MANAGEMENT OF WATER DELIVERY SYSTEM IN PROSIDA (INDONESIA)

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the Degree
of
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WATER RESOURCES DEVELOPMENT

By

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APRIL, 1984

To

Hartini my wife
Miko my son
Mita my daughter

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CERTIFICATE

Certified that dissertation entitled 'MANAGEMENT OF WATER DELIVERY SYSTEM IN PROSIDA (INDONESIA)' which is being submitted by Mr. Nicolaas Darismanto, in partial fulfilment of requirement for the award of the degree of Master of Engineering (Civil) in Water Resources Development of the University of Roorkee is a record of candidate's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for award of any other degree or diploma.

This is further to certify that he has worked for a period of more than six months from October 15, 1983 for preparing this dissertation.

Roorkee :

Dated: April 18, 1984

(C. P. Sinha)

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SYNOPSIS

The great wastage of irrigation water occurs during conveyance and application from main intake to the farm field. In fact most of these losses could be saved if there is a proper water distribution planning and a correct supervision during its implementation.

Irrigation water management of a completed project should be focused on how the water is delivered, applied, used and removed from the field. Water delivery should be designed to deliver water according to crop water requirement, with a predetermined method of irrigation water distribution. Water use in an irrigated farm is the end result of a complexity of operations carried out at different points in the irrigation system starting from the source of water ending at the point of delivery for farmer use.

Water management at PROSIDA command area evolves from planning decisions to design of cropping patterns to effectively use anticipated water surplus and operational decision use according to experiences and knowledges. Where PROSIDA as the implementing agency for Indonesian irrigation projects financed by the World Bank through International Development Association (IDA) got duties from the Government to improve the physical conditions of the system as well as to improve the management of water for irrigation.

With a view to evaluating the performance of PROSIDA command, particularly its water delivery system, and suggesting improvement measures, this study is undertaken. It is seen that in order to achieve good water management the backing of high quality service related to quantity, quality and timing of supplies of irrigation water, its distribution and use, adequate number of fully qualified and trained staff is needed. Simplicity of operation and farmers' participation in water use activities are the key to the success of delivery system.

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CHAPTER - I

INTRODUCTION

1.1 GENERAL

The Indonesian archipelago consists of main islands : Sumatra, Kalimantan, Java, Sulawesi and Irian Jaya and about 30 smaller archipelagoes totalling 13,677 islands of which about 6000 are inhabited. The total population of Indonesia is about 154,000,000.

This archipelago forms a highway between two oceans (the Pacific and Indian Ocean and a bridge between two continents (Asia and Australia).

The area of land is about 1,920,000 sq km and the area of the sea is about four times larger than the land area. The whole area extends about 5110 km from east to west (95^o - 141^o east longitude) and about 1888 km from north to south (6^o north latitude and 11^o south latitude).

Jawa island is the most fertile and populous island. The area is about 132,600 sq km but inhabited by more than 100,000,000 people or 65 percent out of Indonesia's total population. A chain of mountains runs from west to east, and is flanked in the north by lowlands and in the south by limestones ridges. Most of the rivers in Java run northward, only a few go to the south coast. Java is a highly volcanic, 15 out of 112 volcanoes are active (1).

Sumatra straddles the equator and contains a long mountain range called the Bukit Barisan. The mountainous portion is small and there are vast stretches of lowland, consisting principally of marshy alluvial plains covered with forest and low vegetation. The terracing bordering the rivers are alluvial.

Kalimantan, the largest island in the archipelago has a vast terrain of lowland, consisting principally of alluvial and swampy plains and make good farming when reclaimed. The area occupied by mountains are relatively very small.

Sulawesi, in contrast to Sumatra and Kalimantan, is mountainous and hilly, with the exception of the central portion of the island where there is a large expanse of low-land of recent alluvial mountains which is very fertile.

Irian Jaya is characterised by extremes ranging from the sweltering, swampy lowlands of the coast to snow capped mountain peaks, soaring upto 5,300 m.

Nusa Tenggara (Bali, Lombok, Sumbawa, Sumba, Flores and others) rise out of the Indian Ocean in what was considered once a wide strait. Separating the continents of Asia and Australia. Skirting the coast line of these islands, a narrow shelf exists from where steep mountains containing numerous volcanoes arise. These islands particularly Bali and Lombok are very fertile owing to the great quantities of volcanic ash (2).

Maluku is a group of islands between Sulawesi and Irian Jaya. The islands are mostly mountainous and densely forested, but Aru and Tanimbar islands are flat and swampy, some volcanoes are to be found on the islands. In fact the great chain of volcanoes that runs through Sumatra and Java is continued eastward into Maluku islands, the most active volcanoes being on Ternate and Banda islands.

The climate of Indonesia changes every six months i.e.

(1) dry season (June to September) is influenced by the Australia continental air masses

(2) rainy season (December to March) is influenced by the Asia continental and Pacific Ocean air masses passing over oceans. The air contains steam and brings rain to fall on Indonesia.

Tropical areas have rainy seasons almost the whole year. The climate of the central Maluku is contrary to other Indonesian areas. Rainy seasons in June to September and the dry seasons from December to March. The transitional periods between the two seasons are April to May and October to November.

The temperature in Indonesia can be classified i.e. :

- An average temperature of 27°C for beach places.
- An average temperature of 25°C for inland and mountain areas.

- An average temperature of 22°C for mountain places (it depends on the height of mountain).

As a tropical zone Indonesia is island have average relative humidity with an interval 75 percent - 85 percent, with maximum humidity 100 percent and minimum 50 percent.

Surface winds and rainfall are closely related. East winds are generally dry and quick, in rainy season winds are generally from the west and north west. West wind generally develop quick. The dry season with east winds come from Australia.

Fast winds occur usually in the sea (± 30 - 60 knots). The wind average velocity is between 5 - 10 knots. In the transition season (April to May and October to November). The wind situation becomes variable. Rainfall variability in fixed places is influenced by the climatological situation that place. Mountain places are generally more rainy. Inside rainfall is influenced by the situation of air streams meeting (1).

Actually Indonesia is blessed with abundance of water, but it tends to be available in the wrong place, at the wrong time and with quality, which create adverse effects on human welfare and on the quality of life.

The rainfall in Indonesia varies widely between 700 mm/year to 7,000 mm/year, with an average of 2,810 mm/year, whereas the evapotranspiration is generally within the range of 1,000 mm/year to 1,500 mm/year.

The water resources potential in Indonesia related to its population can be classified into three categories, i.e. :

(a) Good water potential region, with more than 100,000 m^3/capita/year consists of Kalimantan and Irian Jaya islands.

(b) Fair water potential region between 10,000 - 100,000 m^3/capita/year consists of Sumatra, Sulawesi islands and Maluku archipelago.

(c) Poor water potential region with less than 10,000 m^3/capita/year consists of Java, Madura, Bali island and Nusatenggara archipelago.

Figure 1.1 show the map of water potential of Indonesia.

The alluvial type of land which has good properties for irrigated agriculture and with the slope of less than 8 percent, covers an area of 16.8 million hectares or nearly 4 percent of the total land area of the whole Indonesia. This type of soil as well as the volcanic soils, are quite suitable for rice cultivation.

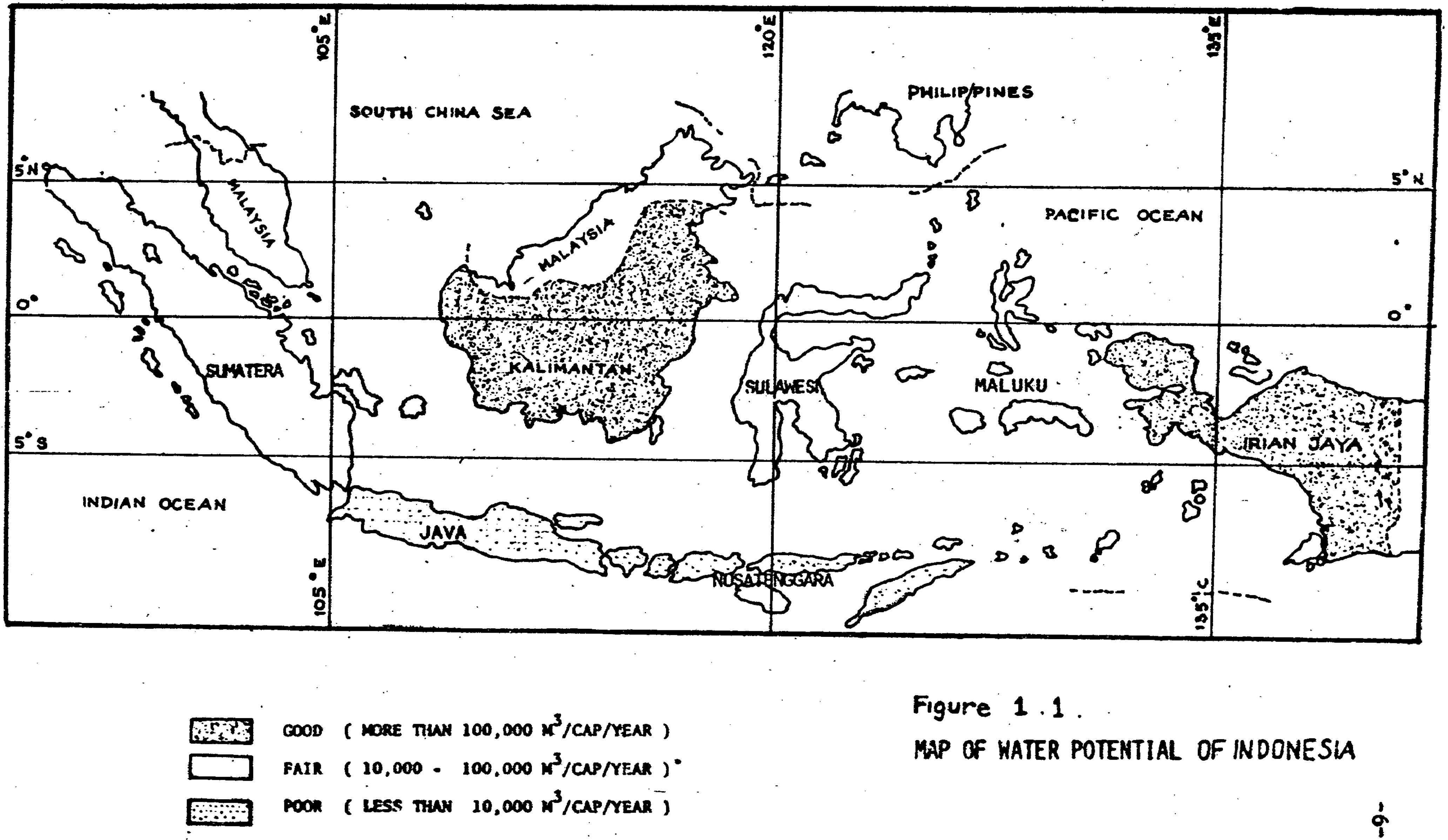


Figure 1.1.

MAP OF WATER POTENTIAL OF INDONESIA

Besides a large number of hectares of swamp land can be found in several islands, among others in Sumatra, Kalimantan and Irian Jaya. The productivity of this kind of soil is substantially improved with drainage and better control (3).

1.2 IRRIGATION FACILITIES

The majority of irrigation areas, especially with technical irrigation facilities are concentrated in Java.

In some places, there are several conventional methods using the local technologies such as :

- water wheel in West Sumatra is kind of equipment used to lift up the water from the river to the rice field. It is common practice in West Sumatra. The typical water wheel is made of bamboo and wood and propelled by human power or water power itself.

- Subak system in Bali is a traditional Balinese water user associations. All decisions and regulations concerning the distribution of water to the members is governed by the Subak so many things are astonishing of Subak activity for example, construction of irrigation tunnel with length about 3 km using local technology. It means without modern equipments, without surveying, without designing only using common sense and belief of the God with the high effort. Certainly, that activity needed a long time. Generation who have idea and worked do not enjoy the result but their posterities will enjoy it.

- The use of water-pails (ebor) in Central Java, the 'ebor' system is a method of lifting water from a river, canal, etc. to irrigate rice fields, using the bamboo stakes. This method practiced by individual farmers as well as by a group of people organized by the head of the village.

- The Tidal Irrigation systems are found along the coast of East Sumatra, West Kalimantan and the Southeast of Kalimantan and were originally swamps.

  By using of a canal system of the main, secondary and water course, the tidal fluctuations can be used to transform the swamps into rice fields. The system was done under the coordination with the transmigration program.

- Polder System

  Polder is an irrigation system dependent on the control of the water table on lowlying land. Besides constructing dykes around the polder, this system has an arrangement for the distribution and disposal of water. The supply and disposal at excess water is done mechanically by using pumps.

Polder Alabio with an area of 6,000 ha is located in south Kalimantan, Polder Mentaren, 2,300 ha is in Central Kalimantan.

- Experience of using local raw material is found in the construction of simple weirs, groynes, gabions, wooden or bamboo shuttering for river training, or other simple structures.

Irrigation system in Indonesia are usually classified according to type and quality of irrigation facilities provided i.e. 'Technical, semi-technical and simple'.

Technical irrigation systems are those which have a water supply system which is separate from the drainage system and where the volume of incoming water delivered can be measured at a number of points.

Semi-technical system have fewer permanent structures, have only one water measurement device (usually at the major intake) and the supply and drainage system are not always fully separate.

Simple systems have no measurement devices, and conveyance systems for water supply and drainage are not separate, with the possibility of recirculation of water.

A further classification of irrigation systems is on the basis of the controlling authority. Most of Indonesia's irrigation systems (about 80 percent are under the control of Ministry of Public Works. The remainder are known as 'Village irrigation systems'. Village irrigation systems which are managed operated and usually constructed under the leadership of village chiefs.

Irrigation areas in Indonesia spread in many islands can be seen in Table 1.1 (3).

1.3 CANAL SYSTEM

Canals are constructed for various objectives such as irrigation, hydroelectric power or navigation. In Indonesia, the navigation canals are uncommon. Irrigation canals are utilized for power generation mainly in the head reaches of a canal in areas where vertical falls have to be provided to accomodate the extra slope of the terrain. Power houses are constructed on these falls for generation for hydroelectric power.

An irrigation canal system involves many design features and consists of a number of canal works and canal reaches. A canal takes off from the head works of either a water storage dam or barrage or a diversion dam. Irrigation water flows through the complete canal system before it reaches the farmers' field to be irrigated.

The canal network consists of main, secondary, tertiary, quarternary and field channels are termed according to their capacity and orientation with respect to the head works.

Table - 1.1 Irrigation Areas in Indonesia (hectares)

Island/ Province	Gravity						Tidal and Swamp Lands	Total	%
	Technical	Semi Technical	Simple	Total Public Works	Village	Total Public Works & Village			
J a v a	1,631,289	384,667	551,288	2.567,244	532,958	3,100,202	-	3,100,202	59
B a l i	-	44,355	8,291	52,646	51,174	103,820	-	103,820	2
Sumatera	224,259	320,172	281,952	826,383	293,017	1,119,400	214,400	1,333,800	25
Kalimantan	3,490	15,184	41,226	59,900	15,920	75,820	107,600	183,418	3
Sulawesi	139,794	84,671	44,704	269,169	84,904	354,073	-	354,073	7
Nusa Tenggara	63,343	61,070	51,455	175,868	38,496	214,364	-	214,364	4
Maluku	-	1,419	-	1,419	-	1,419	-	1,419	0
Total	2,062,175	911,538	978,916	3,952,629	1,016,469	4,969,098	322,000	5,291,098	100

Source :

1. Directorate of Irrigation Directorate General of Water Resources, Ministry of Public Works 1979.
2. Directorate of Swamp Land Development, Ministry of Public Works, 1979.

1.3.1 Main Canal

'Main Canal' takes its supply directly from the source of the river, size of the main canal will depend upon the size of the irrigation system or the area that will be irrigated.

The capacity of main canals in PROSIDA varies from 50 cum per second to 10 cum per second. The direct irrigation is usually not carried out from the main canals.

1.3.2 Secondary Canal

'Secondary Canal' take off from the main canals and convey the water to different major parts of the irrigated areas. Secondary canals in PROSIDA carry a discharge from 5 cum per second to 0.4 cum per second. The direct irrigation is generally not done from large secondary canals, however, smaller branch canals may be provided with outlets of division structures for delivery water to the fields.

1.3.3 Tertiary Canal

'Tertiary Canals' are smaller canals taking their supply from secondary canals and supplying water to Tertiary boxes. The carrying capacity of tertiary canals are usually less than 210 litres per second.

1.3.4 Quarternary Canals

'Quarternary Canals' are the smallest canals take off from tertiary canals. A quarternary canal is carrying only about 15 to 21 litres per second.

1.3.5 Field Channels

Field channels is carry water to the individual fields from the quarternary canals. In rice irrigated areas of hilly land, however, field channels are normally absent as the conventional practice is to irrigate from field to field. The overflow from the upper field irrigates the adjoining lower field and so on, successively.

In Indonesia, the canals such as main canals and secondary canals up to end of diversion structures are constructed, operated and maintained by the Government whereas the canals such as tertiary and quarternary are constructed once by the Government and operated and maintained by the farmers.

1.4 PROGRESSIVE DEVELOPMENT OF IRRIGATION

The staple food of the Indonesian people is rice, only a small percentage having maize, sago, cassava etc. as their daily food consumption. Therefore, agricultural areas for rice cultivation is needed as much as possible.

The water needed for this irrigation, namely for wet rice is assumed between 10,000 - 14,000 m^3/ha, if all of canals and ditches are in good condition.

Small irrigation schemes were established many centuries ago and in the middle of 19th century major schemes, some in order of about 50,000 ha were undertaken, mostly to supplement rice and sugarcane.

The oldest large irrigation schemes was established by the completion of Lengkong Barrage at Brantas River, East Java in 1857. It has 10 bays of 10 m each with stop logs and had been used to irrigate 40,000 ha of paddy fields in Sidoardjo at Brantas Delta. A similar type of this head work is Rentang Barrage in Cirebon, West Java at Cimanuk River, which was completed in 1917 and 90,000 hectares area to be irrigated.

The Glapan Weir in Tuntang River, Central Java, was built in 1853 - 1859 and could irrigate 16,000 ha area. By the completion of Sedadi Weir at Serang River in 1889, these Glapan Sedadi irrigation system, which had been used to irrigate a large valley of 46,000 ha. A canal has dug to link the Tuntang main canal and the Serang main canal in order to supply water to the Serang area in dry season.

Until the Ist world War, a number of other irrigation schemes had been established by the completion of Pekalen weir, Jati weir both are in East Java. Notok weir, Sukowati weir, Danawarih weir which are in Central Java.

In the period between the Ist World War and the 2nd World War, a number of modern Headworks were built not only in Java but also in other island such as : Cisadane barrage, Ciujung barrage in West Java, Serayu water works, Malahayu Reservoir in Central Java, Argoguruh weir at Sekampung river in South Sumatra for 60,000 ha, Sadang barrage in South Sulawesi for 50,000 ha.

After the proclamation of the Republic of Indonesia in 1945, some multipurpose project had been established. Jatiluhur multipurpose project has been constructed at the Citarum river, West Java, with a reservoir capacity of 3,000 x 10^6 m^3 capable irrigating 240,000 ha of paddy fields plus hydro-electric power of 125,000 KW.

The Brantas river basin project in East Java consists of some hydroelectric power dams : Karangkates, Selorejo, Badak, with a total capacity of 108,000 KW plus supply water for 28,000 ha irrigation area.

Some major projects which are under construction. The south Kalimantan Tidal Irrigation Project, which is designed for reclamation of 250,000 ha of Swampy area. The Barito river basin development, which would be able to irrigate 250,000 ha and a reclamation area of 200,000 ha. In this river basin, there will be constructed a multipurpose reservoir with a reservoir capacity of 1,200 x 10^6 m^3 and will produce 30,000 KW of electric power plus irrigation water for 50,000 ha.

1.5 WATER LAWS

'The General Water Regulation' was enacted on September 26, 1938 and concerns primarily with the distribution of irrigation water to the rice and sugarcane fields in Java.

The Government has been revising the Water Laws and regulations with 'The Law on Water Resources Development No.11-

1974 and Government Regulation of the Republic of Indonesia No. 22 - 1982. The Act lays down that :

(i) Water may be freely used for domestic purposes i.e. drinking, live-stock, washing, swimming, floating of wood, navigation etc., provided no damage is inflicted to water ways, their banks or dams and the pre-existing water rights of third parties are met. If no machinery is used, it is also permissible to draw small quantities of water to flush sand, gravel or stones from the water course. Moreover, in the event of fire or any public calamity, the water may be used freely.

(ii) The use of public waters for the irrigation of crops, the sanitation of inhabited centres situated on lands belonging to Indonesians and for the domestic use of such centres, must be regulated by the water authorities of these territories in accordance with the provisions of this law, all existing rights and titles being respected.

(iii) Article 26 of the Act places all public waters, except those on native settlement lands, under a concessionary regime. It is prohibited, for example, to use public water without a concession for the irrigation of areas not belonging to native or to transport water by mechanical means for the irrigation of native lands.

(iv) Certain servitudes (rights of way and of occupation) are attached to holdings and must be respected by the owner and the person entitled to the use thereof. These servitudes cover the governmental construction of works for the conveyance, discharge, diversion and storing of water upon payment of an indemnity.

The Provincial Water Regulation does not essentially differ from the General Water Regulation and is adapted to the needs and conditions of the provinces concerned. Other aspects, such as the use of ground water and the disposal of waste water, are treated very briefly.

1.6 ADMINISTRATION OF IRRIGATION AND DRAINAGE

The Ministry of Public Works with headquarters at Jakarta, is responsible for all aspects of water resources development in Indonesia. The Directorate General of Water Resources Development is the authority under the Ministry responsible for planning, design, execution, operation and maintenance. The functions are further divided among the Directorate of Irrigation, Directorate of River, Directorate of Swamp, Directorate of Hydro Engineering, Directorate Plan and Programming of Water Resources Development, Directorate of Logistic and special projects. One of the special project is called PROSIDA.

1.7 SCOPE OF STUDY

Since 1969, Indonesia has been running a series of Five Year Development Plans (REPELITA) with the main objective the provision of food and clothing. To achieve these goals the government through PROSIDA started with a programme of rehabilitation of existing irrigation system, in which about 800,000 ha of existing irrigation scheme located mainly in near the most densely populated areas in Java would be rehabilitated. The World Bank through the International Development Association (IDA) has offered credits to support this programme. The Directorate General of Water Resources Development of the Ministry of Public Works has been appointed to undertake the implementation of the project and PROSIDA has become the executive body of the project. Therefore Proyek Irigasi IDA (PROSIDA) as the implementing agency for Indonesian irrigation projects is needed for supporting the rehabilitation programme.

In this dissertation, the scope of the present study will be restricted to a special project in Indonesia PROSIDA will be taken as case study.

Chapter II deals with problems of PROSIDA Command area i.e. description of the project, water management problem, management of problem soils and water conveyance distribution.

Chapter III consists of principles and application of irrigation water management such as : water control dimension, application of irrigation water, evapotranspiration, effective rainfall, canal losses, these are very important which should be known to farmers and O and M staff.

Chapter IV provides a detailed case study of water distribution, this study covering method of water distribution, consideration in delivery planning, preparation of irrigation delivery plan, techniques of preparing irrigation schedule. These methods should be used in PROSIDA command area.

Chapter V deals with the water delivery management in Indonesia i.e. water source facilities, available discharge, how to apply rotational method and organization set-up where a dynamic organization should need the backing of fully qualified trained staff.

Chapter VI studies irrigation water management in some other countries such as India, The Philippines and Taiwan.

Conclusions derived from the study have been summarized in Chapter VII as well as suggestions for improvement in water delivery management.

CHAPTER - II PROSIDA IN BRIEF

2.1 Description of the Project

2.2 Water Management Problem

2.3 Management of Problem Soils

2.4 Water Conveyance Distribution

CHAPTER - II

PROSIDA IN BRIEF

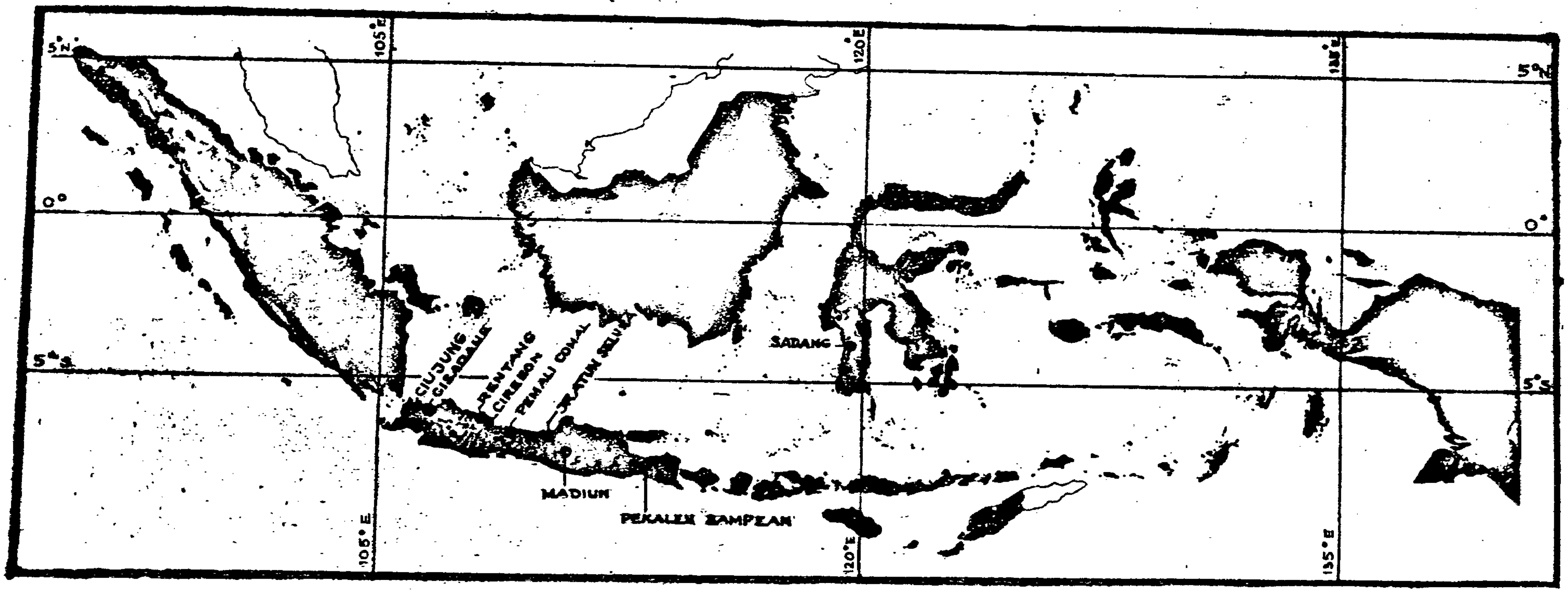
2.1 DESCRIPTION OF THE PROJECT

The main purpose of irrigation development during Five Year Development Plan is to accentuate on agricultural production. Irrigation is a vital input for agricultural production therefore, the Government of Indonesia through the Ministry of Public Works decided that the main target of irrigation development should be 'Rehabilitation' and 'Extensification' programs. The rehabilitation and the extensification projects are located throughout Indonesia and they are under the Directorate General of Water Resources Development.

Irrigation Rehabilitation Programme is special project which gets finance from the World Bank through International Development Association and as such the project is called 'Proyek Irigasi Dengan Bantuan I.D.A.' (Indonesian) abbreviated as 'PROSIDA'.

PROSIDA has 8 sub-projects and 1 project, namely Ciujung (24,000 ha), Cisadane (50,000 ha) Rentang (96,000 ha), Cirebon (82,000 ha) are sub-projects located in West Java. Pemali Comal sub-project (123,000 ha) and Sedeku Project (86,000 ha) located in Central Java. Madiun (120,000 ha) and Pekalen Sampean (229,000 ha) both are sub-projects located in East Java. Sadang sub-projects (54,000 ha) located in South Sulawesi. Figure 2.1 shown location of PROSIDA sub-projects.

Fig. 2.1. LOCATION OF PROSIDA SUBPROJECTS



All PROSIDA sub-projects are under the authority of the PROSIDA head office. Sedeku Project handles all activities by itself excepting that finance is controlled through PROSIDA head office.

In general the projects are old irrigation projects and the condition of irrigation networks were destroyed such that they could not distribute the water as efficiency as necessary. If this condition was left it as it is, the irrigation system could not be operated again. Other problems are that the water conveyance facilities of the project deteriorated due to lack of maintenance and operation management as well as damages of weirs, barrages, canals and related structures due to disasters. Under the circumstances rehabilitation of the project is necessarily to be done.

Rehabilitation project of Cisadane, Rentang, Sedeku (ex Glapan Sedadi) was started in 1969, together in the First Five Year Development Plan ('REPELITA I'). Afterwards Ciujung, Pemali Comal and Sadang got finance for rehabilitation and these Pekalen Sampean, Cirebon and the last is Madiun sub-project.

Activities of the project are as follows :

Survey, investigation, design, construction, operation and maintenance abbreviated as 'SIDCOM', whereas the main purposes of the project in irrigation development are Rehabilitation. Extensification and Intensification. The physical objectives of the projects are :

- Rehabilitation of existing irrigation network.
- Development of new irrigation network including tertiary network.
- Development of drainage system.

The non-physical objectives of the project are :

- Improvement of operation and maintenance
- Investigation of skill, equipment and personnel.

