A CRITICAL STUDY OF DESIGN AND PLANNING OF THE WORKS IN SOME SMALL IRRIGATION SYSTEMS IN THE PHILIPPINES

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

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in

IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is presented in this dissertation entitled, **"A CRITICAL STUDY OF DESIGN AND PLANNING OF THE WORKS IN SOME SMALL IRRIGATION SYSTEMS IN THE PHILIPPINES "**, in partial fulfillment of the requirement for the award of the degree of MASTER OF TECHNOLOGY IN IRRIGATION WATER MANAGEMENT, submitted in WATER RESOURCES DEVELOPMENT TRAINING CENTRE, INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE, is an authentic record of my own work carried out during the period from July 2003 to June 2004, under the supervision and guidance of **Professor Raj Pal Singh,** Emeritus Fellow, WRDTC and **Dr. Deepak Khare,** Associate Professor, Indian Institute of Technology, Roorkee.

The matter embodied in this dissertation has not been submitted for the award of any other Degree.

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SYNOPSIS

The Philippines population is predominantly rural and two-thirds of this population depends on farming for their livelihood. In term of employment, about one-half of the labor force is engaged in agricultural activities. The most extensive use of water is for agriculture. In the past, many outstanding irrigation systems like The Agno River, Magat River, Jalaur River, Camiling River, Tarlac River, Siffu River, Libungan River, Pampanga-Bongabon and The Abulog River Irrigation Systems had been constructed for irrigating vast areas.

After implementation of various major, medium and minor schemes up to the end of The Ten-Year-Plan, vast irrigation potential has been exploited by various irrigation sources like canal, wells and others.

It is seen from the above that after construction of any irrigation schemes or projects and canals, these have their important place and have to function efficiently and serve the purpose, for which they have been planned, designed and constructed carrying the designed discharge capacity in the field. The deterioration of discharge is due to many factors like accumulation of silt; cracking of lining; failure of drainage; growth of weeds etc.

Losses in the fields are also getting considerably increased due to various factors. The responsibility of Irrigation Department ends with the construction and operation of canal system up to the turnout level. It is now realized that if irrigation projects are to yield optimum results, all aspects, right up to the farm level from the inception of planning, design, construction, operation and maintenance of canal system are to be considered carefully. Water is an important input in irrigation, which is becoming scarce material and is to be managed efficiently. The maintenance of canal system in irrigation project can be done efficiently, if all problems associated with planning and maintenance are identified at appropriate stages and solutions are arrived at.

In this dissertation, various concepts behind design, planning, operation and maintenance of irrigation systems are presented. Some specific field problems that are associated with the design and maintenance are also highlighted.

INTRODUCTION

1.1 Background

The Philippines population is predominantly rural and two-thirds of this population depends on farming for their livelihood. Rice in the Philippines is cultivated in 3.3 million hectares or 28 percent of the country's total arable land and only 1.8 million hectares is irrigated. In 1970 Philippines was able to export rice to Vietnam, Malaysia and United States when the country's population was 36.8 million. Although the country was self-sufficient in rice from 1980 to 1983 and in 1987, it has become the top importers of rice in Asia as reflected by the figures in the past decades. In 1990, the country imported 620,800 MT, increased to 862,300 MT in 1996 and up to a record high of 2.1 million MT in 1998 because of the occurrence of El Nino. It however dropped to 831,000 MT in 1999. Import figure in year 2003 was 890,000 MT a 26% reduction from 2002 import of 1.2 million MT and the Department of Agriculture target to cut rice imports by 50% in 2004.

Why Does the Philippines Still Import Rice?

- The amounts of harvest from irrigated rice fields in the Philippines are not different from those in other countries in Asia. However, the limited rice production area cannot meet the demands of the Philippine's growing population which increases 2.5% each year.
- Agricultural areas are being converted to subdivisions, and industrial and commercial areas.
- Frequently occurring typhoons and floods.
- Post production losses due to improper drying and harvest practices.
- Weak sales support and inefficient or lack drying and storage facilities and equipment.
- High postharvest losses.

These factors are aggravated by the inadequacy of irrigation facilities to sustain rice production.

The last major irrigation system development was completed in 1980 and after that period no major investment for new irrigation systems were provided. The current efforts are dedicated to the rehabilitation of existing systems and create more investments on small irrigation system (Concepcion, 2000).

1.2 General Description of Small Irrigation System

Small-scale irrigation can be defined as irrigation, usually on small plots, in which small farmers have the controlling influence, using a level of technology, which they can operate and maintain effectively. Small-scale irrigation is, therefore, farmer-managed: farmers must be involved in the design process and, in particular, with decisions about boundaries, the layout of the canals, and the position of outlets and bridges. Although some small-scale irrigation systems serve an individual farm household, most serve a group of farmers, typically comprising between 5 and 50 households.

Small-scale irrigation covers a range of technologies to control water from floods, stream-flow, or pumping:

Flood cropping

- Rising flood cropping (planted before the flood rises).
- Flood/tide defense cropping (with bunds).

Stream diversion (gravity supply)

- Permanent stream diversion and canal supply.
- Storm spate diversion.
- Small reservoirs..

Lift irrigation (pump supply)

- From open water.
- From groundwater.

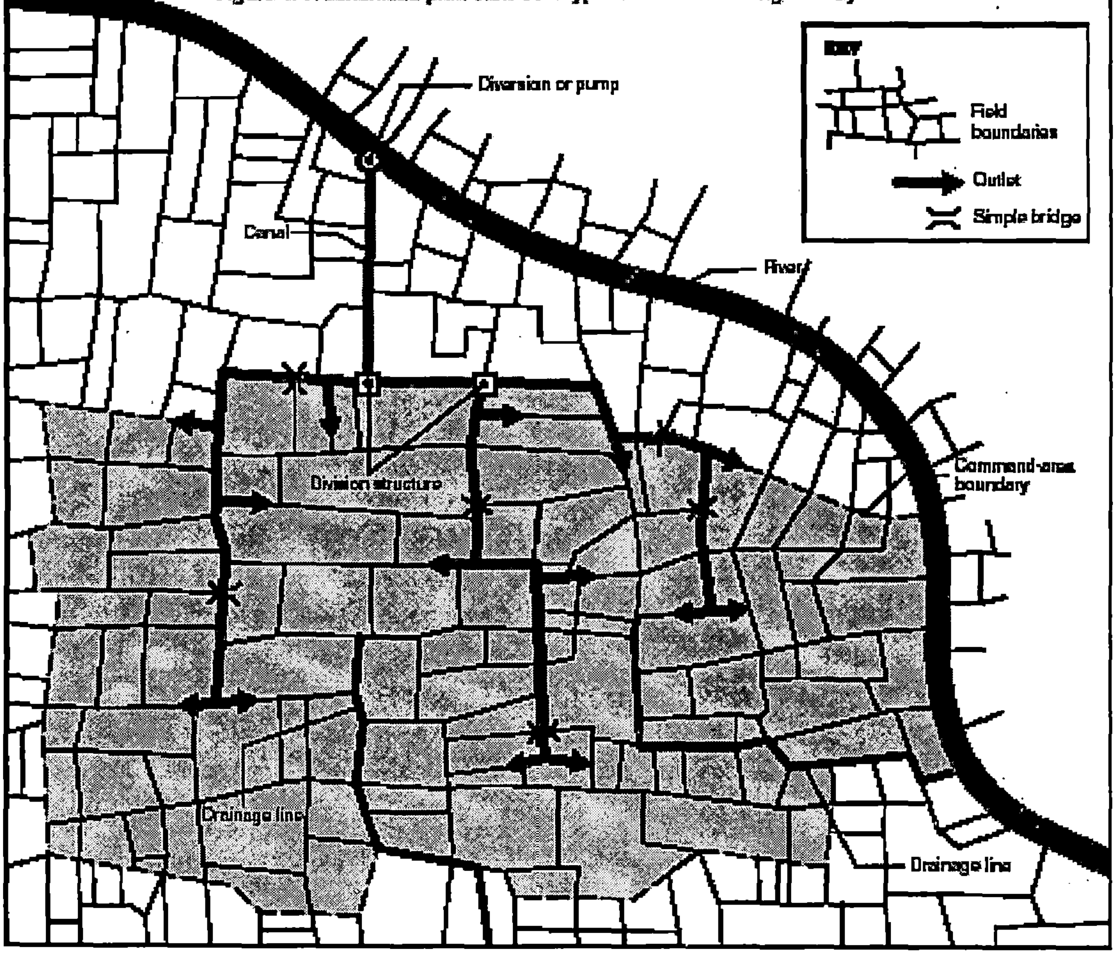


Figure 1. A schematic plan view of a typical small-scale irrigation system

1.3 OBJECTIVES OF THE STUDY

Irrigation system should be designed and operated to supply water in a predictable, adequate, and equitable manner so that water is used effectively and efficiently. However, many old irrigation systems do not perform in the best manner because they use excessive water that is inefficiently delivered and applied. This may stem from the original or from deterioration of the system or both. The rehabilitation of an inefficient old irrigation system is quite often necessary to meet extended water demands and to ensure the area against water shortage (K.H. Yoo and J.R. Busch 1985).

This study review basic steps in the design procedure, operation and maintenance of an irrigation system existing and in practice in the Philippines. It identifies the shortcoming of some of the present procedure and suggests ways for the safety of the works and sustainable supply of water.

The objectives of the present study are as follows:

(i.) To review the literature on Small Irrigation Systems.

(ii.) To review critically the Design Procedure of Small Irrigation Systems in the Philippines.

(iii.) To review critically the Operation and Maintenance of Small Irrigation Systems in the Philippines.

(iv.) To study the Design, Operation and Maintenance of similar canals in India.

(v.) To compare the Design, Operation and Maintenance Aspects of Small Irrigation Systems of the Philippines with India.

(vi.) Finally, identify the shortcomings in the Small Irrigation Systems of the Philippines and suggest ways and means for all possible improvement.

PROFILE OF STUDY AREA

2.1 Physiography

The Philippines is one of the largest island-group in the world with 7,100 islands and islets, is strategically located within the area of nations that sweeps southeast from Mainland Asia across the equator to Australia.

It's boundaries are formed by three large bodies of water: on the west and north by the South China Sea; on the east Pacific Ocean; and on the south by the Celebes Sea and coastal waters of Borneo. It lies between the latitudes 4^0 30' N and 21^0 20' N, and the longitudes 116^0 55' E and 126 E.

The total land area of the Philippines is 300 thousand square kilometers or 30 million hectares. It constitutes two percent of the total land area of the world and ranks 57th among the 146 countries of the world in terms of physical size.

The Philippines, advocates the archipelago doctrine, as such it gains exclusive to all resources living or non-living and at the bottom of an area of about 276,000 square nautical miles.

The Philippines is divided into three major island groups:

- Luzon, with an area of 141thousand square kilometers;
- Visayas, with an area of 57 thousand square kilometers; and
- Mindanao, with an area of 102 thousand square kilometers.

2.2 Climate and Rainfall

The Climate of the Philippines is tropical and maritime. It is characterized by relatively high temperature, high humidity and abundant rainfall. It is similar in many respects to the climate of the countries of Central America. Temperature, humidity, and rainfall, which are discussed hereunder, are the most important elements of the country's weather and climate.

Temperature

Based on the average of all weather stations in the Philippines, excluding Baguio, the mean annual temperature is 26.6° C. The coolest months fall in January with a mean temperature of 25.5° C while the warmest month occurs in May with a mean temperature of 28.3° C. Latitude is an insignificant factor in the variation of temperature while altitude shows greater contrast in temperature. Thus, the mean annual temperature of Baguio with an elevation of 1,500 meters is 18.3° C. This makes the temperature of Baguio comparable with those in the temperate climate and because of this, it is known as the summer capital of the Philippines.

The difference between the mean annual temperature of the southernmost station in Zamboanga and that of the northernmost station in Laoag is insignificant. In other words, there is essentially no difference in the mean annual temperature of places in Luzon, Visayas or Mindanao measured at or near sea level.

Humidity

Humidity refers to the moisture content of the atmosphere. Due to high temperature and the surrounding bodies of water, the Philippines has a high relative humidity. The average monthly relative humidty varies between 71 percent in March and 85 percent in September. The combination of warm temperature and high relative and absolute humidities give rise to high sensible temperature throughout the archipelago. It is especially uncomfortable during March to May, when temperature and humidity attain their maximum levels.

Rainfall

Rainfall is the most important climatic element in the Philippines. Rainfall distribution throughout the country varies from one region to another, depending upon the direction of the moisture-bearing winds and the location of the mountain systems.

The mean annual rainfall of the Philippines varies from 965 to 4,064 millimeters annually. Baguio City, eastern Samar, and eastern Surigao receive the greatest amount of rainfall while the southern portion of Cotabato receives the least amount of rain. At General Santos City in Cotabato, the average annual rainfall is only 978 millimeters.

Although the Philippines is endowed with abundant rainfall and prima facie, there could not be any need for irrigation as in arid and semi-arid countries, yet close examination of the rainfall pattern in space and time shows that on a large part of the islands practically no crop is possible in the dry season without irrigation. Even in the rainy season it has been found that irrigation helps in increasing yield.

The Seasons

Using temperature and rainfall as bases, the climate of the country can be divided into two major seasons: (1) the rainy season, from June to November; and (2) the dry season, from December to May. The dry season may be subdivided further into (a) the cool dry season, from December to February; and (b) the hot dry season, from March to May.

