought. In irrigated areas, the average yield of paddy is 25 mds. (2,050 lbs.) per acre. Overlooking the benefit accruing from supplementary irrigation, the net benefit comes to Rs. 25 X 10, or Rs. 250.000 per acre. The total cost of production, inclunding the irrigation charge, comes to approximately Rs. 125.000. The cost benefit ratio is therefore 1:2.

FUTURE PROGRAM

Like any achievement of consequence, the project had a humble beginning with only 40 power pumps in the years 1955-56. The results were very encouraging and during subsequent years steady progress was made. See Table 3.

TABLE 3. INCREASE IN THE USE OF POWER PUMPS.

Year	Power Pumps Used	Area Irrigated (in acres)
1955-56	40	2,658
1956-57	135	10,000
1957-58	541	29,000
1958-59	848	32,793
1959-60	1,150	47,370
1960-61	1,367	62,143

In the coming years, this project will be further expanded and about 630,000 acres will be brought under power pump irrigation within the next three years.

The project so far has been entirely planned and executed by Government agencies but has recently been turned over to the Agricultural Development Corporation. This Corporation has more freedom than a Government agency and it will be possible to expand rapidly and to cut down the cost as far as is practicable. One of the main functions of this body is to encourage private enterprise. As a beginning, power pumps will be leased to private parties or cooperatives for a yearly fee based on the depreciation of the machine and interest on the capital. The private organizations will be at liberty to use the sets according to their own plans and programs. It is hoped that this method will encourage maximum use of the pumps throughout the year and will also help to cut down the costs involved. The Corporation will provide these organizations with adequate maintenance facilities through a network of workshops both stationary and mobile, and will realize from such organizations the actual costs of the servicing and repairs done for them. Spare parts will be stored at various places within easy reach. In Table 4. the irrigation targets for the next three years are indicated:

TABLE 4. GOALS FOR PUMPED IRRIGATION

Year	Area in acres to be irrigated by power pumps
1962-63	292,000
1963-64	456,000
1964-65	630,000

APPENDIX A
EQUIPMENT FOR TYPICAL PUMP SETTING

1. **Engine.** Two-cylinder, vertical, cold starting, four-stroke Diesel, aircooled and fitted with hour counter, 15 H.P. at 1500 R.P.M. at site.

2. **Pump** Centrifugal; 6-in. suction; 6-in. delivery; 1500 R.P.M.; 45,000 Imperial gallons per hour at 40-ft. head; 40 ft. total head; suction head, 10-15 ft.; delivery head, 25 to 30 ft.

3. **Accessories.** One footvalve with strainer, — 1 No.
one 90° — bend, — 1 No.
one 60° — bend, — 1 No.
one 45° — bend, — 2 Nos.

Two pieces 6" galvanized steel pipes in pieces of 4' length each, and flanged both ends.

Six pieces 6" galvanized steel pipes in pieces of 10' length each and flanged both ends.

The engine and the pump specified above are directly coupled and mounted on a trolley with steel wheels.

APPENDIX B
COST ESTIMATE

The entire cost is divided into fixed costs and variable costs:

FIXED COSTS

Depreciation: (first cost-salvage) (life expentancy)
Interest : (first cost-salvage) (interest rate)/2
Housing : Rs. 0.10 per s.f. of storage space occupied

VARIABLE COST

Maintenance = 4% of the first cost of the machine.
Fuel consumption = 0.4 lbs. of fuel per H.P. per hour.

Oil	= 1/30th of quantity of fuel.
Transport cost of fuel	= Approximately Rs. 0.10 per gallon from supply point to the work site.
Pay and allowances of field staff	= Actual expenditure made on the field
Supervision cost	= 10% of the expenditure on the field staff.

Variable costs are based on practical field experience.

UNIT COST

The unit costs are based on actual costs which are the sum of the variable and fixed costs.

Hourly rate: (actual cost)/(annual hours of operation)

Acre rate: (actual cost)/(total acres irrigated annually).

Typical unit costs are:

	Cost per acre	Cost per hour
1. 6-7 H.P. set (discharge 1 cusec)	Rs.60.70	Rs.2.2
2. 14-15 H.P. set (discharge 2 cusec)	Rs.48.5	Rs.3.0
3. 50-55 H.P. set (discharge-5 cusec)	Rs.30.5	Rs.6.7

As the size of the unit increases, the operation cost proportionately comes down. A uniform acre rate of Rs. 45.00 has, however, been fixed by the Government. The exchange rate is Rs.4.31 = $1.00.

Discussion. The unit officers ordinarily have diplomas in mechanical engineering. Because the fields are small and the water is delivered directly to them, there is no problem of laying out channels. Assistant supervisors usually have a diploma in agriculture, a three-year course after high school.

The size of the pump setting is based on the availability of blocks of land near the river, which are of the order of 50 acres. These are not the most economical size from the point of view of pumping. The flooding occurs mostly in the monsoon months when pumping is not done. Transportation is generally difficult so the units are made as independent as possible. The average number of acres served by a single pump has decreased since the project was started because smaller blocks of land are now being brought under cultivation. The average size of the field operated by an individual cultivator is about two acres. Operation and maintenance of the pumps are handled, entirely by the Government. A unit group, headed by a supervisor and with assistants and mechanics numbering about 10 people, handles about 50 pumps. In addition, an individual operator is provided for each pump. The life expectancy of the pumps is estimated to be about eight years. Some pumps are made in Pakistan, others are imported.

Aus and aman are varieties of rice. Aus is grown in the late summer season, aman during the floods and boru during the winter. Research has shown that the production of aman can be as high as 60 maunds per acre.

It is hoped to reduce the pressure of population on the land by the development of industry. In some districts the population is as high as 3,000 per square mile. All the land is privately owned so there are no public lands available for new projects. After projects now underway are completed, Pakistan has in mind recliming land from the sea in East Pakistan.

Silting apparently adds fertility to the land. However, it clogs the drainage. Due to the continued silting, the rivers become higher than the land so that the land slopes away from the rivers, leaving saucer-like depressions which are difficult to drain and dry up.

The training of operators will be expanded. There are two or three pump factories in West Pakistan; one in East Pakistan has been started and will build the pump engines soon. About 9,000 pumps are now in use.

LARGE PUMP IRRIGATION DEVELOPMENT IN EAST PAKISTAN

by

Mr. Moh'd Anwar Jaleel [1]

INTRODUCTION

This paper deals with the present status in East Pakistan of water resources, pump usage and related agriculture. The background to development is provided in relation to hydrology, topography, flood protection and drainage. Attention is focused on the need for irrigation and other means to make the optimum use of available water for increasing food grain production, which is the urgent need of East Pakistan.

This province has imported 500,000 to 600,000 tons of food grains every year since 1956, at an average annual cost of Rs. 200 million. One major task of the East Pakistan Water and Power Development Authority is to develop the water resources for raising a second crop in the dry (Rabi) season in addition to protecting the wet season (Kharif) paddy crop against drought failure. Out of the present cultivated area of 21 million acres, only 4 million grow a second crop. Under the Second Five-Year Plan, ending in 1965, it is proposed to raise food grain production by 21%. Double cropping through irrigation and reclamation will account for 32% of this increase; the rest will be through the use of fertilizers, improved seeds, pest controls, etc. Irrigation during this period is to be provided for double cropping about one million acres. Other projects will aim at improving an additional million acres through reclamation and flood protection.