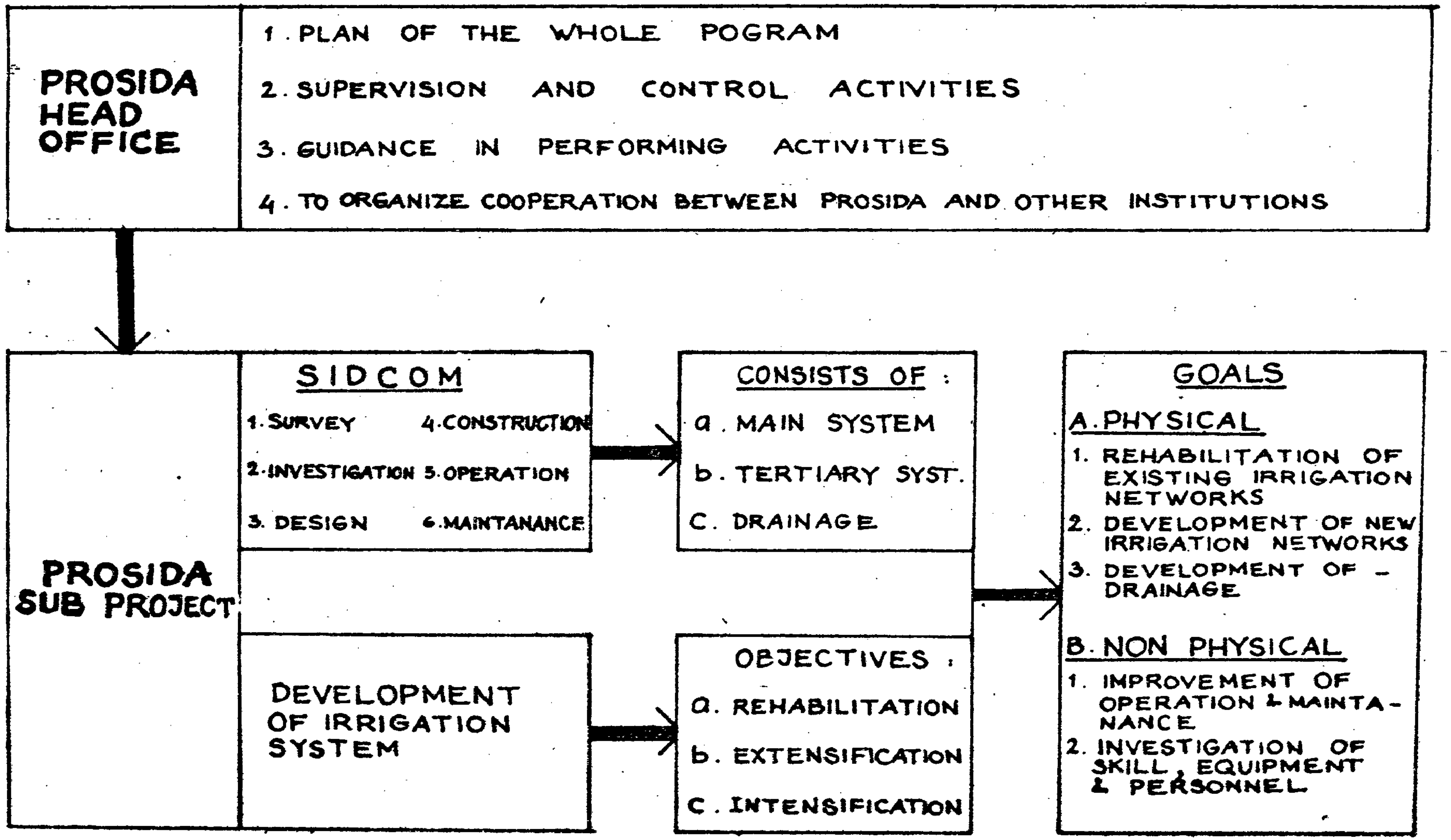
The scheme of Prosida's activities is shown in Figure 2.2.

After finishing irrigation rehabilitation and development of new irrigation network, management of operation and maintenance is absolutely needed, so that the optimum result and optimum life time of irrigation network can be achieved.

Operation and maintenance of irrigation at main system is responsibility of the Government i.e. Provincial Public Works whereas at tertiary system it is the responsibility of the farmer who use the water for irrigating their area.

However, the PROSIDA helps the Provincial Public Works and farmers in 'Pre-Operation'. It carries out investigations continuously as well as other efforts for improving operation and maintenance. It aims at improving the efficient utilization of irrigation water so that the water available can irrigate more command areas. Preparative efforts of operation under PROSIDA are as follows :

Figure 2.2. SCHEME OF PROSIDA'S ACTIVITIES



(1) To construct hydrometric measurement devices in river and irrigation canals.

(2) To maintain, to repair and to complete rainfall measurement and to construct agroclimatology station.

(3) To collect the rainfall data, and to calculate available discharge at weir in rainy season and dry season and also to calculate any effective rainfall at farm level which gets irrigation water.

(4) To investigate sediment transport at rivers, main canals for knowing sediment volume which has to be drained and how to operate.

(5) To investigate the irrigation efficiency in the main canals as well as water loss during conveyance and application.

(6) To investigate how much water requirement for paddy is there during tillering, seedling, growing, ripening and harvesting.

(7) To investigate reservoir operation so that input and output will be in balance. It means the reservoir will not be deficient in dry season and not too much loss in rainy season.

(8) To discuss about cropping pattern and irrigation schedule with irrigation Committee at district level and residency level.

(9) To organize training at :

- Sub-District Irrigation Committee.
- Chief of Water User Farmers, Ulu Ulus and Chief of Villages where the regions which get tertiary development.
- Chief of Irrigation Section level, Chief of Irrigation sub-section level and Irrigation Area Supervisor.

(10) To give information to the farmers about irrigation project and tertiary development with films, slides and 'Local Indonesian Broadcasting'.

2.2 WATER MANAGEMENT PROBLEM

The traditional irrigation system is mainly designed for protective irrigation and not adopted to the modern intensive agriculture based on high yielding crop varieties and multiple cropping techniques with increased fertilizer use requiring frequent irrigation.

Many problems of land planning and water management of grave importance now confront irrigated agriculture. In Indonesia large quantities of water harvested from watersheds and diverted from streams and small quantities from ground water sources are used for irrigation. Large quantities are lost by seepage and evaporation from main, secondary and tertiary canals and field channels. The loss from tertiary canals to the field alone is estimated to be about 15 - 40 percent of the water delivered at the canal outlet. Improperly designed field irrigation systems and unscientific water application methods are leading to huge losses of water by seepage and deep percolation below the root zone. Seepage and deep percolation represent the loss of a valuable resource developed at high cost. In some of the areas in Cisadane, Ciujung, Rentang, Pemali Comal and Sedeku Project, not only is the loss of water a great concern but the damage it creates by water logging and accumulation of harmful salts is also considerable.

A large part of the waterlogged portion is located in areas where canal irrigation has made rapid progress. In many cases the source of waterlogging and salt problems could be traced to the faulty planning of irrigation schemes that were executed without due consideration for drainage. Excessive seepage and deep percolation losses over years have pushed up the sub-soil water table in canal command areas and have brought unwanted salts to the surface, rendering the area barren.

Efficient water management is, therefore, an essential feature of Irrigation Development under PROSIDA.

Integrated development of water resources, efficient methods of conveyance and distribution of water on the farm, judicious methods of water application, proper soil management practices and cropping patterns for high water use efficiency, scientific timing of irrigation according to the developmental rhythm of the plant and the removal of excess water, are important aspects of a comprehensive irrigation development programme.

Irrigation Projects can not be considered complete until well engineered provisions have been made to apply water efficiently at times and in amounts consistent with the physical properties of soil plant growth as to remove the surplus water wherever necessary.

2.3 MANAGEMENT OF PROBLEM SOILS

Water management proficiency requires that the technician learns the water requirements of the plants to be grown and how much of that water can be furnished from soil stored moisture and how much and how often it must be applied through irrigation.

In Indonesia, primarily, irrigation is practised to provide a better moisture environment for rice. Secondary objectives may be to help upland crops and bring about desired physical and chemical changes in soil, or temperature control, leaching of salts, or to provide moisture for preparatory cultivation.

The position of water table should be considered, because there is an indication of whether or not a drainage problem exists. A higher water table means that something has to be done to reduce the amount of water in the soil.

Under ordinary conditions in arid regions, the water table should not be occasionally closer than 1.2 metres below the soil surface.

A shallow water table will cause salt to accumulate on the soil surface from direct evaporation. A high water table will also cause poor aeration conditions and as such some form of artificial drainage must be provided.

Where artificial drainage is required, it is important to know the location and position of the water table. It is also important to know the texture characteristics of the soil profile. Procedure how to know the location and position of the water table are as follows :

(i) In the area selected for study of a water table problem, layout a regular grid location for the water table observation holes. The spacing may be 1 or 2 kilometers in large areas or as little as 50 meters in a normal spacing.

(ii) Make a vertical hole in the soil, keeping notes of the soil texture, structure, colour changes, soil conditions and wetness for each of the layers. As special note should be made of the depth for the first appearance of visible water in the soil being removed.

(iii) The completed hole should be covered or protected so that animals will not stop in it and the hole can be left for observation.

(iv) Observations of the water level in the hole should be made periodically. Observations may be made hourly, daily, weekly, monthly or annually, depending on the need. For farm drainage design, daily observations are usually required. The observations consist of measuring and recording the distance from the soil surface to the water table using tape or a chain or a rod.

(v) If elevation changes and slope of the water table are important, elevations of the soil surface should be determined at each auger hole for reference. Data from the observations holes can be used to make maps of depth to water table and water table contours.

(vi) If the hole is unstable or if long term observations are needed, a perforated pipe surrounded with coarse and previous material can be used to line the hole (4).

2.4 WATER CONVEYANCE AND DISTRIBUTION SYSTEM

A properly designed water distribution system will make irrigation easy and efficient. Several types of structures are used to divert, convey and control irrigation water. Good irrigation structures are an essential part of an irrigation layout. Efficient structures will save money, labour, land and water.

Farm irrigation distribution system can be classified into two groups : surface canals and underground pipe lines, but the latter is not common in Indonesia. Canals may be either unlined earth canals or lined canals.

Farmers in Indonesia depend mainly on earth canals for conveying water to irrigate their fields. In permeable soils, like sand and sandy loam, seepage losses in earth canals may be as high as 10 to 40 percent of the water delivered to the canal. The loss by seepage is directly proportional to the length of the canal.

Rats, crabs and other rodents borrow through the banks and bottom of unlined canals. These holes may form a network of holes below ground surface. Such canals may result in the loss of large quantities of irrigation water beside poor water control. Earth canals require continuous maintenance to control moss and weed growth, and to repair damage by livestock, rodents and erosion. Erosion in earth canals is a serious problem on steep slopes.

CHAPTER III : DISCUSSION OF IRRIGATION WATER MANAGEMENT

3.1 WATER CONTROL DIMENSION

3.1.1 Water use subsystem

3.1.2 Water application subsystem

3.1.3 Water Delivery subsystem

3.1.4 Water removal subsystem

3.2 APPLICATION OF IRRIGATION WATER

3.2.1 Condition of soil moisture

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3.3 EVAPOTRANSPIRATION

3.3.1 Blaney-Criddle's method

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3.4 EFFECTIVE RAINFALL

3.5 FACTOR INFLUENCING EFFECTIVE RAINFALL EFFECTIVENESS

3.5.1 Rainfall characteristic

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3.5.3 Crop characteristics

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3.6 CANAL LOSSES

3.6.1 Evaporation

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3.6.3 Direct Measurement of seepage losses

CHAPTER-III

DISCUSSION OF IRRIGATION WATER MANAGEMENT

3.1 WATER CONTROL DIMENSION

The main purpose of the water control dimension is to supply water to an area for crop production. This dimension contains four subsystems : water delivery, water application, water use and water removal.

The purpose of each subsystem is as follows :

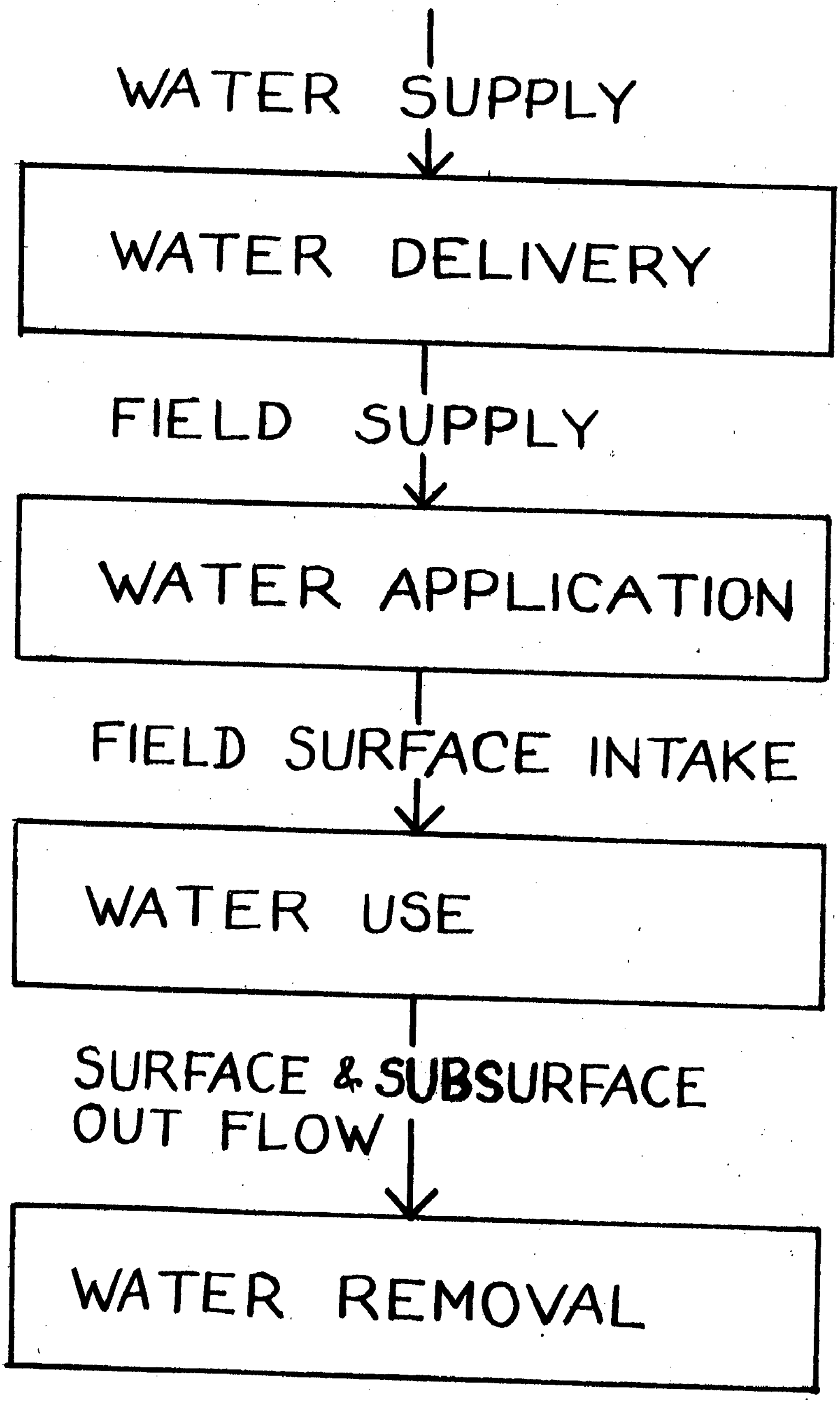
Water delivery	:	Convey water from the water supply source to the field.
Water application	:	Distribute water over the field to fulfill the water requirements of the crop.
Water use	:	Storage and supply of water to plants for crop production
Water removal	:	Remove excess water for optimum crop production

The scheme of water control subsystem is shown in Figure 3.1 and the process of flow shown in Figure 3.2. By accomplishing the water use subsystem the goals of all other subsystems (delivery, application, and removal) should be met.

Thus, the effective operation of the overall water control system depends on the water use subsystem.

The performance of the water use subsystem is tied to each of the other subsystems. For example if stress reduces

Fig. 3.1. SCHEME OF THE WATER CONTROL SYSTEM



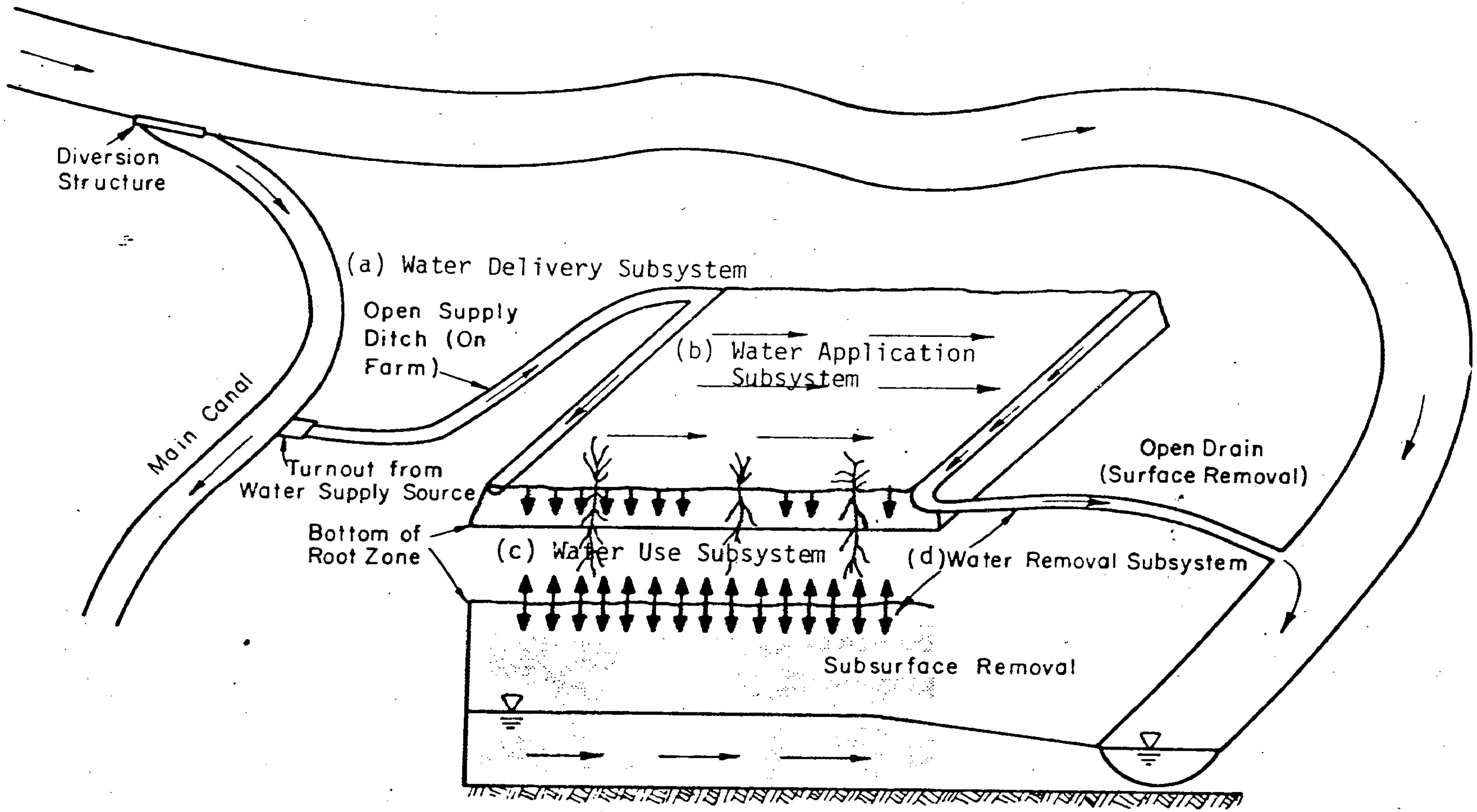


Figure 3.2. The water control subsystems: (a) water delivery, (b) water application, (c) water use, and (d) water removal.

yield, then the most efficient delivery subsystem will not produce optimum crop production. The functions of the water use subsystem become functions for each of the other subsystems. In fact, in a series, the output of each subsystem must be regulated by the functions of each succeeding subsystem as the output becomes the input to that subsystem. To water use subsystem will be discussed first because of its key role in the water control system (6).

3.1.1 The Water Use Subsystem

The water use subsystem (Figure 3.3) accepts water from the water application subsystem and transmits water through the soil for storage or deep percolation. The subsystem transports water to plant roots through the plant structure and then leaves where it is transpired and to the soil surface where it is evaporated. The excess water flows through the root zone as deep percolation and it is the input to the drainage or water removal subsystem.

The water use subsystem has the following functions :

(1) Supply the water requirements for crop growth (quantity and quality) for :

a. The peak rate of use.

b. The total seasonal requirement.

c. To prevent excessive stress.

d. To provide adequate aeration and acceptable inundation.

(2) Maintaining acceptable levels of soil salinity.

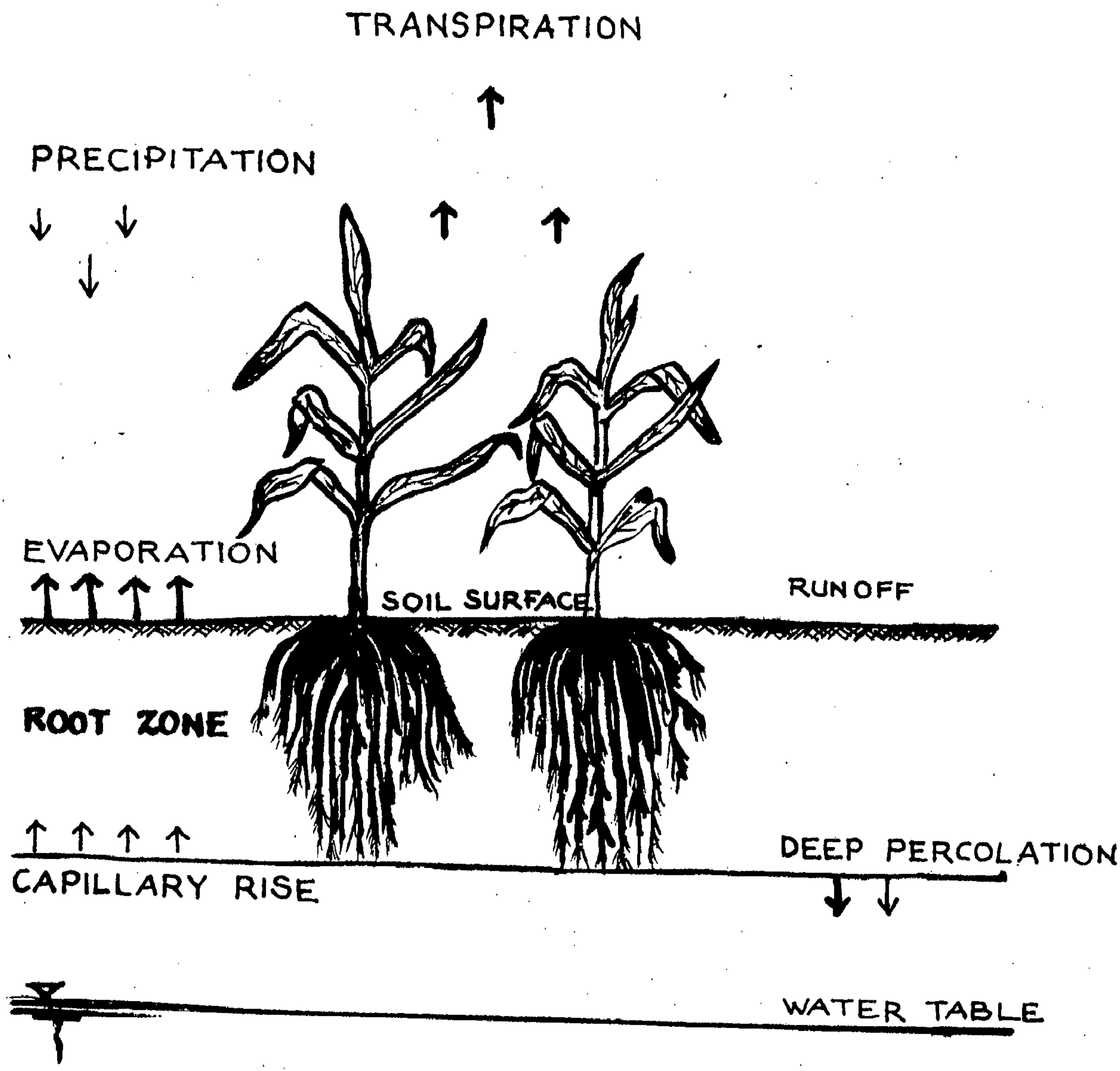


Fig. 3.3. THE WATER USE SUBSYSTEM

(3) Maintaining appropriate environmental(soil and air) temperatures.

(4) Ensuring adequate nutrients.

(5) Providing soil condition for :

a. Plant support.

b. Preventing soil crusting.

c. Facilitating tillage or harvesting operations.

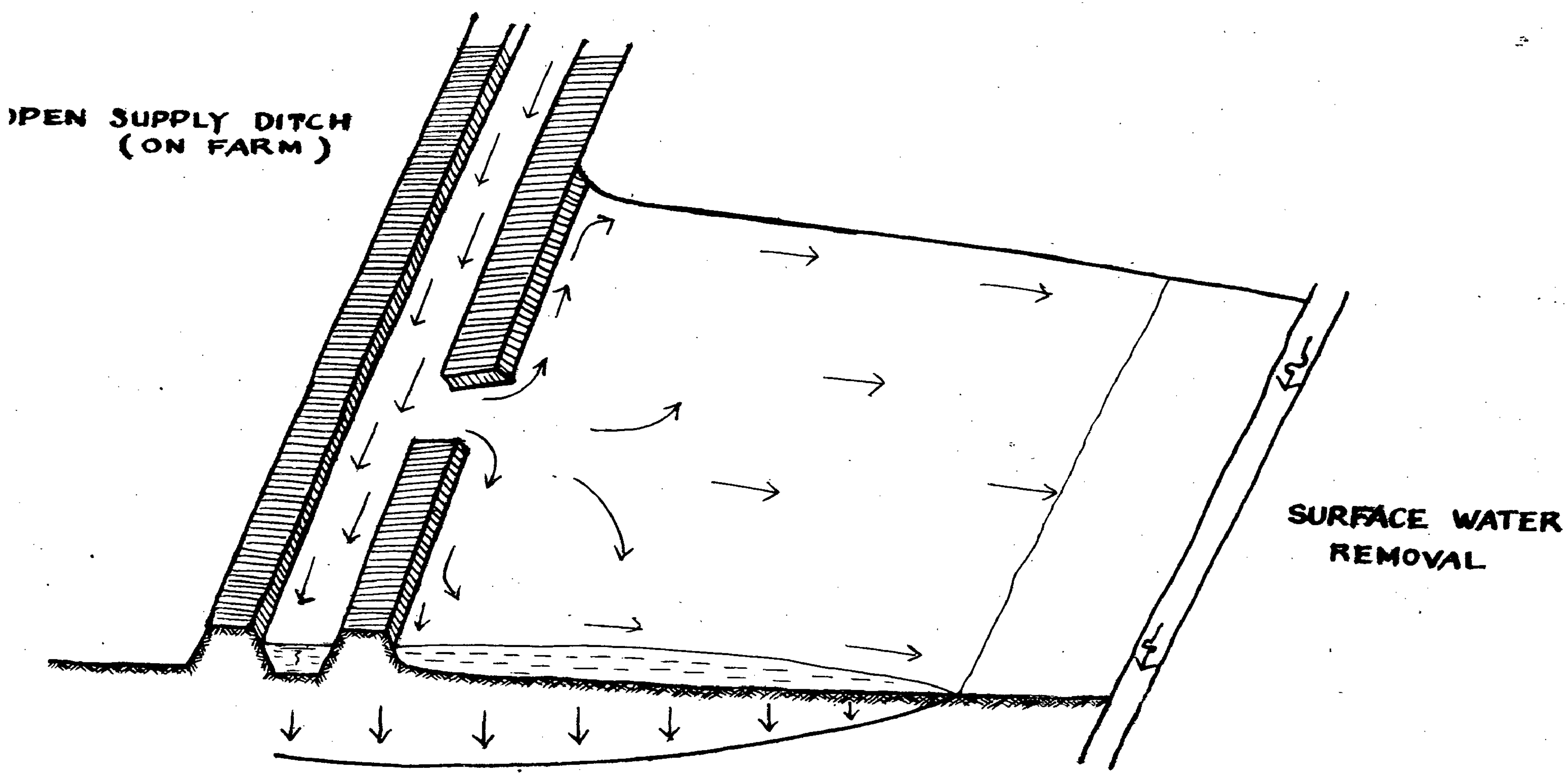
d. Providing water for germination and seedling emergence.

Function 1 and its subset are of direct concern to the management of the water use subsystem. Generally the soil water deficit at the time of irrigation determines the desirables amount of water to apply. Exceptions to occur, such as when the inundation time to permitting the desired amount of water to infiltrate is too long and would cause crop damage. In highfrequency irrigation, maintaining some soil water deficit may utilize rainfall more effectively. Knowledge of the soil water deficit directly or indirectly specifies the amount of water to be applied (6).

3.1.2 Water Application Subsystem

The water application subsystem supplies water to the water use subsystem by distributing the water over the surface of the field (Figure 3.4). Water application must provide water for the functions of the water use subsystems as well as fulfil the functions of water application. The traditional functions of the water application subsystem are as follows :

Fig. 3.4. THE WATER APPLICATION SUBSYSTEM



1. Distributes the desired amount of water with the designed uniformity.
2. Satisfies erosion control standards.
3. Provides necessary surface drainage.
4. Is economically appropriate and socially acceptable to the management abilities of the farmer.

The process of water application to a field can be described by the following state variables :

a. Field geometry (length and width).
b. Water supply rate.
c. Slope.
d. Infiltration rate.
e. Surface roughness.
f. Channel shape.
g. Management.

The boundary and initial conditions of the system must also be specified to completely describe the state of the system.

Water application subsystem is accomplished by the farmer by operating the system to meet functional objectives(usually unstated) of both water use and application.

In the process he answers the following three basic management problems :

1. 'How do I irrigate'
2. 'When do I irrigate'
3. 'How much water do I apply'

Performance standards include an analysis of the effectiveness(technical, social,economic) of the water application system. Performance parameters for the water application subsystem are included in those previously defined for the water use subsystem (6).

The operation of the water application subsystem can be described by measurement of the subsystem state variables.

Knowledge of the appropriateness of these variables can be determined by comparing the existing values with the values of an appropriate design. Performance can also be determined by measurement of the state variables.

3.1.3 The Water Delivery Subsystem

The water delivery subsystem is that structure which delivers a water supply to an area served by the water supply source. The area served by the water supply is the fields receiving irrigation water. The water supply source may be a storage reservoir or a canal and may be operated by a private, public works (government).