Climate Types

Based on the distribution of rainfall, four climate types are recognized, which are described as follows:

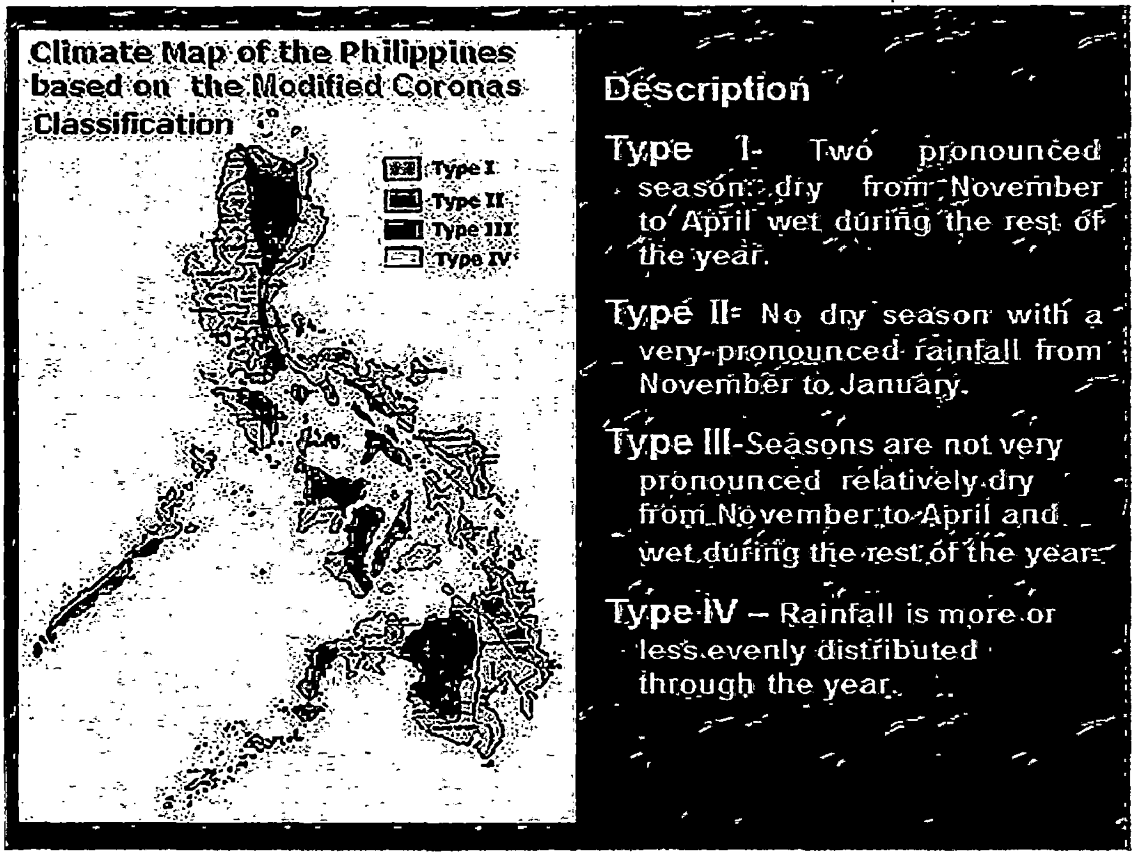


Figure 2. Climate Map of the Philippines

Typhoons have a great influence on the climate and weather conditions of the Philippines. A great portion of the rainfall, humidity and cloudiness are due to the influence of typhoons. They generally originate in the region of the Marianas and Caroline Islands of the Pacific Ocean, which have the same latitudinal location as Mindanao. Their movements follow a northwesterly direction, sparing Mindanao from being directly hit by majority of the typhoons that cross the country. This makes the southern Philippines very desirable for agriculture and industrial development.

2.3 Land Resources

Land Area

The Philippines is an agricultural country with a land area of 30 million hectares, 47% of which is agricultural land. In the Philippines, prime agricultural lands are located around the main urban and high population density areas.

Land resources in the country are generally classified into forestlands and alienable and disposable lands. A total of 15.8 million hectares were classified into forestlands, and 14.2 million hectares are alienable and disposable lands. Out of 14.2 million hectares alienable and disposable lands, 93% or 13 million hectares are classified as agricultural lands.

Land Distribution

The total area devoted to agricultural crops is 13 million hectares. This is distributed among food grains, food crops and non- food crops. Food grains occupied 31% (4.01 million hectares), food crops utilized 52% (8.33 million hectares), while 17% (2.2 million hectares) were used for non-food crops.

For food grains, the average area utilized by corn was 3.34 million while rice occupied 3.31 million hectares.

Of the total area under food crops, coconut accounted for the biggest average harvest area of 4.25 million hectares, sugarcane with 673 thousand hectares; industrial crops with 591 thousand hectares; 148 thousand hectares for fruits; 270 thousand hectares for vegetables and root crops; 404 thousand hectares for pasture and 133 hectares for cutflower.

According to land capability, 78.31 % of the alienable and disposable lands are prime agricultural areas; 6.1 million hectares are highly suitable for cultivation.

2.4 Population

The population of the Philippines was 19.32 million in 1948, 27.09 in 1960; 36.8 in 1970; 49.14 in 1980; and further to 60 million in 1990. Last year the country's population was 84 million and it is increasing at the rate of 2.5 % each year. The computed annual rate of increase is thus 4.06 % during the period 1960-1980 and 3.2 % during the period 1980-2000. This rate of increase is among the highest in the world.

The Philippines has remained a rice importer can be primarily attributed to the rapid increase in the country's population.

In the Far East and South East Asia, rice production has been a major undertaking throughout recorded history. However, for many countries in this region, rice production has not increased as fast as the population growth. In most of these countries, increased food production will depend on an increased in yield per ha. and the number of crops produced per year (Zandsta, 1980).

2.5 Farm System / Structure

Philippine agriculture is characterized by a mixture of small, medium and large farms.

Majority of the farms in the country are all small farms averaging about 2 hectares. These are simple farms, which are owned and managed by single families ranging from subsistence to commercial production.

Farming is generally undertaken on small farms. Two-thirds of all farms in 1988 were no larger than three hectares. Eighty-five percent of all farms were no more than five hectares. Over a period of ten years ending in 1996, the proportion of small farms had been expanding. The Philippine Agrarian Reform Council Secretariat reported that the government had acquired and distributed about 4.1 million hectares of agricultural lands to agrarian reform beneficiaries. Under this Program implementing the comprehensive agrarian reform law, a farm household cannot own a farm larger than five hectares. A typical farming system consists of major crops, with rice, corn and coconut as common base crops, and a few heads of livestock and poultry.

Small farms principally produce rice, corn, coconut and many crops. Prior to CARP, there were large plantations in rubber, coffee, oil palm, cacao, banana, pineapple, etc. Contract growing schemes operate in corn seeds, banana, tomato, cucumber, oil palm, asparagus and broiler chicken.

2.6 Soils

Soils of the island are very diverse. Although the lateritic weathering processes occur everywhere except on the highlands, few true laterites have developed. Immature soils and volcanic soils are common, while soils from coral limestone occur in various stages of development in the southern islands. The average soil fertility is fair.

2.7 Water Resources

Surface Waters

Being a natural resource, water availability is not only a climatologically factor but also site-specific concern particularly the watershed area. 421 rivers and a large number of very small streams, which flow directly to the sea, drain the Philippines, with a land area of 297,000 square kilometers. There are ten river systems with drainage basin areas greater than 3,000 square kilometers and the aggregate area of these basins is 85,270 square kilometers or about 28% of the total area of the country. The remaining 411 river systems have catchments areas of less than 2,000 square kilometers, and the majority has catchments of less than 500 square kilometers.

The low flow season in most rivers occurs during March to May when a relatively dry period is associated with the dominance of the North Pacific trade winds air stream.

Groundwater

In many areas in the Philippines there are abundant supplies of ground water and they are presently being used for industrial and domestic purposes.

The major groundwater reservoir of the Philippines is about 50,000 square kilometers (ADB, 1994). Larger aquifers are in the Cagayan Basin (10,000 square kilometers). A number of small aquifers are distributed over the whole country. The extent of aquifer thickness and water bearing characteristics vary considerably: in some areas, deep aquifers with water bearing strata are found but, elsewhere, there are small localized aquifers of limited potential.

Individual shallow wells were installed in individual farmers field as a way to augment irrigation in lowland areas not covered by the National and Communal Irrigation System. The total number of shallow tube wells is 23,240, covering at least 69,720 hectares as of 2002.

In the Philippines, there are large areas that are suited for shallow well irrigation. These are the flats alluvial places that are presently used for rainfall or irrigated rice production. Shallow wells can be used as primary irrigation water supply source or a supplementary water source for rain – irrigated uplands.

2.8 Field Water Management

Irrigation systems in the Philippines are classified into three broad categories; (a) National Irrigation Systems; (b) Communal Irrigation Systems; and (c) Private Irrigation Systems. The first category is typified by systems under the direct control and supervision of the National Irrigation Administration (NIA). Those of the second category are commonly community owned and operated systems.

The distinction between Communal and National systems is determined by who owns, operates and maintains. In communal systems, the farmers own the system, with some construction assistance from NIA. In National Systems, NIA operates the system up to the turnout level and collects irrigation fees for services rendered. The NIA systems are generally larger than communal systems. More than 50 percent of the communal systems are under 50 ha in area. Although the majority of the community systems are small, their total coverage comprises a significant portion of country's irrigated area.

As of end 2003,

- **Service Area of 10,894 Irrigation Systems**
  - 1,387,235 ha or 44.37 % of the Potential Irrigable Area
- **Breakdown of Service Area**
  - 689,113 ha (50% of Total Service Area) --------------191 NIS
  - 523,922 ha (37%) --6,702 CIS
  - 174,200 ha (13%) --------------------------------------- 4,001 PIS

The Bureau of Soils and Water Management (BSWM), in collaboration with Local Government Units (LGUs) and assisted by the Department of Agriculture-Regional Field Units (DA-RFUs) accelerate the establishment of Small Water Impounding Project (SWIP) and Diversion Dams (DD) wherever feasible to support rice production areas which National and Communal Irrigation Systems cannot service.

2.9 Problems Relating to Irrigation

- **The principal problems are:**

  - Weed growth and silting in the irrigation channels are the basic problem in the Philippines.
  - Owing to the low percentage of collection of irrigation fees, inadequate Operation and Maintenance Funds cannot maintain a number of irrigation systems.
  - There are appreciable seepage losses from canals, but linings can be built only on a limited scale due to scarcity of funds.
  - Typhoons that periodically visit cause a serious setback to the development plans by causing damage to the infrastructure of irrigation and land deterioration.
  - Increasing vulnerability to drought and land degradation on account of poor Watershed and Land Management.
  - Increasing population and increasing recurrence of extended dry spell, and alternating incidence of El Ni. o and La Ni. a. These conditions resulted in continuing loss in soil productivity, decline in water availability, and create serious stress on the marginal lands that become the primary source of subsistence for the marginally poor farmers.

2.10 Present Development, Future Plans and Potentials

The last major irrigation system development was completed in 1980 and after that period no major investment for new irrigation systems were provided. The current efforts are dedicated to the rehabilitation of existing systems and create more investments on irrigation system.

Republic Act 8435- Agricultural and Fisheries Modernization Act (AFMA) of 1997 declares food security to be a paramount goal of the state.

AFMA provides for the intensified development of the irrigation facilities for increased food production in order to meet the food requirements of the present and future generations.

The Department of Agriculture, (DA) being the principal agency responsible for the promotion of the country's agricultural growth and development has been mandated to implement the Ginintuang Masaganang Ani (GMA) for which the construction of Diversion Dam is one of the major components.

Rationale

Irrigation is the major component of the AFMA for which 30% of the total annual budgetary outlay is being allocated. The law is also includes small-scale and farmer-managed irrigation systems.

Target

800,000 ha existing irrigated areas sustained and maintained 18,000 ha additional areas irrigated.

Plan of Action

- The National Irrigation Administration (NIA) shall rehabilitate existing irrigation systems, assist LGUs in the repair of communal irrigation systems, and construct new systems.
- The Bureau of Soils and Water Management (BSWM), in collaboration with LGUs and assisted by DA-RFUs, shall accelerate the establishment of small water impounding projects (SWIP) and diversion dams (DD) wherever feasible to support rice production areas which national and communal irrigation systems cannot service.
- Supplemental irrigation water shall be provided through the construction of new shallow tubewells and the rehabilitation of low-performing wells.
- Identification micro-watersheds in areas covered by SWIP/DD and STWs shall be co-managed with LGUs and concerned irrigators' association with technical assistance for BSWM.
- Service roads shall be rehabilitated or improved.

- Draining system shall be constructed/repaired/rehabilitated.
- On-farm water management methods shall be improved.
- Use of re-used or tail-end water shall be maximized.
- Nonpolluting technologies on irrigation water management shall be promoted.
- A comprehensive training program on sustainable water management shall be conducted.
- Memorandum of Agreement on irrigation watershed management shall be forged with relevant agencies.
- Cloud-seeding sorties shall be conducted where necessary and advisable.

Protocol

- **Small Scale Projects**

  STW installation rehabilitation

  Mode of implementation: Da-RFUs, NIA with program recipients

  Target: 3,558 units /1,316 units

  Beneficiaries/Recipients: Individual farmers/FOs

  Mode of availment: Soft loan/grant

- **Open Surface Pump**

  Mode of implementation: DA-RFUs/NIA with program recipients

  Target: 25 units

  Beneficiaries: Individual farmers/FOs

  Mode of availment: soft loan

- **Small Farm Reservoir**

  Mode of implementation: BSWM with FOs, LGUs, other stakeholders

  Target: 1,543 projects

  Beneficiaries: Individual farmers

  Mode of availment: grant

- **Small Water Impounding Project/ Division Dam Rehabilitation Construction**

  Mode of implementation: DA-RFUs/ BSWM implements the projects in coordination with FO's, LGUs and other stake holders.

  Targets: 13 SWIPs, 73 DDs

- *Beneficiaries/Recipients:* FOs
  Mode of availment: grant

- **Cloud Seeding**
  Mode of implementation: BSWM conducts seeding operations, as requested requested.
  Targets: 514 sorties
  Beneficiaries: farmers

Because of the peculiar situation of the Philippines, it is expected that typhoons will continue to visit the country and wreck havoc on irrigation facilities and canals. For this reason, the Department shall provide for this contingency.

An integral component of DA programme is to continue its coordination activities with other agencies engaged in agricultural production and infrastructure construction. This activity will be pursued as vigorously as before.

New World Record

Enthused by a new world record in rice harvest in Mindoro, the Department of Agriculture said it would try to replicate the feat in other areas of the country.