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1 Deputy Director, East Pakistan Water and Power Development Authority.

GEOGRAPHICAL AND GENERAL FEATURES

East Pakistan was constituted a province of Pakistan under the Indian Independence Act, 1947. It comprises the eastern territories of the pre-partition province of Bengal, together with the Sylhet District, formerly part of Assam.

The area of the province is 54,141 square miles and the population was 51 million at the time of the 1961 census. There are some 60,000 villages in the province. The average density of population in the 15 districts, excluding the two Chittagong districts, is about 850 per square mile, while the densest population is found in the Tipera, Dacca and Noakhali districts, where many rural areas approach 3,000 persons per square mile.

Except for the Chittagong district and the neighboring hill tracts in the east and in the eastern hills of Sylhet, which are not subject to flooding on a large scale, the country consists almost entirely of flood plains and the deltas of three great rivers: the Ganges, the Brahmaputra and the Meghna and their tributaries. In elevation the land slopes gently from about 200 feet above sea level at the northern boundary of Rangpur to 150 feet 300 miles from the sea, from 50 feet above mean sea level to only a few feet above at the sea coast. Most of the area lies below elev. 80, the approximate elevation at the point of entry of the Brahmaputra at the Indian border. The land to the west of the Brahmaputra is relatively high, but the land to the east falls away to a depression in the Mymensingh and Sylhet districts.

The flood plains and delta are generally comprised of very fertile soils. The area is largely cultivated and studded with thousands of villages, often situated on earthen mounds to avoid the flood water. In the Chittagong Hill Tracts, the country is intersected by parallel ranges of hills oriented approximately north-south and largely covered by forest. There are 17 civil districts and three divisions for purposes of civil administration.

PAST DEVELOPMENT

Historical evidence indicates that a system of water control and use was evolved in the Gangetic Delta some 3,000 years ago. It consisted of broad shallow canals which carried the crest waters of the river floods, rich in fine silt, to the lands. The canals were so spaced that water could be distributed with reasonable facility to the rice fields by means of cuts in the banks called «munwas,» which were closed when the flood season had passed. During the monsoons, much of the land was covered with water. To avoid inundation, villages were located on higher ground, generally raised still higher by earth obtained by the excavation of tanks, which had the double advantage of retaining the monsoon wate for use during the dry season. These tanks dot the country by the thousands. The lands were bunded to control the amount and time of inundation and, in the tidal areas, to prevent sea water intrusion.

The system of water control and use was managed and maintained by the «zaminders» and the tenants, on a more or less forced cooperative basis known as «pulbandi.» The decline of the Moghul Empire in the 18th Century brought about disorganization and negligence in the proper maintenance of the system. Nonetheless, the pulbandi persisted up to the time of independence, although in a less positive and effective manner. As a result of the partition of Bengal, a large number of zamindars migrated to India and some measure of reform in land tenure was initiated; but no effective substitute for the zamindari system has, so far, emerged in the form of local leadership. Government has thus had to assume responsibility for such limited maintenance as is possible under the circumstances

TOPOGRAPHY AND EXISTING CROPPING

In East Pakistan the cropping system and the crops grown are almost entirely controlled by the hydrology and topography of the land. In the wet season, some 80 per cent of the alluvial soils are inundated by rain or river water. The only crop that can be grown on these inundated lands is rice; aus paddy can be grown on higher parts where level will not be higher than one foot; transplanted among paddy in the comparatively lower part where the water level will not become higher than three to four feet; and broadcast amon paddy on deeper land. On some 70 per cent of the cultivable land, only rice is grown.

The highest parts, which are not inundated in the wet season, are used for homesteads, fruit trees, bananas and garden vegetable crops. Where the land is little lower, sugarcane, jute and aus can be grown in the wet season. These soils become dry in September and October and, as a result, there is plenty of time to grow a second crop in the dry season. Due to the light nature of the soil, they can be ploughed easily. For these reasons, they are the most intensively used soils in the province, although their fertility level is not very high in comparison with other soils which are situated at a lower level.

HYDROLOGY AND EXISTING CROPPING

In East Pakistan the climate is very favorable for crops but the heavy annual rainfall is confined to one season. Although the abundance of water during the monsoon constitutes the whole basis for the development of the dominant rice economy, there are several reasons why water control, including irrigation, can substantially raise average yields of paddy over the years. The height, time and rate of the flood all carry dangers, despite the amazing adaptation of certain varieties of rice to deep inundation.

In the case of dry season crops, irrigation can serve three purposes:

A. To remove the present factors limiting yields where winter cropping is now attempted;
B. To make winter cropping possible over a much larger area;

C. To lay a firmer foundation for manuring and other improved practices.

PRESENT STATUS OF AGRICULTURE AND IRRIGATION

In spite of the scarcity of food and the smallness of holdings, with most of the cultivable land already occupied, the greater part of the precious arable land lies idle at present for a least half the year because only direct rainfall as a source of water is put to use. Yet few areas in the world are passed over by more water. The total annual runoff is of the order of a billion acre feet,or 14 feet for each cultivated acre. If even one-third of this volume could be made available when and where needed, it would suffice for perennial cropping on all agricultural land. In the past, very little of the river flow has been used for irrigation and then almost wholly to supplement and make secure the water supply for the monsoon rice crop.

The intensity of cultivation at present is from 80 to 85 per cent except for the hilly tracts, and there is very little additional area that can be put under cultivation. To obtain greater amounts of food grains, irrigation must make up for the vagaries of rainfall. The use of fertilizers to increase yields is possible only with controlled irrigation. Double and triple cropping will also be possible with irrigation.

Irrigation is, however, practiced only to a very small extent, being confined to the cultivation of certain special crops (sugarcane, vegetables, betel-leaf, tobacco and chillies). The water for this purpose is obtained mostly from jhils and khals and it is lifted by hand into raised channels. As lifting by hand is limited to a few feet and the number of jhils and khals in the higher parts is few, the only way to provide the irrigation on an extensive scale is through mechanical pumping from the rivers and streams, or by developing storage reservoirs and gravity supplies.

CURRENT DEVELOPMENTS

The recent schemes for flood regulation, drainage, flushing and overflow irrigation were outgrowths of the traditional indigenous system and have been localized in nature, designed to solve immediate and particular local problems. By draining four million acres over a long period, the cultivable area of East Pakistan could be brought to 74 per cent of the total area of 34.9 million acres. The greatest possibility for development, however, exists in improving agricultural practices and double and triple cropping of the presently cultivated area. The First Five-Year Plan estimated that maximum water availability in winter for agricultural purposes would be roughly **«of the order of 50 million acre feet, which if properly utilized, could be able to irrigate about 13 million acres. To give adequate supply of water, it should be possible to sow 25 million acres in the monsoon and 30% of this area, 20 million acres in winter. Although ample supplies would be of the order of 75 million acre feet, for which it would be obligatory to conserve some of the flood flows in large storage reservoir. Although favorable location for construction of reservoir exists in hill tracts, they are outside the East Pakistan Territory, and thus the opportunity for developing appreciable storage in East Pakistan is limited.»**

POLICY

Irrigation schemes are planned in the following order of preference as regards available resources:

A. Flow irrigation
B. Lift irrigation
C. Tubewell irrigation

These schemes are less economical in their descending order.