The purpose of the on-farm water delivery subsystem is to convey the water from the water supply source to the field based on the functional requirements of the water application and use subsystems.

The water delivery subsystem serves both the water application subsystem and water use subsystem. The functions of the water use subsystem and the water application subsystems must also be provided by the water delivery subsystem. For example, a major design variable of the water application system is the design water application rate for a border. This specifies a desired flow rate that is necessary to properly irrigate a field. Thus, a primary function of the water delivery subsystem would be to supply this design flow rate to the field. Likewise, the water use subsystem must supply the peak consumptive use rate for a field. Thus, the flow rate through the water delivery subsystem must be sufficient to supply this peak demand by the water use subsystem. All other defined functions of the water use and water application subsystem must also be met by the water delivery subsystem.

The additional functions of the water delivery subsystem relate to convergence of water from the supply source to the field in relationship to the following conditions :

1. At a constant, regulated rate
2. At the proper elevation
3. With seepage controlled
4. Without excessive erosion or sedimentation
5. At appropriate water quality
6. With safety (cross flows, accessibility, drainage damage).

The subsystem must be built maintained, and operated within socio-economic limitations. The functions are performed by a delivery system based upon the physical and management factors which influence water delivery(6).

Factors which Influence water Delivery :

The factors or state variables which influence water delivery are as follows :

1. Flow rate.
2. Cross section.
3. Hydraulic radius.
4. Roughness.
5. Slopes.
6. Seepage rate.
7. Management.

The seventh factor which influences water delivery is reflected in the management decisions of the farmer as affected by the allocation rules and operational norms for the system. The first five physical factors are the basic parameters in channel. The sixth factor, seepage rate affects all aspects of the previous five primarily by increasing or decreasing the flow rate.

The flow rate supplied to the field must be regulated according to the following factors :

a. Total quantity.
b. Supply peak demand.
c. Constant flow at an appropriate time for application.
d. Dependable flow.

The total quantity of water supplied by the delivery system must be sufficient to meet the seasonal volume of water requirements for the particular crop. The quantity of water supplied must also meet the other functions, such as the crop consumptive use rate or the water application rate. These are key factors which establish the capacity of the delivery system.

A dependable flow rate must also be ensured by the water delivery system. The extreme variability inflow rate makes it possible for the farmer to quantitatively apply water since the only alternative to knowing the flow rate is to provide a means for flow measurement. If a regulated flow rate is provided, then time could be used as a substitute for slow measurement. With such variability in the flow rate, however, the farmer cannot quantitatively supply water to the field. Another major effect of the variability of the flow rate is that the appropriate flow rate for proper application of water to the field cannot be provided.

Under the functions of the water application system, a particular flow rate is needed for efficient application of water. When the flow rate varies from turn to turn in such fluctuating manner, then this appropriate flow rate for water application is not provided. When faced with a fluctuating water supply rate, the farmer must manage his irrigation practices dependent upon the minimum flow rate. The result is that crop area and crop requirements will be a function of the minimum flow rate and all flows delivered above this minimum flow rate will tend to be excess(6).

An appropriate, constant cross section must be provided to maintain a head and to deliver water at an appropriate elevation. The cross section must also be provided for the design flow rate as defined by the functions of the various subsystems.

The hydraulic radius should be a minimum for the design flow in order to minimize the cuts and fills associated with channel construction as well as to minimize the cost of construction. When unlined channels are used for the delivery system, the minimum cross section also provides minimum seepage.

The Manning's n or coefficient roughness for a channel must be carefully selected for the design. A range in n between $0.02 \leq n \leq 0.10$ is a common range used for design. Thus, the appropriate n must be carefully selected.

The design slope is important in maintaining the minimum cross section in order to reduce the cost of channel construction and to ensure that sedimentation or erosion does not occur. For some water delivery systems such as those using siphons, a level or nearly level section must be provided to supply water to the field. Thus, the selection of the design slope is important to several aspects of the operation of the water delivery and water application subsystems.

The seepage rate accepted for the design should first consider that losses in delivery water are an important factor in the operation of the water delivery subsystem. A very high loss rate accepted for design will likely affect the dependability of the delivery of the water supply.

Also, the effect of the seepage rate on the depth, in channel storage and operational losses of the delivery system should be evaluated and explicitly included in the design.

Realistic assumption concerning the system's maintenance should also be considered in selecting design seepage rate that will be included as part of the design parameters for the subsystem.

Because of the influence of seepage rate on the various functions of the water delivery subsystem, alternative systems such as a lined channels or pipe lines should be considered when the effects of seepage losses that are high are explicitly considered. Selection is frequently based on the best benefit cost ratio (6).

3.1.4 The Water Removal Subsystem

The water removal subsystem is defined as the removal and disposal of surface and subsurface waters from land to improve agricultural operations. The objective of drainage is to provide an environment for plants that will result in optimal production of crops. The sources of water may be from precipitation, irrigation, seepage from ponds and canals, seepage from adjacent aquifers, floods and application of water for special purposes such as temperature control. In most irrigated areas, natural drainage is adequate and drainage system are needed to supplement natural drainage. We must be careful, however, to identify drainage as either a problem or a symptom of another problem such as over irrigation or an undesirable leaky canal system. The major components of the water removal subsystem are depicted in Figure 3.5.

The water removal subsystem has the following primary functions :

1. Maintain given salinity levels within the soil profile.
2. Provide proper root aeration.
3. Improve workability of lands.

Maintain given salinity levels within the Soil Profile :

All irrigation waters contain salts which, if allowed to accumulate within the root zone, will reduce crop yields. Some water must be allowed to percolate through the root zone to the level within the root zone. This excess water must be removed from the area either naturally or by artificial drains in order to prevent waterlogging.

The amount of water that must pass through the root zone to keep salinity at acceptable levels is called the leaching requirement. To evaluate this, we need to know the following information :

a. Amount of salts in the irrigation water.
b. Evapotranspiration rates.
c. Crop type to select appropriate salinity levels within the soil.

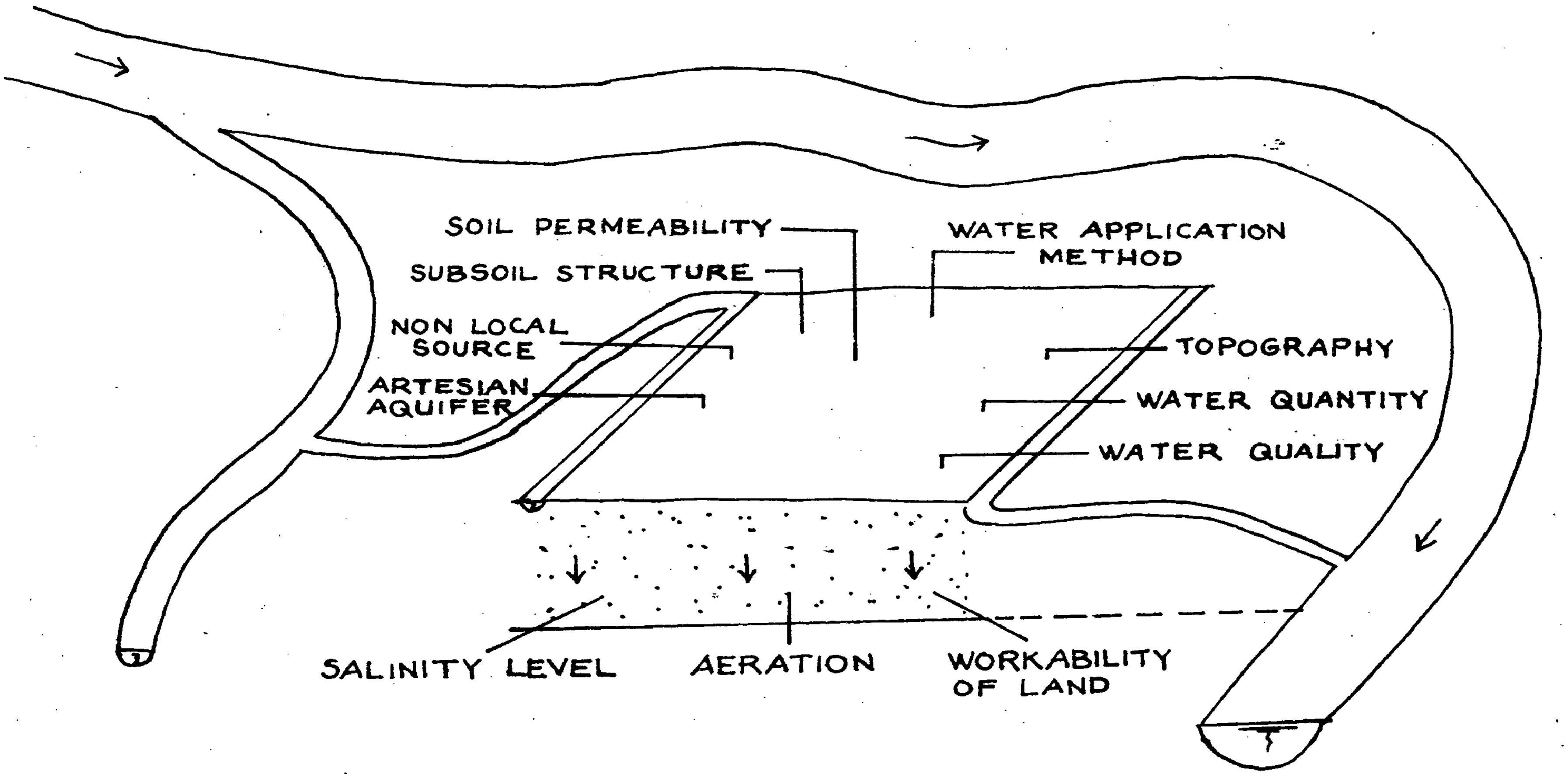


Fig. 3.5. COMPONENTS OF WATER REMOVAL SUBSYSTEM

d. Disposal site.

On a unit area basis, the amount of salts entering the soil is roughly proportional to the product of electrical conductance of irrigation water (EC_i) and the volume of applied water D_i. Additional salts may be added due to sources such as fertilizers but this will be small compared to that added by the irrigation water. The amount of salts leaving is proportional to the product of electrical conductance of the drainage water (or ground water) and the volume per unit area of drainage water (D_d). Salts removed by the harvesting of crops is small and may be neglected (6).

The leaching requirement (LR) is :

$$LR = \frac{D_d}{D_i} = \frac{EC_i}{EC_d} \qquad \ldots \qquad (1)$$

If the period of time considered is too long, EC_i and EC_d are average values during the period.

Over a sufficient period of time, water added which is not removed by evapotranspiration will drain out of the root zone. In other words

$$D_d = D_i - D_e \qquad \ldots \qquad (2)$$

Where D_e is the volume per unit area of water representing evapotranspiration. Since D_d may be evaluated in terms of LR by equation (1) then

$$D_i = \frac{D_e}{1-LR} \qquad \ldots \qquad (3)$$

For a situation in which a given level of soil salinity is being maintained. An equivalent equation in terms of electrical conductivity is

$$D_i = D_e \frac{EC_d}{EC_d - EC_i} \qquad \ldots \qquad (4)$$

If the value of EC_d currently is too high, then water in excess of that given by equation (4) will have to be applied until a new equilibrium is established at a lower value of EC_d.

3.2 APPLICATION OF IRRIGATION WATER

Water influences crop growth directly and also influences crop performance indirectly through its effect on the soil and crop management practices like land preparation, sowing time, fertilizer use,cropping patterns etc.

Crops need water in large quantities and at specific intervals. Improper scheduling, over irrigation, lack of proper drainage, etc. often lead to reduction in crop yields, waterlogging and salt imbalance in soils. In some cases vast stretches of agricultural land have been rendered unproductive due to these problems. The irrigation requirement depends on several factors like land grading and levelling, water conveyance and distribution, timely supply of water in right quantities, methods of water application, adequate inputs and effective and efficient agronomic techniques, drainage etc. Therefore, the knowledge of soil, water, plant and atmospheric relationships effecting the irrigation requirements of crops and an integrated approach is needed for economising irrigation water use in crop production.

There are three main factors which highly influence the amount of irrigation water to be applied and the time of application :

(1) Condition of soil moisture.

(2) Irrigation water requirement.

(3) Availability of water.

For the whole area, conveyance losses and the available water supply should also be taken into account for that purpose(7).

3.2.1 Condition of Soil Moisture

The condition of soil moisture in the plant root zone is a very important factor in the plant growth. The moisture content in the soils varies widely according to the soil compositions, grain size distribution etc.

The soil water availability is based on the following classification :

(a) Hygroscopic water, is the water that is not effected by gravitational and capillary forces, could be removed from soils by heating them to 105°C.

(b) Capillarly water, is the water that fills the micropores and is not effected by gravity force. Water can be removed from the micropores either by capillary movements or by plant roots.

(c) Saturation water is reached when all voids are filled. If the soil is left free to drain, a portion of water is lost until in the soils remains only that part of water at 'field capacity'.

The available water for the plant is from the field capacity until it reaches the hygroscopic water content(wilting point). Below this wilting point, the plant is unable to suck out the soil water.

In fact, the exchange of water from soil to plant requires energy, in plants energy is stored as sugar. In soil of bad texture and low water content, greater energy is required by the plants to obtain their water and nutrient requirements. This will cause the reduction of sugar and that means the yield will be much less. This is one of the reason why paddy fields are kept flooded in saturation condition.

Readily available moisture (Figure 3.6) is the moisture above the permanent wilting point but is held so tightly by the soil rapidly enough to prevent wilting. The water in the soil above the permanent wilting point throughout the entire range of moisture content up to field capacity can be used by plants and is considered the readily available moisture. The field capacity and the permanent wilting point are both low. Consequently, the amount of readily available moisture is small(8,9).

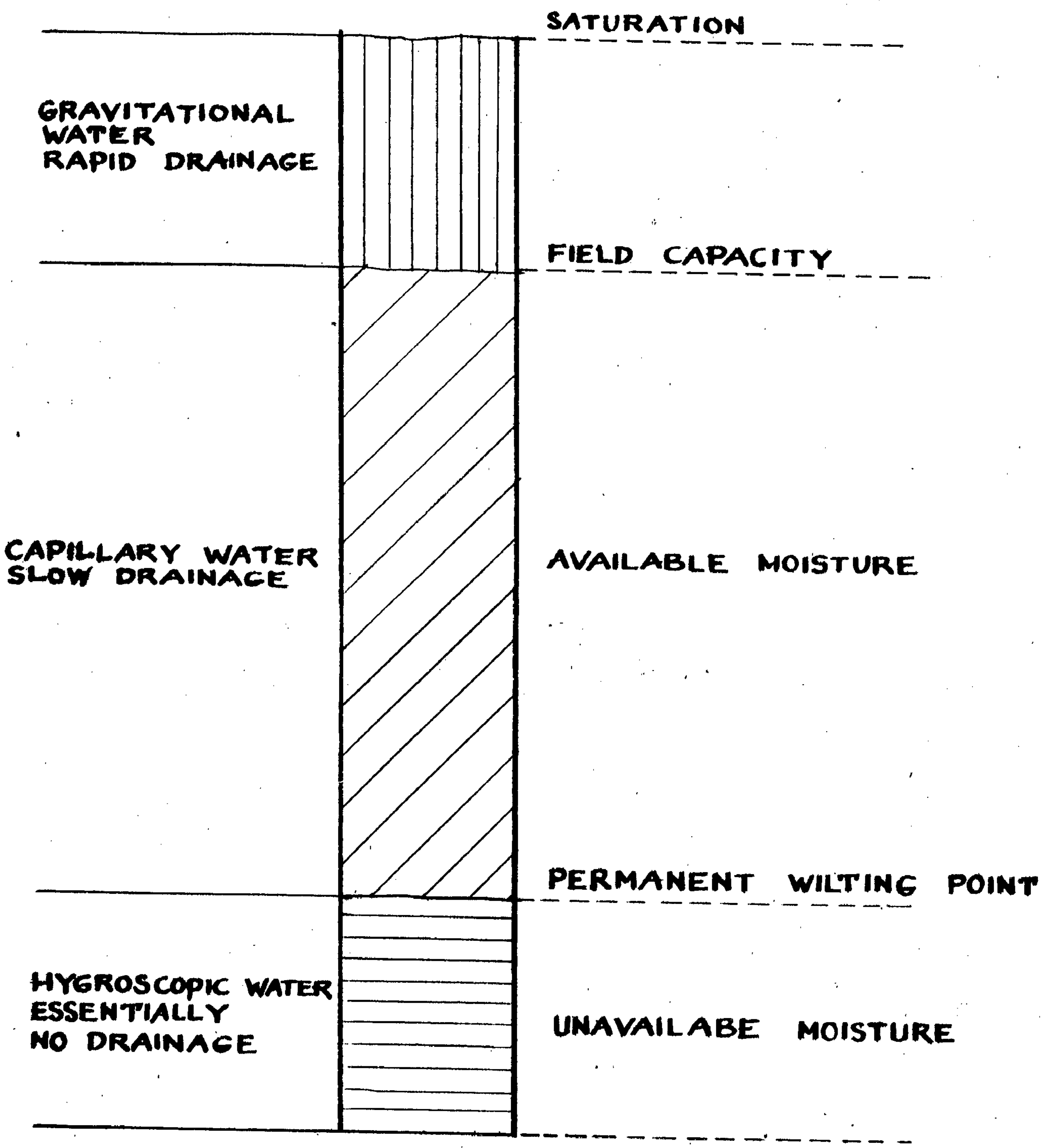


Fig. 3.6. CLASSES OF SOIL - WATER AVAILABILITY TO PLANTS AND DRAINAGE CHARACTERISTIC

3.2.2 Depth of Irrigation Application (d)

(i) Depth of irrigation application can be defined as the amount of water required to refill the soil moisture to field capacity. Soil is capable of storing a limited amount of water and only part of this is available to the plant, water must be applied to the field before this portion is wholly depleted. Irrigation Management and Design are very much concerned with this application of water, which has two main problems : the timing and the quantity of water to be applied.

(ii) The infiltration rate of a soil is the maximum rate at which water will enter the soil mass through the surface. Infiltration rate is affected by the moisture content of the soil. A water table near the soil surface reduces the infiltration rate because of the distribution of moisture in the adjacent soil layers.

(iii) Another important thing in this relationship is the depth of the effective root zone. This rooting depth together with the rooting density influence the pattern of moisture extraction from the soil profile by the plant(10).

Example :

A basin irrigation method is used for irrigation of rice. At the time of irrigation, the depth of effective root zone h_e = 0.80 m and the rate of evapotranspiration ET = 7 mm/day. The soil moisture before irrigation has been investigated and Table 3.1. shows the results.

Table 3.1 shows the result of the infiltration test in the field. The water application efficiency $\eta_a = 0.8$.

Table 3.1 - Result of Soil Moisture before Irrigation

Depth (cm)	Field Capacity	P.W.P.	Soil moisture before irrigation, % vol.
0 - 30	24% vol	10% vol	14% volume
30 - 60	20% vol	9% vol	16% volume
60 - 150	14% vol	8% vol	12% volume

To determine the water depth application, we have to calculate the readily available moisture and net moisture deficit (= net M_d) within the root zone that is h_e = 1.00 m = 100 cm.

Readily available moisture (RAM) = (f.c) - (Soil moisture before irrigation)

Table3.2 - Calculation of Moisture Deficit(M_d)

Depth of soil(cm)	f.c. vol. %	Soil moisture before irrigation vol %	RAM vol. %	Net M_d=10xh_exRAM (h_e= depth of soil)
0 - 30	24	14	24-14=10	$10 \times 30 \times \frac{10}{100}$ = 30 mm
30 - 60	20	16	20-16= 4	$10 \times 30 \times \frac{4}{100}$ = 12 mm
60 - 100	14	12	14-12= 2	$10 \times 40 \times \frac{2}{100}$ = 8 mm
100 - 150	14	12	2	
				Total M_d = 50 mm (within root zone)

With the water application eff = η_a = 0.8

(1) The depth of irrigation application (d)

$$= \frac{50}{0.8} \text{ mm} = 62.5 \text{ mm}$$

(2) With the rate of evapotranspiration E_T = 7 mm/day the irrigation interval (T_i) = $\frac{50}{7}$ = 7.14 days (η_a being cancelled).

(3) To apply the water with the required depth (=62.50 mm) we should consider the infiltration rate, but the data of infiltration rate is not available.

3.3 EVAPOTRANSPIRATION

Evapotranspiration or consumptive use for a particular crop can be defined as the amount of water used by the plant in transpiration during their growth or retained in the plant tissue and evaporation from adjacent soils or from plant leaves, in any specified time. The values of evapotranspiration may be different for different crops, and may be different for the same crop at different times and places.

If there are no field measurement data available then the methods of estimation based on climatological data to predict the evapotranspiration can be followed. Most of the formula and estimating methods have been based on the correlation between the potential evapotranspiration and meteorological factors as the air temperature, solar radiation, air humidity and wind speed etc.(11).

So many methods for calculating evapotranspiration such as : Penman, Blaney-Criddle, A.F. Meyer, USBR etc. but the most simple and commonly used method in Indonesia are :

1. Blaney-Criddle's method
2. Penman's method

3.3.1 Blaney Criddle's Method

This method had been useful in estimating the reference crop evapotranspiration where the air temperature is the only climatic data available. The formula used in this method is :

$$ET_o = C \left[P(0.46T+8) \right] \text{mm/day}$$

Where :

ET_o = reference crop evapotranspiration in mm/day for the month considered.

T = mean daily temperature in ^oC over the month considered.

P = mean daily percentage of total annual day time hours obtained from Table 1 for a given month and latitude.

C = adjustment factor which depends on minimum relative humidity sunshine hours and day time wind estimates.

This method, however, was recommended to be used with scepticism under the following conditions :

(1) Equatorial regions where temperatures remain fairly constant, but other weather parameters change.

(2) Small islands where air temperature is effected by the surrounding sea temperature showing little response to seasonal change in radiation.

(3) Climates with a high variability in sunshine hours during transition months.

The procedure calculation are as follows :

Given data :

Latitude	-	6^oS
Mean daily temperature(T)		26.5^oC
Relative humidity(RH min)		75 percent

Month	-	April
n/M	-	0.8(Medium)
u day time	-	0.26 m/sec.

Calculation :

Mean daily percentage (P) from table 1 (FAO 24) for $6^{o}S$ on April		0.27
P(0.46 T + 8)	-	5.45 mm/day
R_H min = 75 percent	-	High
n/N = 0.8	-	Medium

From Figure 1, block VI line 1 (FAO 24), reference crop evapotranspiration (ET_o) = 4.0 mm/day.

Take the value of K = 1.35

Then E_t = 1.35 ET_o

= 1.35 x 4 mm/day = 5.4 mm/day

3.3.2 Penman's Method

Penman has been suggested for areas where measured data on temperature, humidity, wind and sunshine duration or radiation are available.

A slightly modified Penman is suggested that to determine ET_o, involving revised wind function. The formula used in this method is :

$$ET_o = C \left[W.R_n + (1-W).f(u)\ (e_a - e_d) \right]$$

Where :

ET_o = Reference crop evapotranspiration in mm/day

W = temperature related weighting factor

R_n = net radiation in equivalent evaporation in mm/day

f(u) = wind-related function

$(e_a - e_d)$ = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in m bar.

C = adjustment factor to compensate for the effect of day and night weather conditions.

The procedure of calculation are as follows :

Given data :

Relative duration sunshine (n/N)	80 percent
Mean temperature (T_{mean})	26.6°C
Latitude	6° South of Equator
Mean relative humidity(R_H mean)	75 percent
Altitude	22 m
Month	April
Wind velocity at 2 m above ground surface (u)	0.26 m/sec 22.46 km/day

Calculation :

e_a at 26.6°C from Table 5(FAO, 24).

Interpolation between 26 and 27°C we get 34.89 m bar

$e_d = e_a \times R_{H\ mean} = 34.89 \times \frac{75}{100}$ = 26.18 m bar

$(e_a - e_d) = 34.89 - 26.18$	$= 8.71$ m bar
u	22.46 km/day
$f(u) = 0.27(1+ \frac{22.46}{100})$, from Table 7 (FAO 24)	0.33
(1-W) Table 8(FAO 24) by interpolation	0.244
W Table 9 (FAO 24) or W =1-0.244	0.756
n/N given	0.80
R_a from Table 10 (FAO 24)	14.70 mm/day
$R_s = (0.25 + 0.50\ n/N)R_a$	9.56 mm/day
$R_{ns} = (1-\alpha)\ R_s$ where $\alpha = 0.25$	7.17 mm/day
$RnL = f(T).f(e_d).f(n/N)$	
Where :	
f(T) from Table 13(FAO 24)	16.02
$f(e_d)$ from Table 14(FAO 24)	0.12
f(n/N) from Table 15 (FAO 24)	0.82
$R_{nL} = 16.02 \times 0.12 \times 0.82$	= 1.58 mm/day
$Rn = R_{ns} - R_{nL}$	5.59 mm/day
u day(given)	0.26 m/sec
u day/ u night (assumed)	2
Take $R_{H\ max} \geq 90$ percent	
Factor (C) from Table 16(FAO 24) by interpolating	1.10

Hence, the value of reference crop evapotranspiration

ET_o for this month $= C\ [W.R_n + (1-W).f(u) \times (e_a-e_d)]$

$= 1.10\ [0.756 \times 5.59 + 0.244 \times 0.33 \times 8.71]$

$= 4.03$ mm/day

The actual evapotranspiration (E_t) = $K.ET_o$

where K = crop factor depends on its stage of growth can be found by field measurement.

The results of field measurements is done by the Institute of Agriculture Bogor, together with the Prosida sub project i.e. Rentang Irrigation sub project.

The average value for rice crop in Tambi Agroclimatological Stations are as follows :

Stage of growth	Recommended Value of K
Ist month	1.10
2nd month	1.35
3rd month	1.05
4th month	1.05

If we take the value of 2nd month K = 1.35

Then E_t = 1.35 ET_o = 1.35 x 4.02 mm/day = 5.43 mm/day

Comparison the values of evapotranspiration (E_t) from the same data between the two methods are :

Blaney-Criddle's method E_t = 5.4 mm/day

Modified Penman's method E_t = 5.43 mm/day

The above two methods are likely to provide the most satisfactory results.

3.4 EFFECTIVE RAINFALL

Effective rainfall is rainfall falling during the growing period of the crop that is available to meet the evapotranspiration requirements of crop. It does not include the rainfall lost through deep percolation belcw the root zone or through surface runoff. Thus not all rainfall is effective, only water which reaches, and stay in the root zone of the crops can be effective.

Many irrigation schemes in Java had been designed and constructed before the 2nd world war, and the designer had not taken into account the effective rainfall. Therefore, the present irrigation water consumption is very high, which causes low irrigation efficiency. Since paddy, which is the main crop,needs a lot of water and Indonesia has a very high rainfall intensity then this must be utilized by any irrigation engineer including the O and M engineer.

3.5 FACTORS INFLUENCING RAINFALL EFFECTIVENESS (12)

3.5.1 Rainfall Characteristics

In humid areas, storms of large magnitude and high intensity occur frequently during the crop season. The storms often bring down water in excess of that which can be stored in the soil profile for consumptive use. This excess water is lost either as surface runoff or as percolation below the root zone.

When such storms occur soon after an application of irrigation water, almost all of the rainfall may be lost as runoff. Thus in areas of high total rainfall during crop season the effectiveness of rainfall is low by comparison.

3.5.2 Land Characteristics

The opportunity time is the time interval between receipt of rain water and its recession by soakage. The opportunity time is long on a flat and levelled land areas whereas it is shortened on sloping land. The amount of effective rainfall is also effected by physical bonndaries i.e. surrounding agricultured fields, roads buildings and play grounds etc.

3.5.3 Crop Characteristics

The degree of ground cover, rooting depth and stage of crop growth are influencing the rate of water uptake by the plant and the effective rainfall is directly proportional to the rate of water uptake. During the period of vegetative and the flowering, the evapotranspiration is usually high and decline toward maturity stage. The proportion of effective rainfall will increase for deep rooted crops. Therefore, the nature of crop is an important factor to determine the effective rainfall.

3.5.4 Management Practices

Terracing, ploughing, ridging and mulching will reduce the runoff and hence effective rainfall will increase. For well planned irrigation schedules the effective rainfall will increases,while the random practices will reduce the effective rainfall.

In Philippines, the irrigation staff use the following procedure to estimate the effective rainfall :

R_e = (Paddy spillway height) - (Antecedent paddy depth)

For example : Condition of the paddy field are as follows :

- Stage of growth - maximum tillering with crop water requirement 8 mm/day.

- two days after the starting water delivery, say in rotational system of 5 days, a heavy rainfall occurs at 120 mm.
- the depth of submergence of paddy field before that interval of rotation is 50 mm.

Then the total 'antecedent paddy depth' = 50 + 2 x 8 mm.

= 66 mm

The paddy spillway height at this stage of growth = 150 mm.

Thus the effective rainfall is :

R_e = 150 mm - 66 mm = 84 mm or

$R = \frac{84}{120} \times 100$ percent = 70 percent

3.6 CANAL LOSSES

Land losses has been defined as the quantity of water lost during the passage of water from the main canal to the paddy field through main, secondary, tertiary canals and quarternary canals or farm ditches. Actually, conveyance losses may not be only evaporation and seepage of water in a canal. It also includes operation losses which may be the sum of error of water measurement devices, leakage from cracks in canals, gates and related structure.

3.6.1 Evaporation

The water lost by evaporation is generally very small, as compared to the water lost by seepage in certain canals. Evaporation losses are generally of the order of 2 to 3 percent of the total losses. They depend upon all those factors on which the evaporation depends, such as temperature, wind velocity, humidity etc. In dry season, these losses may be more but seldom exceed 7 percent or so.

3.6.2 Seepage

There may be two different conditions of seepage i.e. (a) Percolation, (b) Absorption

(a) Percolation

In percolation there exists a zone of continuous saturation from the canal to the water table and a direct flow is established. Almost all the water lost from the canal joints the ground water reservoir (9,13).