On October 1, 2003, Ernesto P. Pablo Sr. harvested an average of 14.6 MT of palay (unmilled rice) per hectare in his three-hectare farm in Rizal, Occidental Mindoro. Breaking the old record of 12 MT set by the Philippine Rice Research Institute in Nueva Ecija. He also bested his previous personal record of 11.8 MT per ha. early last year (2003).

The Department of Agriculture Secretary ordered the Director GMA rice program to accelerate the planting of hybrid rice varieties to over 300,000 hectares of regularly irrigated lands.

This is a major breakthrough considering the current target of the National government rice sector the "Ginintuang Masaganang Ani Program" to have an average rice production increased by 1.0 T/ha for areas covered or an average yield of 5-6 T/ha, ushering in rice sufficiency in the country.

GMA rice program director claimed that once the 2.5 million Filipino rice farmers begin planting the new breeds, the country would not only become self-sufficient in rice but would be able to export its products to other countries.

The irrigation development programme aims at further accelerating the generation of irrigation areas and improving existing systems for the production of rice and other crops, such as sugar, foodgrains, bananas, vegetable, etc.

GOALS AND OBJECTIVES

- The goals of the Ginintuang Masaganang Ani Rice Program are to:
  1. Attain national food security at all times.
  2. Reduce poverty incidence in the rural areas.
  3. Increase net farm income.
  4. Ensure sustainability of the natural resource base.
  5. Enhance people empowerment.
- Specifically, the program seeks to:
  1. Improve profitability as reflected by increase net farm income;
  2. Provide adequate food supply that is accessible and affordable to everyone at all time;
  3. Increase productivity through:
     - promotion of cost-effective technologies;
     - conservation and management of natural resources; and
  4. Provide a favorable policy conducive to increase agricultural investments and global competitiveness.

REVIEW OF LITERATURE

3.1 GENERAL

Irrigation is high and inefficient use of water. It uses about 80 percent of world's fresh water supply at an efficiency rate of 38 percent. An increase in this efficiency of about 10 percent would supply all the fresh water needed for residential use.

Despite the 5000 years of experience in planning and operating irrigating system all over the world, many are still operated inefficiently and ineffectively. In fact, history has shown those classic and extensive systems existing and in use for over a long period, has disappeared perhaps for various reasons but mismanagement and neglect of adequately required operation and maintenance has undoubtedly played a dominant role. Decaying of well-established systems in a short period of nearly 100 years in Mesopotamia in 12th century AD is a striking example.

Normally the reasons for unsatisfactory performance vary on-site conditions and may include the following.

(i) Poor organizational structures

(ii) Inadequate involvement of water users

(iii) Lack of funding for operation and maintenance

(iv) Lack of well-planned O&M programmed.

(v) Inadequate application of available experience and improved technology

(vi) Inadequate training to related personnel

(vii) Perception for more prestige in Development of new projects rather than maintaining the existing one.

(viii) Rehabilitation is convenient rather than good O&M.

3.2 DESIGN, OPERATION AND MAINTENANCE OF IRRIGATION CANALS IN ANDHRA PRADESH

3.2.1 Canal Design

The Chief requirements of uniform canal are as follows:

(i) A clean regular bed;

(ii) Straight clean slopes;

(iii) Uniform berm widths, and

(iv) Uniform regular top width and outer and inner faces of both banks.

The various States in India adopt Kennedy's, Lacey's, Manning and Kutter's formulae for the design of earthen channel sections, and the practices vary from state to state.

3.2.2 Design Procedure for Alluvial Channels.

In an alluvial channel the bed and banks are not rigid but are free to adjust themselves by scour and deposition. The design of such channels is more complicated than the incised channels carrying negligible or no sediment in them.

The procedure for alluvial channel design is mostly based on Kennedy and Lacey. The regime theory is applicable to channels with sand beds and cohesive to slightly cohesive banks caused by berming action, and carrying normally less than 500 ppm bed material load. Since bed and bank conditions vary from State to State, changes in constants in Kennedy or Lacey's equations are understandable.

According to Kennedy's method the velocity in a non-silting, non-scouring channel is given, by

$$\mathbf{V=0.446m_1\,D^{0.64}}$$

Where, V is velocity in meter/second

D is depth in meter
$m_1 = V/V_0$ - is the critical velocity ratio

V_0 is the Kennedy's critical velocity.

3.2.3 Design Procedure for Unlined Incised Canals

For unlined incised canals, the procedure commonly adopted is to determine width and depth of a canal for a given discharge assuming rugosity coefficient, side slopes of the canal section, maximum permissible velocity and bed gradient. Since bed slope, rugosity coefficient and velocity are known, Chezy – Kutter or Manning formula permits the hydraulic mean depth to be worked out. Area of the cross section is given *by* Q/V, and wetted perimeter by A/R. Knowing P and R and side slopes of the canal cross-section, it is possible to work out width and depth. For estimation of velocity it is suggested that Manning formula may he used in all the States in preference to Chezy. The Manning's formula could be written in terms of discharge Q as

$$Q = \frac{PR^{5/3} S^{1/2}}{N}$$

The canal design would normally require the parameters *P, R,* and *S* to be determined. Normally Q and N are given as Design Data. For estimation of the three unknowns, viz., *P, R* and S, the following two equations are used for trapezoidal section in addition to Manning equation.

3.2.4 Choice of Suitable Formula for Design

In most of the States only Manning's equation and very rarely other equations are used. It is therefore suggested that Manning's equation may be used throughout the country, as Chezy equation does not materially improve the design of canal section.

3.2.5 Longitudinal Slope

The slope is fixed primarily according to the country slope. In general the slope required to obtain maximum permissible velocity would make construction to be economical. The requirement of providing maximum possible irrigation would indicate flatter slope guided by minimum permissible velocity.

3.2.6 Coefficient of Rugosity

The value of coefficient of rugosity is assumed in different States on the basis of discharge capacity and bed and bank conditions of the canal. The N value recommended in different States varies from 0.02 to 0.03. The variation in *N* value is however, known to be caused in actual practice due to several factors such as weed growth, different boundary materials, conditions of canal, maintenance, etc. According to CWPC, the recommended values of *N for* certain canals in good condition are as follows:

Q (Cumecs)	N
Greater than 1.41	0.0225
1.41 to 0. 14	0.025
Less than 0.14	0.03

3.2.7 Maximum and Minimum Permissible Velocities

In unlined incised canals, maximum permissible velocities are specified so that discharge is passed through with the smallest possible sections without causing erosion. The values of the permissible velocities generally adopted by various States are from 0.3 m/sec for ordinary silt to 4.57 m/sec for rock cuts.

In no case, the velocity should be too low to encourage weed growth or deposits of water borne material.

3.2.8 Bed Width to Depth Ratio

For minimizing the losses due to absorption and evaporation and for economical design of canal in cutting in very hard and very porous strata, the values of B/D between 1 and 5 are beneficial. For wide canal the value of *B/D* is, however, requires to be increased beyond 5. A graph relating discharge with B/D ratio as given by CWPC is being widely used.

Critical Velocity Ratio*:* The need for specifying V/V_0 values is to prevent deposition of bed material mostly consisting of sand. Adoption of V/V_0 value of 1.1 to 0.85 from head to the tail end appears to provide safety against deposition of bed material on an all India basis. Canals taking off from reservoirs and tanks carry much less or no sediment and unless there is appreciable bed and suspended load to be carried, these criteria need not be applied.

3.2.8 Side Slope

The side slope is an important parameter in canal design. Steeper side slopes make the canal section narrow and deep leading to small water surface width with an increased unit discharge. The flat slope makes the depth shallow leading to wide water surface width with a reduced unit discharge. Evaporation and percolation losses are obviously more in latter sections than in the former. A standardization of the side slope values for different types of soils is given below:

Type of soil	Cutting H: V	Embankment H: V
1	2	3
Very light loose sand to average sandy soil.	1.5:1 to 2:1	2:1 to 3:1
Cotton soil and similar soils	1:1 to 1.5:1	2:1
Gravelly soil	1:1 to 1.5:1	1.5:1
Murrum hard soil	0.75:1 to 1.5:1	1.5:1
Rock	0.25:1 to 0.5:1	-

3.2.10 Freeboard

Freeboard is governed by considerations of canal size, location, velocity of water, storm water inflow, water surface fluctuations, wind action, soil characteristics, percolation gradient, operating road requirement, availability of excavated material, etc. The following values of free board are suggested.

Discharge in cumecs up to	0.70	0.70 to 1.41	1.41 to 8.50	Greater than 8.50
Free Board in meters	0.46	*0.61*	0.76	0.91

3.2.11 Top Width of Banks

To permit inspection of canal banks and movement of light traffic on both sides of the canal, adequate width is required to be provided on top of side banks. The top widths are fixed rather arbitrarily as below considering soil characteristics, earth available for construction, capacity of channel, etc.

Discharge	*Top width*
Up to 1.41 cumecs	1.1 to 1.8 m
1.41 to 10 cumecs	1.5 to 3 m
Greater than 10 cumecs	4.5 to 6 m

3.2.12 Planning and Layout of Canal System

The following are some of the salient points to be considered in the planning and layout of canal system for irrigation. The same have been followed to the extent possible, in many of the canal systems of Andhra Pradesh irrigation projects.

- Capacity of canal system is fixed on the basis of the following considerations
  (a) Culturable commanded area
  (b) Water allowance, and
  (c) Transmission losses.
- The main canal is generally carried on a contour alignment, until either it commands full area to be irrigated or it attains the top of watershed. From such a point, it is aligned down to the watershed ceasing to be contour line.
- After reaching the watershed, the main canal is situated along the main watershed and branch canals along secondary watersheds since it will generally be observed that the slope of the main water shed is less than the slope of the secondary watershed and the branches are required for irrigating the area up to the adjacent drain- ages on either side of the watershed crest.
- While selecting the alignment, consideration of economy shall be borne in mind. Deep cuttings or high embankments are generally avoided by suitable detouring after comparing the overall costs of the alternative alignments.
- The alignments of canals consist of straight lines with circular curves. Radius of curves adopted is usually 10 to 1 5 times the bed width.
- The cross-sectional area of a canal generally does not increase from upstream, to downstream.
- A change in the hydraulic slope is generally not introduced unless a control structure is placed in-between.

Balancing depth is adopted wherever possible.

3.2.13 Conveyance Efficiency and Canal Capacity

Considerable amounts of water are lost in the canal system from the point of diversion to the irrigation outlet and further in the watercourses. These losses are called the conveyance losses. In the case of earthen canals, the conveyance losses may range from 25 percent to 40 percent or more of the head discharge.

Seepage and evapo-transpiration losses can be minimised by proper design, construction, operation and maintenance. Operational losses can only be marginally reduced by careful operation; while accidental losses can be reduced to some extent by care in construction, operation and maintenance. Among these the only factor considered in design generally is the seepage loss and no allowance was hitherto made for the operational and accidental losses. It is important to make an allowance of 10 to 15 percent in fully lined systems and somewhat higher percentages in unlined systems to provide for these losses.

It is customary practice to assume certain rates of canal losses in terms of so many cusecs per million square feet of wetted canal surface, depending upon the soil type and canal capacity. Data on actual observations of these losses are limited but even the limited data have shown that actual losses are generally much higher than those assumed in design calculations.

Canal losses have a dual adverse effect: they reduce the project area, which can be commanded with the available water supply, and contribute to water- logging and possible salinity.

3.2.14 Maintenance of Canals by Lining

Water is conveyed from the source by canals. Sometime, these are lined in order to reduce seepage losses, which may be as much as 20 percent of the total withdrawals.

Aim of canal linings .is to:

(i) Improve capacities of existing canals.

(ii) Reduce seepage losses and extend irrigation with the waters so saved,

or to prevent water logging.

(iii) Enable flatter slopes to be adopted for the canals by increasing the command.

(iv) Reduce the cross sections, lined canals have higher velocities and a smaller rugosity; land acquisition and cost of canal structures can also be reduced to some extent.

(v) Provide additional stability to channel sides.

(vi) Ensure continuous operation of canals without annual closure for silt clearance, weed clearance, etc., and reduce the maintenance cost.

Lined canals are expensive and cost 3 to 4 times more than the unlined ones of equal capacity. Lining is therefore used on a selective basis only after careful economic analysis and mostly in porous soils or reaches of canals and reaches of high water table. Where water supply is limited and water is very valuable, lining is useful.

3.2.16 Maintenance of Irrigation Canals

After the completion of construction of irrigation system in any irrigation project, it is essential to maintain it for its proper and efficient functioning. There are various reasons due to which a canal may cease to function efficiently. These are:

(i) Silting of canal.

(ii) Breaching of canal due to week banks.

(iii) Weed growth.

(iv) Overflow of canal banks

When the silt is deposited on the bed and sides the capacity of the canal reduces. It is better to exclude silt by providing silt excluder and ejector. Curved wing- cum-silt vanes and silt tunnels-cum-curved wings can be fitted near the head of an off-taking canal for exclusion of silt. However, none of these methods can put a complete cheek over the entry of silt in the channel and hence silt is deposited in the channel bed even after the best care. The measures are adopted to remove the silt are:

(a) Flushing.

(b) Silt scouring fleet: The method consists of having three lower barrages connected to the upper barge by a cable operated by winch. The lower barges have movable shutters. The silt is kept agitated by maneuvering the barge up and down.

(c) Stirring of silt by pumping water.

(d) Dredging.

(e) Excavating the silt by manual labor.

3.2.17 Strengthening of Canal Banks

To prevent breaching of tile canal bank, it has to be strengthened properly so that valuable loss of irrigation and property is prevented due to breaching of a canal section. There are four methods of strengthening a canal bank

(a) External silting system.

(b) Internal silting system.

(c) Formation of berms by internal silting.

(d) Formation of back berm.

3.2.18 Weed Control

Waterweeds are unwanted plants that grow profusely in water under certain favourable conditions. They reduce the discharging capacity of channel by reducing the area of the channel section and velocity of flow. The problem of weed growth is more marked in Deccan where the heavy weed growth may reduce the channel discharge to even less thin 15 percent. The nuisance has therefore, to be checked to permit and. channel to function efficiently.