Reclamation of marshy and waterlogged lands to secure wet season cultivation, dependent on the monsoons, is planned.

Before independence, very little attention was paid by the Government to the area now constituting East Pakistan, and little development of water resources was done in order to permit the raising of a second crop in the dry season. The shortage of food and the increasing population have focused attention on the need for a master plan for development of the water resources of East Pakistan. The economic requirements of irrigation projects in a humid zone are hard to meet although the need for water and increased cropping intensity is pressing due to the impact of an increasing population. Until this plan crystallizes, priority must be given to

schemes which offer the best immediate returns and to those which are more effective in relatively dry areas. In this category, the supplying of water for irrigation from pumps is of the foremost priority.

The East Pakistan Water and Power Development Authority has included the following schemes of pump irrigation in the second Five-Year Plan period:

A. Ganges Kobadak Project

B. Dacca-Narayanganj-Demra Irrigation Project

C. Low lift pump irrigation scheme in the northern districts of East Pakistan.

In addition to the above, the following multi-purpose projects also involve irrigation partially by pump:

A. Tipperah-Chittagong Multi-purpose Project

B. Old Brahmputra Project

C. Meghna Valley Project

The first two schemes are ready for execution, while scheme «C» is currently under investigation.

FARM UNIT LAYOUT, DISTRIBUTION AND DEVELOPMENT IN EAST GHOR CANAL PROJECT, JORDAN

by

Mr. Fah'd Natur

INTRODUCTION

Farm unit layout, land distribution and farm development are very important phases of the East Ghor Irrigation Project. They embrace technical, economic, social and legal considerations. Some of the situations and problems discussed in this paper may be of particular significance to Jordan, but probably most could be found in any new Middle Eastern irrigation project.

A very brief description of the project and the project area follows. More details may be found in the proceedings of the Third NESA Regional Irrigation Practices Seminar, 1960.

The Jordan Valley is part of the famous geologic fault that extends from the Bekaa Valley in Lebanon to the Lakes region in Africa. The valley is 200 meters below sea level in the north and 400 meters below in the south, and has a subtropical climat in this valley the land and water resources are only partially developed. There are about 500,000 dunums (one dunum is about 1/4 acre) of irrigable land with inadequate rainfall. On the other hand, there is the Jordan River and its tributaries; a great part of this water runs off as waste into the Dead Sea.

The East Ghor Irrigation Project is only the first stage in the complete development of land and water resources in the Jordan Valley. This Project takes water from the Yarmouk River and other tributaries of the Jordan River. When complete, it will irrigate 120,000 dunums. The first of the three sections of this stage is now finished, to serve 30,000 dunums. The second section is under construction and the third and last section is scheduled to be begun in 1962. All will be complete in 1963.

With the envisaged storage on the Yarmouk River, Jordan can irrigate the 500,000 dunums of the valley. Construction will be accomplished in five stages, each of four years, duration.

The objective of the project is not only to build the system and bring water to the farmer at the highest point of his farm unit, but the complete economic devlopment of the area. This means irrigation, land development, agricultural education and market development. The end objective is to raise the standard of living for the small farmers of the area and to increase the national income of the country.

With the public expenditures involved in the construction and development of the project, and with the above-mentioned objectives in mind, the need was felt for a land ownership reform program. Without such a reform, the large landowner could become richer at the expense of the general public interest.

THE LAND OWNERSHIP REFORM PROGRAM

A better understanding of the need for such a land ownership reform program is illustrated by Table 1, which gives the distribution of land ownership in the project area before the reform.

The East Ghor Canal Authority Law No. 13

1 Irrigation Agronomist, East Ghor Authority, Amman, Jordan.

TABLE 1. LAND OWNERSHIP IN THE PROJECT AREA BEFORE THE REFORM PROGRAM.

Ownership in Dunums		0-9		10-19		20-29		30-75		76-100		101-500		501-1000		over-1000	
		Owners	Area Owned Dms.	Owners	Area Owned Dms.	Owners	Area Owned Dms.	Owners	Area Owned Dms.	Owners	Area Owned Dms.	Owners	Area Owned Dms.	Owners	Area Owned Dms.	Owners	Area Owned Dms.
1st. Section	No.	349	1308	172	2402	133	3185	203	8906	36	3061	56	10710	12	8091	1	2194
	%	36.3	3.3.	179	6.0	13.8	8.0	21.2	22.4	3.7	7.7	5.8	26.9	1.2	20.2	0.1	5.5
Second Section	No.	451	1819	238	3323	114	2752	283	12213	27	2426	41	6584	7.0	4192	2.0	2284
	%	38.8	5.1	20.5	9.4	9.8	7.7	24.3	34.3	2.3	6.8	3.5	18.5	0.6	11.8	0.2	6.4
Third Section	No.	509	2369	298	4210	131	3132	380	17967	50	4382	155	30521	13	9499	7	10766
	%	33	2.86	19.3	5.08	8.5	3.78	24.6	21.69	3.3	5.29	10	36.84	0.84	11.47	0.46	12.99
All Project Area	No.	1309	5496	708	9935	378	9069	866	39086	113	9869	252	47815	32	21782	10	15244
	%	35.69	3.48	19.3	6.28	10.31	5.73	23.61	24.71	3.08	6.24	6.87	30.2	0.87	13.73	0.27	9.63

for 1960 included provisions for the needed land ownership reform[1].

In this law, the minimum limit of ownership is 30 dunums (plus or minus 10%) and the maximum limit is 500 dunums. The formula adopted by this law for the different ownership categories is as follows:

Irrigable Land Owned Before the Project	Irrigable Land to be Allotted in the Project Area
30 — 75	Allot equal area
76 — 100	75 du. plus 50% of excess over 75 dunums
101 — 500	87.5 du. plus 25% of excess over 500 du.
501 — 1000	187.5 du. plus 22. 5% of excess over 500 du.
over — 1000	300 du. plus 10% of excess over 1000 du. but not to exceed 500 dunums.

With the enforcement of this law, the ownership picture in the project area is very much improved. Table 2 shows the new status:

STEPS IN LAND OWNERSHIP REFORM

The steps undertaken by the East Ghor Canal Authority to effect this reform program are:

A. **Land Classification.** Land classification was finished in 1954, not for this particular objective of land ownership reform but for the planning phase and the economic feasibilty studies of the project. Nevertheless, land classification served as a basis for land evaluation, for land distribution and for the farm unit layout and design.

This land classification was carried out according to the standards of the U.S. Bureau of Reclamation modified to fit local conditions.

B. **Land Expropriation.** In compliance with Article 9 of the East Ghor Canal Authority Law, the Authority expropriated all land and water rights below the main canal in the project area. This was a first step toward the proper design of farm units and toward land redistribution with minimum concern for the boundaries of old holdings.

C. **Land Evaluation.** Article 9 of the Authority Law sets the procedure for evaluation of expropriated property in the project area.

Land and water rights evaluation was performed by committees called «Land Evaluation Committees.» Each committee consisted of a judge as chairman and four other members representing the Ministry of Agriculture, the Lands Department, the landowners in the sub-district where the evaluation is carried out and the East Ghor Authority. The official land clasification previously executed by the Authority and personal inspection of the land were the bases of this evaluation. In the first section, the land classification

1 Copies of relevant articles from this law may be obtained upon request from the author.

TABLE 2. LAND OWNERSHIP UNDER PROJECT LAW.