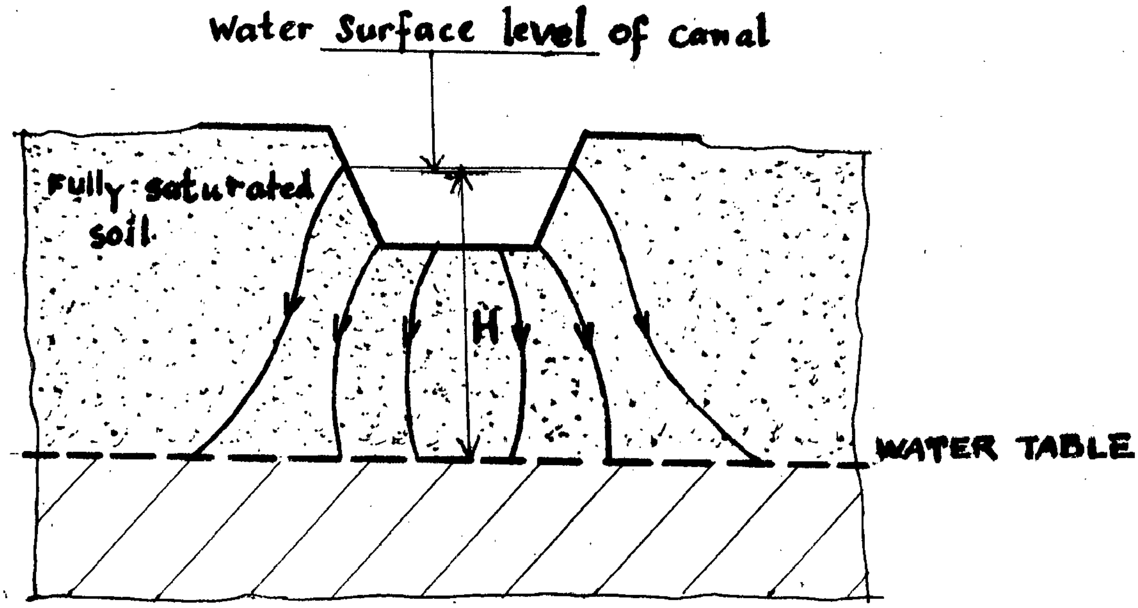
The loss of water depends upon the difference of top water surface level of the canal and the level of water table (i.e. H) as shown in Figure 3.7.

(b) Absorption

In absorption, a small saturated soil zone exists round the canal section, and is surrounded by zone of decreasing saturation. A certain zone just above the water table is saturated by capillary (13). Thus there exists an unsaturated soil zone between the two saturated zones, as shown in Figure 3.8.

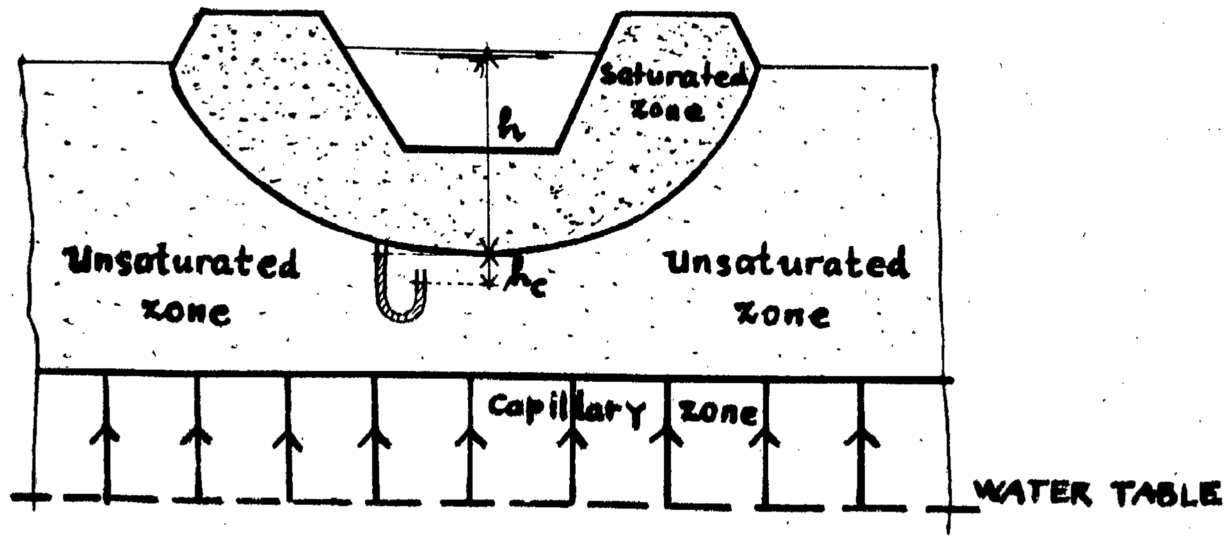
In this case, the rate of loss is independent of seepage head(H) but depends only upon the wake head h(i.e. distance of water surface level of canal to the bottom of saturated zones plus the capillary head h_c as shown in Figure 3.8.

Fig. 3.7. PERCOLATION



Q depends on H

Fig. 3.8. ABSORPTION



Q depends on $(h+h_c)$

The seepage losses depends upon the following :

(1) Type of seepage, i.e. whether 'percolation' or 'absorption'

(2) Soil permeability

(3) The condition of the canal. The seepage through a silted canal is less than that from a new canal.

(4) Amount of silt carried by the canal, the more silt lesser are the losses.

(5) Velocity of canal water, the more velocity lesser will be the losses.

(6) Cross section of the canal and its wetted perimeter.

(7) Ground water table and drainage conditions.

One of the first steps to minimise conveyance losses should be the use of all practical protective and corrective measures to overcome seepage and leakage from canal systems and structures. These systems should not be operated with the water surface higher than the designed normal water surface elevation. Increases and decreases in system flows should be time closely to minimize operational wastage (9,13).

The next step may include the installation of linings or the replacement of open canals with closed conduit. Proper maintenance of canals and structures are essential in obtaining minimum conveyance losses. The water delivered to each water user should be limited to the amount beneficially used. But the operating personnel should avoid shortage of water at farm level because of the under estimate value of conveyance losses.

Sometime, there are some figures which can be used in estimating these losses in old schemes, according to its canal capacities.

Table 3.3 shows such information from old irrigation schemes in alluvial plane in Java.

Table 3.3 - Percent losses to design capacity in Canal System

Canal System	Percent losses to design capacity	Remarks
Main canal	5% Q_1	Losses between main intake to secondary off-takes
Secondary canal	10% Q_2	Losses between secondary off-takes to tertiary off-takes
Tertiary canal	20% Q_3	Losses between tertiary off-takes to farm inlet

3.6.3 Direct Measurement of Seepage Losses

The seepage from unlined channels can be determined by direct measurement on the channels, are as follows :

(i) Inflow Outflow Method :

This method utilizes measurement of discharges at the upstream and downstream ends of the reach under study and the difference is taken as seepage loss from the reach. Existing calibrated weirs and flumes in the canals can be used for measuring flows. The method is not very accurate as the order of error involved in measurement of canal discharge may be of the same order or even higher than the quantum of seepage loss involved.

(ii) Ponding Method :

This method can be applied to smaller reaches of a canal. This method consists in measuring the rate of drop in a pool formed in the section of the canal to be tested. Since the observations can be made with reasonable accuracy, the results are taken as a good indication of the average loss from the section. A modification of the ponding method consists of adding water to the pond to maintain a constant water surface elevation. Ponding tests can be made only when the canal is not in use(14).

Example :

Measurement of Conveyance Loss by Ponding Method :

A canal section about 500 m long is closed at both ends with earth dikes or existing structures such as check gate, to preclude inflow and outflow thus creating a 'pond'.

A gauge is installed in this 'pond' and water surface level readings are taken preferably at the interval of every 8 hours.

Observations of a duration of 48 hours are made. From the average cross section of the pond and changes in water surface level, the amount of the water loss can be determined.

From the netted area, the water loss per unit surface area per unit time can also be determined. This is usually expressed in m^3/m^2/day.

The water loss may be expressed in m^3/sec per metre length of canal which is the total water loss in cubic metres per second divided by the length of the ponded canal in metres. Table of measurement of conveyance loss by ponding method as shown in Table 3.4.

Table3.4- Measurement of Conveyance Loss by Ponding Method

Name of Canal :

Section :

Sub-Project :

1. Date of Measurement
2. Time of starting observation
   a. Water depth (m)
   b. Average cross section (m^2)
   c. Volume of impounded water (m^3)
   d. Area of wetted surface of canal (m^2)
3. Time of ending observation
   a. Water depth (m)
   b. Average cross section (m^2)
   c. Volume of impounded water (m^3)
   d. Area of wetted surface of canal (m^2)
4. Time Interval
5. Volume of water loss (m^3)
6. Average wetted surface area (m^2)
7. Loss for time interval (m^3/m^2)
8. Loss per day (m^3/m^2/day)
9. Loss per metre of canal m^3/S (cms/m)
10. Remarks

Observed by :

Computed by :

Checked by :

CHAPTER IV : WATER DISTRIBUTION SYSTEM

4.1 METHOD OF WATER DISTRIBUTION

4.1.1 Golongan system

4.1.2 Pasten system

4.2 CONSIDERATION IN DELIVERY PLANNING

4.3 PREPARATION OF IRRIGATION DELIVERY PLAN

4.4 TECHNIQUES OF PREPARING IRRIGATION SCHEDULE

4.5 COMPARISON BETWEEN SUPPLY AND DEMAND

CHAPTER - IV

WATER DISTRIBUTION SYSTEM IN INDONESIA

4.1 METHOD OF WATER DISTRIBUTION

Planning and design of irrigation projects must include details of terminal distribution systems, which play a key role in securing the optimal use and control of developed water. In this connection, it should be noted that water distribution systems should be designed so that water is delivered evenly and effectively to the project area and that re-use of drained water must be carefully planned. It is common experience, that areas located in the higher reaches of the canal get plentiful supply of water and those located in the tail end reaches denied this facility. The water supply in the tail end reaches is every meagre and insufficient for the healthy growth of crops. This happens on account of the wasteful methods of irrigation practised in the higher reaches and sometime also due to the greediness of the cultivator to take more water to his lands.

There are two major water delivery systems now being popularly practised. One is the ' demand scheduling system ' which has been broadly accepted in U.S.A. It needs a larger size of farm to reduce the water control and measurement facilities, and the farmers for whom the system is adopted should be well experienced and knowledgeable in irrigation. The other one is the ' rigid scheduling system' which has been successfully implemented in Taiwan, Indonesia, Philippines and other

Asian countries, may be as the same as 'warabandi' in India.

The success of this system very much depends on efficient water controllers who must be experienced in both irrigation and farming, and will interact effectively with farmers and water users during the growing season.

'Golongan system' and ' pasten system' are commonly used in Prosida common area. Golongan system is combination of both rigid scheduling system and demand scheduling system whereas, pasten system in demand scheduling system is used for day to day water distribution.

1.1 Golongan System

The principal irrigation water in Prosida Command Area depend on seasonal river discharge. In the beginning of wet season, when the planting period should commence, the irrigation water supply is still short and is not adequate for land preparation over the whole area. Then, the planting dates of the whole area should not commence at the same time. By the Golongan system the irrigation area is divided into several golongan or units and one unit consists of some tertiary blocks or one secondary block. The available water is allocated to specific' golongan'(group) in turn with 10 days or 15 days difference in their commencement.

The number of golongan can be 3 to 5 according to the water availability and the availability of the farm labour which is important in land preparation.

A collective bed nursery is recommended for each 'golongan' and land preparation for nursery will be irrigated prior to the planting date of the ' golongan'. If the first golongan is A, second is B and the third is C for the year, then next year C will be the first, A the second and B the third 'golongan', since the first golongan has some advantages such as assurance of water availability, greater possibility of success in dry season growing period etc. In practice the water supplies for all ' golongan' are continuous flow during the wet season. Only when there is a heavy rainfall the ' Juru Pengairan' will reduce the discharge or close the gate temporarily.

During dry season when the allocated discharge to the tertiary canal falls below a critical level say less than 60 percent of normal allocation, then rotation within distribution canal or tertiary canal is followed for each golongan.

1.2 Pasten System

'Pasten' has been defined as the amount of water which should be delivered to an irrigation area according to the water availability and the distribution structure, expressed in liter/second/ha.

$$\text{Pasten} = \frac{A}{A \times Te \times Le}$$

Where Q = discharge at the off take.

A = 'palawidja' relative area (in hectares)

'palawidja' means upland cross such as maize, groundnut, soyabean etc. which is calculated on the basis of the following factors :

a)	'palawidja' crops	1
b)	Paddy nursery, land preparation	20
c)	Paddy main crop, land preparation	6
d)	Paddy main crop	4
e)	Young sugar cane(or nursery)	1.5

Te = terrain coefficient or field coefficient water losses.

Le = Coefficient of conveyance losses.

For example :

Given : A tertiary unit of 120 hectares should be irrigated from an offtake.

The available discharge Q = 160 l/sec.

The situation of crops consists of

Paddy main crop	90 ha
'palawidja' crop	30 ha
Coefficient of losses	$= T_e \times L_e = 1.4$

Problem : How to apply the ' Pasten' system

Solution :

Paddy main crop = 90 x 4	=	360 ha relative
'Palawidja'(other than paddy)	=	30 ha
Total	=	390 ha relative area

The value of 'pasten' (q) $= \frac{160}{390 \times 1.4} = 0.293$ l/sec/ha

Thus the 'palawidja' crop will be given = 0.293 l/sec/ha
and the paddy main crop will be given = 4x0.293 l/sec/ha

= 1.172 l/sec/ha = ± 10 mm/day

Obviously, these values will be different when the available water at the offtake changes. Therefore every week, 'Juru Pengairan' should check these values and write them on the 'Pasten Board' which is always installed at every offtake. The gate keeper should adjust the gate opening accordingly. These procedures are simple and understandable by both farmers and irrigation personnel, but they do not take into account :

(a) effective rainfall

(b) properties of soils

(c) actual water requirement at every stage of growth which are key factors in the achievement of fairly high efficiency(15).

4.2 CONSIDERATIONS IN DELIVERY PLANNING

There are several important factors to be considered in Irrigation Delivery Planning. They are as follows :

(1) Type of soil in the service area and its properties.

(2) Kind of crops to be grown, and the area of each crop in the service area. Also the growth period of each crop is important.

(3) Crop water requirement of each crop at every stage of growth.

(4) Estimation of field water requirement of water duty for each tertiary unit (or quarternary unit).

(5) Possibility or alternatives of water distribution scheduling.

(6) The available water supply for the system which can be found through hydrologic and water source investigation. The rainfall data and reliable discharge records are very important for achieving a fair efficiency of irrigation water.

If the water source is a reservoir with enough water available for dry season and wet season, the calculation of water balance will be simple. But if the water source is the natural runoff of a river without storage facilities, then continuous and maximum diversion of the available river flow, according to system capacity, should be encouraged most of the time. It is important that the dependable flow of water is known.

(7) Updated lay-out of the major flow points of the service area and areas to be served by each.

(8) Water losses in the conveyance system.

All this information, factors (1) - (8), must have a good balance of water supply and water demand during the growing season(14).

4.3 PREPARATION OF IRRIGATION DELIVERY PLAN

Preparation of the irrigation delivery planning should start from fundamental irrigation service unit to cover the entire irrigation system. The following steps should be taken:

(1) At least 90 days (3 months) prior to the planting period 'Juru Pengairan' should give the following reports to the 'Pengamat Pengairan'.

1.1 request from the farmers on the water allocation for their next crop season, given via ' Ulu Ulu'.

1.2 Kinds of crops and area of each crop

1.3 updated condition of the irrigation facilities.

(2) Based on these reports (from several ' Juru Pengairan') 'Pengamat' should evaluate the area to be irrigated and the maximum water allocated for the service area. Also the capability for operation, then should be submitted to the Irrigation Section Office together with the results of the evaluation of the no.1 reports.

(3) Request of water from industrial estates such as sugar factories etc. should be submitted to the section office at the same time as reports No.1 and No.2.

(4) The Chief of the irrigation section office should assign all 'Pengamat Pengairan' to make a field check of all request in their service area, including requests from Industrial Estates and their adjacent areas.

(5) Then 60 days (2 months) prior to the planting dates the chief of Irrigation Section Office should submit

his proposals for irrigation delivery planning starting dates of each 'golongan' to the irrigation Committee.

(6) Then the Bupati (Head of administrative District) will call all members of the irrigation committee for a meeting. At the same time copies of the proposals are submitted to all members for study. Special note given to the Agricultural Office for the provision of information on the availability and the arrival of recommended seed, fertilizers and other necessities as part of their responsibilities.

(7) Meeting of the Irrigation Committee should produce a final decision on irrigation water delivery planning, at least, a preliminary plan with some revisions to be done later. If necessary, another meeting will be called for the following week.

(8) The final plan of irrigation water delivery for the growing season should be announced by the Bupati as the Chairman of the Irrigation Committee.

(9) Irrigation water will be delivered in accordance with the fixed cropping pattern irrespective of farmers' willingness to follow it or not. Thus the proposed cropping pattern on which the irrigation schedule is based should be fitting to the natural environment of the project area and also be acceptable to local farmers.

Moreover, it should be on optimum pattern for the effective use of water and land, and should be profitable to individual farmers.

(10) There are always possibilities of modification of planning and adjustment of discharges during implementation, but it should be based on the balance of water supply and demand.

4.4 TECHNIQUES OF PREPARING IRRIGATION SCHEDULE

Techniques of preparing irrigation schedule should be based on individual circumstances, but we can recognise some different scheme conditions.

(1) scheme with no storage facility which have sufficient water for double cropping of paddy from run of the river.

(2) scheme with no storage which have sufficient water for wet season paddy crop but only partial dry season paddy crop.

(3) Multipurpose project from which the available water could be used for hydropower, irrigation public water supply etc.

Scheme (2) is the general case throughout Java and Sumatra, Scheme(1) and Scheme (3) are found in West Java and south Sulawesi.

There are some points to be considered in preparing irrigation scheme by 'Golongan' system as follows :

1. The planting date should be determined so that most profitable application of the limited water available during the dry season could be achieved.

2. Water requirement in the paddy field varies from day to day, but planning of an irrigation schedule on the day to day basis is feasible. Also predicting water availability from dependable flow of the river is not easy on the day to day basis.

Thus, adopting intervals of 10 or 15 days are a fairly acceptable basis for planning of water delivery, then the balance of water supply and demand can be achieved fairly accurate.

The size of each 'golongan' should be approximately the same and it depends not only on the water availability but also on the availability of farm labour. There will be a rotation of 'golongan', each area must have a chance to be the first 'golongan'.

In Prosida's irrigation scheme, with supply water from the river flow, the second paddy crop(in dry season) will not cover the whole area because of shortage of water. Then the last ' golongan' (3rd golongan or 4th golongan) is recommended to grow upland crop such as maize, groundnuts, sweet potato etc.

Sometimes, in drought only one third or half of the service area will be successful in this growing period.

The recommended second paddy crop area of the authorised second paddy crop area known as ' paddy gadu' has the guarantee of having sufficient supply of irrigation.

Figures 4.1 show the example of cropping pattern and the irrigation schedule with ' golongan system' (16).

4.5 COMPARISON BETWEEN SUPPLY AND DEMAND

By comparing the irrigation water demand and the available water supply which are tabulated in the same intervals of the same period, the general status of water balance during operation can be observed.

Preventive measures for those periods during which water deficit occurs should be taken. These measures depend upon the time when the water deficit occurs.

Suppose the deficit occurs in a transplanting period, prolonging this period to a maximum allowable duration or cutting down the crop area is desirable, if additional water supply from the source cannot be done. If the water deficit occurs during the period of main field irrigation, rotational irrigation practices can be adopted.

If the amount of deficit is so high that the above mentioned practices are impracticable then the cropping pattern and irrigation schedule, and the area of each 'golongan' should be modified. It is recommended that the last 'golongan' should be modified first to have a quick decision. It is fair, because

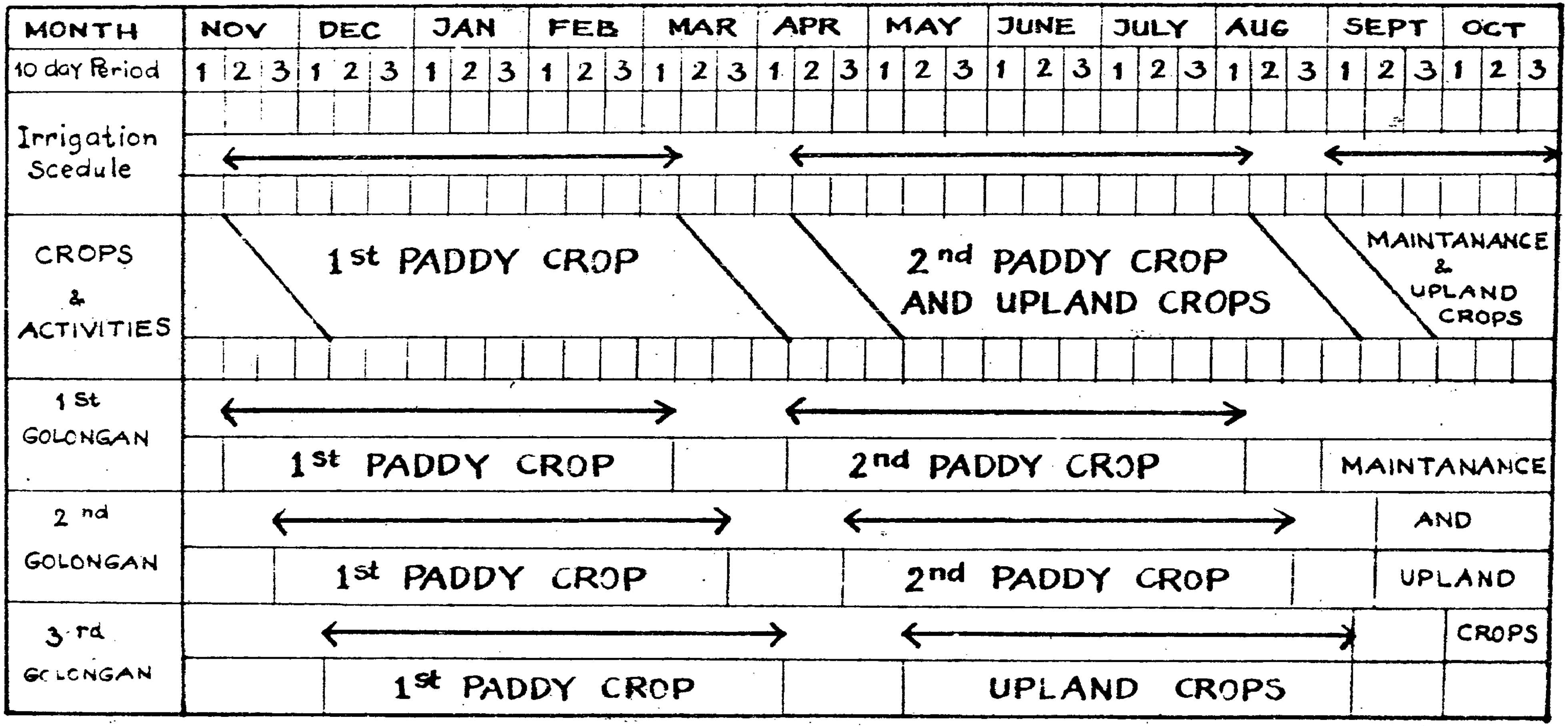


Fig. 4.1. CROPPING PATTERN & IRRIGATION SCHEDULE WITH GOLONGAN SYSTEM

every block of paddy field in the service area will have a chance to be the last ' golongan' as well as the first 'golongan'. The water balance and irrigation schedule are shown in Figure 4.2(15).

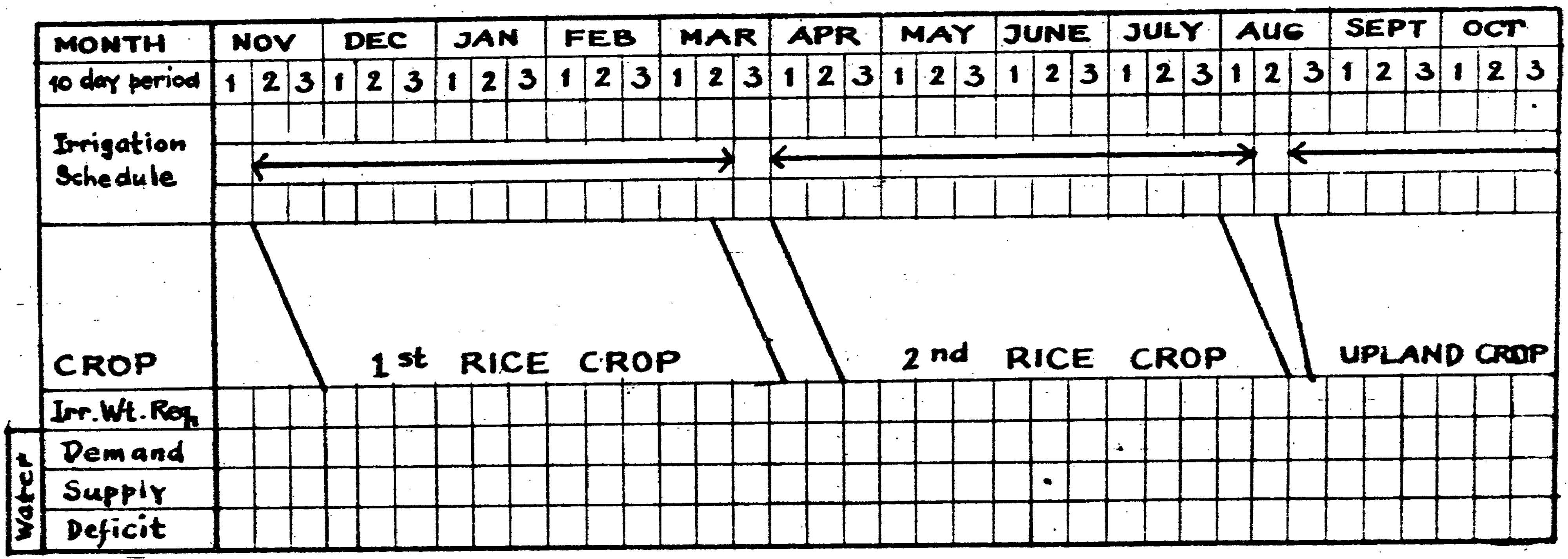


Figure 4.2. WATER BALANCE & IRRIGATION SCHEDULE

CHAPTER - V : WATER DELIVERY MANAGEMENT IN INDONESIA

CHAPTER - V

WATER DELIVERY MANAGEMENT IN INDONESIA

5.1 GENERAL

Water delivery management of a completed irrigation project is generally focussed on how to deliver water from the source to the farm. It requires well equipment and well maintained control and regulating facilities and well trained and alert operators.

Figure 5.1 shows the details of water delivery and disposal drainage systems. Successful management of water delivery system depends upon proper coordination of the operation of Headworks. The management of the conveyance system and the management of distribution system. Good communication, understanding and awareness of responsibilities among the operators and supervisors or personnel who concerned these works are essential (17).

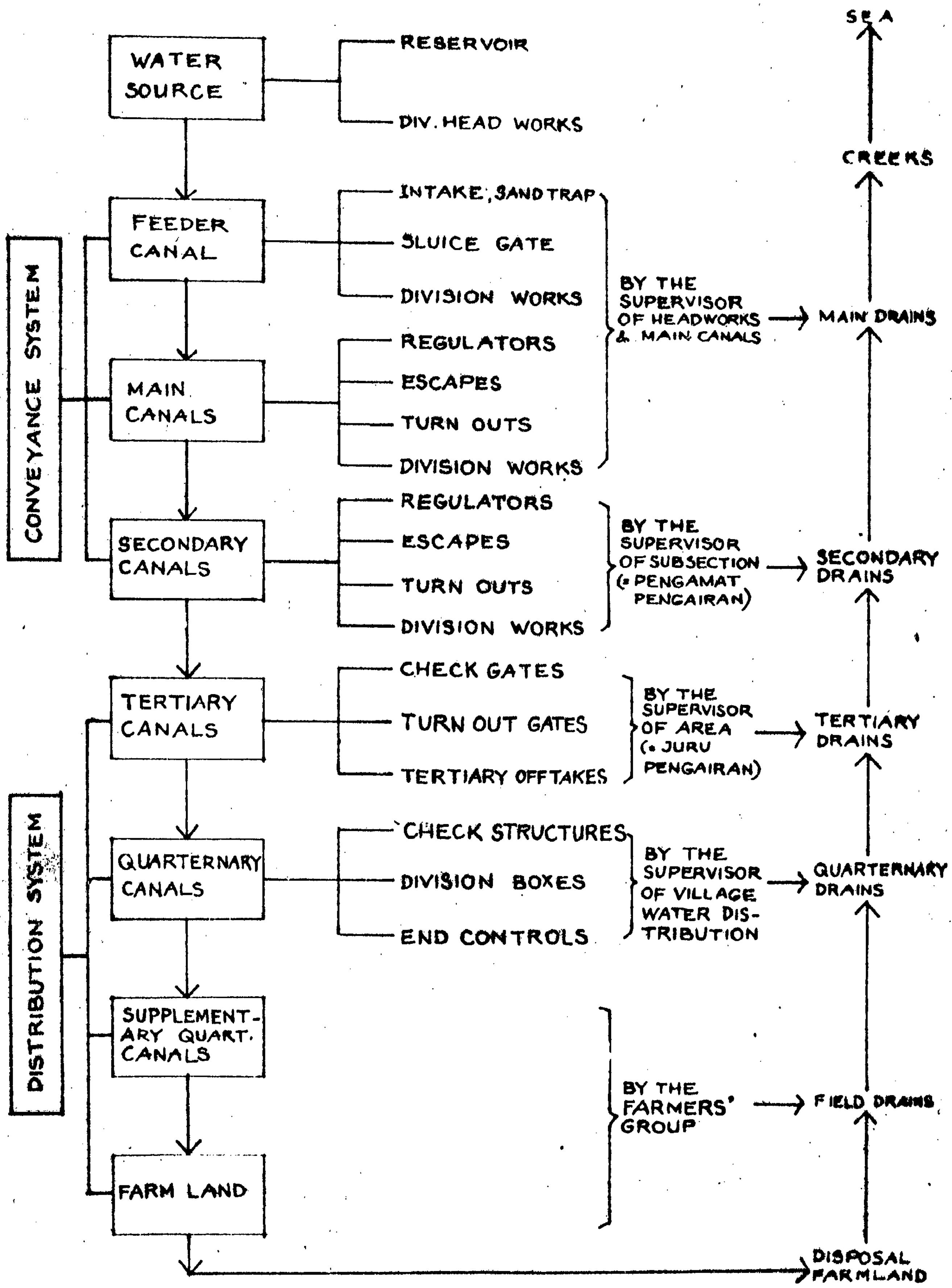
5.2 WATER RESOURCES FACILITIES

Generally, water source facilities for an irrigation scheme can be represented as a diversion structure on the river which consists of barrage or weir plus river intake or a reservoir.