3.3 OPERATION AND MAINTENANCE OF IRRIGATION DISTRICTS IN MEXICO

BACKGROUND

The sub-sector irrigation agriculture is of crucial importance for the Mexican economy. Irrigated land covers about 5.5 million hectares, a third of all lands harvested, and contributes about half of the total value of agricultural production. The irrigated land is classified according to the size or its works as well as to the form of organizing its operation into two types: a) "irrigation units," made up of more than 25000 small irrigation systems which annually irrigates nearly 2.5 million ha (in general they have always been operated and maintained by the users; and b) the irrigation districts consisting of large-scale irrigation, numbering about 80 and yearly irrigating about 3 million ha, (the latter have been operated by the government, until recently).

THE TRANSFER PROGRAMME

Although the transfer process was initiated in 1988, it did not really begin until 1989. With the creation of the National Water Commission (NWC), a national programme for transferring the irrigation districts to Water Users Associations (WUAs) was organized, and in order to support this process for repairing the deteriorated infrastructure and to strengthen the WUAs a loan from the World Bank was obtained.

Transfer of irrigation districts to WUAs can be attributed to varied reasons. The most important among these is the deterioration of the irrigation infrastructure for lack of adequate maintenance, reduction of funds allocated to O&M over the years as the participation of its users has to decreased, and the reduction of government subsidies: in 1988, water charges only covered a 15% of the O&M costs. Additionally, this situation put the irrigation district users in an economic advantage over the producer of the small irrigation scheme, who had to pay the full cost of the irrigation service, creating a privileged sector of producers. On the other hand, the government was not able to put out the considerable amount of money required for the operation and the adequate maintenance of the works. Finally, it was considered that the only way to guarantee the good operation of the infrastructure was by giving the responsibility of district management to its users, since they are the people whom directly benefit from the profit of these works.

Users receive technical support from the operational staff, which mostly consists of the Agricultural Engineers.

The analysis of the hydraulic data points out an important improvement in the conveyance efficiency. In Riyo Mayo, an increment of almost 10%, and in Delicias of more than 20% in the conveyance efficiency, has been achieved after water management was turned over to the WUAs. In other districts, these increment have been even more important, but in some cases as in the Rio Lerma Irrigation District in the Guanajuato State, the increment in the conveyance efficiency, after the transference has been the result of a significant reduction of the so-called "administrative losses," of which the principal cause is the corruption of some persons working in the distribution system, who sell water without reporting the volume delivered; therefore when the WUAs received the responsibility of water distribution, an improvement in the conveyance efficiency was immediately observed.

It is important to point out the increase in the participation of the water users in the improvement of water management and the maintenance of the hydraulic works as well as in the organization of the WUAs.

3.4 OPERATION AND MAINTENANCE OF SMALL IRRIGATION SYSTEM IN INDONESIA

Farmers originally built and managed most small irrigation systems. Over the years various programs assisted these irrigation systems, particularly during the 1970s and early 1980s when Indonesia obtained abundant income from high oil prices. This was part of a relatively successful policy to improve welfare in rural areas and pursue national rice self-sufficiency (Booth 1988).

Improvement for O&M Government-funded improvements have lined canals and replaced wood or bamboo structures with permanent structures. It is less clear how much impact these improvements have on reducing the burden of O&M or increasing agricultural production and farmer welfare. There is still much scope for improving the technical quality of the infrastructure built by the project (Duve, Fleischer, Krimmel and others 1991).

Some sites clearly show increased production. At others, little seems changed, except that the system functions more smoothly and looks more orderly. Regulations decreed that irrigation systems built or improved by the government become government irrigation systems. Over time, government intervention converted more and more of these farmer-managed systems (irigasi pedesaan) into government systems, listed in the Inventory of Public Works Irrigation Areas.

As time went on some government officials and donors worried that the expansion of government involvement in irrigation was creating a dependency on government and that the government was taking over tasks, which farmers could handle better. Continued takeover would create a tremendous burden on the budget and could lead to a decline in irrigation system performance.

The continual growth of state intervention has been a prominent part of irrigation development around the world. Dissatisfaction with poor performance of government management in irrigation and abundant examples of irrigation systems well managed by farmers has encouraged consideration of turning over management to farmers. Irrigation turnover in various forms is the subject of increasing interest internationally (Vermillion 1991).

Indonesia's program to turn small irrigation systems over to water user associations is one case of an effort to restructure responsibilities in irrigation management. Through turnover, governments may be able reduce expenditure of scarce resources on activities which farmers are better able to carry out themselves. Governments can focus their efforts on activities, which require greater financial capability, technical expertise or political authority. Irrigation agencies can support and work in partnership with more self-reliant local management of irrigation. The general principle should be to use the government resources on those improvements, which for technical or financial reasons are most difficult for farmers to carry out themselves.

Promoting Participation in Irrigation

Beginning in the early 1980s the Indonesian Department of Public Works conducted a series of pilot projects and studies directed at improving participation in irrigation (Tobing 1989). The Department of Public Works was concerned that benefits from government construction assistance had been less than expected and hoped that if farmers' sense of ownership could be strengthened this would lead to better development and management of irrigation system.

The International Irrigation Management Institute (IIMI) and an Indonesian non-profit government organization, the Institute for Social and Economic Research, Education and Information (LP3ES), assisted the Department of Public Works in developing a participatory process of design and construction of minor improvement to irrigation systems and strengthening of formal water users association in Indonesia (Murray-Rust and Vermillion 1989, Judawinta 1991), Bruns and Dwi Atmanto 1992).

By the middle of 1994 the Indonesian Ministry of Public Works had transferred almost one thousand five hundred small irrigation systems, which irrigate more than 115,000 hectares, to water user associations in ten provinces. Almost a thousand more systems irrigating over 28,000 hectares in Central Java had completed preparation and were awaiting formal transfer. This is part of a long-term policy to gradually transfer all irrigation systems smaller than 500 hectares to water user associations. Such system irrigates more than 1.5 million hectares. This represents a major shift from previous patterns of government intervention in irrigation. Turnover converts government investments into locally owned and managed common property.

3.5 *SMALL-SCALE IRRIGATION DESIGN - FAO*

Small-scale irrigation can be defined as irrigation, usually on small plots, in which small farmers have the controlling influence, using a level of technology, which they can operate and maintain effectively. Small-scale irrigation is, therefore, farmer-managed: farmers must be involved in the design process and, in particular, with decisions about boundaries, the layout of the canals, and the position of outlets and bridges. Although some small-scale irrigation systems serve an individual farm household, most serve a group of farmers, typically comprising between 5 and 50 households.

Small-scale irrigation covers a range of technologies to control water from floods, stream-flow, or pumping:

3.5.1 Water Requirement and Irrigable Area

Crops require a large amount of water for irrigation, and it is important to calculate water requirements accurately, both to design the supply canal and the pump (if any), and to check that enough water is available from the source.

The amount of water required by a crop depends on the local environment, the climate, the crop and its stage of growth, and the degree to which the crop may be stressed. This requirement may be expressed as a uniform depth of water over the area in millimeters per day (mm/d).

Irrigation Requirements

Reference evapotranspiration (ETo) is the water use of grass (in mm/d) under standard conditions. Local estimates may be available from meteorological offices. Typical values are shown in Table 1. For most crops, the reference evapotranspiration at mid-season can be taken as a reasonable estimate of the peak water requirement.

It is reasonable to assume that 70 per cent of average rainfall is available to the crop; the net irrigation requirement (In mm/d) can be estimated as:

$$I_n = ETo - (0.70 \times P)$$

where P (mm/d) is the average rainfall. If a personal computer is available, then the reference evapotranspiration and net irrigation requirements can be estimated conveniently and accurately using the FAO CROPWAT program and the CLIMWAT database.

Additional water has to be supplied to take account of field application losses which, with surface irrigation, are typically about 40 per cent, giving an application efficiency of 0.60. The field irrigation requirement (I_f) can be estimated as:

$$I_f = \frac{I_n}{0.60} = \frac{ETo - (0.70 \times P)}{0.60}$$

The field irrigation requirement represents the rate (in mm/d) at which water must be delivered to the field to prevent the crop suffering a shortage of water.

Design command area

The required canal discharge depends on the field area to be irrigated (known as the 'command area'), and the water losses from the canal. For a design command area A (m2), the design discharge required Q (l/s) for irrigation hours (H) every day, is given by the field-irrigation requirement multiplied by the area, divided by the time (in seconds):

$$Q = \frac{I_f \times A}{H \times 60 \times 60} \text{ plus canal losses}$$

Irrigation-Canal losses

Water is lost from canals by seepage through the bed and banks of the canal, leakage through holes, cracks and poor structures, and overflowing low sections of bank. The canal losses depend on the type of canal, materials, standard of construction and other factors, but are typically about 3 to 8 litres per second (l/s) per 100 metres for an unlined earthen canal carrying 20 to 60 l/s. Losses often account for a large proportion of water requirements in small-scale irrigation, and may be estimated by 'ponding' water in a trial length of canal, and then measuring the drop-of-water level. When the water-surface width in the canal is W meters, a drop of S millimeters per hour corresponds to an average canal loss of:

$$\frac{W \times S}{60 \times 60} \quad \text{l/s per meter length}$$

Example: What design discharge is required for a canal to irrigate an area of 10 hectares in the semi-arid subtropics, when the mean daily temperature is 30oC, and the mean rainfall is 0.2 mm/d during the peak period (midseason)? The canal is 800m long and is to operate for 12 hours per day.

Losses from a similar canal are measured as 48mm per hour with a water-surface width of 1.5m.

ETo = 7.5 mm/d; (see Table 1)

Hence the net irrigation requirement is:

$I_n = 7.5 - (0.7 \times 0.2) = 7.36$ mm/d;

and the field irrigation requirement is:

$I_f = 7.36/0.60 = 12.3$ mm/d

Canal losses = $\frac{48 \times 1.5}{60 \times 60} = 0.02$ l/s per metre length

$A = 10\text{ha} = 10 \times 10\,000\ \text{m}^2$

$Q = 12.3 \times (10 \times 10\,000) + 800 \times 0.02$

$= 28 + 16 = 44$ l/s

This design discharge of 44 l/s should be compared with the water available from the source. If less is available, the area may need to be reduced, or the irrigation time increased.

3.5.2 Canal design

Water may be conveyed from the source to the field by unlined or lined canal, pipeline, or a combination of the two. The unlined canal is the most common method in use.

A typical cross-section of an unlined earthen canal for small-scale irrigation is shown in Figure 2.2. To minimize losses, the canal banks should be built from clayey soil and constructed in layers, with each layer compacted using heavy rammers.

The required size of the canal can be decided using Manning's formula:

$$Q = A \times \frac{R^{0.67}}{N} \times s^{0.5}$$

A design chart, such as Figure 3.2, can be used.

For example, for a trapezoidal canal in clay soil with side slopes of 1 to 1.5, a design discharge of 44 l/s, and a slope of 0.001 (or 1 m/km), use a bed-width (B) of 0.5 m, and a depth (D) of 0.25 m.

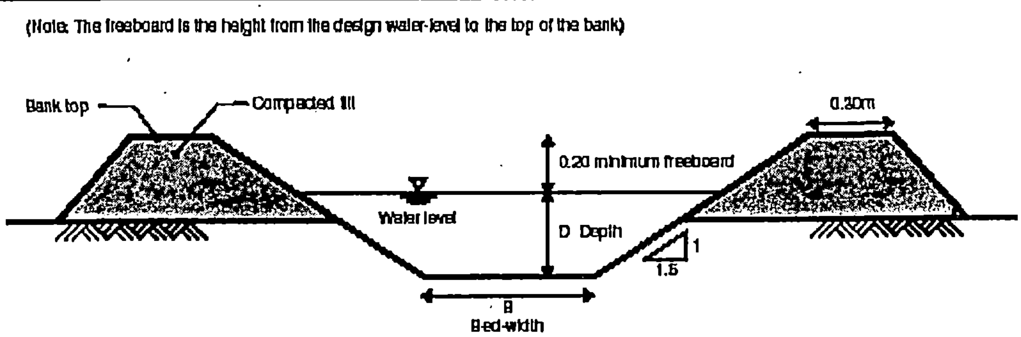
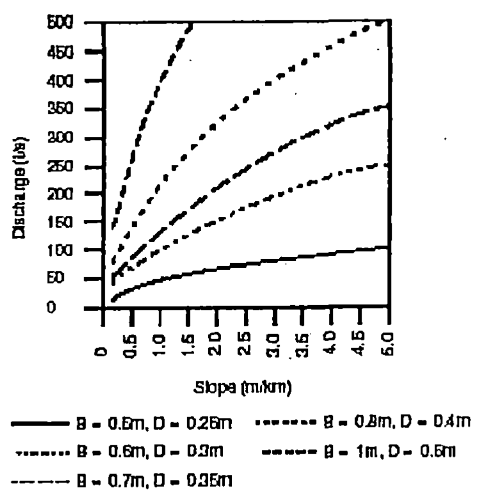


Figure 3-1. A typical cross-section of an unlined earthen canal

Table-3-1. Evapotranspiration (Eto) in mm/day for different agro-climatic conditions (FAO, 1977)

Regions	ET₀ in mm per day		
Mean daily temperature	*<10°C*	*20°C*	*>30°C*
Tropics			
Humid	3-4	4-5	5-6
Sub-humid	3-5	5-6	7-8
Semi-arid	4-5	6-7	8-9
Arid	4-5	7-8	9-10
Sub-tropics			
Summer			
Humid	3-4	4-5	5-6
Sub-humid	3-5	5-6	6-7
Semi-arid	4-5	6-7	7-8
Arid	4-5	7-8	10-11
Winter			
Humid - sub-humid	2-3	4-5	5-6
Semi-arid	3-4	5-6	7-8
Arid	3-4	6-7	10-11
Temperate			
Humid - sub-humid	2-3	3-4	5-7
Semi-arid - arid	3-4	5-6	8-9



B = Bed Width D = Depth

Figure 3-2 Discharges of trapezoidal canals

3.5.3 Distribution outlets

Outlets or division structures are used to distribute the water among a group of farmers. If the flow is less than 30 l/s, one farmer can probably use it efficiently for surface irrigation through one outlet, but larger flows need to be divided fairly between several outlets. In either case, it is important that outlets can be closed when not in use, and that water cannot leak out. The outlet shown in Figure 3.3 uses a pre-cast concrete, circular gate, which has proved to be effective in various countries, lasting longer than either a wood or metal gate. Simple bridges made from planks of wood or a concrete slab is also needed (see Figure 1), so that people and animals can cross the canal without damaging it.