Range of Ownership in Dunums	Land Owners		Land Owned	
	Number	Percentage	Dunums	Persentage
30 — 75	2131	86	75,842	65.0
76 — 87.5	104	4	8,443	7.2
88 — 187.5	222	9	24,180	20.6
188 — 500	34	1	8,387	7.2
Total	2491	100	116,852	100.0

maps were superimposed on the old parcellation maps for the use of the evaluation committees. This procedure proved to be of great help in saving time and effort during inspection of the fields. After land evaluation was finished for a village, evaluation schedules were set up on special forms.

D. **Farm Unit Layout** — See page 309

E. **Land Distribution.** Steps D. and E. will will be discussed separately in the rest of this paper.

CONSIDERATIONS IN FARM UNIT LAYOUT

The sizes, shapes and arrangements of the farm units, as well as the procedure for farm unit layout, are the most important aspects of this subject. Following is an outline of the steps taken:

A. **Size of the Farm Unit.** The East Ghor Canal Law states that minimum land ownership is 30 dunums (plus or minus 10%) of Class 1 and 2, or 50 dunums (plus or minus 10%) of Class 3 land. Farm units are designed in such sizes. Land classes are a very important factor in determining farm unit size. One dunum of Classes 1 or 2 land is considered equal to 1.7 dunums of Class 3 land. This relationship was arrived at after an economic study of land classes under the master plan. The net income of 15 dunums of Classes 1 and 2 land was approximately equal to the net income from 26 dunums of Class 3 land.

Class 4 land, which is the land affected by excessive salt accumulation in the profile, is treated as being in the land class it will revert to after the salts are leached out. Leaching of Class 4 lands is performed jointly by the Authority and the farmer.

TABLE 3. FARM BUDGETS

Item	Land Class as 1 & 2				Land Class 3	
	Unit	Vegetable	Fruit	General	Vegetable	General
Land area	dnms.	30	30	30	50	50
total crops	»	44	40	39	68	61
Vegetables	»	27	14	12	42	15
Fruit	»	0	9	0	0	0
Grain	»	10	10	12	16	17
Forage	»	6	6	14	8	27
Roads, ditches, etc. - 3%	»	1	1	1	2	2
Investment	Dollar	3291	4131	3641	4291	4941
Farm receipts	»	2539	2772	2094	2783	2557
Crops	»	2312	2545	1202	2556	1095
Livestock	»	227	227	892	227	1462
Farm expenses	»	1510	1598	1214	1734	1357
Net farm income	»	1029	1174	880	1049	1200
Interest on investment	»	165	207	182	214	247
Net income	»	864	967	698	835	953
Cropping per cent		147	133	130	136	122

Class 6 land is not counted either under the old ownership or in the land to be allotted to the farmer.

The minimum size of the farm unit was decided after economic studies of the budgets of farms using appropriate intensive cropping patterns. In these budgets, allowance was made for giving the new farmer an opportunity to attain a decent standard of living in addition to paying off the water charges, the installments on the cost of the new land he acquired, and the construction costs of the project.

In a recent economic study of the project area undertaken by the Harza Engineering Company of Chicago, U.S.A., the farm budgets listed in Table 3 were presented.

These net incomes are the incomes that the farmer has to live on and to use for paying for the land; they include water charges, construction costs and additional land development on his farm unit.

The situations analyzed in the table are assumed to be representative of the project area. Management, irrigation and agricultural practices are assumed to represent average conditions during the development period.

In designing farm units, the size cannot be exact the same for every unit. This is so because farm unit design depends on many other technical factors that will be discussed later. For this reason, the law gave the designer a leeway of plus or minus 10% of the size of the farm unit.

B. **Shape of the Farm Unit.** The general shape of the farm unit is rectangular except in cases where this is made impossible by the topographic features. This shape is the most suitable for obtaining good farm sub-divisions, a good farm management plan and a high efficiency of irrigation application. Efficiency of water application with minimum labor requirement, as well as soil and water conservation, is a main cansideration in designing units for irrigated agriculture. The following factors affect the farm unit layout and the shapes of farms:

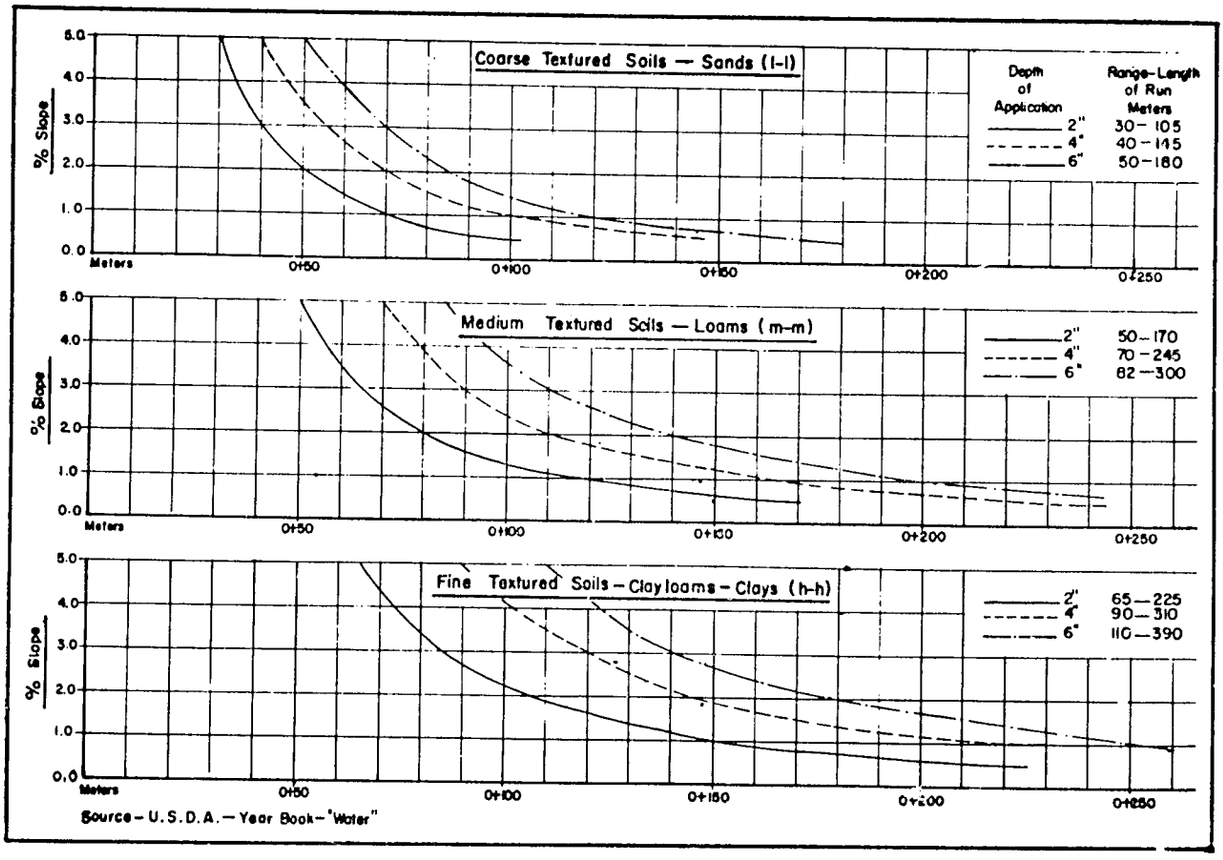
1. **Choice of the Irrigation System to be Used on the Farm Unit.** This is one of the most important factors. Its importance stems from the objective of the project. High efficiency of water application is desired, with minimum waste and labor. In designing a unit, consideration must first be given as how the unit is going to be irrigated most efficiently. Thus, a suitable irrigation system must be chosen for the farm.