5.2.1 Diversion Structure

The diversion structure of an irrigation scheme which sometimes is called the head works of the system, is used to

FIG. 5.1. MANAGEMENT OF WATER DELIVERY AND DISPOSAL DRAINAGE SYSTEM



divert the required supply into the canal from the river(13).

There are some important parts in the procedure of operation headworks :

(1) Fluctuation of water level and changes of river flow should be carefully observed by the personnel in charge of the supervision of headworks.

(2) Constant regulation of barrage's gates and intake gates or sluice gates of a weir and intake gates, is essential for attaining a stable flow into the system and to protect the intake structure from destruction. The adjustment of gate opening should be made twice a day and may be more during the flood season.

(3) Periodic survey of river flow and its cross section is recommended to recalibrate the discharge rating curve.

(4) A communication facility link between flood control station and the headworks supervisor office on the site must be provided. Also link between the irrigation section office and head works supervisor office should be installed.

(5) All water level positions and gate positions must be recorded. Usually, to have a good record of water level and river flow, two automatic (or non-automatic) water level recorders are installed. One is at a flood-

control station 10-20 km upstream of the weir and another one just upstream of the weir on the river.

(6) Guidance for the operation of a stilling basin and sluice gates must be given to the operators. In some irrigation schemes where the problems of sedimentation and erosion have been critical, a special guidance for operating headworks and related structures must be provided.

Some techniques for handling the headworks can be shown as follows :

(a) In case the divertable water in the river is greater than the planned diversion requirement and there is no danger of high sedimentation, it is advisable to divert a water discharge greater than the planned value up to the maximum canal capacity.

(b) In case the divertable water smaller than the required discharge in the plan, the available water should be entirely and continuously diverted into the system.

(c) In case there is flood which can cause damage to the canal system and carrying too much silt and sand, the main intake should be temporarily closed, which means that the water supply is temporarily stopped. Partial closure of main intake gates is sometimes is recommended if the river has a high concentration of sediment (especially during the rainy season).

5.2.2 Storage Reservoir

A storage reservoir with gated spillway and gated sluiceway, provides more flexibility of operation, and thus gives better control and increased usefulness of the reservoir. Storage reservoirs are therefore, preferred on large rivers which require better control, while retarding basins are preferred on small rivers.

In storage reservoirs, the flood crest downstream, can be better controlled and regulated properly so as not to cause their coincidence. This is the biggest advantage of such a reservoir and out weighs its disadvantages of being costly and involving risk of human error in installation and operation of gates (13).

The operation and management of a reservoir is somewhat different with the operation of a barrage or weir plus intake, because of the differences in physical characteristics of the reservoir and the staff should understand how to read and interpret this information and data and operating criteria.

The following are some of those important characteristics which should be known to staff (O and M).

1. Storage capacity of a reservoir is the maximum volume of water that can be stored in the reservoir. The capacity of reservoirs on dam sites is determined from the contour maps of the area. The area enclosed within each contour within the

reservoir site can be measured with a plainmeter. The contour elevations and the areas enclosed at respective elevations can be plotted in the form of a curve called 'Area Elevation Curve' (Fig. 5.2). The integral of the area elevation curve is nothing but 'Elevation Capacity Curve' (Fig.5.2).

In the absence of topographic maps, the cross sections of the reservoirs can be surveyed, and the capacity computed from these vertical cross sections by using 'Trapezoidal' or 'Prismoidal' formulas.

(a) Volume (V) $= h \left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \ldots\ldots A_{n-1} \right]$

(For Trapezoidal Formula)

(b) Volume (V) $= \left[(A_1 + A_n) + (A_2 + A_4 \ldots) + 2(A_3 + A_5 + \ldots) \right]$

(For Prismoidal formula)

2. Normal Pool Level is the maximum elevation to which the reservoirs water surface will rise during normal operating conditions (See Fig. 5.3). It is equivalent to the elevation of spillway crest or the top of the spillway gates for most of the cases.

3. Minimum Pool Level is the lowest surface elevation which has to be kept under normal operating conditions in a reservoir, is called minimum pool level (See Fig.5.3). This level may be fixed by the elevation of the lowest outlet in the dam or may

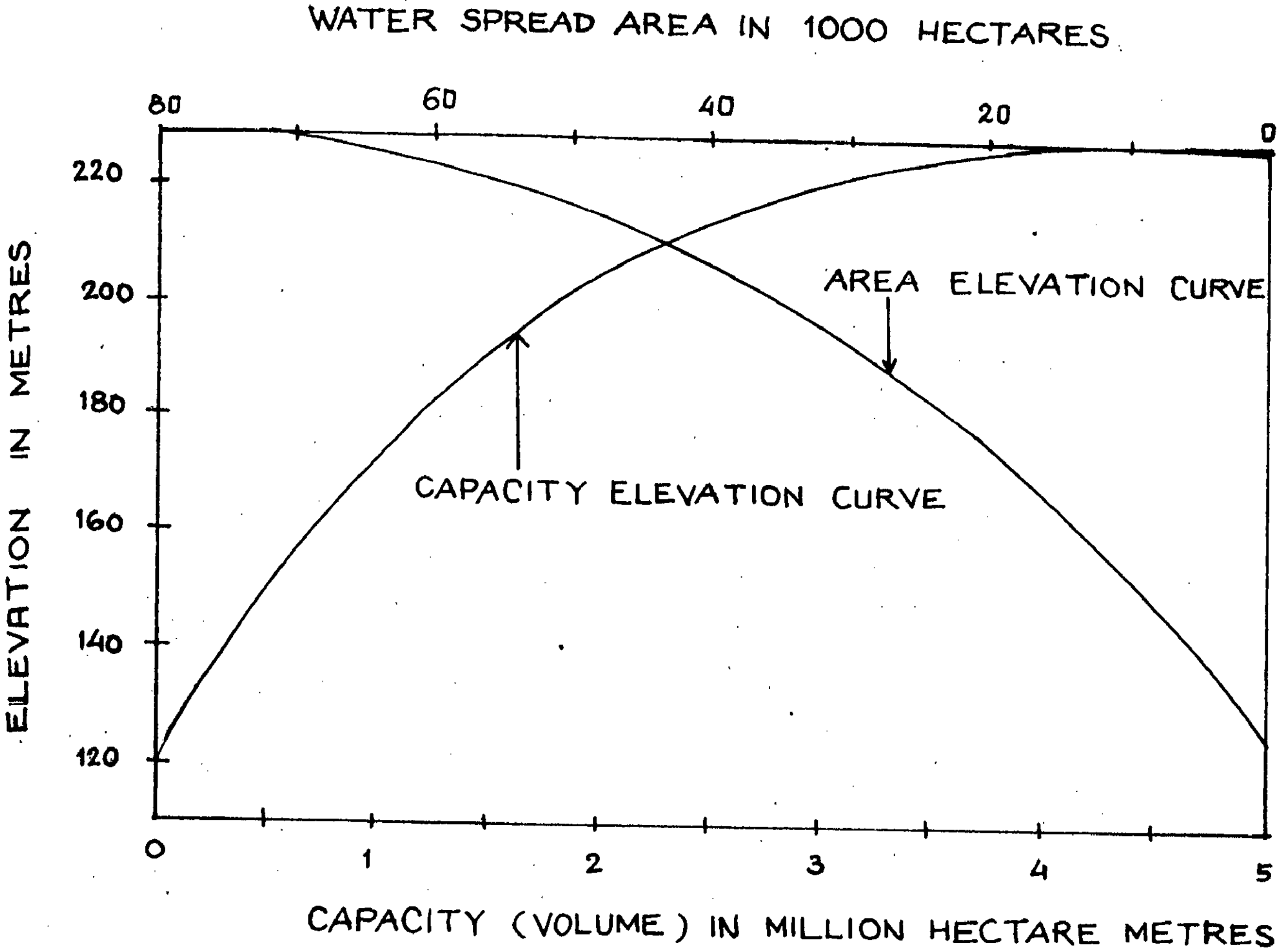


Fig. 5.2. AREA & CAPACITY ELEVATION CURVE

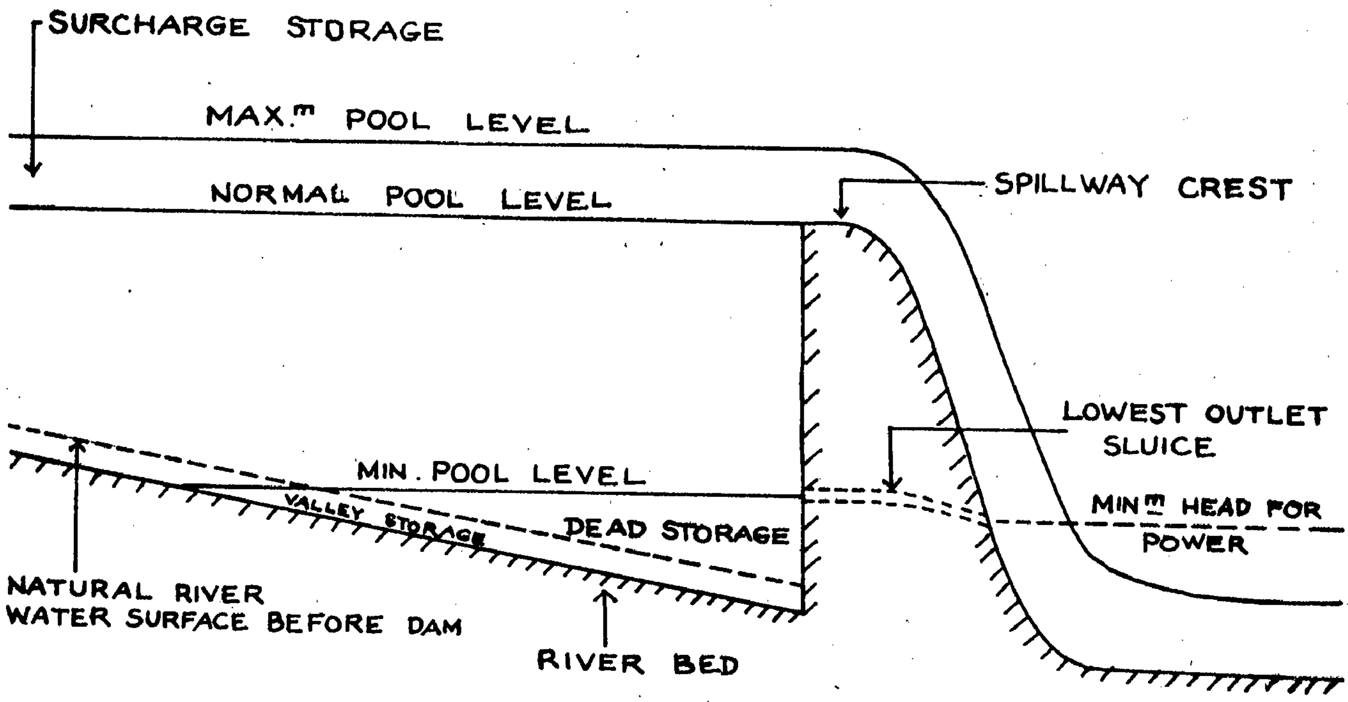


Fig. 5.3. STORAGE ZONES OF A RESERVOIR

be guided by the minimum head required for efficient functioning of turbine.

4. Useful storage is the volume of water stored in the reservoir between the minimum pool and normal pool levels.

5. Head storage is water stored in the reservoir below the minimum pool level and it is not of much use in the operation of the reservoirs.

6. Maximum pool level is the maximum level to which water rises during the worst design flood so that the discharge over the spillway and will cause the water level to rise in the reservoir above the normal pool level.

7. Surcharge storage is the volume of water stored between the normal pool level and the maximum pool level.

8. Reservoir yield is the amount of water that can be drawn from the reservoir in a certain interval of time. The time interval may vary from a day for small distribution reservoirs to a month or a year for larger reservoirs. Yield is dependent upon inflow and will vary from time to time.

9. Reservoir leakage in most reservoir is caused by the permeability of the reservoirs bank. It is usually low, except if the walls of the reservoir are of badly fractured rock, permeable volcanic material or cavernous limestone, serious leakage may occur. This leakage may result in serious

damage to property and danger to human life (13).

5.3 AVAILABLE DISCHARGE

Available discharge sometimes is called Dependable Flow. River discharge is not constant, but it will change depending upon chronology, of the day, the month and the year, however there is always a tendency that the discharge in rainy season is greater than the discharge in dry season.

Since the river discharge is usually fluctuating the discharge which determines the area to be irrigated is to be found out. One of the methods for determining the magnitude of available discharge is data collecting of average of half monthly discharge, then to find out 80 percent dependable discharge.

It means :

- Estimate discharge will be fail by 20 percent
- If we take 10 years period, it means only in 2 years, the discharge (Q) will less than the 80% dependable discharge.

Example of average of half monthly discharge is shown in Table 5.1 and calculation of dependable flow can be seen in Table 5.2.

Table 5.1. AVERAGE OF HALF MONTHLY DISCHARGE

in l/sec

YEAR	JAN		FEB		MAR		APR		MAY		JUNE		JULY		AUG		SEP		OCT		NOV		DEC	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
1970	1210	1200	1100	1120	965	870	830	750	800	850	780	840	820	790	665	672	1230	1310	1470	1490	1440	1370	1260	1240
1971	1115	1100	897	915	800	700	336	610	720	715	630	800	795	522	730	890	1190	1270	1490	1460	1420	1340	1240	1220
1972	1030	1040	815	616	412	650	670	580	630	700	301	699	577	755	535	831	1115	1240	1115	1320	1290	1270	1210	1205
1973	970	900	860	737	570	337	495	480	355	615	485	474	700	375	602	855	837	975	1360	1340	1310	1260	1220	1210
1974	1099	1080	595	800	720	570	595	430	475	413	418	400	437	600	765	1000	990	1250	1200	1260	1270	1220	1205	1210
1975	942	970	716	714	476	400	465	700	550	579	510	318	502	690	870	1090	934	1230	1390	1100	1150	1210	1205	937
1976	1200	1150	671	363	900	510	630	301	400	521	356	500	640	430	695	721	795	1100	1450	1200	1220	1230	1220	1215
1977	840	768	620	673	650	750	422	235	500	476	450	570	685	645	900	930	960	1240	1470	1430	1270	1240	1165	1000
1978	989	800	780	789	525	800	550	650	452	675	590	550	725	720	800	1150	1200	1260	1490	1460	1240	1210	1206	1115
1979	815	687	697	995	600	448	375	530	595	750	710	735	760	825	950	1050	1150	1230	1200	1260	1240	1175	1185	1203
1980	1150	725	963	897	850	480	730	371	690	790	620	750	860	570	835	980	1050	1220	1360	1310	1290	1115	1216	1232
1981	1000	850	990	950	690	600	780	395	760	810	550	785	595	860	990	1115	1090	1210	1380	1320	1010	1210	1222	1200

Remarks : Observation of discharge during 12 Years (Starting from 1970 to 1981)
The most important is smallest discharge (in dry season) whereas The discharge in rainy season, if $Q > 1200$ l/sec is not required.
Suppose Area Irrigated : 700 Ha and water requirement : 1.5 l/sec/ha
$Q_{max} = 700 \times 1.5 = 1050$ l/sec

Table 5.2. AVAILABLE DISCHARGE (DEPENDABLE FLOW = Q 80%)

in l/sec

YEAR	JAN		FEB		MAR		APR		MAY		JUNE		JULY		AUG		SEP		OCT		NOV		DEC	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
1	1210	1200	1100	1120	965	870	830	750	800	850	780	840	860	860	990	1150	1230	1310	1490	1490	1440	1370	1260	1240
2	1200	1150	990	995	900	800	780	700	760	810	710	800	820	825	950	1115	1200	1270	1490	1460	1420	1340	1240	1232
3	1150	1100	963	950	850	750	730	650	720	790	680	765	795	790	900	1090	1190	1260	1470	1460	1310	1270	1222	1220
4	1115	1080	897	915	800	700	670	610	690	750	630	750	760	755	870	1050	1150	1250	1470	1430	1290	1260	1220	1215
5	1099	1040	860	897	720	650	630	580	630	715	590	735	725	720	835	1000	1115	1240	1450	1340	1290	1240	1220	1210
6	1030	970	815	863	690	600	595	530	595	700	550	699	700	690	800	980	1090	1240	1390	1320	1270	1230	1216	1210
7	1000	900	780	800	650	570	550	480	550	675	510	570	685	645	765	930	1050	1230	1380	1320	1270	1220	1210	1208
8	989	850	716	789	600	510	495	430	500	615	485	550	640	600	730	890	990	1230	1360	1310	1240	1210	1206	1205
9	970	800	697	737	570	480	465	395	475	579	450	500	595	570	695	855	960	1220	1360	1260	1240	1210	1205	1200
10	942	768	671	714	525	448	422	371	452	521	418	474	577	522	665	831	934	1210	1200	1260	1220	1210	1205	1115
11	840	725	620	673	476	400	375	301	400	476	356	400	502	430	602	721	837	1100	1200	1200	1150	1175	1185	1000
12	815	687	595	616	412	337	316	235	355	413	301	318	437	375	535	672	795	975	1115	1100	1010	1115	1165	937

<u>Calculation of Depenable Flow :</u>

There is an observation of discharge during 12 Years (Starting from 1970 to 1981)

Then, Q is arranged in Decending Order (From biggest to Smallest)

No. 12 is shown Q 100% generally to be fullfiled every year (Safe, but Q is small)

No. n = Q 80% (May be 8 Years is ensured during 10 Years)

Equation : $\frac{n}{12} = 80\% = 0.8 \longrightarrow n = 12 \times 0.8 = 9.6$

Take n = 10 (rounded)

5.4 APPLICATION OF ROTATIONAL METHOD

Rotational irrigation, as practiced in Japan, Taiwan, India, Indonesia etc. provides each small unit of an area served by a turn out the total flow over a predetermined period of time so that the unit stores water that will be needed until it has its next turn of irrigation. The flow is thus rotated among a number of units, which constitute the total service area of the turnout. The volume of water to be applied and the irrigation interval are determined on the basis of the size of the unit, evapotranspiration, seepage and percolation requirements and conveyance losses (16).

In Prosida, the method of the irrigation water delivery by rotation can be applied within each 'Golongan', it means : by dividing it into some rotational areas. One rotational area consists of some 'Rotational units' which should be irrigated by a gated turn out. Irrigation water distribution is done by rotation among the units. A flow measuring devices is essential in this method.

Each rotational unit receiving sufficient water, during the irrigation term, to last a cycle of rotational interval. One cycle on rotational interval is completed in number of days equivalent to the number of rotation units.

<u>For Example</u>

Number of rotational units = 5

Field irrigation requirement = 1.6 ℓ/sec/ha

One cycle of rotational interval = 5 days

Then :

Each unit receives 5 times its daily field irrigation requirement = 5 x 1.6 ℓ/sec/ha = 8 ℓ/sec/ha at the time(=day) of irrigation period.

There are two methods commonly used for PROSIDA command area in practicing rotation such as :

1. Fixed time - variable discharge :

The irrigation water is distributed to each unit in a fixed time duration, say 24 hours, and the discharge is varied according to the area to be observed.

<u>Example</u>

A rotational area consists of three units, unit A = 8 ha Unit B = 10 ha and Unit C = 7 ha. Rotational intervals = 3 days.

The discharge required for each unit

$$Q = \text{Area} \times \text{Rotation interval} \times \frac{(\text{Evapotranspiration} + \text{Percolation})}{\text{Field efficiency}}$$

If

Q = discharge in ℓ/sec

A = Area in ha

I_r = Rotation interval in days

E_t = Evapotranspiration in mm/day

P = Percolation in mm/day

e_f = Field efficiency

$$Q = A \times I_r \times \frac{E_t + P}{e_f} \times \frac{1}{8.64} \ \ell/\text{sec}$$

suppose (E_t+P) of the example = 7 mm/day and e_f = 80 percent

Then $Q = A \times 3 \times \frac{7}{0.8} \times \frac{1}{8.64} \ \ell/\text{sec}$

The discharge will be required can be tabulated as follows :

TABLE -5.3

Rotation Unit	$E_t + P$	e_f	Discharge = Q
A = 8 ha	7 mm/day	80 percent	24.3 ℓ/sec
B = 10 ha	7 mm/day	80 percent	30.4 ℓ/sec.
C = 7 ha	7 mm/day	80 percent	21.3 ℓ/sec.

TABLE - 5.4

Rotation Unit	Q = discharge delivered to and at		
	The Ist day	The 2nd Day	The 3rd Day
A	24.3 ℓ/sec	-	-
B	-	30.4 ℓ/sec	-
C	-	-	21.3 ℓ/sec

It is shown, to irrigate 10 ha area, the canal capacity should be at least 30.4 ℓ/sec or about 3 ℓ/sec/ha.

2. FIXED DISCHARGE - VARIABLE TIME

The irrigation water is distributed to each unit in a fixed discharge, the time of which is varied according to the area served.

Example

Three units of A = 8 ha, B = 10 ha and C = 7 ha, area irrigated by rotation of fixed discharge - variable time, starting time is 08.00 O'Clock and rotational interval =3 days. Then :

Total area = 8 + 10 + 7 = 25 ha

$E_t + P = 7$ mm/day

$$Q = A \times \frac{E_t + P}{e_f} \times \frac{1}{8.64} \ \ell/\text{sec}.$$

$$= 25 \times \frac{7}{0.8} \times \frac{1}{8.64} = 25.32 \ \ell/\text{sec}.$$

Time of delivery for each unit (T) $= \frac{\text{Each Area}}{\text{Total area}} \times 24 \times I_r$

$T_A = 8/25 \times 24 \times 3 = 23.0$ hours

$T_B = 10/25 \times 24 \times 3 = 28.8$ hours = 28 hours 48 minutes

$T_C = 7/25 \times 24 \times 3 = 20.2$ hours = 20 hours 12 minutes

Schedule of water delivery : (starting time 08.00 O'Clock)

Rotational Unit	Starting Time of Irrigation		
	First Day	Second Day	Third Day
A	08.00 AM	-	-
B	-	07.00 Am	-
C	-	-	11.48 AM

Other method for calculating rotation is stressing method (19).

<u>Given:</u> Area of an irrigation network = 15,000 ha (Figure 5.4), divided into two groups such as :

Area of A = 7,000 ha, there is a tertiary block (A') with area of 100 ha.

Area of B = 8,000 ha, there is a tertiary block (B') = with area of 100 ha.

From July Ist to July 15th period, the water requirement are as follows :

For A' - q_A = 1 ℓ/sec/ha (Flowering period)

For B' - q_B = 1.20 ℓ/sec/ha (Tillering period)

In that period, the available discharge at intake = 12,500 ℓ/sec.

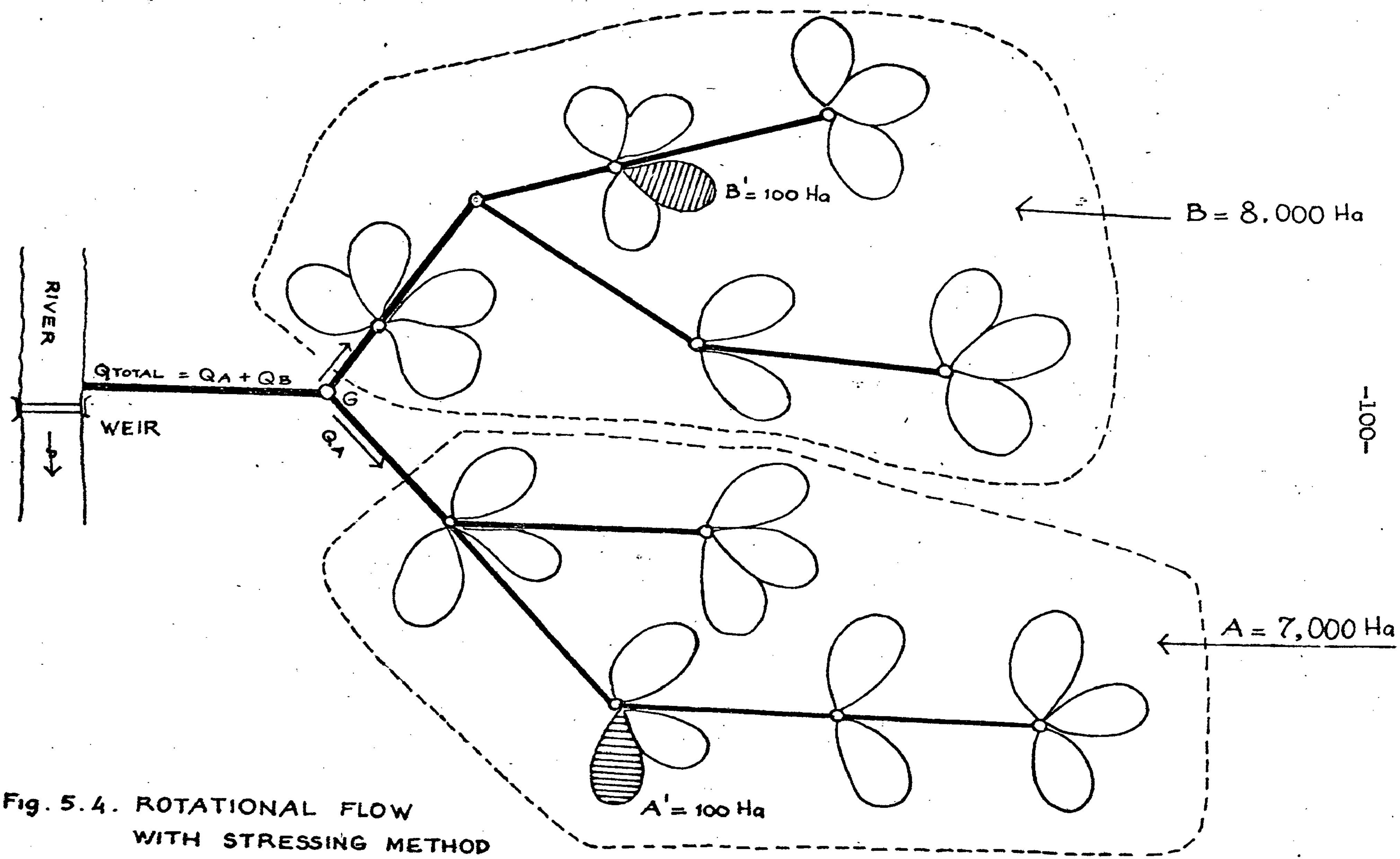


Fig. 5.4. ROTATIONAL FLOW WITH STRESSING METHOD

Problem: How to apply water distribution at each tertiary gate of A' and B'.

(For making simple calculation, water loss factor at main and secondary canals should be neglected).

Solution:

Q_A = 7,000 ha x 1 ℓ/sec/ha = 7,000 ℓ/sec.

Q_B = 8,000 ha x 1.2 ℓ/sec/ha = 9,600 ℓ/sec.

Total discharge required = $Q_A + Q_B$

= 7,000 + 9,600 = 16,600 ℓ/sec.

Available discharge (given) = 12,500 ℓ/sec.

$$\text{Stressing Factor} = \frac{12,500}{16,600} \times 100 \text{ percent} = 75 \text{ percent}$$

There are two methods, how to apply-stressing in the main irrigation network such as :

a. Stressing total

b. Stressing intermittent (Giliran)

a. Stressing Total :

Because the available discharge less than the discharge required, so that, the discharge will through all gates should be reduced. According to the above calculation the discharge will be 75 percent Q required.

Hence: $Q_{A'}$ = 75 percent x 1 ℓ/sec/ha x 100 ha = 75 ℓ/sec.

$Q_{B'}$ = 75 percent x 1.20 ℓ/sec/ha x 100 ha = 90 ℓ/sec.

Total volume of water flow during 1 week (7 days) are :

$V_{A'}$ = 75 ℓ/sec x 7 days = 525 ℓ/sec days
= 45,360,000 liters = 45,360 m^3

$V_{B'}$ = 90 ℓ/sec x 7 days = 630 ℓ/sec days
= 54,432,000 liters = 54,432 m^3

b. Stressing Intermittent (Giliran) :

If the water become reduced, we usually apply intermittent. Suppose intermittent will apply at a division structure (G) and intermittent interval is taken 1 week (7 days), Fig. 5.4.

Q_A = 7,000 ℓ/sec
Q_B = 9,600 ℓ/sec.

Intermittent interval = 7 days

$T_A = \frac{7000}{16600}$ x 7 days = 2.95 days
= 2 days + 22 hours + 48 minutes

$T_B = \frac{9,600}{16,600}$ x 7 days = 4.05 days
= 4 days + 1 hours + 12 minutes

1. During intermittent, if the tertiary gate is not changed, so that reduction of discharge will not equal.

Let's see explanation below :

$Q_{A'}$(fixed) = 100 ha x 1 ℓ/sec/ha = 100 ℓ/sec.
T_A=2.95 days

$Q_{B'}$(fixed) = 100 ha x 1.20 ℓ/sec./ha = 120 ℓ/sec.
T_B = 4.05 days.

Volume of water flow to tertiary blocks are :

$V_{A'}$ = 100 ℓ/sec x 2.95 days = 295 ℓ/sec days < 525 ℓ/sec days
$V_{B'}$ = 120 ℓ/sec x 4.05 days = 486 ℓ/sec days < 630 ℓ/sec days

So, during intermittent, if the discharge through the tertiary gates of A' and B' are not changed. Therefore, the water loss will create or stressing intermittent will not equal.