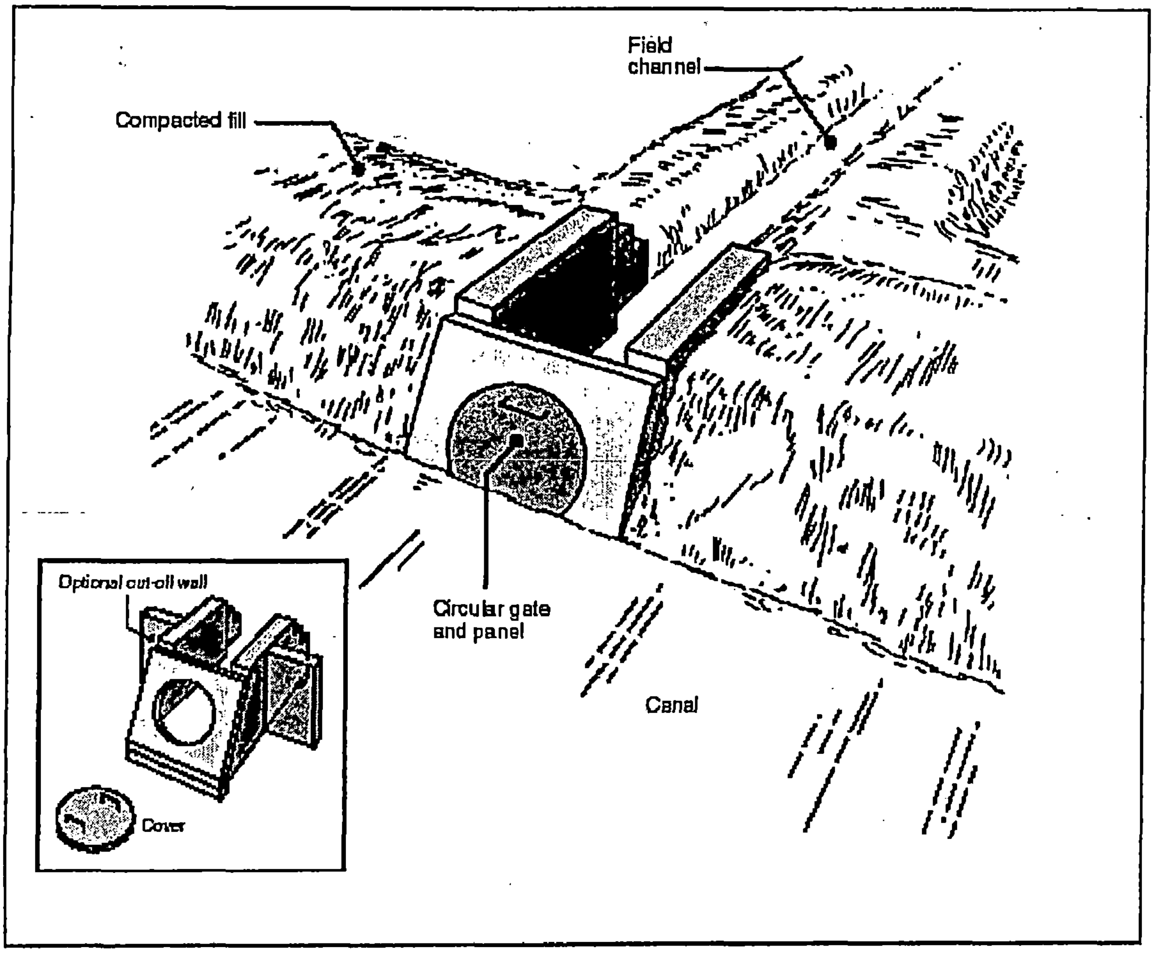


Figure 3-3. Pre-cast concrete circular gate and Panel with outlet structure

3.6 THE HUERTA OF VALENCIA

3.6.1 Operating Procedures

The plain (*vega*) of Valencia is one of several rich irrigated areas in South-eastern Spain, formed by stream deltas that are defined on three sides by mountains and on the fourth by the Mediterranean Sea.

Hot and sunny summers and nearly free-frost winters characterize the climate of *huerta* (intensively irrigated areas that surround or adjoin town), so a variety of crops can be grown in various rotations, producing two or three harvest a year. The principal crops are potatoes, onions, corn and vegetables, of which celery; spinach, cabbage, cauliflower, lettuce, beans, and artichokes are important varieties. In addition there are small hectarages of melon, peanuts, citrus, and rice. The Valencians have developed operating procedures that allow each farmer great freedom to select from among this variety of crops those he wants to cultivate.

The farms are small; eight-three percent occupy less than 1 ha. and virtually all of them occupy less than 5 ha. This extreme fragmentation of farmland is the consequence principally of two factors that have operated with increasing acceleration over the last on hundred and fifty years.

The areas rainfall is scant and irregular; it is supplemented by river water distributed to farms by canals and, to a considerably lesser extent, by groundwater abstracted with wells and pumps.

The traditional operating procedures of the irrigation recognize three conditions of water availability- abundance (*abundancia*), seasonal low water (*estiaje ordinaryo* or *mitjania* in Valencian), and extraordinary drought (*sequia extraordinaria* or *nesesitas gran* in Valencian)- and they prescribe different rules for each.

Groundwater is readily available and was used principally to supplement river water when the river was low. In many cases these wells were the product of private initiative. A group of landowners would organize a company and sell shares to raise the capital necessary to drill the well and install the motor. Having developed the groundwater, they would sell it by the hour to themselves as shareholders and to other farmers. Profits were distributed among the shareholders. In other cases the irrigation communities themselves developed the groundwater.

3.6.2 Governing Institutions

The typical irrigation community includes all holders of land with rights to water in a canal's service area. Each landholder- but no farmer who is a renter or sharecropper – is entitled to one vote in the community's legislature or general assembly (*junta general*), although his right to canal water and his share of the community's expenses for maintaining and operating the canal are measured roughly in proportion to the land he owns. The assembly which meet every two years, vote on proposed changes in the canal's policies, rules, and regulations (*ordenanzas*) concerning water distribution, canal maintenance, and other matters; on taxes for major replacements and new construction; and on officers to administer the canal's affair. The assembly elects a committee consists of four to eight (electos), each representing the users of a given lateral or zone of service area.

3.6.3 Short Term Operating Procedures

3.6.3.1 Periods of Ordinary Low Water

In periods of ordinary low water all farmers share water shortage in proportion to the number of hectares with right to water that they irrigate. This is accomplished by lengthening the time between deliveries of water. When the water reaches a farmer, he takes what he needs, but he will have to wait longer than in periods of abundance for the water to return for the next irrigation of his fields.

Canal officers may, in periods of ordinary low water, transfer water from one or more of the smaller laterals to another. Their discretion in this regard is prescribed by a general criterion for action and certain specific constraints. The general criterion, which is stated in different ways in the several ordinances, provides that water may be transferred if the farm served by one lateral need water whereas those in the other would not suffer if deprived of it. This criterion is derived from a more general principle, also to be found in the ordinances, that all farmers have an obligation to give aid to those who have the greater need. The transferred water is called favor water (*agua de gracia*).

On days when water is running in a lateral those farmers who wants to irrigate will take it in turn (*por turno*), generally in order from the head to the tail of the channel. Once a farmer opens his headgate, he takes all the water he needs, without any restriction of time; and he defines his own needs principally in terms of the water requirement of the crops he has chosen to plant. The only limitation is that he may not waste water. If a farmer fails to open his headgate when the water arrives there, he misses his turn and must wait for the water to return to the farm on the next rotation.

3.6.3.2 Periods of Extraordinary Drought

For periods of extraordinary drought the water users of Valencia have devised ingenious steps to enable the canal communities to continue distributing water according to the basic principle of the huertia: that water is supplied to each farmer in proportion to the area of the land he irrigates. As drought becomes more and more extreme, however, the effective discretion of the individual farmer to define his requirement becomes more limited, and ultimately the rule that water in proportion to land has to be abandoned.

Distribution to the canal of proportionate share of river water, initiated in the regimen of ordinary drought, additional steps are taken, however. It is designed to increase the utility of the limited water available in the river channel. It requires that the canals on the right and those on the left banks of the river alternate in taking water, each bank irrigating two days at a time. This measure does not increase the increase the volume of water that otherwise be abstracted by each canal, for a while it doubles the water in the canal at anytime it halves the time it is available. It does insure, however, that farmers will receive more of this volume in usable irrigation water than it would otherwise. Without this measure it would be difficult to raise the canal's water to the level of farm turnouts and to reach turnouts at the end of delivery routes. This measure is applied, the Valencian say, to double the water (*doblar el agua*). To initiate *la dobla*, the syndics flip a coin to determine which canals-those of the right or of the left bank-are to receive water for the first two days.

The canals that practiced rotations among their laterals during ordinary low water continue to do so in extraordinary drought, but they may need to alter their procedure because the canals will receive water only on alternate two-day periods.

As the water diminishes, the time between successive irrigations may become so long that the normal procedure, allowing each farmer to take all that he needs when the water reaches him, will have to be modified if all or most farmers are not to lose their crops.

A second modification of the normal operating procedures for distributing water among farms has been given priority to certain crops and in any rotation to deny all farmers water for non-priority crops. If there is insufficient water to meet the needs of all farmers for their priority crops, preference is given to those priority crops that, based on inspection by canal officers, are in greatest need of water.

3.6.3.3 Period of Water Abundance

Basically when water is abundant all principal canals, all their laterals, and all irrigators on each lateral take the water they need approximately when they need it. And since abundant water is likely to be an excess of the needs of land with rights, fields without right can also be supplied.

Even where water is abundant, however, the distribution network may not be sufficiently large or elaborate to serve all farms that demand water at the same time. Some form of operating procedure, or scheduling, is required because of the mechanics, or more properly the hydraulics, of distribution. Thus in some canals the procedure of rotation and repartitions among laterals t6hat is common during ordinary low water is continued when water is abundant; in other canals this procedure is relaxed. In most cases farmers along a lateral will continue to take water in turn, but the waiting period between successive turns will be short. Thus operating procedures for periods of water abundance may be complex, but this should not obscure the basic characteristic of water distribution in this season, namely that farmer gets the water they want approximately when they want it.

3.6.4 Long-Term Operating Procedures

Water shortage are of two types: short term, caused principally by climatic conditions in one or several successive growing seasons, and long term, caused principally by increased demand of water in response to continued expansion of the irrigated area. Proportionality is, as we have seen, the basic principle of Valencia's short-term operating procedures. But if limited water is distributed in proportion to land holdings, then of necessity there will be a restrictive definition of lands that can be served, for otherwise water would come to be divided into parts so small as to be useless. Thus those who hold land with water rights enjoy the benefits of the short-term operating procedures. Irrigable lands without rights but within reach of a canal's distribution network enjoy only the uncertain benefits of excess water and adjacent lands out of reach of the canal's lateral are either dry or irrigate exclusively with wells.

3.6.5 Community Objectives

The canal community say that their regulations are for the purpose of ensuring that all members enjoy the benefits of irrigation water with equality (*igualdad*) and equity (*equidad*). They use equality in two senses. In so far as it refers to participation of landowners in determining the canals' operating procedures, the meaning is absolute equality-one man, one vote. When the term is used in reference to the quantity of water provided to farmers, however, it means proportionate equality. The procedures are intended to guarantee that all users are favored equally in case of abundance and that all suffer equally in drought; but equal in this sense means in fixed proportion to the relative needs of crops in the farms and service areas of the several laterals and canals.

3.6.6 Conflict Resolutions

Principal objective of Valencia's farmers in determining procedures for allocating and distributing irrigation water and in establishing institutions to operate these procedures has been to mute conflicts among neighbours- that is, among users of the same canal, among the several canal communities of the huerta, and between huerta and upstream users.

The objective then, is to provide order and predictability so that water users can realize their other goals related to increased income, popular control, and social justice. To this end irrigators will adopt operating procedures and institutions that discourage conflicts and settle those that arise. Potential and actual conflicts among members of a community are resolved within the community itself on the basis of principles, rules or regulations to which all members have consented.

3.6.7 People's Participation and Control

All landowners have an equal vote in a canal community's general assembly and this assembly approves the canal's operating procedures, elects the executive committee whose members represent the principal service areas of the distribution network, and chooses directly or indirectly the canal's administrative officers. Furthermore the farmers of each lateral constitute a limited community, with equal votes, to choose ditch riders and special guards.

SMALL IRRIGATION SYSTEM EXISTING AND IN PRACTICE IN THE PHILIPPINES

4.1 PASINGKALAN DIVERSION DAM PROJECT

4.1.1 Salient Features

(i) Location	:	Barangay Pasingkalan, Municipality of Ramon Magsaysay, Zamboanga del Sur
(ii) Diversion Dam		
a) Height	:	0.70m
b) Width	:	8.00m
c) Length	:	9.00m
(iii) Service Area	:	50 ha.
(iv) Canal		
a) Design Discharge	:	0.10 cumecs
b) Bed Width	:	0.30m
c) Water Depth	:	0.20m
d) Bed Slope	:	16 to 46 m. per km.
e) Side-Slopes	:	1:1
f) Length	:	1134 m
(v) Flumes	:	6 units 1.00m x 0.80m
(vi) Road Crossing	:	4 units
(vii) Division Box	:	2 units
(viii) Culvert	:	1 unit
(x) Total Project Cost	:	P 904,420.95

This Diversion Dam/ Small Water Impounding Project has been entirely investigated, designed and implemented by the Department of Agriculture - Regional Field Unit-9, the lead agency mandated to implement the components of Ginintuang Ani Program (GAP) in the region with a Project Cost of P404, 420.95). This was implemented in the year 1996; all works were satisfactorily completed the same year.