   Factors affecting the choice of irrigation system are the slope of the land, the soils and the economics of land preparation for the alternative systems.

   In general, the land slope is 2 to 4 per cent westward and about 2 per cent southward. Because of this, most units will be using the furrow system of irrigation. Some units in the flatter areas could use border or basin systems.

   With the choice of the system, the direction of the irrigation is decided. In most cases, this is straight down the slope, using controlled runs and heads of water. This system, in contrast to the contour furrow system, has the advantages of a lower cost for installing the head ditches, no survey being needed to install the furrows, more tolerance of land surface uniformity and requirement of less control. Financial considerations have also limited the amount of land development possible.

2. **Length of Irrigation Run.** The next step is determination of the length of the irrigation run. The length of the farm unit in the direction of irrigation is taken as being equal to or a whole multiple of this irrigation run. The length of run is affected by many



factors, among which are the following:

(a) **The Land Slope.** The greater the slope in the direction of irrigation, the shorter is the length of run.

(b) **Head of Water.** The larger the head of water, the longer the irrigation run, provided that this head is non-erosive.

(c) **Depth of Application.** The greater the depth of application needed, the greater the time of application should be and, consequently, the longer the run.

This application depth depends on the depth of the root system of the crop irrigated and on the soil texture. Soil texture determines the amount of available moisture the soil will hold. The depth of application is also affected by the level of soil moisture depletion at recharge of the root zone. The conservative figure of 50 per cent depletion is used.

(d) **Soil.** In addition to affecting the length of run by their water-holding capacities, soils affect it by their infiltration rates. The greater the infiltration rate, the shorter is the irrigation run. To serve as guides in the design of the farm units, a set of curves was prepared showing lengths of runs with different soil textures, slopes and application rates. These curves are shown in Fig. 1. They are based on tables prepared by

the U.S. Soil Conservation Service. Soils are grouped in three general groups as being light, medium or heavy.

3. **Head Ditch Design.** The location of the head ditch is another very important factor in the design of farm units. This depends on the farm irrigation system chosen. Generally, the location of the head ditch is along the upper boundary of the farm unit and, consequently, this boundary is chosen to follow approximately a grade line.

   Head ditches will have slopes ranging from 0.05 to 0.3 per cent. Any excessive slope will need drop structures, which cost about JD. 5 (or $14) each. To minimize the cost of drop structures, the designer is allowed to introduce up to two angles in the upper boundary of the unit in order to stay within the specified range of slope given above. Most of the boundaries are either straight or have one angle. A very small percentage have two angles, when the topography of the land makes it absolutely necessary.

4. **Topographic Configurations.** This factor, in addition to affecting the shape and length of the farm units, affects also the location of surface drains and laterals. Open drains are located to follow the low spots in an area where surface drainage is required.Laterals generally traverse the high points to enable them to serve units on both sides, which saves on the length of lateral required and consequently cuts down the cost.

5. **Extent of Land Development Envisaged.** In designing the farm units, the amount of land leveling and smoothing to be performed on them is always taken into consideration. Resulting limitations will be discussed later under **Farm Unit Development.**

6. **Surface Drainage and Tail Ditches.** No matter how efficient and controlled water application is, there will always be some excess water at the tail end of the irrigation run. With improved irrigation practices, this loss is kept to a minimum.

   To avoid flooding of the lower farm units and to protect their head ditches and the lateral system below, excess water is removed by tail ditches. Groups of tail ditches connect with a natural drainage channel or an open drain. Consequently, great care is taken in laying out the farm units to develop a good surface drainage pattern and to avoid blind ends in tail-ditch systems.

7. **Accessibility to Farm Units.** The importance of this factor cannot be overestimated. The farmer has to transport to his farm unit supplies and machinery and has to take his produce out. Therefore, each farm unit must be served by a public road or a lateral operating road.

8. **Economics of Alternatives.** In most cases, idea' situations in every aspect are hard to reach. Some factors will have to be sacrificed for other, more important, factors and a compromise reached. In alternative layouts, the following factors are weighed against each other:

   (a) Efficiency in water application, farm management and operation and maintenance of the irrigation system.

   (b) Costs of the system, which involve:

      i. Cost of a lined lateral system for the particular area under study on a per dunum basis.

      ii. Cost of the drainage system and length of the tail ditches to be installed.

iii. Cost of installing head ditches and drop structures in them.

iv. Cost of land preparation needed for the proper irrigation of the unit.

v. Cost of land required for laterals, drains and roads.

PROCEDURE FOR FARM UNIT LAYOUT

A. **Land Classification Amendments.** Land classification is very important in determining the size of the units and the lengths of run are based on soil information found in the land classification. Land classification for the area was conpleted in 1954. After that time, some changes in soils, topography or drainage occurred and the land class had to be changed accordingly.

1. **Soils.** Some soils have accumulated salts since 1954, especially where drainage was restricted and the water table became high. On the other hand, some areas which were saline have been leached and can no longer be so considered.
2. **Topography.** Some Class 3 lands have been leveled since 1954 and now their class must be changed to Class 1 or 2. Some other lands were affected adversely by floods, especially at the streams. Those floods deposited large quantities of rock cover on the lands affected, changing their class. In contrast, some areas have been improved by active clearing of rock cover during the past few years.
3. **Drainage.** Some new drainage problem areas appeared due to increasing irrigation from the side wadis with no provisions for drainage. Some old drainage problem areas do not have this deficiency any more, due to private drainage works constructed since 1954. Because of the importance of land classification in farm unit layout, the first step is the amendment of the old classification to indicate the condition of the land at the present time. Power for land reclassification is vested only in the Authority Board. A reclassification policy was worked out whereby the Technical Division recommands changes and the Managing Director approves them on behalf of the Authority Board.

B. **Layout Procedure.** The Field Layout Section surveys the coordinate grid system in the area and constructs concrete-monumented coordinate points on a 500-meter grid to serve as horizontal control for all the survey work to follow. Two sets of 1:2500-scale topographic maps with land classification superimposed on them are sent by the Design Section to the Field Layout Section. It marks on these maps the boundaries of permanent crop areas and the points of irrigation of these areas. These boundaries are important in order to avoid the crossing of valuable well-developed orchards with laterals or drains as much as possible, and in order to have the permanent crops of one owner in one farm unit. Many problems of land distribution are avoided in this way.

The Field Layout Section also lays out on these maps the primary surface drainage pattern for the area and the final main alignment, with culvert locations corresponding to the surface drainage pattern. One set of maps containing all the information is sent back to the Design Section.