2. In order to equal stressing will be achieved, during intermittent at structure of G(Figure 5.4), the flow discharge to the tertiary block should be arranged as follows :

T_A = 2.95 days, How much $Q_{A'}$ in order to get $V_{A'}$ = 525 ℓ/sec days and

T_B = 4.05 days, How much $Q_{A'}$ in order to get $V_{B'}$ = 630 ℓ/sec days.

During 2.95 days, gate of A' should be opened for flowing discharge =

$$= \frac{\text{Volume A' 7 days}}{T_A} = \frac{525 \text{ ℓ/sec days}}{2.95 \text{ days}}$$

178 ℓ/sec = 100 ℓ/sec.

During 4.05 days, gate of B' should be opened for flowing discharge

$$= \frac{\text{Volume B' 7 days}}{T_B} = \frac{610 \ \ell/\text{sec days}}{4.05 \text{ days}}$$

$$= 156 \ \ell/\text{sec} \quad > \quad 120 \ \ell/\text{sec}.$$

Formula for calculating Intermittent Stressing :

(1) $T_A = \frac{Q_A}{Q_A + Q_B} \times T$ or $T_B = \frac{Q_B}{Q_A + Q_B} \times T$

(2) $(q_A)_s \times T_A = S \times (q_A) m \times T$

OR

$(q_B)_s \times T_B = S \times (q_B) m \times T$

Where

T = intermittent interval at division structure

S = Stressing percentage

$= \frac{\text{Available discharge}}{\text{Requirement discharge}} < 1$

T_A = intermittent time for group A

T_B = intermittent time for group B

$(q_A)_n$ = normal discharge at tertiary gate of A

$(q_B)_n$ = normal discharge at tertiary gate of B

$(q_A)_s$ = Stressing discharge at tertiary gate of A

$(q_B)_s$ = stressing discharge at tertiary gate of B

Using the above problem :

$$(q_A)_n = 100\ \ell/\text{sec.}$$

Intermittent interval = 7 days

$$S = \frac{\text{Available Discharge}}{\text{Requirement Discharge}} = \frac{12,500}{16,600} = 75 \text{ percent}$$

$$T_A = \frac{7000}{7,000 + 9,600} \times 7 \text{ days} = 2.95 \text{ days}$$

$$(q_A)_s \times 2.95 \text{ days} = 75 \text{ percent} \times 100\ \ell/\text{sec} \times 7 \text{ days}$$

$$(q_A)_s = \frac{75 \text{ percent} \times 100 \times 7}{2.95} = 178\ \ell/\text{sec.}$$

And also :

$$T_B = \frac{9,600}{7,000+9,600} \times 7 \text{ days} = 4.05 \text{ days}$$

$$(q_B)_s \times 4.05 = 75 \text{ percent} \times 120\ \ell/\text{sec} \times 7 \text{ days}$$

$$(q_B)_s = \frac{75 \text{ percent} \times 120 \times 7}{4.05} = 156\ \ell/\text{sec.}$$

5.5 ORGANISATIONAL SET-UP

The types of water management organizations in Indonesia is the organizations with mixed control by farmers and governments officials, where the main irrigation system is managed by 'government officials' while the tertiary irrigation is controlled by 'farmers associations'.

The organization will be successful if the staff has the ability and training to under take the work, understand the responsibilities of this work and is provided with the necessary equipment and facilities to carry out.

The management role of 'Unity of command' each member of staff is responsible to only one supervisor although his function may affect many departments this should be clearly shown in the organization chart in order to inform each employee what authority he has for getting a job done and to help him in understanding the flow of authority in the organization (20).

The whole system of irrigation operation, repair and maintenance can be divided into three main operational areas, namely :

(1) Regulatory, coordinating and advisory role towards provincial irrigation organizations, performed by the 'Directorate of Irrigation'.

(2) Operation and maintenance of primary systems by the 'Provincial Irrigation Offices'.

(3) Operation and maintenance of tertiary system and water management at farm level by the 'farmers' through 'farmers' associations' concerned.

Irrigation O and M Organization chart at Provincial level is shown in Figure 5.5 whereas at section level is shown in Figure 5.6.

The persons selected for management positions of the O and M Organization shall have been properly trained and will be properly compensated to justify the trust placed in them and the responsibilities placed on them for the operation and maintenance of facilities representing an investment a lot of money.

Management personnel will have a good formal education and are to possess leadership ability, be hard workers, willing to assume responsibility and shall be capable. Management personnel will also be well versed in hydraulics, structure design and in construction practices (21).

Operation and maintenance of irrigation schemes are specialised professional posts, for which a substantial background of knowledge is required at all levels. The acceptable qualifications for each level are usually as follows :

(1) Field workers are unskilled labours, their education should be at least elementary school, they have little change of promotion to higher levels.

(2) Skilled labours, their education should be from secondary school. The gate operators, Ditch tenders

Fig. 5.5. IRRIGATION O & M ORGANIZATION CHART AT PROVINCIAL LEVEL

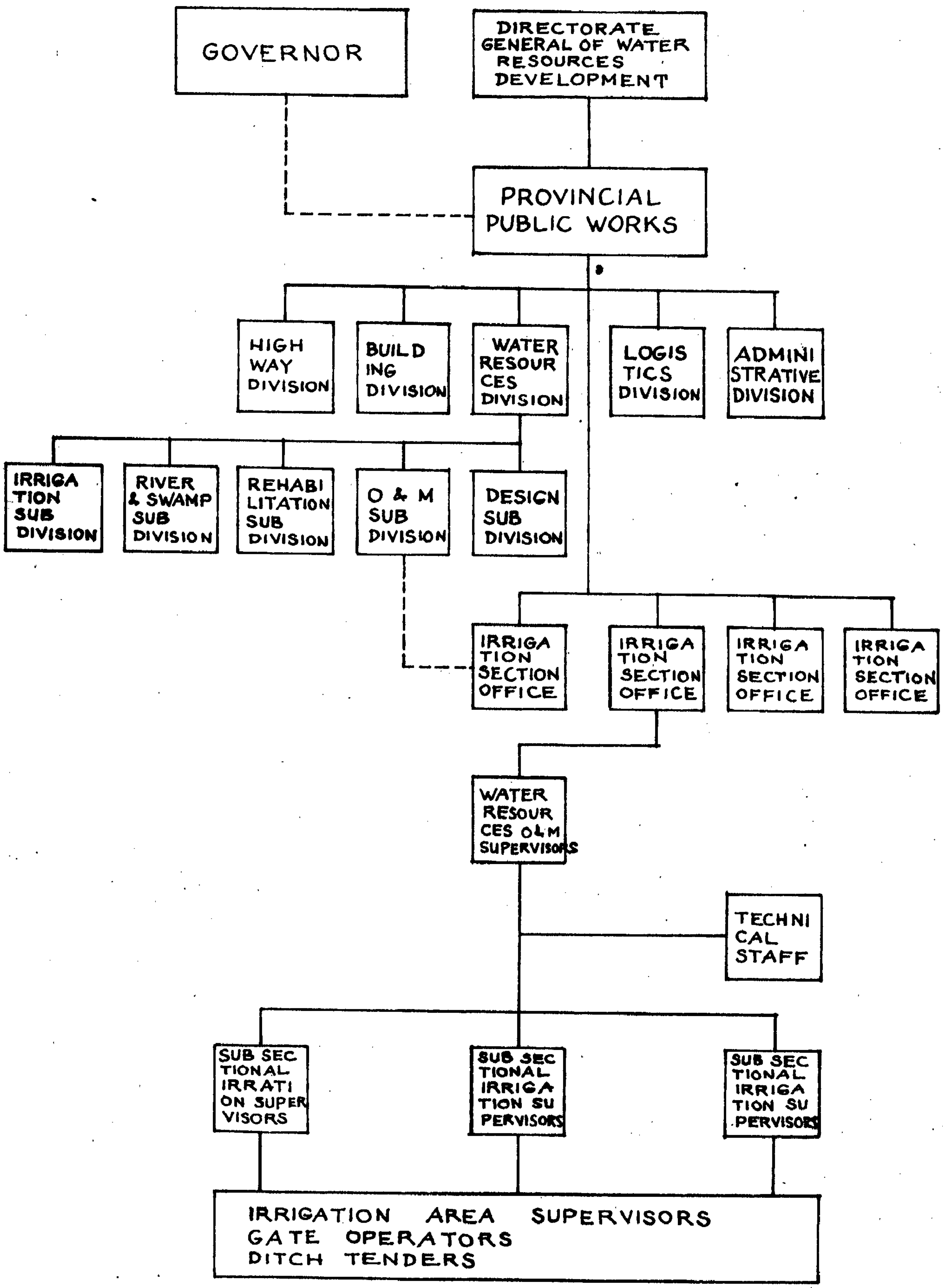
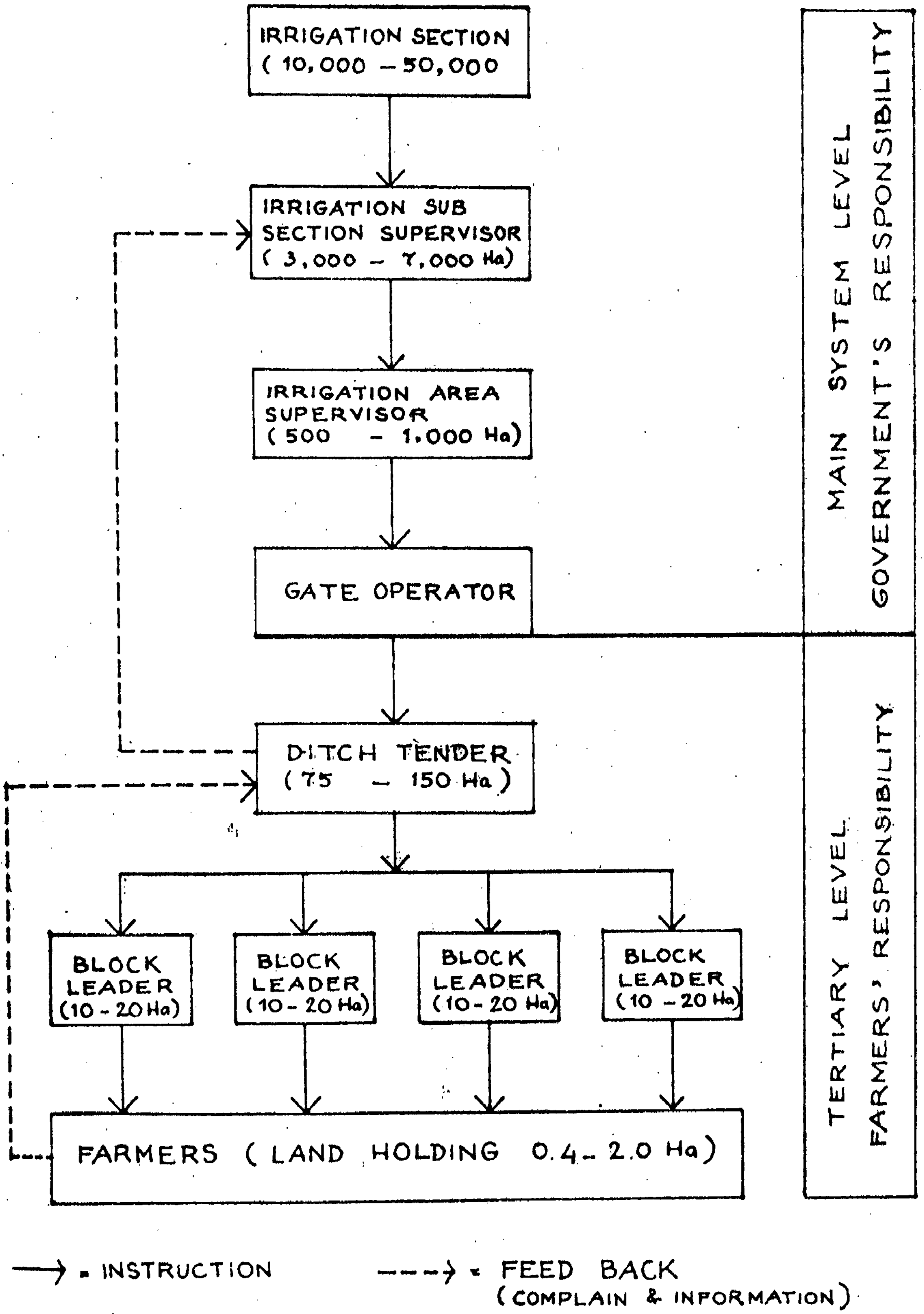


Fig. 5.6. IRRIGATION O & M ORGANIZATION CHART AT SECTION LEVEL



are in this category and they have chance for promotion either as 'Juru Pengairan' (Irrigation area supervisor) or as staff in section office.

(3) 'Juru Pengairan' (Irrigation Area Supervisor) Irrigation area supervisors should be from technical secondary school or secondary school with 2-3 years field work experience and short training. They have opportunities for promotion to irrigation sub-section supervisors on as technical staff in the section office.

(4) 'Pengamat Pengairan' (Irrigation sub-section supervisor) as supervisors, they must have technical high school. Diplomas or high school diplomas with joining a short training and several months work - in section office. During their assignment as 'Pengamat' they may attend special courses which enable them to improve their skills and ability. A promotion to section staff is possible and then a chance to be 3-year engineering course is opened.

(5) 'Kepala Seksi Pengairan' (Chief of Irrigation section office), must have 3-year engineering diploma known as Bachelor of irrigation engineering . Opportunity for promotion to higher level or further training or course is always opened.

For the establishment of a suitable organization and a workable operation system, to ensure the effective use of the available facilities and water resources, the provision of relevant information and guidance is essential. Some of the information is indispensable for the establishment of the organization. However some of them are not likely to be reasonably accurate without investigation over a long period of time. The operation and maintenance engineer should study and understand the criteria used for the design of this scheme. Then the operating criteria of the system must be developed based on this design criteria. Past experience and information from the adjacent areas or similar regions can be utilised in the initial stage of operation. This operating criteria must be revised from time to time based on up-dated feed back information.(15,16,20).

5.5.2 'Juru Pintu' (= Gate Operator) is officer in charge of the proper and timely operation of gates on a Head work complex, canal system, drainage and other related irrigation structures. He operates and maintains his assigned gates according to instructions given to him by 'Pengamat Pengairan'. Normally he is required to live at or near the place of his work, so he can be readily available at all times for needed gate adjustments or attendance to emergencies. The major functions of the position include the following :

(a) Operates assigned gates in accordance with instruction given by 'Pengamat Pengairan'.

(b) Maintains gates in good operating condition.

(c) Checks, takes and records the discharge from the river and canal at 8.00 A.M. and 3.00 P.M. for every day.

(d) Takes and records reading of main gauge, evaporation pan etc. for every day.

5.5.2 'Juru Pengairan'(= Irrigation Area Supervisor) is responsible for the control and supervision of operational and maintenance staff in on area of about 500-1000 hectares of irrigated land. He serves as liason and provides guidance on proper use of irrigation facilities to the water users and the 'Ulu Ulu' who supervise water distribution within the tertiary blocks. The major functions of the position include the following :

(a) Attends to proper operation and maintenance of government irrigation systems in his area with particular emphasis on good water management.

(b) Gathers, collects, records and submits to 'Pengamat' field data on rainfall, canal and river discharges, crops, status of farming activities, etc. needed for efficient operation.

(c) Provides extension services to water users when possible.

(d) Cooperates and coordinates with other government private institutions involved in irrigated crop production.

5.5.2 Pengamat Pengairan (= sub-section supervisor) is responsible for the daily supervision of O and M activities in a sub-section which normally covers an irrigated area of about 5,000 ha. This area may be composed of a single irrigation system, two or more irrigation systems on part of a major irrigation system. He may have under him 3 to 6 juru pengairan and a number of juru pintu, may be pump operators and labourers depending on the area covered by the sub-section. The functions of the position include the following :

(a) Directs and supervises operations and maintenance activities of all government irrigation system within the sub-section jurisdiction.

(b) Plan and direct efficient data collection-recording, processing, evaluation, submission and presentation for decision making implementation of action and for future planning purposes.

(c) Coordinates with government and other offices involved in irrigated crop production for the successful implementation of irrigation programs as approved by Irrigation Committee.

(d) Maintenance records of the irrigation systems within the sub-section.

(e) Submit statistical data to the section office.

(f) Hold a meeting of all 'juru pengairan' in this area at the beginning of every 10 days to discuss the water supply and crop situation.

(g) Make field visits during every 10 days in order to :

(1) Check that recommended discharges are being maintained at some structures.

(2) Check whether the discharge measurement being recorded by 'Juru Pengairan' as well as rainfall data.

(3) Evaluate the water availability during the planting period and the water required by the plants.

(h) Review all the requests of water from each 'Ulu Ulu' and check it with the actual area planted.

(i) Recommend which area are the best to grow dry season paddy and the minimum area to be planted.

(j) Liaise with Agricultural extension workers to co-ordinate the irrigation and agricultural practices.

(k) Liaise with 'Camat' (= the head of Administrative Sub-District) where there are disputes over water distribution canal and structure maintenance or any damage done to irrigation facilities.

(l) In addition to Juru's regular contact with Ulu Ulu, Pengamat should hold a meeting with Ulu Ulu in this area at least once every 3 months to discuss irrigation problems.

(m) Make a written report on state of canals structures and general condition of his area for maintenance programme to the chief of section, including recommendation of any particular repair.

5.5.4 Kepala Seksi Pengairan (= Chief of Irrigation Section Office) is responsible for the management of all operation and maintenance activities in an irrigation section normally covering 20,000 to 35,000 hectares of irrigated land. This include control and supervision of operation and maintenance of all irrigation systems as well as river conservation in the section. The functions of the positions include the following :

(a) Supervises operation and maintenance activities of all government irrigation system within the section.

(b) Provides technical and administrative supervision to all government irrigation employees under the section.

(c) Supervises implementation of field works, related to conservation of all rivers within the section jurisdiction.

(d) Is a member of the irrigation committee and coordinates with other offices involved in irrigated crop production. As a key person in irrigation committee, he must have complete and up to date data so support his proposals for any irrigation activities.

(e) Maintains records of the irrigation systems within the section.

(f) Submits statistical data to the irrigation district office.

(g) Responsible for the calculation and allocation of water to be distributed according to the water availability requests.

(h) Give clear instructions to all Pengamats on water distribution, operation procedures, planting dates programme for maintenance works, steps to be done in emergency during the flood seasons etc.

(i) Direct responsible to the Chief of irrigation provincial (15,16,20).

5.6 WATER USER ASSOCIATION

5.6.1 'Ulu Ulu Desa'(Village Ditchtender)

The responsibility of a village ditchtender is determined by the administrative boundaries of his village and not by the area commanded by a tertiary canal as in the case of canal detchtender 'ulu ulu Vak').

He is responsible for regulating the flow of irrigation water, organizing comunal labour to maintain terminal irrigation facilities, and communicating with their superiors and government officials, especially the village head 'Lurah') and irrigation area supervisor.

Village ditchtenders are usually appointed by 'Lurah' with the consensus of the Head of Administrative sub-District ('Camat').

5.6.2 'Ulu Ulu Vak' (Canal Ditchtender)

The responsible of canal ditchtender correspond to irrigation command areas not to the village area. He is responsible for regulating the flow of irrigation water, organizing comunal labour to maintain terminal irrigation facilities. Canal ditchtender was elected by and directly responsible to the farmers and land owners served by the tertiary system, not to his 'Lurah'.

Canal ditchtender was expected to take technical instruction in improving water management from the irrigation area supervisor.

He is responsible for operation and maintenance in tertiary level and he take charge of the tertiary canal (18).

5.6.3 Darma Tirta

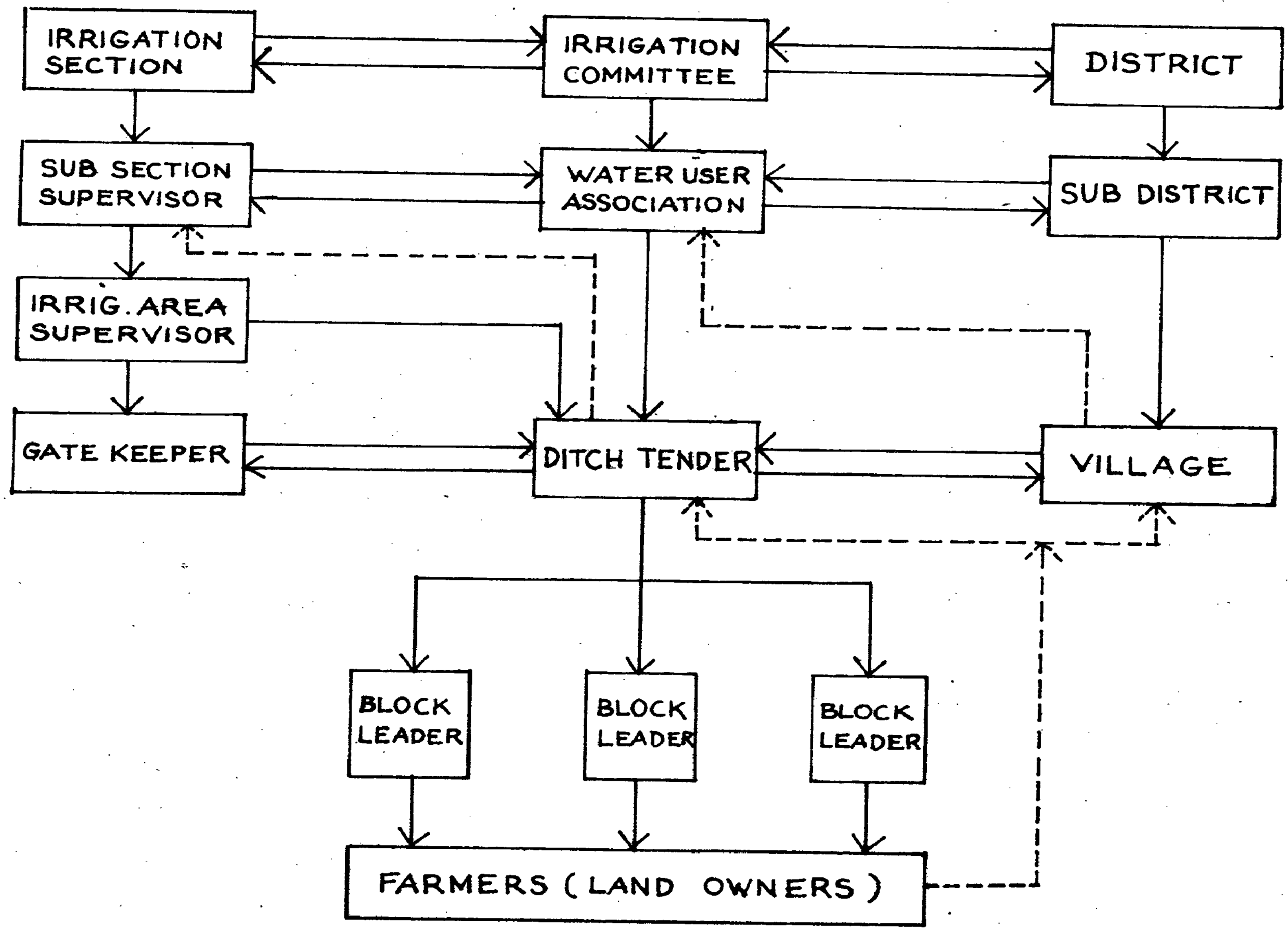
'Darma Tirta' is an organization of water user farmers in Central and East Java. 'Darma' is duty and 'Tirta' is water, therefore, Darma Tirta is a duty to manage the water utilisation as efficient as possible.

Based on the Central Java Governor's decree No.188-1975 Dharma Tirta had been developed in Pemali Comal command area. The purposes are to overcome the irregularity income of canal ditchtender and to encourage the farmers' participation in operation and maintenance of irrigation services, however, the result was not satisfactory.

In the beginning farmers showed a good deal of cooperation, they were honest and obedient, they followed what is the leader said. But there are so many problems such as : lack of leadership, they are illietracy so that they could not keep then along time.

The main problem seems to be the 'lack of leadership'. In order to solve this problem it seems imperative to establish a Water Use Association at 'Irrigation sub-section supervisor'. In this manner a - Water Use Association will cover about 3,000 - 7,000 ha irrigated area. The service of canal ditchtender or village ditchtender which is already working be utilised in the form of a supporting body without disturbing their existence (Fig 5.7).

FIG. 5.7. ORGANISATIONAL CHART OF WATER USER FARMER



CHAPTER VI : STUDY OF IRRIGATION MANAGEMENT IN SOME OTHER COUNTRIES

6.1 INDIA

6.2 THE PHILIPPINES

6.3 TAIWAN

CHAPTER - VI

STUDY OF IRRIGATION MANAGEMENT IN SOME OTHER COUNTRIES

6.1 INDIA

6.1.1 General

Great diversity is a characteristic of India; it applies to natural features such as topography and climate, and also to socio-economic patterns. Irrigation and drainage are no exceptions to the rule of diversity.

In North India the Indo-Gangetic plain has been developed into one of the biggest irrigated regions in the world, fed by snow from the Himalayan mountains and by monsoon rainfall. The plain is lower than 150 m in altitude on the average is 2,414 km long and 250 - 300 km wide, providing extensive fertile land for cultivation. The rivers relating to the plain are the Indus, the Ganges, and the Brahmaputra.

The Rajasthan desert in northwest India is a fertile and promising area for producing good crops by irrigation.

South India provides a high potential for irrigated agriculture and water power, though there are no perennial rivers. In the river basins running to the east and west, gigantic irrigation projects are under way.

In India mostly tropical and subtropical climate, average annual evaporation ranges from 1500 to 3000 mm, average annual rainfall varies from 11,735 mm in Assam to 254 mm in Rajasthan. The average for the whole country is about 1,143 mm (equivalent to two and half of than in Indonesia), where, however, annual fluctuation is low. Most part of the country usually suffer from drought one year in five, which means that irrigation is essential for successful agriculture. In Assam, the exception, drainage is more necessary than irrigation.

General problem that create in this country are as follows :

(1) Reservoirs in big irrigation projects are suffering from heavy silting which decreases storage capacity two or three times faster than was estimated, so soil erosion control is essential.

(2) Due to the large surface area of water in reservoirs, evaporation is tremendous.

(3) Irrigation unaccompanied by drainage has caused damage to crops in the form of waterlogging and salinization, so it is necessary to survey in detail the ground water in irrigated areas.

(4) In canals conveying water from a reservoir, water weeds can easily grow if there is no silt in the water. If

there weeds are not controlled, the effective capacity of the canals will decrease.

(5) Terminal supply ditches having less than 3 ft^3/sec or equal to 85 ℓ/sec capacity have been constructed and maintained by farmers, but this program has not been carried out effectively. The modernization of water management is becoming an urgent problem in India.

(6) Water is wasted because of the widespread use of the continuous method of irrigation. Farmers need to learn the proper use of water and to understand the harmful effects of over irrigation.

(7) Major and medium projects are administrated by the Irrigation Department of the Central Government, whereas minor ones are taken care of by various national and local government agencies, resulting in some confusion over administration of water management at farm level.

6.1.2 Administration of Irrigation and Drainage Works

Ministry of Irrigation, at the Centre is responsible for the policy for development and regulation of the country's water resources, coordinating, synthesing monitoring statewide irrigation programmes. The major and medium new irrigation works are required approval by the National Planning Commission. The Ministry of Irrigation and its technical adjunct the Centre of Water Commission examine the schemes from engineering economics and allied aspects and recommended them for acceptance by the Planning Commission. Central organizations like the Central Water Commission function largely as planning coordination, design and research.

The State Irrigation or Public Works Departments are in charge of irrigation works have a long experience in water resources for irrigation and other use. They have generally in built specialisations in the fields such as : planning, design, research, operation and maintenance of irrigation works. Their specialist skills are supplemented by the expertise available at the central level, at all stages of project formulation and implementation.

The State Agriculture Departments are responsible on field jobs such as soil surveys and promoting suitable cropping pattern and provision of other inputs like fertilisers and good seeds. During the stage of development of irrigation facilities created. Other Government like Revenue and Cooperation have also to play their roles. As the work of providing on farm - development and infrastructure facilities is multi-departmental and multi-disciplinary in nature, integrated 'Command Area Development Authorities' are also being set-up now-a-days for large projects.

6.1.3 Irrigation Water Management

Irrigation Facilities

India is surely one of the most prominent countries in the world in sector of irrigation, in both scale and diversity. In this country both surface and ground water are used for irrigating large tracts of land. According to present estimates there is a potential to irrigate 73 million hectares of cropped area from surface water and 40 million hectares from ground water.

A. Surface Irrigation Schemes

The irrigation schemes utilizing surface water resources can be further classified into :

(a) Diversion works including lift irrigation

(b) Storage works

(a) Diversion works including lift irrigation

Streams with dependable flows are harnessed by way of constructing diversion works across them which consists of (1) a weir or a barrage to raise water level, (2) a canal taking off above the weir, (3) auxiliary structures such as head regulators, by means of which the quantity of water admit'ed into the canal is limited and controlled, scouring sluices and other protective works sufficient to secure the weir from being out flanked by floods in the stream.

In case of lift irrigation schemes water is lifted through a pumping station of permanent nature or on floating barrages depending upon the flow characteristic of the river, and then irrigation is done by gravity canal system.

(b) Storage works

Storage works, on the other hand, impound a reservoir of water and consists of :

(1) A dam which upholds water on its upstream side.

(2) One or more supply sluices through which irrigation water is drawn.

(3) Surplusing arrangement to pass-of any flow in excess of what can be safely impounded.

In the northern part of India comprising rock and fertile Indo-Gangetic alluvium plains, all the big canal systems like Ganga Canal, Sarda Canal, Kosi and Gandak Canals are purely diversion schemes.

Only in case of Punjab and Haryana the canal system has now been backed up by storage reservoir like Bhakra and Pong. In case of Uttar Pradesh, there is only one storage dam on Ramganga River Contrary to this in the southern part of this in the southern part of this country practically all the irrigation schemes are of storage type because the rivers are now snowfed and therefore non-perennial.