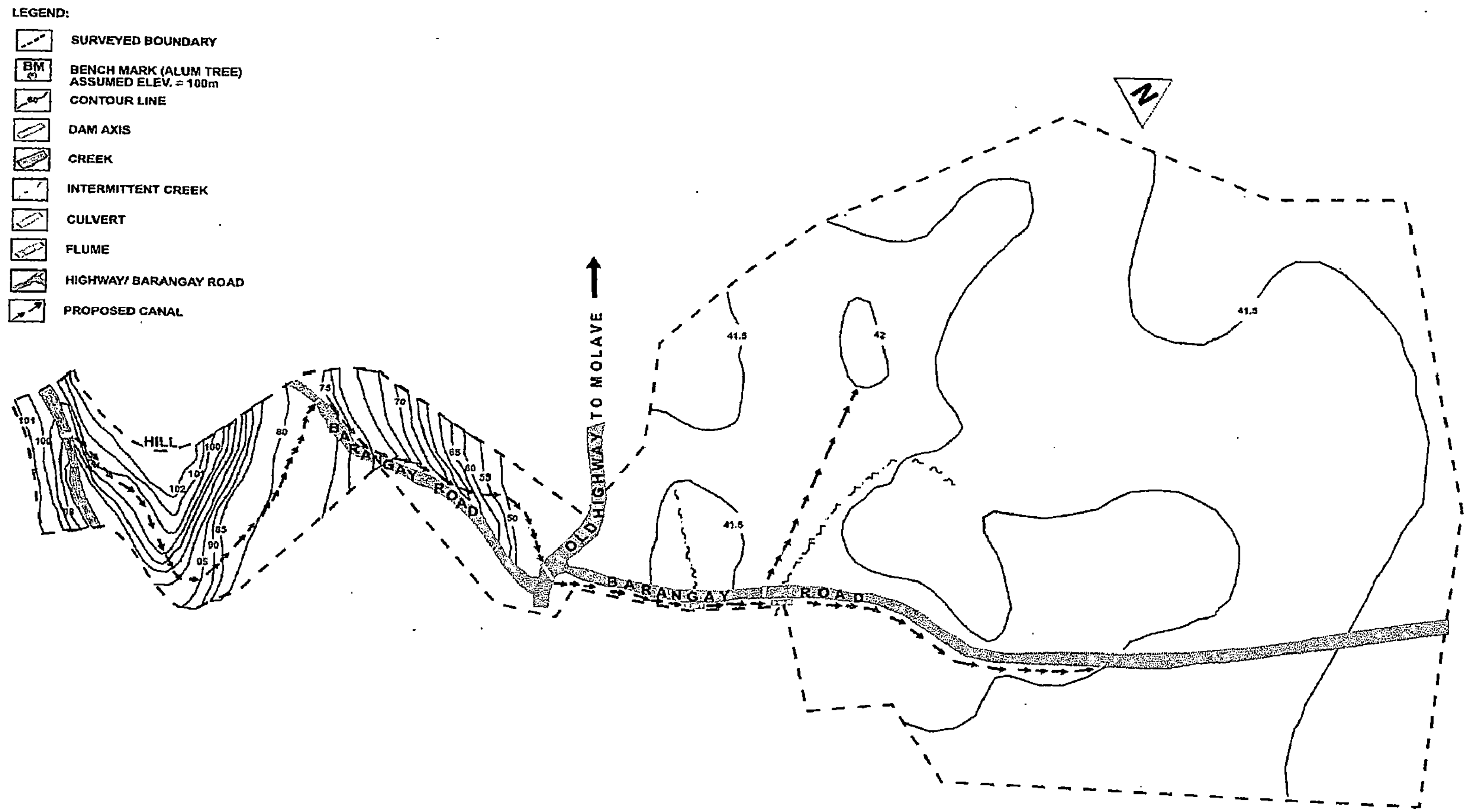


Figure 4-1. Farm Plan of Pasingkalan DD

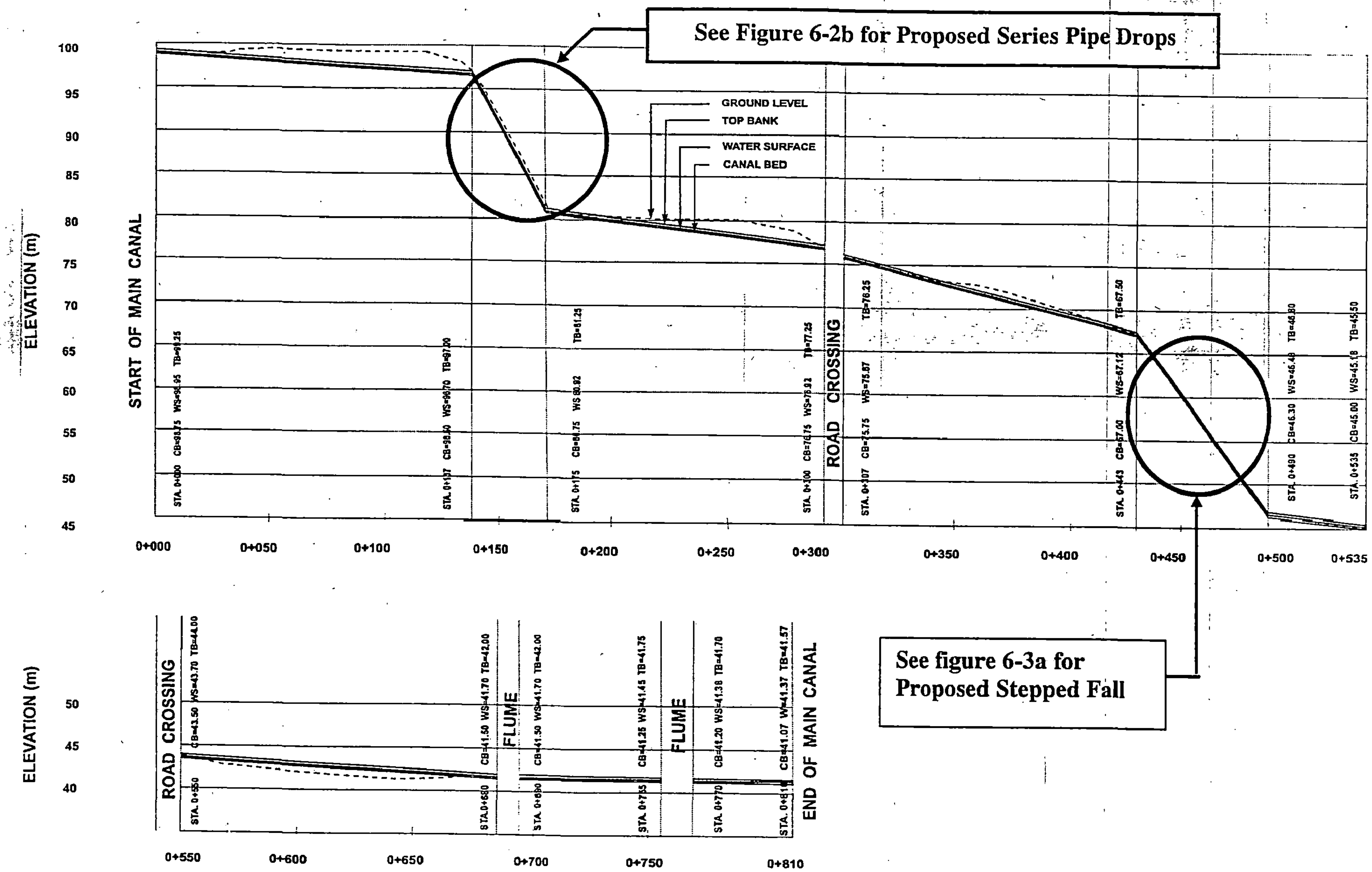


Figure 4-2. PROFILE OF MAIN CANAL

Table 4-1. HYDRAULIC PROPERTIES OF MAIN CANAL

STATION		Q	b	m	n	S	d	D	V
FROM	TO	(cumec)	(m)				(m)	(m)	(m/s)
0 + 000	0 + 137	0.10	0.30	1.00	0.03	0.016	0.20	0.50	1.00
0 + 137	0 + 175	0.10	0.30	1.00	0.03	0.414	0.11	0.50	3.39
0 + 175	0 + 300	0.10	0.30	1.00	0.03	0.032	0.17	0.50	1.30
0 + 300	0 + 307	ROAD CROSSING							
0 + 307	0 + 443	0.10	0.30	1.00	0.03	0.064	0.15	0.50	1.68
0 + 443	0 + 490	0.10	0.30	1.00	0.03	0.440	0.11	0.50	3.47
0 + 490	0 + 535	0.10	0.30	1.00	0.03	0.026	0.18	0.50	1.20
0 + 535	0 + 550	ROAD CROSSING							
0 + 550	0 + 680	0.10	0.30	1.00	0.03	0.015	0.20	0.50	0.98
0 + 680	0 + 690	CONCRETE FLUME							
0 + 690	0 + 755	0.10	0.30	1.00	0.03	0.004	0.26	0.50	0.60
0 + 755	0 + 770	CONCRETE FLUME							
0 + 770	0 + 810	0.10	0.30	1.00	0.03	0.003	0.27	0.50	0.53

The project initially consists of 1 Diversion Dam, 2 units road crossings, 2 units concrete Flumes, with a Main Canal length of 810m. It irrigates an area of 20 ha. rice field with an average yield of 5.5 Mt/ha.

Republic Act 8435- Agriculture and Food Modernization Act (AFMA) of 1997 declares food security to be a paramount goal of the state.

AFMA provides for the intensified development of the irrigation facilities for increased food production in order to meet the food requirement of the present and future generations.

In the year 2000, this project was Expanded/Rehabilitated. The service area was increased from 20 ha to 50 ha. rice field. The additional area, which used to have, 2 cropping in a year with an average yield of 3.5 hectares now have 3 cropping with an average yield of 5.5 ha.

4.1.2 Type of Structures/ Channels

Diversion Dam- This is the structure that raises the water flowing through rivers, creeks to a desired height. The water is then diverted to conveyance canal (e.g. main canal, laterals, and farm ditch) to supply the requirements of the areas served. Excess river flows over the dam and discharges to their main waterways.

Main Canal- Is any channel irrespective of the carrying capacity, which depart from river and also draws the supply directly from river or reservoir.

Flumes- These structures are used to convey or carry water above depressions such as rivers or creeks.

Road Crossings- These structures are used to convey water under roads or railroads. Pipe conduit is generally used for these purposes.

Division Box- This regulating structure is used to divide the flow from a supply pipe or channel among two or more channels or pipes.

Culvert – This cross-drainage structure carries storm runoff or drainage under the canal.

4.1.3 Design Concept

Diversion Dam - The selection of the best type of dam for a particular site calls for thorough consideration of characteristics of each type, as related to the physical features of the site and the adaptation to the purpose the dam is supposed to served, as well as economy, safety and other pertinent limitations.

The final choice of type of dam is generally be made after consideration of these factors.

Important physical factors in the choice of type of dam.

- ***Topography***- Topography in large measure, dictates the first choice of dam. A narrow stream flowing between high rocky walls would naturally suggest a concrete overflow dam. The low rolling plain country would, with equal fitness, suggest an earth fill dam with a separate spillway. For intermediate conditions, other considerations take on more importance, but the general principle of satisfactory conformity to natural conditions is a safe primary guide.
- ***Geology and Foundation Conditions***- Foundation conditions depend upon the geological character and thickness of the strata, which are to carry the weight of the dam, their inclination, permeability and relation to underlying strata, existing faults and fissures. The foundation will limit the choice of type to a certain extent, although such limitation will frequently be modified, considering the height of the proposed dam. The different foundations commonly encountered are:

  (i) Solid rock foundation

  (ii) Gravel foundation

  (iii) Silt or fine sand foundations

  (iv) Clay foundations

  (v) Non-uniform foundations

  The availability of sand and gravel for concrete at a reasonable cost locally and perhaps even on property, which is to be acquired for the project, is a factor favorable to the use of a concrete structure.

- ***Spillway size and location***- the spillway is a vital appurtenance of a dam. Frequently its size and type and the natural restrictions in its location will be the controlling factors in the choice of the type of dam. Spillway requirements are dictated primarily by the runoff and stream flow characteristics, independent of the site conditions or type or size of the dam. The selection of specific spillway types will be influenced by the magnitude of the floods to be bypassed. Thus, it can be seen that, on streams with large flood potential, the spillway will become the dominant structure and the selection of type of dam could become a secondary consideration.

Main Canal - The channel dimension i.e. bed slope, bed width and water depth are chosen in such a way that the channel will carry the required discharge at a velocity appropriate to the particular class of silt carried (see figure 4-3).

Design Considerations

- The most commonly adopted bed slopes from economic considerations are from 1 in 4000 to 1 in 2500, except in steeply sloping terrain where these slopes are not feasible.
- Due to small cross-section of the canal, a side slope of 1:1 is most commonly adopted for most of the soils.
- Freeboard.- Canal banks is extended above the canal normal water surface as a safety measure to protect the conveyance system from overtopping. Freeboard provides for a canal water surface higher than normal which may be caused by sedimentation in the canal, temporary disoperation of the canal, excess flows caused by storm runoff entering the canal through drain inlets, additional water depth resulting from a rougher friction coefficient than used for design, and waves produced by wind or surges which accompany sudden changes in flow.