The Design Section proceeds to design the distribution system and the farm unit layout, taking into consideration the factors discussed above. The Section collaborates frequently with the Farm Development Section in order to meet specifications for farm units more effectively. The design is made on overlay tracing paper placed over the topographic maps received from the Field Layout Section. When the design is finished, the maps and the overlay tracing sheet containing the layout

are sent to the Farm Development Section for checking and comments. This section makes a final check of the layout from the following aspects:

1. Shape of the units.
2. Slopes of the upper boundaries of the farm units.
3. Lengths of runs based on the soil type and slope.

The Farm Development Section discuss their comments with the Design Section and a unified layout is produced ; or they may work out a new layout if their differences with the Design Section's layout are too great. In this case, both layouts are sent to the Field Layout Section for a field check and for the more suitable one to be selected.

The unified office design is sent to the Field Layout Section for a field check on the laterals and sub-laterals. Also this Section reviews the office layout and suggests revisions. The layout with revisions is then sent back to the Design Section. These revisions are reviewed and acted upon by the Design Section and the Farm Development Section. The Design Section prepares plane table sheets for the system taken from the revised overlay. The distribution system and the farm unit boundaries appear on these sheets, which are then sent to the Field Layout Section for a field check.

The Field Layout Section performs the final survey of the system shown on the plane table sheets. This survey includes a check on the head ditches. If some head ditches are found to be unsatisfactory, either too steep or going uphill, the surveyor puts on the plane table sheets two to three contour lines to indicate the topography on both sides of the head ditch. In some special areas, elevations are checked on a grid, taking the head ditch as a base line and including both sides of it. The plane table sheets with appropriate supporting field notes are then sent back to the Design Section. The Design Section finalizes head ditch design and designs the irrigation system, with horizontal control shown on the plane table sheets and vertical control on both the plane table sheets and the construction plans.

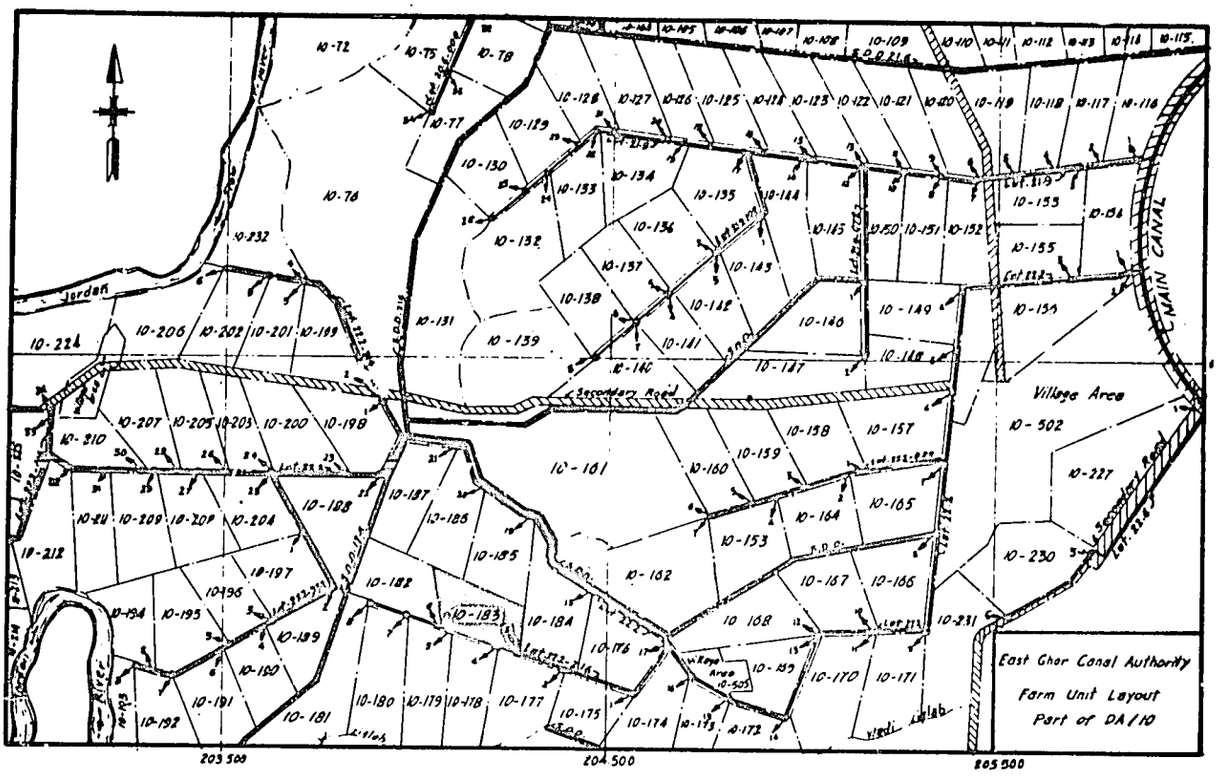
The system and the layout are then transferred to maps of 1:5000 in scale and these, with supporting information, are sent to cadastral mapping crews. These crews lay the units out in the field, place the boundary marks and make 1:2500 cadastral maps. The cadastral maps are sent to the Lands Department for a primary check on areas. If there are no problems, those maps are inked and the exact area of each land class in each farm unit is planimetered and reported in tabular form. The cadastral maps are then ready for use as the legal description on which the issuance of title deeds is based.

C. **Preparation of Fam Unit Plats.** When the final layout is finished, the Design Section prepares 1:1250-scale maps for each individual farm unit on a transparency. These maps or plats show the boundaries of the unit, the delivery point the land classification and the topographic relief of the land. The maps are sent to the Farm Delopment Section which adds to them the suggested farm irrigation systems, showing the head ditches, field ditches, tail ditches and proposed field sub-divisions. They also add any soil information available, such as soil profiles or infiltration rates.

Five sets of the finished farm unit plats are sent to the Development Division and one is kept in the Farm Development Section. The Development Division uses these plats as a guide for surveying the head ditches for the irrigation system. They also use the information on them for their land development program.

These plats are designed to serve as history sheets on each farm unit. Permanent structures on the farm unit, fertilizer tests or demonstrations, crop rotations and all relevant soil and agricultural information will be shown on them. When a depend-

FARM UNIT LAYOUT



able amount of information is accumulated on the plats, they may be assembled by areas to serve as guide books for extension workers in the future.

A typical farm unit layout is shown in Fig. 2.

FARM UNIT DISTRIBUTION

Article 9 of the East Ghor Authority Law establishes the legislation and procedure for land distribution. In compliance with this Law, the Authority appointed a committee consisting of an Authority employee as chairman and eight other members.

The Lands Division calculates the original land owned by each landowner, sub-divided into the various classes. These records are supplied to the Farmers Selection Committee, which then issues letters to these farmers requesting them to meet with the Committee within 60 days. Farmers sign these notification letters and return a signed copy to the Farmer Selection Committee: thus a record is made that the notification letter was received.

The farmers are then interviewed by the Committee. At this time they fill out a special form.[1] The Committee checks these applications with respect to their legal aspects as well as the preciseness of the figures and the degree of priority of the applicant.

The Committee accompanies the applicant to choose his new farm units. In doing this, they are aided by a map that shows both the old parcellation and the new farm unit layout. Consideration is given to allotting the farmer land that he owned before or as near to his original land as possible. If he had permanent crops before, the Committee tries to give him units that include these crops. The tendency is to concentrate the new ownership in one block of units, except in a few cases where the farmer had permanent crops in more than one locality.

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1 An English translation of this form may be obtained from the author.