B. Ground Water Schemes

In respect of ground water, the schemes are very small nature like dug wells, shallow tube wells and filter points, bore wells and deep tube wells. Except for the deep tubewells which are owned and operated by Government, all the other types of Ground Water Irrigation Works, are owned privately by individual farmers. The privately owned Ground Water Schemes generally have a command area varying from 1 ha to 4 ha whereas a deep tubewell commands an area varying from 40 to 100 ha. The distribution system comprises open channels or under ground pipes (23).

Water Delivery System Under Surface Irrigation Projects in India :

Systems of water delivery within an outlet command area can be classified into three groups :

(a) Rotational delivery.
(b) Continuous delivery
(c) Delivery on demand.

(a) Delivery by rotation

Rotational method of irrigation [Warabandi or Osrabandi or Shejpali] allows for delivery of water to all the farmers within an outlet command area according to their entitlement. It also facilities application of water in large streams thereby reducing the time required for irrigation. Irrigation efficiencies can be increased if management is efficient.

During the rotation period each farmer in the outlet command area receives water delivered at a discharge fixed for the rotation but the period allotted to him varies according to either the irrigable area of his farm or cropped area to be irrigated.

The practice of allocation of fixed period each week for application of water calculated on the basis of area of farm irrespective of crops grown is called 'Warabandi'. This system is in use in many parts of North India (Punjab, Haryana, U.P., Bihar and Rajasthan). In many parts of South India(Maharashtra, Karnataka, Gujarat), the system of distribution of water is also rotational but the period of allocation of water is based on cropped area sanctioned for irrigation.

For successful operation of rotation system, the capacity of irrigation network should be such as would accomodate flow required for peak water either rotation period should be adjusted on cropping pattern and crop calender altered.

In 'Warabandi' system practiced in many parts of North India, supply of water according to variations in climate, soil and crop is somewhat difficult. But the management of water delivery is simpler. In the rotation system practiced in the South India, closer control over supplies of irrigation water according to variations in climate, soil and crop are to some extent possible. At the same time, water delivery is more complicated. Equitable and assured supply of water according to a set pattern of delivery is possible in both the cases.

On the basis of sanctioned area (as in the case of North India) or sanctioned areas for a particular crops (South India) within an outlet command area, duration of the rotation and the discharge at which water would be delivered should be fixed for each outlet. This can be done in relation to the peak water demand. For variable water demand, either the period of water delivery or discharge at which water is delivered may be changed. Thus to allow for a variable water demand, the discharge can be varied but the scheduling kept constant (i.e. day on which water is made available to individual farmer)or discharge can be kept constant but the scheduling can be varied. An alternative way of varying the scheduling is to skip one or two rotations completely. If the discharge is to be varied, the opening of the gates needs to be adjusted.

If by skipping one or two rotations, the soil moisture does not get depleted below permissible limit for crops, keeping constant discharge and fixed schedule will be convenient from operational point of view. This is practised in North India. If the skipping of the rotations is going to create conditions of moisture stress that would reduce crop yield, farmers should either have a supplemental source of irrigation (like tubewell) or scheduling should be readjusted.

When the above method is not feasible, a fixed discharge but lower than that for the peak (say two thirds or one third) may be kept during the rotation period and the scheduling designed the lower discharge so that interval between successive irrigations is not large. It is not obligatory that the rotation to the irrigated crop area and the discharge.

When scheduling is not varied during the crop season, it should be fixed in relation to the peak water demand. Depending upon the crops and cropped area, this period may be 7, 10 or 14 days. If the discharge for the outlet for a peak period is 30 ℓ/s, when demand is two thirds can be 20 ℓ/s and for one third demand it would be 10 ℓ/s and so on. Time required to irrigate the field will be more when the discharge is less but since the demand is also less, total period required to irrigate will remain within allowable limits. Variation of discharge should be lower than 15 - 10 ℓ/s.

When the discharge during the rotation schedule or schedules is fixed, the time of allocation of each farmer will depend on the cropped area to be irrigated. Since water allowance in litres/second/hectare can be computed, for a predetermined discharge at which water will be delivered at the outlet, time (t) in hours allocable to each farm will be :

$$\frac{\text{Rotation period (in hours)} \times \text{farm area (in hectare)} \times \text{water allowance } (\ell/s/ha)}{\text{discharge } (\ell/s)}$$

The time allotted to tail end farms should be adjusted according to the conveyance efficiency of water course with a view to give slightly longer time to tail end farmers to compensate them for water loss due to conveyance in the water course. Also, while computing the total time required for irrigating outlet command area, the total required for the discharge to fill the water course should be taken into account.

To deliver equitable irrigation supplies to the farmers according to water demand of crops, position of the reservoir storage and supplies made in relation to the demand should be periodically checked. When demand is more than what can be met with, proportionate reduction in the allocated time for irrigation should be made.

Allocable time per hectare to individual farmers within an outlet command area can suitably be adjusted by relating it to permissible water scheduling depending on types and variety of crops, depth of root zone, stage of crop growth and soil but for making such variations farmers should be taken into confidence.

(b) Continuous delivery :

To large concentred cropped areas such as those held by trust or large cooperations, delivery of water can be done continuously instead of by rotation. Where the farmers are few and the supply is more than the demand (as in the rainy season) the system can be used efficiently if proper drainage at the farm level is ensured. Water so supplied on a continuous basis can be redistributed to different fields according to the soil and condition of crop. Operation of the canal under continuous flow is simpler if the canals are small in length and water level is maintained at designed level above the outlet. This method is not suitable when the size of holding is small and irrigation water is to be supplied to a large number of farmers within an outlet command.

Under the system, though each farmer can receive his supplies continuously he may use his share of water intermittently according to the requirement of the crops. The channel should, therefore, have a number of escapes to dispose of surplus water in the channels when the demand for water is less than anticipated.

(c) Delivery on demand :

The method allows a farmer to have supply of water according to his needs but limited to the capacity of the conveyance system.

When water rates are based on volume of water supplied and the cost of water is high, demand method is preferred as it enables use of water economically and more closely according to the crop requirement. During peak demand, when the system cannot supply water continuously to all the farmers according to their requirements, the demand method can still be adopted but in a modified form by introducing rotation.

For the rest of the irrigation season, however, rotation system should be adopted. This system is not generally suitable for most parts of India as it requires a large contingent of well trained staff for operation. During the land preparation and transplanting period of paddy demand method has an edge over other methods when large flows for short periods are required and the demand of each outlet cannot be foreseen and the area under paddy is only a small percentage of the total area.

(d) Rotational planning :

The following steps should be followed while planning for rotational distribution :

(i) For each outlet minor, distributary, branch and main canal, ascertain from the project report the maximum water allowance in ℓ/s/ha of irrigation area for which the system is designed.

(ii) Modify the above value on the basis of actual conveyance capacity and use the modified value as the peak duty limited to the designed peak value for further computations.

(iii) While sanctioning crops for irrigation under an outlet/ minor the peak water demand should not be allowed to exceed the above (modified) value for a minor. Also, total quantity of water should be within the value for a minor. Also, total quantity of water should be within the water allowable for the respective conveyance channels. Within these stipulations, changes can be made in the cropping pattern for each outlet.

(iv) The water allowance computed (ℓ/s/ha) will be the highest at the head of the main canal and lowest at the outlet because of conveyance losses in the system e.g. if water allowance at main canal head is 0.75 ℓ/s/ha and conveyance efficiency at outlet is 80 percent the water allowance at the outlet will be 0.60 ℓ/s/ha. This means that if at the outlet water is released continuously at 0.60 ℓ/s/ha, per hectare of irrigated land the farmer will receive supplies at 0.60 ℓ/s. For a discharge of 0.30 ℓ/s area irrigated in a rotation schedule will thus be 50 hectares. If the outlet are run in a rotation sequence of 7 days such that water is delivered continuously for 7 days and the system is closed for 7 days area that can be irrigated during the rotation schedule of 14 days will be 25 hectares.

(v) The lands may be irrigated turn by turn in a rotation sequence, keeping the same discharge (30 ℓ/s in this case). If the outlet are run continuously for 7 days, the turn for irrigation will come once in 7 days. If they are run in alternate rotation (7 days running, 7 days closure) the turn for irrigation will be once in 14 days.

(vi) Moisture level in the soil for any day is the moisture level on the previous day plus effective moisture from rain or irrigation minus current day evapo-transpiration. The moisture level at the time of irrigation should not be lower than the moisture depletion level at which the crop should be irrigated to get optimum yield. The rate of depletion of moisture depends on atmosphere (solar, radiation, maximum and minimum temperature, effective rainfall etc.).

(vii) Effectiveness of rainfall is dependent on soil type, intensity and duration of rainfall and soil moisture preceding the rain. How much irrigation should be given depends upon moisture depletion level and irrigation efficiency as determined by infiltration rate, available discharge runoff, method of application of water and how well on farm development has been done.

(viii) The gate openings of the outlet should be adjusted to give a constant discharge at 10, 20 or 30 ℓ/s during the rotation period. However if any alteration is needed, it should be done by the canal inspector for the next rotation period but such a change should be communicated to the officer in charge of minor/distributary.

(ix) Before the beginning of the first rotation of the irrigation season or at the end of the second rotation, when sufficient data on land use is available, date and time of allocation of water to every farmer within an outlet command should be decided for all future rotations on the basis of land use pattern for irrigated crops and the farmers intimated well in time.

(x) The data on land use pattern for sanctioned irrigable crops should be furnished by canal inspectors every fortnight to sectional officers who should complete the data and issue directions to the canal inspectors on pattern of water releases and quantity of water to be used during each rotation in the fortnight.

(xi) There may be one or two rotations during which water requirement will be at the peak value. Normally it is convenient to fix rotation schedules outletwise for the peak period and adjust the scheduling for other periods by changing the discharge or changing the period of irrigation. The schedule of irrigation and gate openings of outlets should not be changed by the canal Inspector during the peak rotation period without prior authorisation by the sectional officer. Unauthorised irrigation during this period should be dealt with stringent punitive measures.

(xii) Once the water is released to the water course by or at the instructions of the canal Inspector, the responsibility of irrigating the lands in accordance with approved schedules will be of the common irrigator whose work will be subjected to constant supervision by the canal inspector. He will however not be allowed to operate gates except during emergency when the matter would need to be reported to the Canal Inspector immediately after the latter reports for duty. The responsibility of opening and closing the gate will be of the Canal Inspector or the Gateman acting according to the directions of the Canal Inspector.

(xiii) Water will be delivered to the water course at the outlet point every 7 days (or 10 days) or multiple of 7 days (or 10 days) but the period required for the moisture level not to go below predetermined moisture depletion level (normally 50 percent of available moisture) will be dependent on crop, soil and climate.

(xiv) In order to synchronise within practical limits of canal operation the day on which predetermined moisture depletion will be reached with the day scheduled for irrigating the land, certain flexibilities in operation are necessary.

These can be provided in two ways :

(1) By adjusting gate openings and regulatings the stream size to say 10, 20 or 30 ℓ/s.

(2) By keeping one (or even two) of the 7 days rotation period as free day for carrying out adjustments in the rotation schedule.

(xv) This can be done by fixing the command area under outlet on the basis of 6 days (or 9 days) rotation and keeping the free day to meet the situation arising out of non-supply of irrigation water on fixed days within the rotation schedule to entitled farmers, or because of the requirement of more frequent supply of water due to lands being of shallow depth or to meet greater demand of high water consuming crops.

(xvi) There should be strict vigilence to ensure that the free day is not used for unauthorised irrigation. Indirect control can be exercised when a canal Inspector is allocated a fixed quantum of water during the crop season and water supplies released for him are measured.

Equity in Supply of Irrigation Water to Tailenders:

Conveyance losses due to seepage and operational are gradual increase during the conveyance of water from top(head) to tail end of the water courses, the quantity of water delivered to the farmers at the tail end per unit time is proportionately smaller than to the top end (head reach) farmers Also the supply of water remains uncertain for most of the tail end farmers. For maintaining the same quantum of flow per hectare to the farmers irrespective of the location of their farm in relation to the outlets either the losses should be reduced by lining the water courses or proportionately higher time to the tail end farmers should be given to compensate them for the conveyance losses. The alternative of lining is normally convenient through capital cost or its recovery from the farmers based on the field study of conveyance losses, will ensure equitable supplies to all farmers irrespective of the position of his field in relation to source of supply.

Use of Siphons for Delivery of Water to the Fields :

Use if siphons for delivery of water to the fields from the water courses is advantageous in ridge and furrow irrigation and where soils to be irrigated are highly eordible.

Siphon irrigation is also useful when other systems of irrigation are used (basin, border, strip etc.). Farm turn-outs and distribution boxes are not required when siphons are used.

The siphon should be sufficiently long, durable and suitable for priming. There should be two sets of siphon pipes. While one set is used for irrigating the fields, the common irrigator can adjust the other set in the next field ready for use for irrigating the field after the irrigation of the first field is completed.

The extra loss of head in siphon irrigation, usually of the order of 3 cm should be compensated for by raising the bed level of water courses by 3 cm.

Running of Minors and Distributaries :

The minors and distributaries delivering water to the outlet can be either run continuously or on a rotation schedule. Lower half of a minor may be run for the first half of the rotation period to supply water to the outlets located there, while the outlets in the upper half are kept closed. During the latter half of the rotation period, upstream half of the minor could be operated. When the minor and distributaries are operated in a rotation sequence, their conveyance capacities would be bigger than when they are run on a continuous basis. Since part of the minor would be run for a shorter period seepage losses will be somewhat lower (but not very significantly) than when they are run continuously. In a lined system, however, there is no particular advantage of running the minors and distributaries in a rotation sequence (if the objective is to reduce only the seepage losses). However when the system operates in a rotation sequence, longer time is available to carry out repairs to the conveyance system if lower half of the conveyance system can be properly maintained during the closure period. The upstream half of conveyance system can be maintained when the system is shut down for repairs or when different minors and distributaries are run on a rotation schedule instead of operating them in part length on a rotation sequence.

In Northern India, distributaries and minor are usually run with full design discharge to provide design head at the outlets for supplying irrigation water according to the entitlement of the farmers. During lean periods of supply, when it is not possible to run all the channels with design discharge simultaneously, channels are run in roster according to the availability of water.

For distribution of irrigation water, every minor should be treated as an independent unit for planning. Though for proper management of water, it is preferable to have a uniform cropping pattern in a crop season for the command area under outlets serviced by a minor, in practice, it may not be possible to achieve a uniform cropping pattern. In such cases, sowing of crops in the command area serviced by the minor should be adjusted through extension work and advance planning would enable supplies to outlets to be as uniform as possible. This would require the farmer to be given advance information about releases of water to enable him to adjust dates of land preparation and sowing.

Irrigation from Tail End to Upper Reaches :

Irrigation should be done from tail to upper end of the minor/distributary as it helps to :

(1) Introduce rotational irrigation on the minor/ distributary.

(2) Reduce seepage losses in the system because of rotational system of supply.

(3) Ensure equitable supplies to tail end farmers who do not get assured supplies when there is shortage of irrigation water. It also enables tail end farmers to plan sowing ahead of farmers in the upper reaches.

The soil moisture storage at the end of 'kharif' crop season is likely to be more favourable in the lower reaches, therefore, under some situations enables farmers to have first irrigation in fair weather season or even raise a fair weather crop purely on residual soil moisture. This is decided advantage under some 'tank' irrigated systems which stores water only for kharif use.

Operation of Canals and Branches :

In arid and semi-arid areas, equity considerations require spreading the benefits over a very large area and it, therefore, becomes necessary to conserve water in an optimal way. This can be done by having higher irrigated crop intensity in rainy season than in Rabi season and higher in Rabi season than in the summer season to reduce evaporation losses. When water resources are limited it is advisable to run the irrigation system for 8 or 9 months in Kharif and Rabi season only. Sanction to perennial crops can be done on seasonal basis and farmers forced or persuaded to supplement surface water by ground water for taking to perennial crops.

System operational losses are lower in continuous operation than in rotational operation of the system. Seepage losses on the other hand do not increase significantly in continuously operated system because in unlined channels seepage losses are excessive during the initial and subsequent filling of the canal (e.g. on opening the canal and after closure) and they gradually reduce in time and remain nearly constant after the flow is stabilised.

Since the initial rate of seepage loss is far greater than subsequent rate after the flow is stabilised, there is no appreciable saving in seepage losses by closing the canal after every rotation as is the practice in some Southern States. Because of higher operational losses, the net effect could be an overall increase of irrigation losses.

Moreover fluctuations of water level in the canal, inherent in the adoption of such practice, disturb the canal slopes. In the case of lined canal, the lining gets disturbed if the depletion of canal water level is not done gradually.

The requirement of gradual filling and more gradual depletion makes the operation difficult without giving correeponding advantages. The time available for maintenance can be carried out properly nor there is appreciable saving in losses (24).

Organizational Set-up in Warabandi Area

The Warabandi system the distribution water is carried out by keeping the stream of water as constant and regulating the time of its flow. The entire time in a week is allocated to farmers. Time once lost can not be regained. So if for any reason a farmer is unable to receive his share of water, this system provides no method of compensating him for such a loss as there is no unallotted time. Similarly if the flow of water is less than the authorised for some technical defect somewhere, the loss suffered on this account too, can not be compensated. It, therefore, becomes necessary that distributaries and watercourses must not only flow as programmed but must also flow with their designed supplies. This underlines the importance of having a vigilant, well knit and disciplined organization, capable of making the system work with clock-like precision by maintaining a high level of maintenance control and monitoring (25).

There are two types of establishments i.e. engineering and revenue and both work under a single command. The engineering, establishment is responsible for the maintenance and operation of all works relating to main canals, distributaries and outlet (head of watercourse). The revenue establishment is responsible for correctly recording the area irrigated and the preparation of water bills for individual farmers and passing on the same to District Collector for realisation. In addition, it helps in deciding all disputes and conflicts of watercourses and transfer of areas from one outlet to another. It is none of its functions to monitor or to oversee the distribution itself which is left to the farmers themselves.

The administrative unit is known as a Division. It is headed by an Executive Engineer, who is a middle level officer. He is ex-officio Divisional Canal Officer under the Canal Act. An average division has 70,000 hectares of culturable command area.

A Division comprises 3 or 4 sub-divisions, each headed by a Sub-Divisional Officer, who is the junior most officer. A Sub-Division may have 3 to 4 Sectional Officers to help him.

For the revenue work, a Sub-Divisional Officer is assisted by 2 to 3 Zilledars and each Zilledars is assisted by 10 or 12 Irrigation Booking Clerks. Each Division has one Deputy Collector who supervices the work of Zilledars in a Division. Figure 6.1 shows an organizational chart in Warabandi Command Area (25).

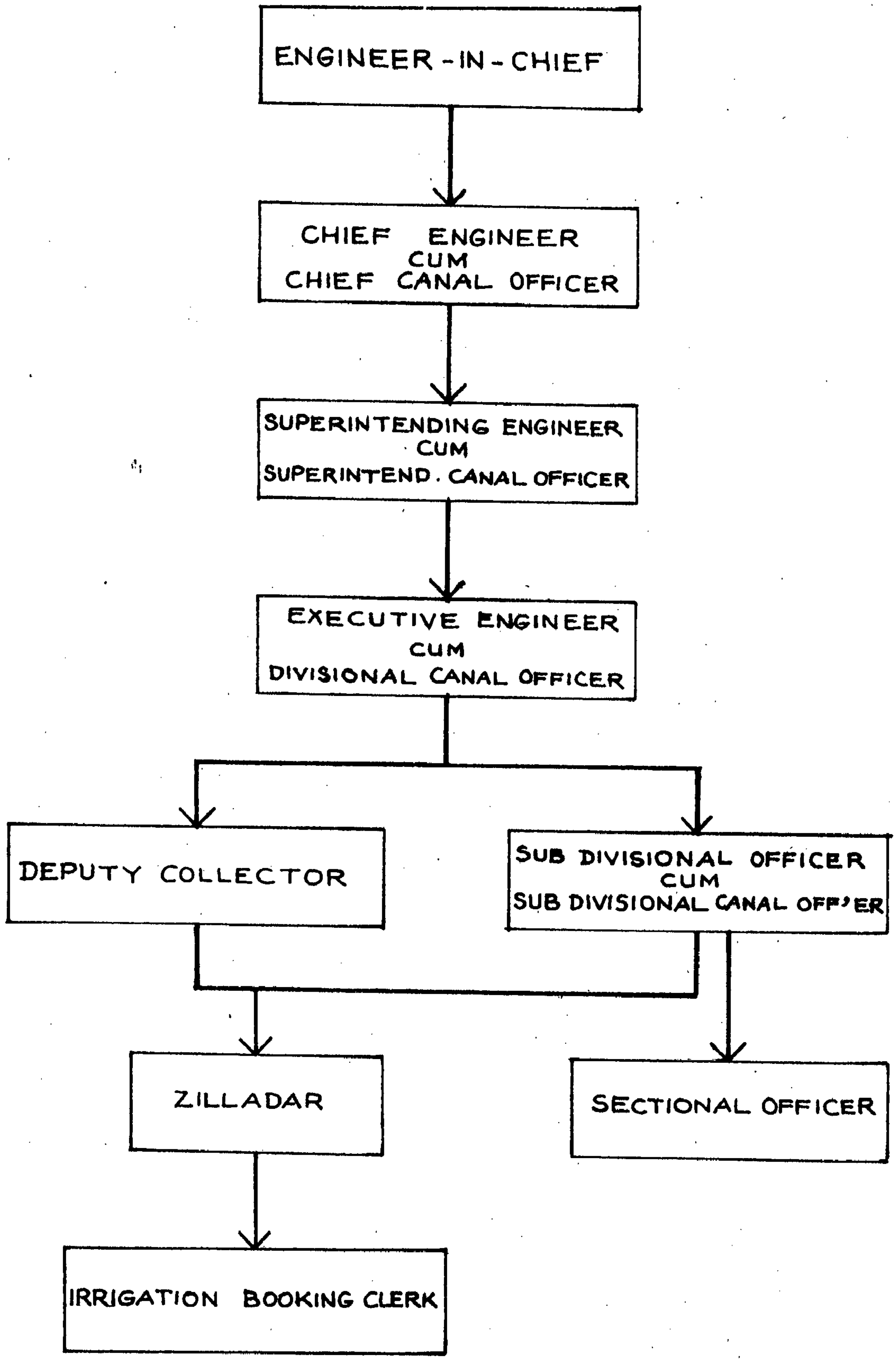


Fig. 6.1. ORGANISATIONAL CHART IN WARABANDI COMMAND AREA

Management of Water Distribution in Warabandi Command Area :

Before a farmer can receive his share of water, he must spend some time filling up his water course between the point of his taking over and the beginning of his holding, which is also generally the point of his handing over. This time is called Bharai. Its value in good soils in four to five minutes per killa (67 m). This debited to the common pool time of 168 hours and credited to the individual accounts of each farmer as shown below.

The cycle of turns on a watercourse of its branch starts from its head, proceeds down wards and. ends at its tail. The supply has to be cut-off from the head when the last farmer is having his turn. The length of upper portion which has been filled with common pool time (Bharai) can be discharged only into his fields and normally the total time spent on its filling should be recovered from him in lieu of this, but he doesnot receive all this water at a constant rate. When the supply is cut-off from head, it starts depleting at tail and gradually approaches zero. Such a supply beyond a limit is not efficient from the point of view of field application. He needs to be compensated for it and this is done by allowing him a certain discount on the recovery Bharai time. The discounted value of Bharai is known as Tharai. Its correct determination is unresolved problem and has not been studied in depth. Its present day values are very favourable to the best farmer and hence there is always a big scramble for being declared as the last. Jharai is credited to the common pool. After allowing amendment for Bharai and Jharai the flow time (F.T.) for unit area and for an individual farmer are given below :

Flow time for a unit areal (F.T.)

$$= \frac{168 - \text{Total Bharai} + \text{Total Jharai}}{\text{Total Area}}$$

Flow time for a farmer

= F.T. for unit area x his area x his Bharai - his Jharai point from the head is usually restricted to about three kilometers, where as in steep topography, the distance may be as short as 0.5 kilometer.

For equitable distribution of water some allowance for absorption in different points of a watercourse, shall have to be made. Depending upon the rate of absorption and the degree of accuracy required the length of a watercourse should be divided into 3 or 4 zones and the actual discharge available in each zone measured. The ratio of the nominal discharge to the actual may be determined for each zone and may be called as Chusal for the zone. Its value shall always be one or more than one. Also determine the areas which are served through nakkas in each zone a_1, a_2 and a_3 ..... are the areas and c_1, c_2 and c_3 ..... are the chusai factors for different zones, then the equations for unit flow time and time for each farmer shall be changed as below :

(i) Flow time per unit area (F.T.) =

$$\frac{168 - \text{Total Bharai} + \text{Total Jharai}}{\text{ac}}$$

(ii) Flow time for each farmer =

F.T. for unit area x his area x Chusai for his zone + his Bharai - his Jharai

These equations hold good for the totally unlined as well as the lined watercourses. In the latter case the zone should be formed that the end of lining is also the end of a zone. Chusai factor for lined portion will be very close to one. This method of preparing the roster reflects this absorption loss and can do full justice to the farmers in the unlined reaches of partly lined watercourse.

6.2 THE PHILIPPINES

6.2.1 General

The Philippines is composed of more than seven thousand islands. A year-around hot climate is characteristic of the whole archipelago, though there is variation in humidity between the China sea side in the west and the Pacific ocean in the east. The durability and intensity of rainfall are the most striking in the world. In Baguio, Luzon, 1,168 mm of rain was recorded in one 24-hour period 14 to 15, 1911. The average annual rainfall in the whole country is 2,530 mm. Accordingly the need for irrigation is not severe, especially in the wet season, but, because the rainfall is often very irregular, supplementary irrigation is needed to increase the paddy yield, and in some islands it is almost a necessity due to aridity area.

The main irrigated crops in Philippines are paddy, sugarcane, bananas, vegetables and other fruits.

Three major irrigation problems are being studied :

(1) Water weeds and silt deposits in canals cause severe troubles in operation and maintenance of the canals.

(2) Water leakage in canals is serious problem, lining is now being added to canals where sandy soil causes most damage.

(3) Water charges are not being effectively collected from farmers (22).

6.2.2 Administration of Irrigation and Drainage Works

The National Irrigation Administration (NIA) was established in 1963 and now in charge of all irrigation and drainage.

NIA is a 'single governmental agency' which has scope of works among as follows :

(1) To investigate and study all available and possible water resources in the Philippines, primarily for irrigation purposes.

(2) To plan, design, construct or improve all types of irrigation projects and appurtenant structures.

(3) To operate, maintain and administer all National Irrigation Systems.

(4) To supervise the Operation and Maintenance and Repair or otherwise administers temporarily all communal irrigation systems constructed. Improve and repair wholly or partially with government fund.

(5) To delegate the partial or full management of National Irrigation Systems to dully organize cooperatives.

(6) To charges and to collect from the beneficiaries of all irrigation systems constructed by NIA irrigation fees.

(7) To construct multipurpose water resources project designed primarily for irrigation, for hydraulic power development and other uses as flood control, drainage and reclamation domestic water supply.

(8) To investigate in coordination with the Bureau of Public Works, unproductive or less productive areas and to plan, design and construct drainage facilities and protective works for agricultural purposes to maximize their productive yield.

The National Irrigation Administration Chart can be seen in Figure 6.2.

In line with the implementation of irrigation development projects which are integrated, a National Committee was organized in the top management level to coordinate policy and

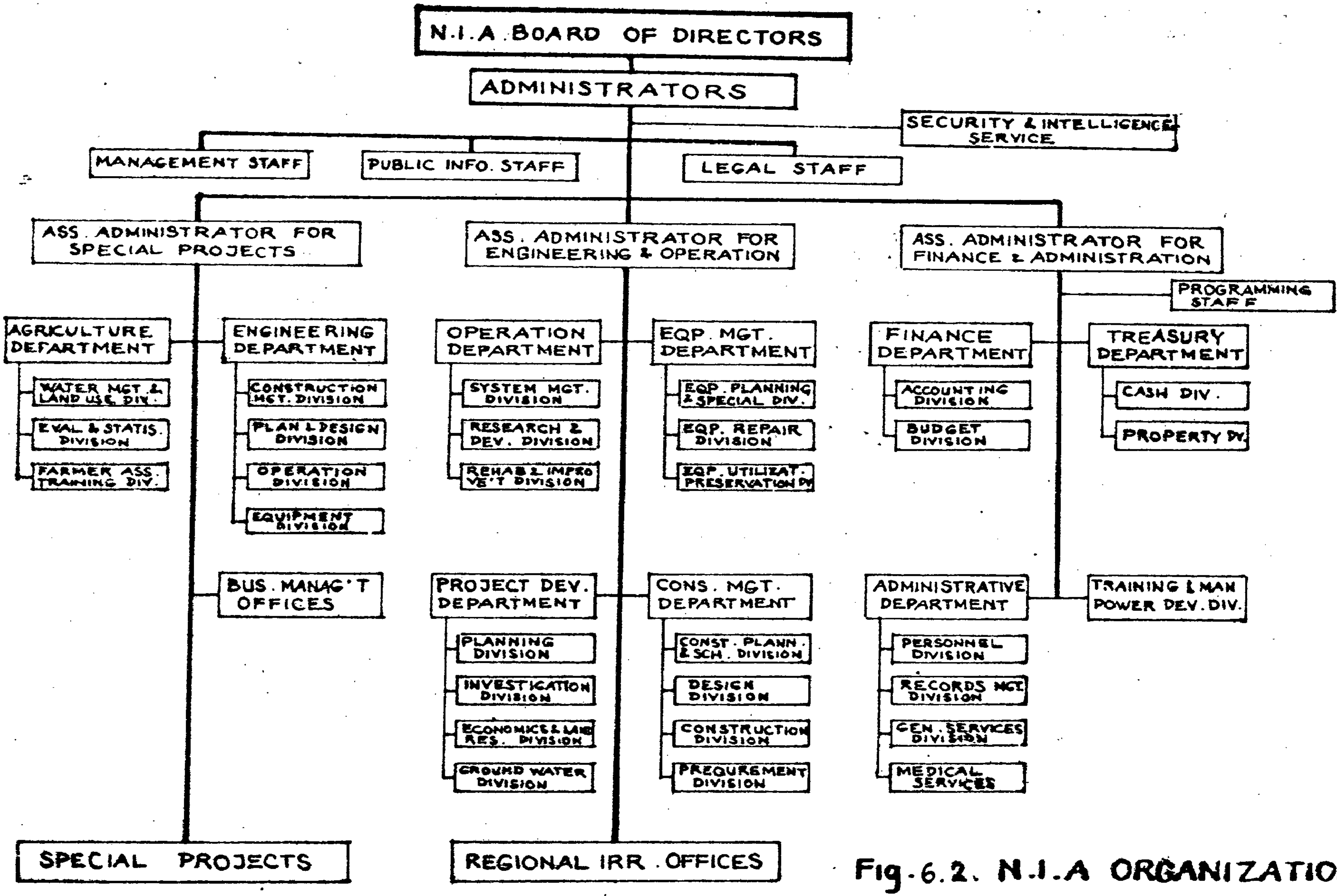


Fig. 6.2. N.I.A ORGANIZATION CHART

cooperation among government agencies involved in agricultural production. The Chairman of this Committee is the representative from NIA and members from concerned ministries and other development entities : Ministry of Agrarian Reform, Ministry of Agriculture, Ministry of Natural Resources, the National Food and Agricultural Council, the Ministry of Local Government and Community Development, the National Economic Development Authority, the Lending Institutions represented by Central Bank, Rural Banks Association of the Philippines, Agricultural Credit Administration and the National Grains Authority.