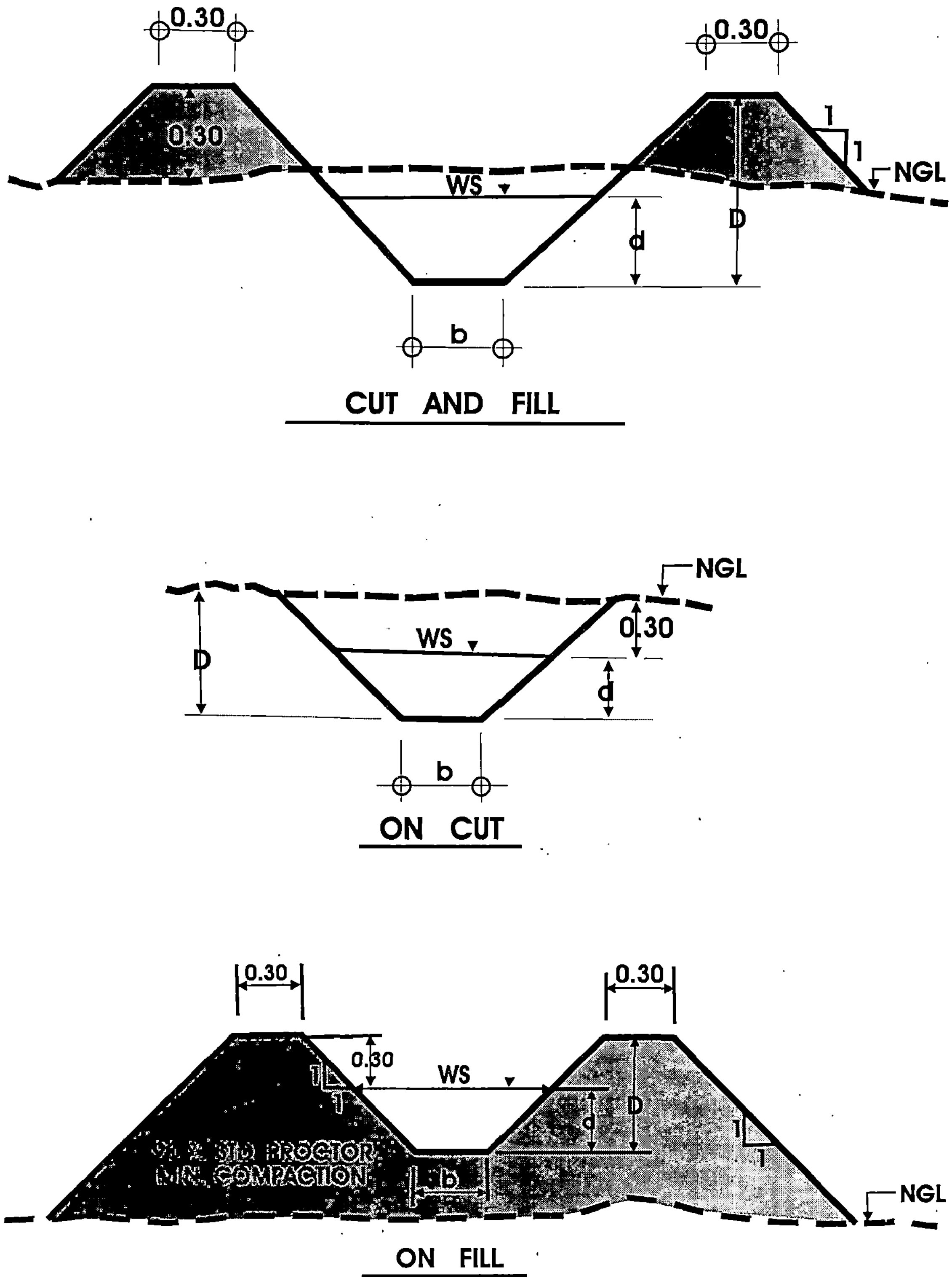


Figure 4-3. TYPICAL CANAL SECTION

DESIGN OF MAIN CANAL

Q = 0.10 cumecs, n = 0.03, s = 0.016, SS = 1:1

For trapezoidal section with side slope = **1**:1

$A = bd + d^2$, when $b = 1.5d$

$A = 1.5d^2 + d^2 = 2.5\, d^2$,

$P = 2.82d + b = 2.82d + 1.5d = 4.32d$,

$R = A/P = 0.58d$

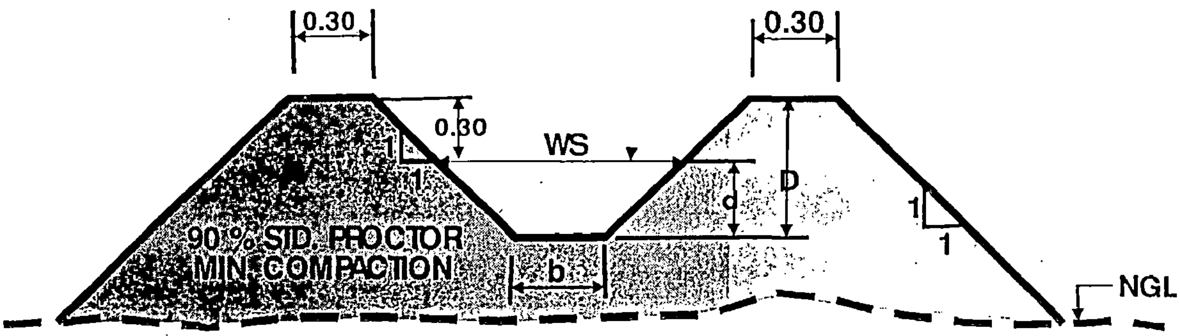
From Manning's formula

$V = 1/n\, R^{2/3} S^{1/2} = 1/0.03\,(0.58d)^{2/3}(0.016)^{1/2} = 2.93d^{2/3}$

$Q = AV$

$0.10 = 2.5d^2 \times 2.93d^{2/3} = 7.32d^{8/3}$

$d = 0.20m$, $b = 1.5d = 1.5(0.20) =$ **$0.30m$, $V = 1.00$ m/s**



ON FILL

TYPICAL CANAL SECTION

The normal freeboard ranges from 0.30m to 0.60m depending upon the size of the canal and local conditions.

Design procedure for Unlined Canals

The procedure for unlined canal commonly adopted is to determine width and depth of a canal for a given discharge. Since bed slope, rugosity coefficient are known, by Manning's formula the hydraulic mean depth can be worked out. Cross-sectional area is given by Q/V, and wetted perimeter A/R. Knowing P and R and side slopes of the canal cross-section, it is now possible to work out for width and depth.

Manning's Formula:

$$V = 1/n \,.\, R^{2/3} \,.\, S^{1/2} \text{ (Metric units)}$$

Normally, "Q" and "n" are given as design data.

Elevated Flumes- Flumes supported above the ground with reinforced concrete, structural steel, or timber used to carry canal water over natural drainage channels or depressions.

Hydraulic Considerations.

- *Ratio b/d*- The most hydraulically efficient rectangular section is one with a b/d ratio equal to 2. Although this ratio is often used, other considerations may suggest that a flume be narrower or wider.

  A study of b/d ratio in regards to hydraulic efficiency and construction cost indicates that an acceptable b/d ratio is in the range about 1 and 3.

- *Slope and Velocity*- The most economical flume section will have velocities greater than those allowed in earth canal. Because velocities in a flume are ordinarily greater than in an earth canal, a steeper slope will be required.

  Studies shows that with the b/d ratio equal to 1, 2, or 3 and for capacities of 100 cusec or less the slope of the flume invert should not be steeper than s = 0.002. This criterion applies not only to the flume design slope but also to the actual flume slope due to construction tolerances that could otherwise result in supercritical slopes.

- ***Freeboard-*** Freeboard for flumes will depend upon a number of factors such as the size of flume, velocity of water, curvature alignment, and anticipated operation.

Transitions.- Wherever a flume is used with a canal, transitioning from the canal section to the flume section is usually required to provide a relatively smooth water surface and to conserve energy. This is usually also true with transitioning from flume section, especially if the canal section is unlined.

The length of the inlet transition is determined by using a maximum convergence angle of 27-1/2 ^{0} between the water surface and the transition centerline.

Concrete transitions provide the following benefits:

(1) A greater capacity is provided by good transitioning.
(2) The required length of pipe may be shortened of the concrete transitioned.
(3) The potential reduction in erosion reduces the treat to the canal bank.
(4) The cutoff wall used with concrete transition reduces the threat of piping by percolation.

Cutoffs.- Cutoffs are provided to reduce percolation around transition and to add stability and structural strength to transition. Cutoffs are required at the end of transitions in concrete-lined canals as well as in other lined or earth canals.

Cutoff walls should, in general, be a minimum of 24 inches deep for water depths up to at the cutoff. For some small structures, 18–inch cutoffs may be satisfactory. The minimum thickness should be 6 inches for 18 and 24-inch cutoffs.

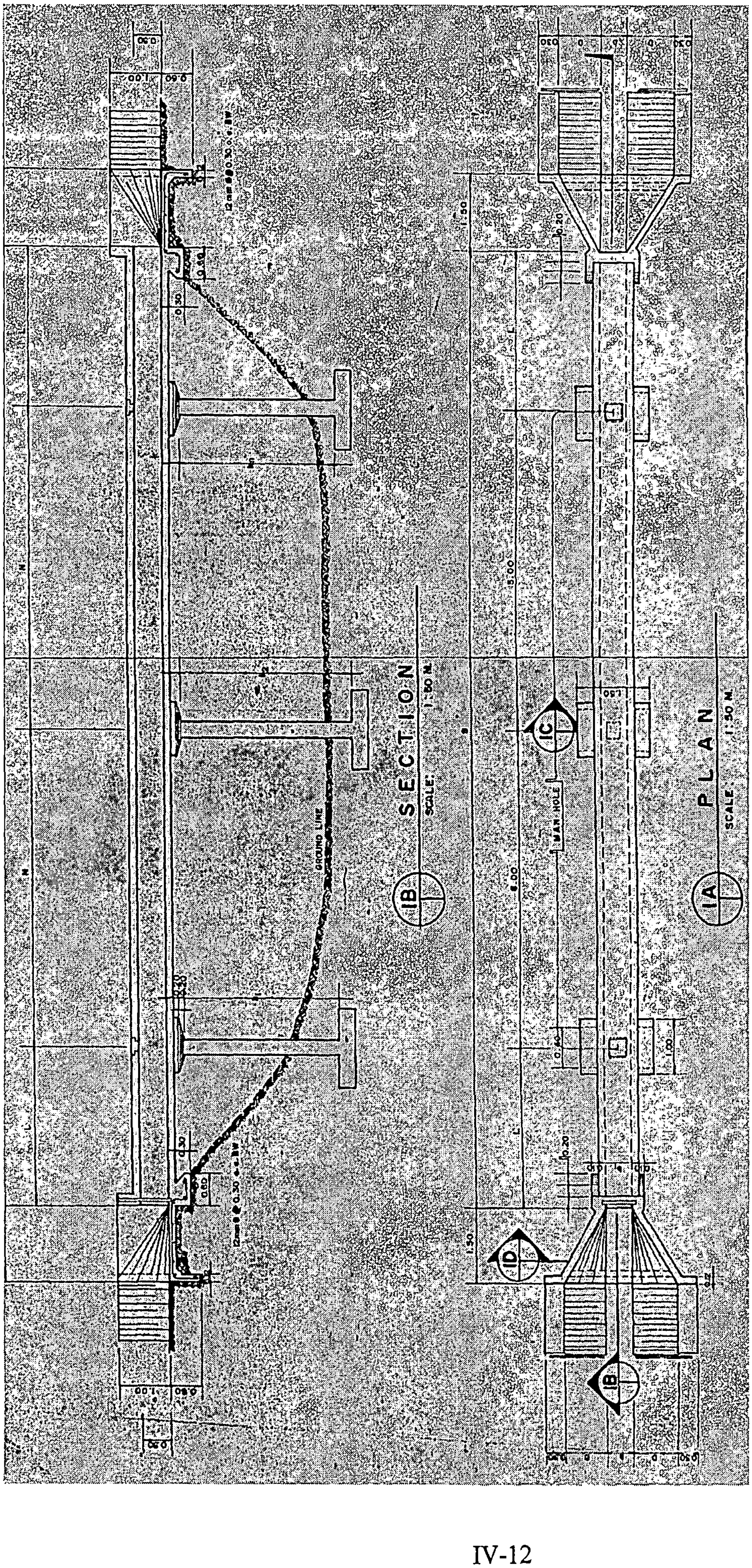


Figure 4-4a. CONCRETE FLUME

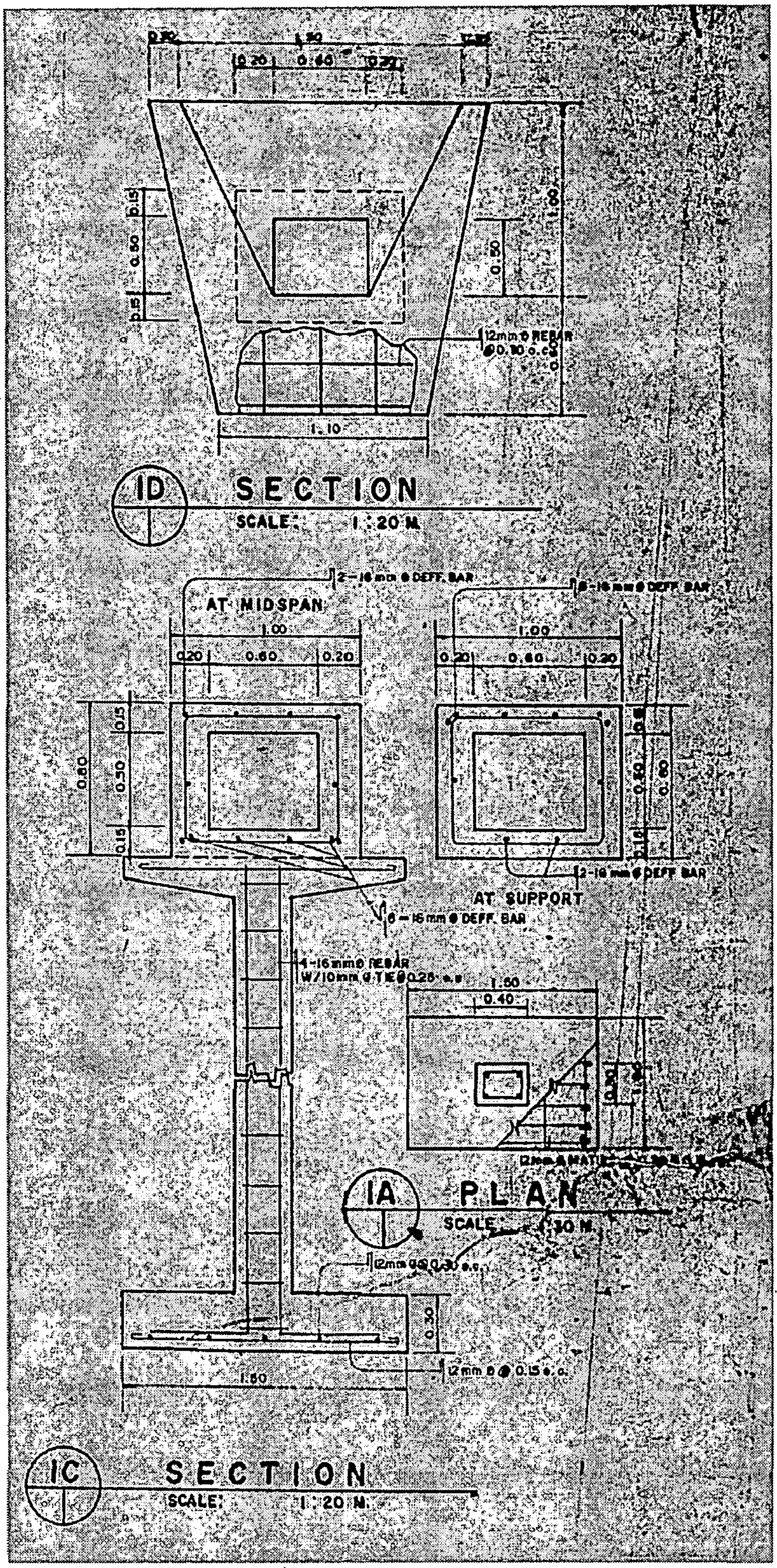


Figure 4-4b. CONCRETE FLUME

DESIGN OF ELEVATED FLUME

Earth canal hydraulic properties

Q = 0.10 cumecs, V = 0.50 m/s , h_v = 0.013

Flume with Rectangular section, b/d ratio = 2

S = 0.001 , n=0.014

$A = 2d^2$,

P = b + 2d,

=4d

R= A/P

R = 0.5d (Best Hydraulic Section)