After the choice is made, the Committee studies the areas of the units allotted in order to comply with the formula stated in the Law. In some cases, must be changed in order the units allotted to comply. In other cases, the farmer accepts an area a little smaller than that which he should receive according to the Law. In such cases the farmers sign papers indicating their acceptance.

When the farmer accepts the units allotted to him, the Committee approves the application and refers it to the Authority Board for final approval. In case of failure to agree on the part of the farmer and the Committee, the case is referred to the Authority Board for a decision.

The Authority Board investigates each case and approves or disapproves the decision of the Farmers Selection Committee. If the allotment is approved, the farmer receives a notification letter to that effect and is shown the boundaries of his new units and the balance due.

If the Authority still owes him some money, he will be paid in four yearly installments with 4% interest. If he owes the Authority money, he is required by the Law to pay his debt in four years, with 4% interest. There is a proposal under consideration now to give new farmers a 10-year period for repayment. When the paper transactions are finished, a title deed is issued to the new farmer.

FARM UNIT DEVELOPMENT

The task is not complete when the farmer has his unit and the water is in the delivery box. The type of use made of irrigation water could mean the success or failure of the project. In order to have irrigation water used properly, resulting in soil and water conservation, the land has to be prepared for irrigation and the farmer must know how to use the water properly. This is where the Development Division of the Authority comes into the picture, with their land development and farmer education programs.

A. LAND DEVELOPMENT

1. **Reclamation.** There are limited areas that are saline or affected by the presence of a drainage problem. Drainage and leaching are done by the Authority and the farmers on a sharing basis. The Authority gives the water needed for leaching free of charge, and provides the farmer with technical help in the leaching process as well as machinery to construct the dikes and basins. The Authority also builds the main drainage system. The farmer provides the labor needed, constructs the dikes and basins, and provides the necessary fertilizer to built up the productivity of the leached area.

2. **LAND PREPARATION FOR IRRIGATION**

   (a) **Head Ditches and Tail Ditches.** The survey team lays out the head and tail ditches in the field, basing their work on the suggested irrigation system shown on the farm plats. Unless it is seen after a field check that a change in that system is advisable, these ditches are staked. Head ditches are designed in the field office and prefabricated. 30 cm drop structures are installed in the head ditches by the Authority. Construction of the head ditches, as well as of the tail ditches, is done by the farmers.

   (b) **Land Preparation.** The survey team performs a topographic check on the farm units to find out whether or not there are topographical problems. If there are none, the land is disked and spot-leveled where necessary, usually not in excess of 15 cm. This is followed by floating twice at an angle to the direction of orrigation and a third time with it to smooth the surface and to fill in any old ditches.

   If there is a topographical problem and heavy leveling is needed,

the unit is graded, elevations taken and blue and red tops installed.The soil profile is checked also, to determine any limitations on land leveling. This leveling is limited to 30 cm in the Ghor area and 45 cm in the more undulating Zor area. Any areas that require a deeper cut are reclassified as 6 (high), because in the Jordan Valley there is more irrigable land than water available.

After the land preparation is finished, water is tried on the farm unit for pre-irrigation, which is needed in the semi-arid area of the Jordan Valley. If the technicians of the Development Division are satisfied with the amount of land preparation and with the performance of water on the land, a «fitness certificate» is issued for the farm. Farm units cannot receive water without the fitness certificate. This is to insure proper use of water and soil conservation.

2. **Educational Program.** Education of the farmers on how and when to apply water and how much to apply is as important as proper land preparation. This is especially so because many of the farmers have never farmed under irrigation, and because even those farmers who have had experience in irrigation farming used to change their old wild flood methods and learn the new, more efficient techniques.

The educational program is carried out by the Extension Unit of the Development Division, which advises farmers on methods of irrigation, furrow direction, crops, rotations, pre-irrigation and all the other problems of irrigated agriculture.

This point, advanced as it is, is not yet the end of the help that the Development Division provides for the farmers. The Division assists in the cooperative movement and in arranging for credit for farmers from the Agricultural Credit Corporation and the Cooperative Union. In the future, they will be helping also in the processing and marketing of the produce.

DISCUSSION

In reply to a question by Mr. Sawaya, it was stated that the large landowners do not like the land reform. Under the law, a system of priorities has been set up. At the time of planning, it was not known how much of the excess land taken from the larger landholders would be turned over to the smaller ones; however, it has worked out that there is a smaller number of landholders now than originally. During the expropriation period, the old owner stayed on his land until the construction and all of the transactions were completed, and then he would move to his new land. The canal rights-of-way were obtained by purchase.

Land classification was based on actual field data. Classes 1 and 2 have essentially the same capability for production; Class 2 costs somewhat more to develop, however.

The Law provides that a farm unit shall be 30 dunums, although in laying these out a variation of not more than 10 per cent is more or less permitted. This farm unit may not be sub-divided. Priorities for chosing the new units are based on previous land holdings. The largest landholder in any new unit has the first priority to choose that unit; the next largest landholder, the second priority, etc. Absentee landords are permitted to own their appropriate share under the Law. However, they must farm it themselves or else rent it to the Authority, who will then rent it to a cultivator. They can not rent it directly.

The amount of leaching water to be given free of charge is based on the land classification, preparing in which the soil profile was checked for salt content.

Farm planning was based entirely on desirable farm layout. Previous culture and buildings were

not taken into account and the land was expropriated in advance of planning so that this could be done.

There are some areas in the East Ghor project area that have low infiltration characteristics. The head in the furrows is determined by the slope, and the soil characteristics determine the length of run.

Some of the farmers displaced by the expropriation may find employment on farms, and it is hoped that the increased business cycle will permit them to find employment in various services. Many of the small farmers were happy at the opportuity to obtain some capital for their holdings, even though they were displaced. While the villages will remain the same, there will be community development, especially in the form of cooperatives.

Land development costs are not included in the capital costs considered at the time of resettlement. It has not been decided what will be the repayment plan for such costs, although it will probably cover 40 years. Approximately 700 farmers have accepted their new deeds and the resettlement is completed in their cases.

It is believed that erosion problems are under control.

Furrow irrigation will be down slope, at a grade of 4 or 5 per cent. The head ditches would have been more expensive had contour irrigation been practiced. Furthermore, the contours would have to be laid out each year. The contour system permits much less tolerance in the land leveling; if they are in regular places, the furrows break across.

There is no set duty of water. The farmer pays one fils per cubic meter for the first 1,500 cubic meters per dunum After that he must pay two fils per cubic meter. Intensity of cropping ranges from 135 to 155 per cent.

CHAPTER XII

FIELD TRIPS AND INSPECTIONS

ANKARA

On April 18 the delegates visited the Soils and Engineering Laboratories of the State Hydraulics Works Directorate and the Soil and Fertilizer Research Institute of the Soil Conservation and Farm Irrigation Directorate, both in Ankara.

SOILS AND ENGINEERING LABORATORIES

The extensive Soils Laboratories of the State Hydraulics Works are especially equipped to obtain information for land classification and for drainage and reclamation planning; chemical and physical tests are conducted for that purpose. The Engineering Laboratories are also fully equipped to study the physical properties of engineering materials, including soils, for embankments and foundations.