The participation of each department/agency in the implementation of the project's Agricultural Development Programme is as follows :

(1) NIA, the executive agency is involved in the construction of infrastructures, formulation and implementation of the project objectives and operation and maintenance of the system.

(2) The Ministry of Agrarian Reform is responsible for the conversion of tenant-tillers into owner cultivators pursuant to Presidential Decree No.27.

(3) The National Food and Agricultural Council is responsible for implementing various agricultural production programmes in each project area.

(4) The Ministry of Local Government and Community Developments is responsible for formulating guidelines and supervising the organization of compact farm associations and irrigators groups.

(5) The Rural Banks Association of the Philippines and Agricultural Credit Administration are responsible for extending credit for agricultural production in the project area.

(6) The National Grains Authority facilitates marketing and acts to stabilizes prices for rice and other cereal crops.

6.2.3 Irrigation Water Management

Irrigation facilities :

Most of irrigation systems in the Philippines are of gravity, run of the river or diversion type. Other types include the reservoirs, communals and pump systems are managed by the NIA, Farmers' associations and Farming Systems Development Corporation (FSDC).

Currently, the upgrading of existing irrigation systems and cooperations of new ones, based on modern irrigation designs, are the two major thrust of the Philippines government in boosting agricultural production. The major concern of the NIA regarding existing irrigation systems is to improve systems efficiency through good system wide irrigation management.

Based on the chronology of events, the two types of National Irrigation Systems, common in the Philippines are the old systems or 'Traditional Irrigation Systems' (TIS) and the newly constructed or 'Improved Irrigation Systems' (IIS).

Many of the old gravity irrigation systems in the country were constructed in 1930s or before. The primary features of the TIS include the diversion dam and the distribution canals with structures for road crossings, checking structures, inverted siphons and unregulated turnouts up to the farm level.

Diversion systems were generally built to guarantee enough water for the wet season (June - October), and provided only limited water for dry season cropping. After the turnout, water flowed without measurement from one farm to the next, from paddy to paddy, according to the relative elevation of the land. Only few farm ditches were built and in cases where topography was a limitation. Water deliveries were usually started from the upstream section of the system and proceeded progressively further downstream.

The major goal of the 'IIS' or newly constructed irrigation systems was to increase the irrigated areas and the optimum utilization of water.

The Philippines government has placed large investments in the new irrigation infrastructures including reservoirs and have instituted them as 'Special Projects' of the NIA.

The Upper Pampanga River Integrated Irrigation Systems (UPRIIS) located in Central Luzon was the first large project of this kind completed in the Philippines. The reservoir can store and supply enough water for the entire service area of greater than 86,000 ha during the dry season compared with only 30 - 50 percent dry season capability of the traditional irrigation systems. This kind of irrigation system has more complete canal networks, terminal facilities, control and measuring structures up to the turnout level and farm ditches in greater density per hectare. However, even with this more sophisticated infrastructure, problems still arise in achieving effective and efficient irrigation performance.

A turnout is designed to serve 30 - 50 hectares. The capacity of the turnout is based on the land soaking and submergence water requirements needed for land preparation for rice crop.

The peak value of this requirement usually occurs during the wet season cropping which starts on the latter part of May or early June for most places in the country.

Main and supplementary ditches are provided at an intensity of about 50 to 60 meters per hectare. Generally, farm ditches are designed for a coefficient of roughness n = 0.03 and side slope is 1 : 2, except where the soil condition requires flatter slopes. The top of the dike is 40 cm for main farm ditches and 30 cm for supplementary farm ditches. However, if the main farm ditch leads to a village or a group of farmers' houses one of the embankments is made 2.0 m wide to serve as a roadway.

Drainage ditches at the lower boundary of the irrigation unit are designed for using a runoff discharge of 5 to 8 ℓ/sec/ha of drainage area, equivalent to 10-year rainfall frequency. All drainage ditches extend to existing drainage channels. The side slope is usually 1 : 1.

Roads built on canal embankments that would be used for transporting farm produce are 4 m wide with 3 m wide gravel surfacing which is 15 to 30 cm thick. Roads used primarily for inspection purposes by operation and maintenance personnel are 2.5 m wide with a gravel surfacing which is 1.5 m wide and 10 cm thick. The density of this roads is about 15 to 20 m/ha.

Water delivery methods :

In Philippines irrigation systems, water delivery methods are divided into three levels.

(i) Simultaneous method :

This method supplies water continuously through all canals and is simultaneously supplied to all fields. Control of flow is less, this method widely used in Asia, may be conducive to excessive diversion and as generally practiced, frequently results in unequal water distribution and low efficiency.

(ii) Rotation Along Section of Canals Method :

Flow in a canal is diverted to selected turnouts for a few days, then is diverted to another set of turnouts further along the canal. This method sometimes practiced in traditional systems when water supply is not sufficient applied simultaneous. The method is adopted in the pilot divisions of the National Irrigation Administration (NIA) - Asia Development Bank (ADB) project.

(iii) Rotation at Farm Ditch Level :

Water is simultaneously diverted through all turnouts, but application is rotated among three to five different on farm blocks on a 24-hour schedule for each turnout area, as in the pilot areas of the NIA - ADB project.

6.3 WATER MANAGEMENT AT FARM LEVEL

Government of the Philippines needs to increase the production of paddy rice, because rice is the country's staple food. Two methods to meet this need were studied : (1) expanding the paddy area and (2) increasing the yield per unit area. The second was considered more important than the first, as it is in most southeast Asian countries.

Proper fertilization coupled with early maturing and improved varieties of seeds has brought a considerable increase in yield, but only in those limited areas provided with irrigation and drainage facilities.

The NIA and the ADB cooperated to begin intensification and demonstration of water management at the farm on 10 pilot projects distributed throughout the country.

The functions of the pilot projects were :

(1) demonstrating the most suitable water management methods for increasing the irrigated area.

(2) adjusting the cropping pattern to increase production.

(3) Creating farmers' associations for planning skillful distribution of water.

(4) Training the NIA officials and key farmers.

The knowledge gained in these projects has been shared with other irrigated areas. Then the government began the upper Pampanga River Project (UPRP) to extend the improved system of water management; this is the biggest project in the country, being expected to eventually irrigate 77,000 ha in the wet season and 72,000 ha in the dry.

The Philippines lacks a suitable system of supply ditches on farms, which results in ineffective water management and the waste of water. This lack is not confined to the Philippines, most other countries have the same problem.

Thus through the main pilot projects, canal density increased to 62 m/ha from 16 m/ha. The density is expected to reach 80 - 100 m/ha (14,23,24).

6.3 TAIWAN

6.3.1 General

Taiwan is located between tropical and semitropical climate zones; making double croppings of paddy rice possible. Most of plentiful rainfall comes in the summer during the syphon session and often causes flood damage. Shortage of rainfall in winter makes it normally difficult to raise crops.

Due to Taiwan's limited cultivation area, multiple croppings are necessary; at present, the cultivation coefficient of paddy field (actually cultivated area/paddy area is near 150 percent.

As it is generally difficult to construct permanent water intake facilities because of the frequency of flash floods, many facilities are simple and temporary.

The shortage of supply water, compared with its demand, forces frugal use of water, and in order to cultivate as many crops as possible, many patterns of cropping are in use, including those for paddy, rice, sugarcane, and miscellaneous grain crops. Thus the rotational method has developed from the conditions facing Taiwan at present.

6.3.2 Administration of Irrigation and Drainage Works :

National administration :

Control over the water resources is a National subject like Indonesia and other countries with authority to the central government to establish water conservancy areas along hydrologic boundaries to assist in the implementation of the law.

Rights to use of water is granted to an applicant after a complex procedure of form filling, bearings and assurances that other will not be adversely effected. One aspect of the right is the opportunity for joint users of water to file an application as coholders of the right. Priority of right is applied in the Taiwan law when scarcity of supply occurs.

An important provision of the water law is that it provides for creation and approval by the central Conservancy Agency of a farm irrigation association to undertake and develop 'farm irrigation works'. The law further provides that such associations shall be public entities with authority to develop their can regulations unless specified in other laws of the nation (14).

Irrigation associations :

The irrigation associations of Taiwan are distinctly different from the water user associations of Indonesia and other countries discussed. This distinction is in the size of the command area under the association and level of involvement with the water user. There are 26 irrigation associations in Taiwan with the largest (the Chianan and Changhua Irrigation Associations) managing an area over 50,000 ha. Five associations command an area between 20,000 and 50,000 ha. three manage between 10,000 and 20,000 ha. nine control areas between 5,000 and 10,000 ha and seven manage irrigated lands of less than 5,000 ha.

The Government initiated a program in 1922 to combine government and public constructed canals under the management of Hydraulic Associations with the purpose of bringing the farmers more directly into responsibilities of irrigation management. In 1945, the Hydraulic Associations were reorganized into irrigation associations with the major change being the introduction of the period of self management by the water users a very significant milestone in the history of irrigation enterprises.

The association is a self governing corporate body organized by farmers to administer the irrigation facilities, construct irrigation works distribute water, assists in planning in new water projects and serve as the direct mechanism for operation of a repayment program. They may be created at the determination of the provincial agency in charge when economic benefits and water use efficiency require the mandatory action, or action to organize can be initiated by 50 or more qualified potential members. Specific rules governing the organization of the associations were enacted by presidential decree.

The associations consist two major bodies, the policy making body and executive body (See Figure 6.3). The former is the representative assembly whose size varies from 15 to 55 according to command area of the association. The association members elect the representatives for a four year term. Two thirds of the representatives must be farmers from the area. The assembly meets twice a year to decide issues relevant to the entity's functions (2,16).

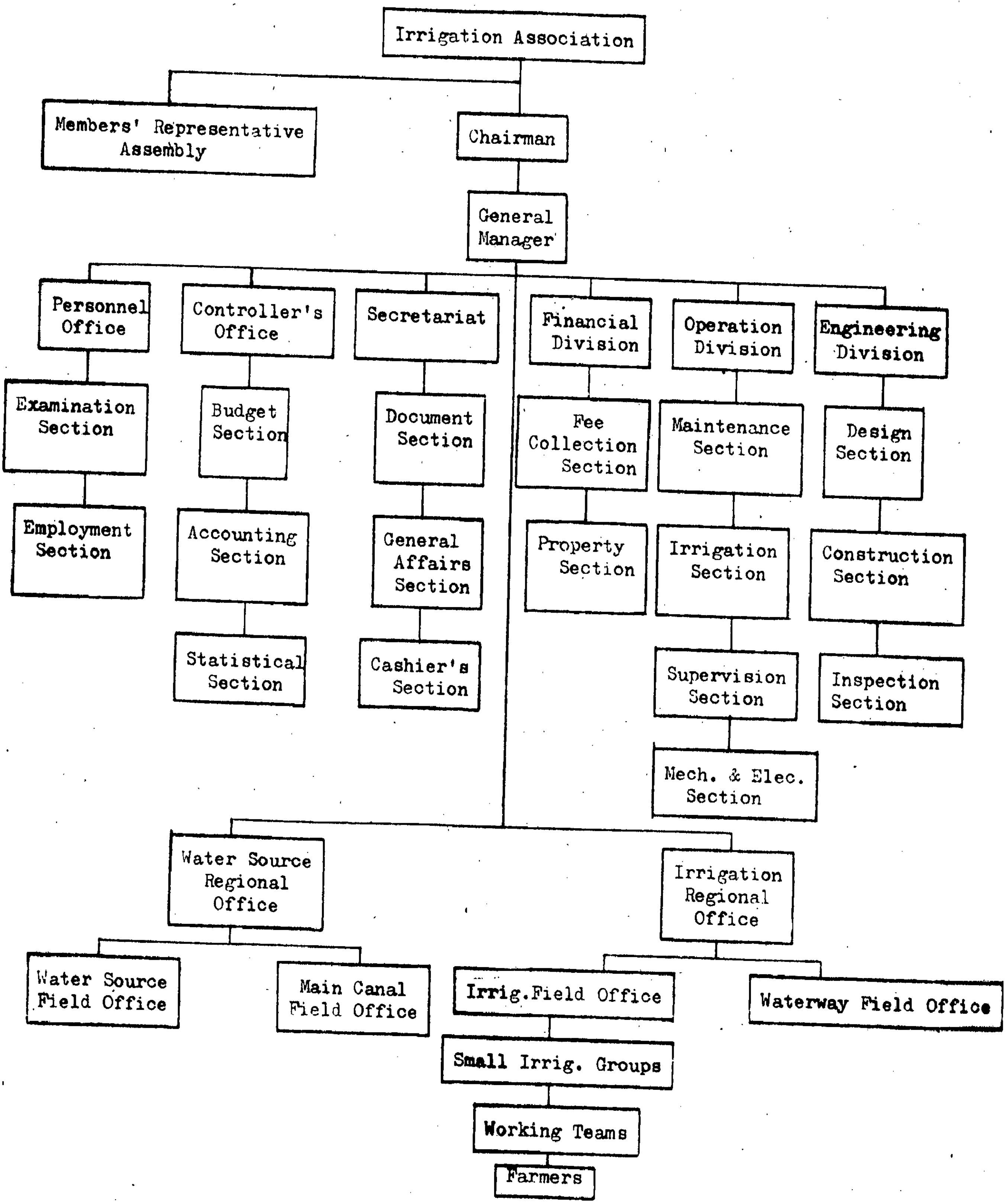
Operation of the association is carried out by the executive body which consists of three levels of administration : head office, regional offices, and field offices. The head office is the nucleus of the organization made up of a Chairman, General Manager and staff offices in the engineering, financial personnel controller, operation and general secretariate.

Association members from irrigation small groups around 50 - 150 ha that operate with working teams of 10-15 farmers elected by the members for four year terms. In addition to collectively working directly with the irrigation and drainage network, water management, establishing common

Fig. 6.3

Organizational Chart of an Irrigation Association

(Taiwan, Republic of China)



seedling beds, and construction of minor laterals and diversion works.

The basic function of the irrigation association is to deliver water to the irrigators. In the normal operation, the associations are also charged to perform the following activities :

(a) Construction, improvement, operation and maintenance of irrigation systems.

(b) Prevention and relief of damage to irrigation systems.

(c) Respond to emergency flood relief and prevention needs.

(d) Financing of irrigation systems.

(e) Rent or purchase land for irrigation projects

(f) Study and development of the benefit of irrigation

(g) Coordination with government policies of land, agriculture, industry and rural development.

(h) Any-thing entrusted by the government agency in charge according to law.

To cover the costs of the association members are required to pay membership fee and assessment for repayment of loans. In addition charges can be made for use of the delivery system and sale of surplus water.

6.3.3 Irrigation Water Management

Irrigation facilities :

In Taiwan, irrigated area is usually divided into irrigation plots of 50 ha each, which in turn are usually sub-divided into irrigation units of 10 ha each, which are irrigated rotationally. Each plot is provided with a double orifice outlet to measure the discharge, the unit is irrigated in order from the downstream side to the upstream. This method is apparently a combination of the upland crops irrigation and the rotational irrigation of paddy rice which are generally practiced in some command areas of Indonesia.

Water delivery method :

Water delivery in the command area is normally not based upon a demand system. The uniqueness of the principle crop grown rice, and the intensive cultivation has led to the adoption of a precise schedule under a method called 'rotation irrigation'. The rotation method results in calculated delivery at regular intervals with a predetermined head of water (2,16). This system was designed approximately 200 years ago under a water short period and is rapidly replacing the demand or continuous irrigation practice. Water can be rotated in one of three ways :

(a) Rotation by sections of main canals

(b) Rotation by laterals and sub-laterals

(c) Rotation by farm ditches.

CHAPTER VII : SUMMARY AND CONCLUSIONS

7.1 SUMMARY AND FINDINGS

7.2 SUGGESTION FOR IMPROVEMENT

CHAPTER - VII

SUMMARY AND CONCLUSIONS

7.1 SUMMARY AND FINDINGS

Management of water delivery system must provide the link between scientific knowledge and practice. It means, the knowledge of water - soil - plant relationship must be presented as simple guidelines for irrigators; climatic, soil and plant growth data must be considered in deciding on the flow of water in the system; cropping patterns must be planned to make the fullest and best use of water.

Management of water delivery procedures should be designed to cover the entire range of integrated activities which may include :

(1) Planning for schemes of water application in accordance with cropping pattern.

(2) Reporting the status of water situations in the field (daily, weekly etc.) and assessing water requirements according to the various stages of plant growth.

(3) Collecting and processing climatological and hydraulic data within the project area.

(4) Planning, allotting, regulating and delivering water along main canals, secondary canals, tertiary canals, quarternary canals according to farm requirements.

(5) Disposing of excess water and evaluating flood water.

(6) Emergency measures during droughts or in the event of flood damages.

Procedures should be updated periodically. This requires a system of feedback of information on the adequacy of the delivery system for review and improvement.

An important consideration in extending the period of land preparation is that the total water supply will be increased by the amount of water lost through evaporation and percolation for the extended period. On the other hand, effecting water supply to irrigation units by rotation reduces such losses.

There are two main methods of water distribution, continuous or simultaneous distribution and rotational distribution. There are different advantages in these systems. In continuous distribution, which may be adopted if the water resources are not a limiting factor, the cost of irrigation works are less as fewer water control structures and measuring devices are required and operational procedures are simpler. In rotational water distribution a more complicated control is needed. However, a saving in water due to less conveyance losses can be expected. Therefore, some methods about application of rotational system which is commonly used in PROSIDA command area has been given.

Success of an irrigation project ultimately depends on the involvement of the farmers in the operation and maintenance of the system. An institution, such as farmers' association, should be set up to help attain this objective.

The transfer of knowledge of water management to the farmers' field is therefore the core of the activities of his extension service. The farmer must know how to use the water, how to apply water in time and quantity, he also must know how to combine the water with other agricultural inputs, i.e. how to manage an irrigated farm in order to obtain high crop returns, he must know how to prepare his fields for the application of water and how to remove excess water and finally he must know to conserve water and soil which are most valuable resources.

Organizationally, an irrigation project should comprise two bodies : one for policy making the membership composition of which may vary according to the situation and another is an executive body with a Chairman and a general manager who leads a team of technical and administrative personnel. The size and extent of the project area will decide if the organization should have two or several levels ranging from the head office to the field office.

Obviously suitable personnel is required at all levels in an irrigation project. In particular engineers who are in charge of the technical operation and maintenance of an irrigation project, should have training in the principles and practices of water management. They should be encouraged to acquire an outlook beyond the confines of engineering and an understanding of the ultimate potential of the projects they are handling.

Management of water delivery system in some countries particularly PROSIDA (Indonesia) has been studied in this dissertation. It has some different in different countries. However the critical review is presented below.

(1) PROSIDA (Indonesia)

The PROSIDA efforts done up to the present time in rehabilitating and extensifying the irrigation system will be useless if not followed by effective and efficient systems and practices of water management at the main system as well as tertiary system upto the farm inclusive.

The land area to grow in PROSIDA command has been extended to the limits of water resources, topographical and soil conditions. Farmers who were in the upstream area of the system considered their rights of using water to be superior to the rights of those further downstream. Even now, there are still farmers who think that more water automatically brings better crop production. The just rehabilitated irrigation schemes must be constantly protected from floods which will cause sedimentation or erosion. And these steps need facilities, equipment and well trained personnel.

All of those steps for improvement can be summarised as follows :

(i) to increase the effectiveness of the management of irrigation schemes by improving the system and procedures of water distribution.

(ii) to conserve the condition of water source and irrigation system facilities as a whole

(iii) to improve the skill and ability of irrigation personnel at all levels to carry out the above mentioned works.

(iv) to support the research and study on soil water plant relationship.

(v) to have a continuous survey on hydrometeorological aspect of the catchment area obtaining data required by points (1) and (2).

In PROSIDA command area, the method of irrigation water distribution by rotation can be applied within each 'Golongan', that is by dividing it into some rotational areas. One rotational area consists of some rotational units which should be irrigated by a gated turn out. Irrigation water distribution is done by rotation among the units. There are some methods as to how to apply rotation such as :

(i) Fixed time - variable time

(ii) Fixed discharge - variable time

(iii) Stressing total

(iv) Stressing intermittent

The water management organizations in Indonesia are mixed with control by farmers and government officials, where the main irrigation system is managed by government officials while the tertiary irrigation is controlled by farmers' association.

(2) India

The distribution of water in Warabandi system is two-tier operation and each is managed by a separate agency. In the upper tier which is managed by the State, all distributaries and consequently watercourses are always operated at their full and not partial discharges. This reduces the running time, and consequently the conveyance losses in distributaries to the minimum. Further, distributaries are operated in eight-day periods. The number of such eight-day periods depends upon availability and crop requirements.

The absorption loss is a direct function of the wetted perimeter and it leads to two important conclusions :

(i) The length of the watercourse must be kept to a minimum and must strike a judicious balance between longer watercourses with fewer distributaries and shortest watercourses with more distributaries. In a flat topography the farthest point from the head is usually restricted to above three kilometers, whereas in steep topography, the distance may be as short as 0.5 kilometers.

(ii) The sum total of absorption losses is likely to shoot up as soon as water leaves the parent distributary and starts its journey in watercourse leading to boundary of a farmer's holding. Therefore, lining of watercourse should take priority over lining of parent channels.

(3) In the Philippines

Water delivery methods are divided into three levels :

(i) Simultaneous method

(ii) Rotation along section of canals method.

(iii) Rotation at farm ditch level.

A joint IRRI - Philippine National Irrigation Adminis-tion (N.I.A.) study was conducted in the Upper Pampanga River project in Nueva Ecija. The study showed slightly, but not significantly, higher mean grain yields and yield per unit of water added for rotational method of irrigation but the additional cost involved for the construction of farm facilities - to implement rotational method was about US $ 83/ha, including the cost of right of way on construction supervision. Also additional costs were incurred in the rotational method because of prlduction losses from the land used up by the supplementary farm ditches, constructed and personnel costs to implement the rotation system which added to about US $ 70/ha.

(4) Taiwan

Water delivery in the command area is normally not based upon a demand system but rotational method already adopted for many hundred years ago. Water can be rotated in one of three ways :

(i) Rotation by sections of main canals
(ii) Rotation by laterals and sub-laterals
(iii) Rotation by farm ditches.

Study about effects of the rotational method was conducted in Taiwan. The study showed that the rotational method gave a number of advantages :

(i) Water saved amounts to 25 - 50 percent of that used in the old method so that it can be used to cultivate a larger area.

(ii) Yield increases as paddy fields become dry and wet alternately waste of fertilizer is reduced, woil aeration is improved, resulting in good root growth and reducing damage from insects and diseases.

(iii) Even distribution of water is achieved in each farm unit as the system is regulated by qualified technicians.

Thus the rotational method exclusively developed in Taiwan is highly efficient in increasing yield as well as in saving water. Further research on this method may lead to even more intensive water management in paddy fields.

How many days can standing water be withdrawn from the field without causing any decrease of the yield. Paddy cultivation is thought to need standing water or near saturation continuously, in order to be continued every year in the same field.

But the rotational method has shown that water need not be kept continuously standing in the field. In this sense, the rotational method in Taiwan might lead to even more rotational water management, and more water conservation, if the relationship between the yield of paddy rice and the possible minimum number of days which water is kept standing on the field is studied in various soil conditions.

Critical similarities in 4 countries have been studied are :

(i) The need to accomodate a labor intensive agricultural and

(ii) The need to permit and encourage self management by local water users in order to increase production of agriculture.

Further the rotational method by golongan system in Indonesia, the operation of warabandi in India and rotational method in the Philippines as well as in Taiwan is similar, though there is a major difference between the rotational of their systems.

7.2 SUGGESTION FOR IMPROVEMENT

The irrigated land in PROSIDA command area has been extended to the limits of water resources, topographical and soil conditions. Farmers who were in the upstream area of the system considered their rights of using water to be superior to the rights of those further downstream. Even now, there are still farmers who think that more water automatically brings better crop production. The just rehabilitated irrigation schemes must be constantly protected from floods which will cause sedimentation or erosion. And these steps need facilities, equipment and will trained personnel.

Some points for improvement of the present practice of management of delivery system in PROSIDA command area could be :

(i) To increase the effectiveness of the management of delivery and distribution systems by improving the systems.

(ii) Improved simple operational procedures of planning irrigation schedule and their implementation of water distribution need to be devised. The methods of checking and cross-checking the activities of subordinates should be simplified so that the day to day management could be implemented properly.

(iii) To improve the skill and ability of irrigation personnel at all levels to carry out the above mentioned works.

(iv) A clear job description of staff at all levels must be provided. Activities and performance of all staff should be controlled and regularly monitored.

(v) Major irrigation schemes like PROSIDA should be managed and operated by irrigation services with closer co-ordination among the agencies involved in these activities.

(vi) To support the research and study of soil-water-plant relationships.

(vii) The organisation should initiate diversification and carry on a training programme for key personnel and improvement on the capability of staff.

(viii) Water user's organization should be encouraged to be responsible for the O and M of tertiary levels.

(ix) Adequate O and M funds must be available in time at the irrigation section offices.

(x) Finally, water delivery system in PROSIDA command area should be designed to deliver water according to crop water requirements, with a predetermined method of irrigation water distribution. The recent technique of estimating crop water requirement is recommended for this purpose.

Then, the last but not the least it is suggested that for improvement intensive irrigation should be put at an achievable level according to individual conditions of the project.

R E F E R E N C E S

1. Ministry of Information, Republic of Indonesia (1983), Indonesia Handbook, Jakarta.

2. Framji, K.K. and Mahayan J.K. (1969), Irrigation and Drainage in the World, Volume I and II, Published by International Commission on Irrigation and Drainage.

3. Annonymous (1980), Water Resources Development and Management in Indonesia, Jakarta Published by Ministry of Public Works, Directorate General of Water Resources Development.

4. Ministry of Secretary of State (1974, 1982). The Law of the Republic of Indonesia No.11/1974 and No.22/1982 about Water Regulation in Indonesia, Jakarta.

5. Dakshinamurti C., Michael A.M., Shri Mohan (1973), Water Resources of India and Their Utilization in Agriculture, New Delhi.

6. Campus Team of Egypt Water Use Management Project (1980), Problem Indentification Training Manual for On-Farm Irrigation System, Cairo.

7. Michael A.M.(1981), Irrigation Theory and Practice, New Delhi.

8. Vaughn E.Hansen, Orson W.Israelsen, Glen E.Stringham (1979), Irrigation Principles and Practice, Salt Lake City - Utah.

9. Bharat Singh (1983), Fundamentals of Irrigation Engineering, 7th Revised Edition, Nem Chand and Bros, Roorkee, India.

10. Soctapa T. (1979), Management and Operation of Surface Irrigation.

11. Dvorenbos and Pruitt W.O. (1977), Guidelines for Predicting Crop Water Requirement Published by FAO, Irrigation Drainage Power No.2, Rome.

12. Ven Te Chow (1980), Handbook of Applied Hydrology - A Capendium of Water Resources Technology, New York.

13. Santosh Kumar Garg (1983), Irrigation Engineering and Hydraulic Structures, Published by Khanna, Delhi, India.

14. Kraatz D.B.(1971), Irrigation Canal Linings, Published by FAO, Irrigation and Drainage Paper No.2, Rome.

15. United Nations (1982), Proceeding of the Seminar on the Improvement of Irrigation Performance at the Project Level, New York.

16. Soctapa T. (1977), Report on Comparative Study on Irrigation Water Management in the Philippines, Taiwan and the Republic of Korea, Jakarta - Indonesia.

17. U.N.D.P.Seminar (1972), Farm Water Management Seminar, Published by FAO, Irrigation and Drainage Paper No.12, Rome.

18. Sutiyadi S. (1983), Irrigation Schedule and Plan of Water Distribution, Published by Ministry of Public Works, Directorate General of Water Resources Development, Jakarta - Indonesia.

19. Sutiyadi S.(1981), Manual of Irrigation Water Distribution, Published by PROSIDA, Directorate General of Water Resources Development.

20. Sagardoy, Y.A., Bottrall A., Uittenbogaard (1982), Organization, Operation and Maintenance of Irrigation Schemes, Published by FAO, Irrigation and Drainage Paper No. 40, Rome.

21. Bottrall A. (1981), Comparative Study of the Management and Organization of Irrigation Projects, World Bank Staff Working Paper No. 458, Washington D.C. 20433, USA.

22. Hitoshi Fukuda (1976), Irrigation in the World Comparative Developments, University of Tokyo Press, Tokyo - Japan.

23. Indian Water Resources Society (1982), Workshop on Distribution Practices, Roorkee - India.

24. Pai A.A. and Hukkeri S.B., Manual on Irrigation Water Management, Department of Agriculture, New Delhi.

25. Malhotra S.P. (1982), The Warabandi and its Infra-Structure, Central Board of Irrigation and Power, Publication No. 167, New Delhi.

26. International Rice Research Institute (1978), Irrigation Policy and Management in Southeast Asia, Los Banos, Laguna, Philippines.

27. International Rice Research Institute (1980), Report of a Planning Workshop on Irrigation Water Management, Los Banos, Laguna, Philippines.