SOIL AND FERTILIZER RESEARCH INSTITUTE

The Soil and Fertilizer Research Institute has the objective of deriving, through proper research, sound recommendations for land development in order to improve the soil, maintain its optimum conditions, for plant growth, and increase crop yields and their quality. Laboratories and greenhouses are available for the study of fertility, salinity, soil physics and soil microbiology and for research on soil morphology and classification.

ADANA-MERSIN

This field trip permitted the delegates to inspect at first hand some of the work covered in the reports of the host country.

LOWER SEYHAN PROJECT-UNIT 1-YP

The Lower Seyhan project is a multi-purpose project intended to: 1) protect the Yuregir and Tarsus Plains from floods, 2) provide full irrigation for 186,000 hectares of land, 3) promote land development, 4) provide low-cost electricity (419 X 10^6 KWH/ann.) and, 5) equip farmers to improve their agricultural techniques.

Unit 1-YP, a typical unit under construction, was visited on April 27 and details of the irrigation and drainage development were inspected. A tile plant, primarily for roof tiles but which also produces drain tiles for use on the project as well as for the general market, was also visited.

TARSUS-BERDAN PROJECT

In the afternoon the delegates inspected the Tarsus-Berdan Project and Diversion Dam, described in the paper, «A Suggested Program for Improved Irrigation Production.»

TARSUS IRRIGATION RESEARCH INSTITUTE AND TRAINING CENTER

The first-day trip wound up with a visit to the Tarsus Irrigation Research Institute and Training Center of the Soil Conservation and Farm Irrigation Directorate. The educational work of this Center and its research program are mentioned in Turkey's paper on education and training and in, «Soil Reclamation and Consumptive Use, Turkey.» The Institute was founded in 1947 in cooperation with the State Hydraulic Works on 450 decares of land and deals principally with salinity and alkali reclamation, soil conservation, fertility, irrigation, drainage and crops.

Y-4 DEVELOPMENT PROJECT

Although the Berdan Diversion Dam was constructed in 1942, the land has failed to come under complete irrigation. To correct this, TOPRAKSU began farm development plans in 1960. Existing tertiaries were redesigned, partially realigned and lined with concrete. Control structures were built and land levelled. Individual farms were laid out and form the basis of loans for farm

development. En route, on April 29, a private citrus orchard under well irrigation was visited. This orchard represents the possible future of the Mersin area under adequate irrigation practices.

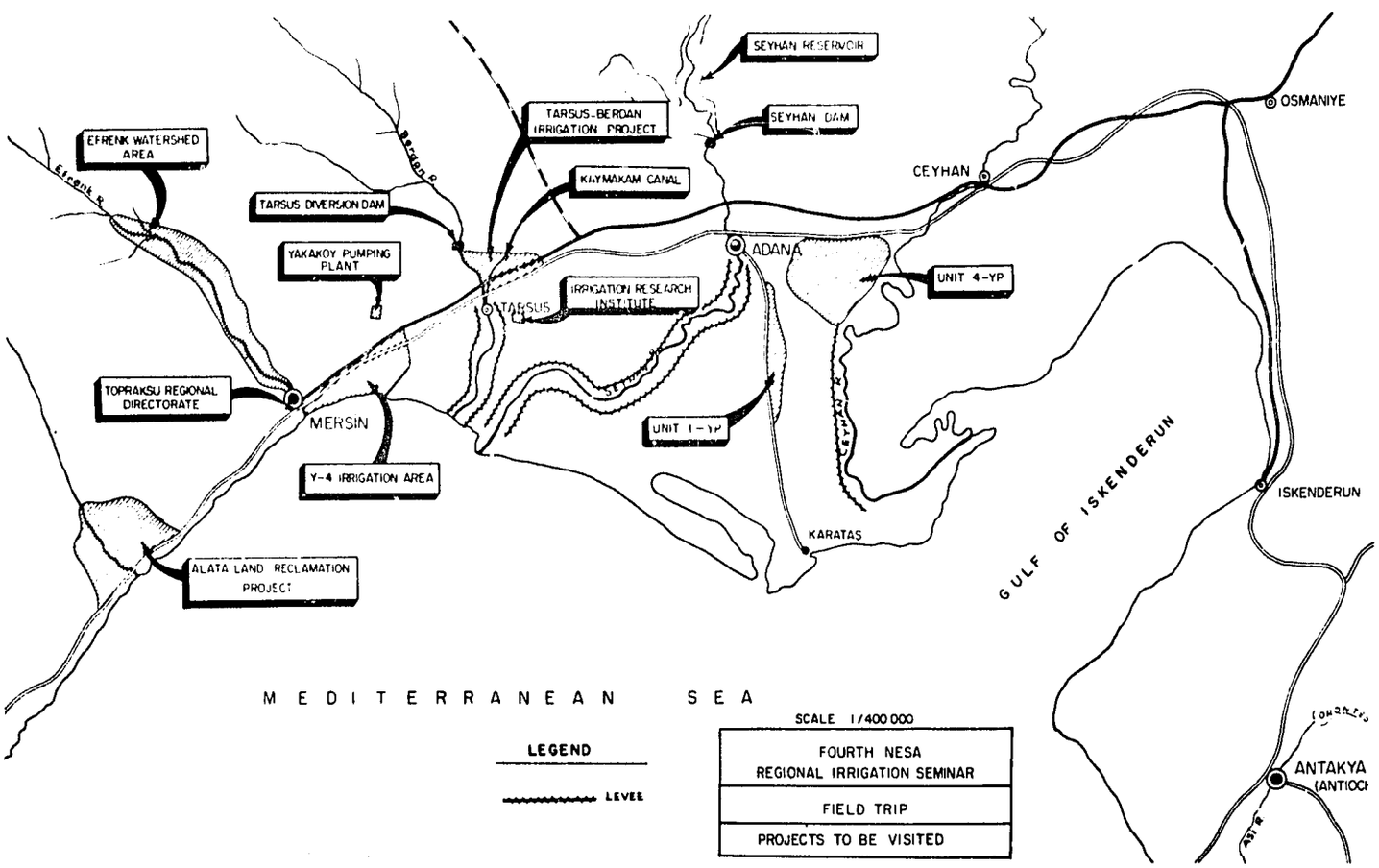
TOPRAKSU REGIONAL OFFICE

The office and shops of this Mersin Regional Soil Conservation and Farm Irrigation Directorate were visited. Details of developing farm plans and of credit extension were explained by the Director and equipment was inspected.

ERFRENK WATERSHED

This is a comprehensive watershed development including a soil conservation and irrigation program designed to combat problems of erosion, summer drought, primitive animal husbandry, and lack of seeds and fertilizer.

Bench terraces are constructed on slopes under of 25 per cent, and the Algerian type of terraces on steeper slopes. Diversion channels and waterways are also constructed. With completion of the devolepment work, apples, peaches, corn and vegetables may be grown on the upper sections, and citrus and vegetables in the lower areas.

ALATA SAND DUNE PROJECT

Swampy areas back of the dunes near the sea constitute a major land resource in Turkey. These can be drained and irrigated, since there irrigation water is usually available. Although there are problems of wind erosion and salt spray, low-water holding capacity and poor topography, these areas became very productive when reclaimed. The Alata project, visited on the afternoon of April 28, is a pilot project in this type of reclamation. The land has been levelled and tile drainage with open-trunk drains installed. The sea dunes have been shaped and planted as a wind protection measure and concretelined irrigation ditches installed.