$V = 1/n\ R^{2/3}S^{1/2} = 1.42d2^{/3}$

Q = AV

$0.10=2d^2x\ 1.42d^{2/3}$

d = 0.285, b = 0.57

adapt d = 0.30 m, b = 0.60 m ; V = 0.73 m/s

Road Crossings- Pipe conduit is generally used for these purposes; it is more economical than a bridge.

Advantages.- Pipe road crossing are relatively economical, easily designed and built, and have proven a reliable means of conveying water under a roadway.

Design Considerations.

- ***Pipe.-*** The pipe may be steel corrugated–metal pipe (CMP), asbestos-cement pipe (AC), precast reinforced concrete culvert pipe (RCCP) or precast reinforced pressure pipe (PCP). Where watertightness of the pipe is of minor concern, the selection of corrugated-metal pipe, asbestos-cement, or concrete pipe is often established by past experience. However, considerations involved with the selection include hydraulic efficiency, corrosion environment, and cost consideration.
- ***Transitions-*** is generally used both at the inlet and outlet of structures. An accelerating water velocity usually occurs at the inlet and a decelerating velocity at the outlet. Transitions reduce head losses and prevent canal erosion by making the velocity changes less abrupt for this purpose. Concrete, earth, and combination of concrete-earth transitions are used for this purpose.
- ***Pipe collars-*** may be provided to reduce the velocity of the water moving along the outside of the pipe or through the surrounding the earth thereby preventing removal of soil particles (piping) at the point of emergence.

  The pipe hydraulic design should be examined to determine if the resulting earth cover from top of the roadway to the top of the pipe meets the following minimum requirements:

(1) At all railroad and road crossings a minimum of 3 feet of earth cover should be provided. If roadway ditches exist and are extended over the pipe, the minimum distance from the ditch invert to the top of the pipe should be 2 feet.

(2) At farm road crossings a minimum earth cover of 2 feet should be provided for both the roadway and the ditches. Farm roads are frequently ramp using 10 to 1 slopes (10 %) when necessary to provide a minimum earth cover requirement.

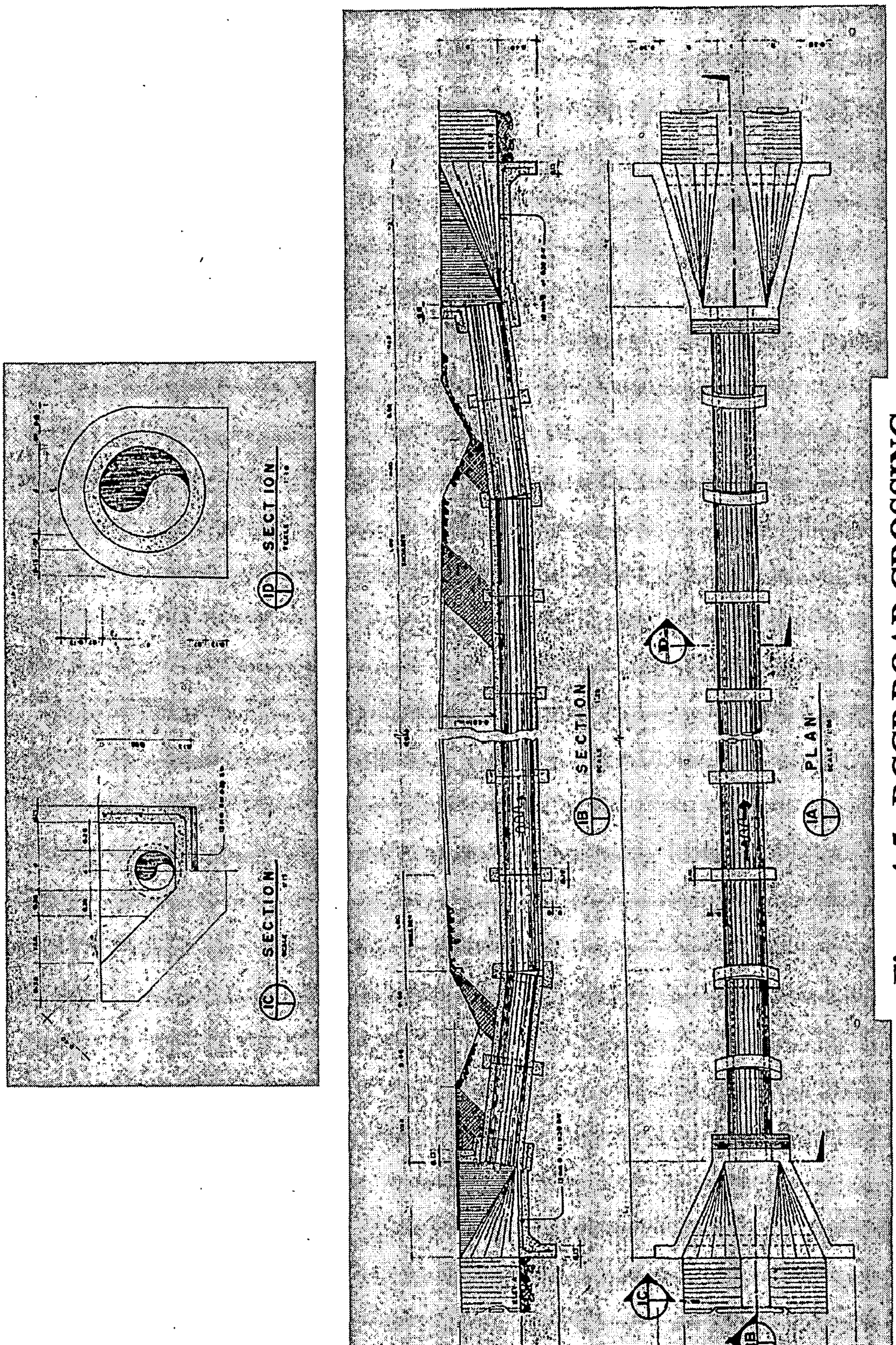


Figure 4-5. RCCP ROAD CROSSING

Division Box – Water must be delivered to the division structure at an elevation that will provide enough head on the weirs to furnish the required flow at the required delivery water surface elevation.

When delivery to the division structure is through a pipe, the velocity in the pipe is held to about 1.5 feet per second to reduce turbulence ahead of the weirs.

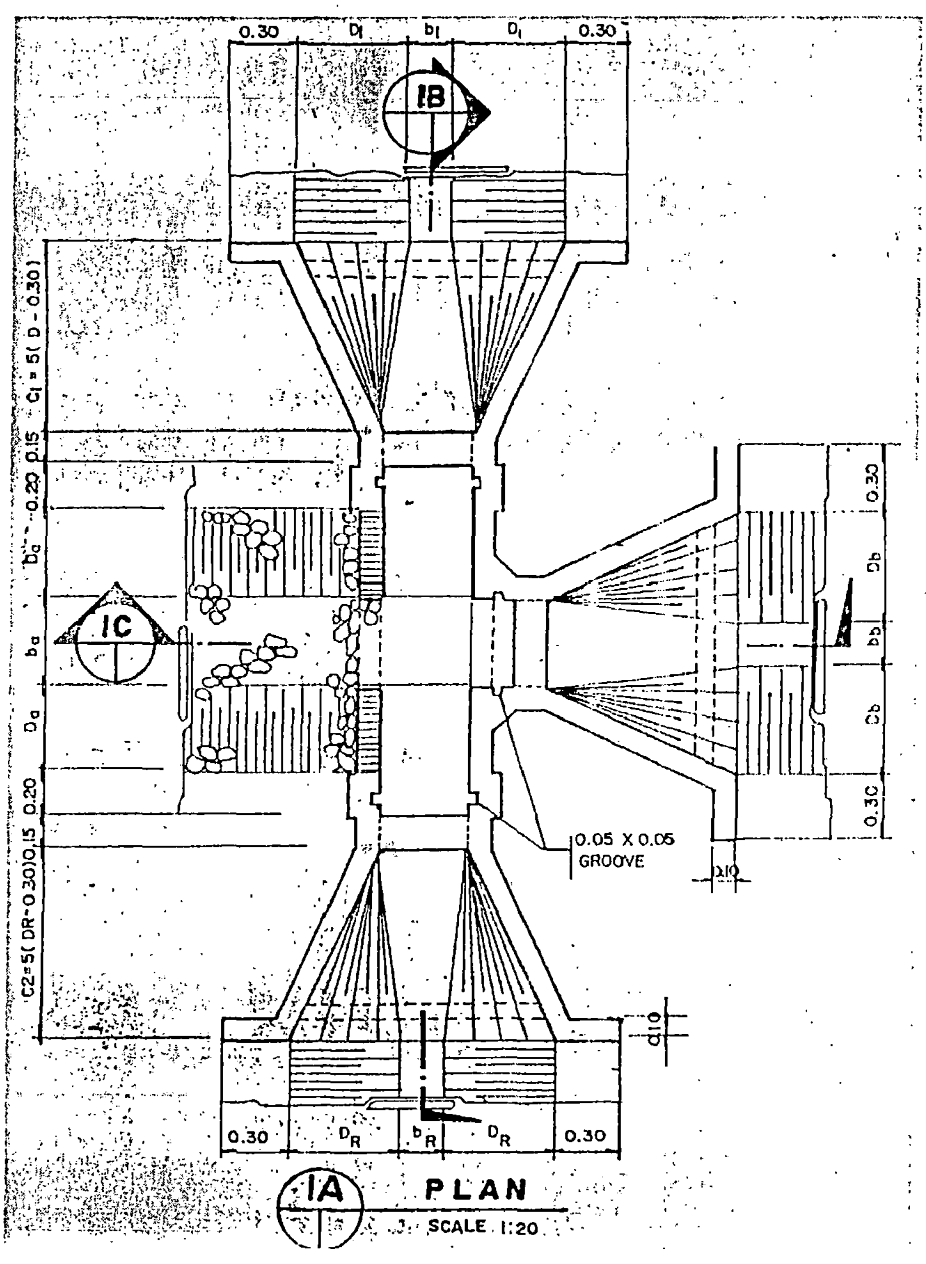
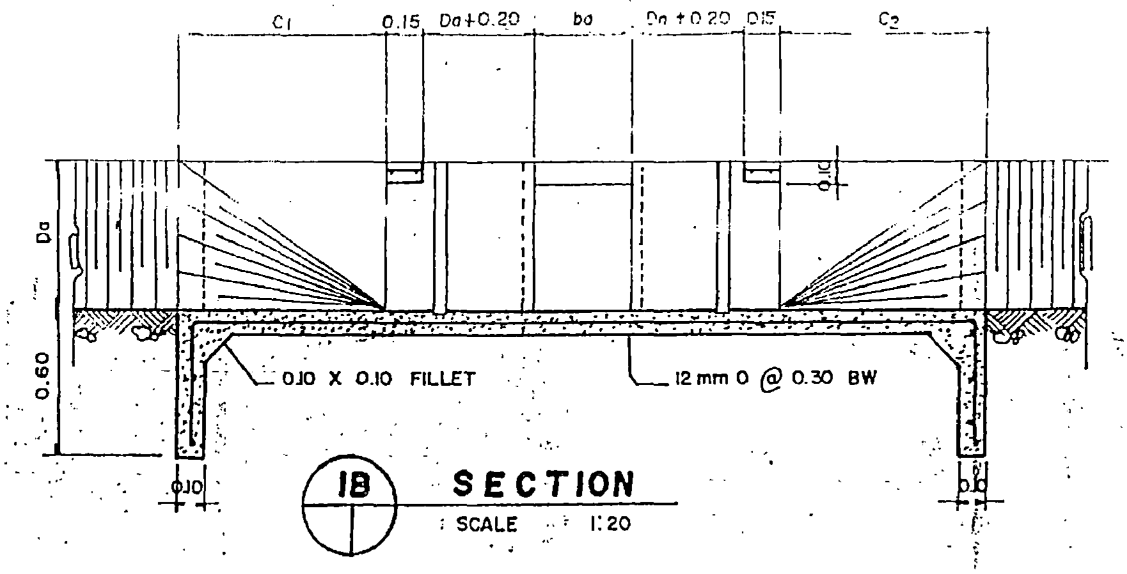


Figure 4-6a. DIVISION BOX RIGHT/LEFT



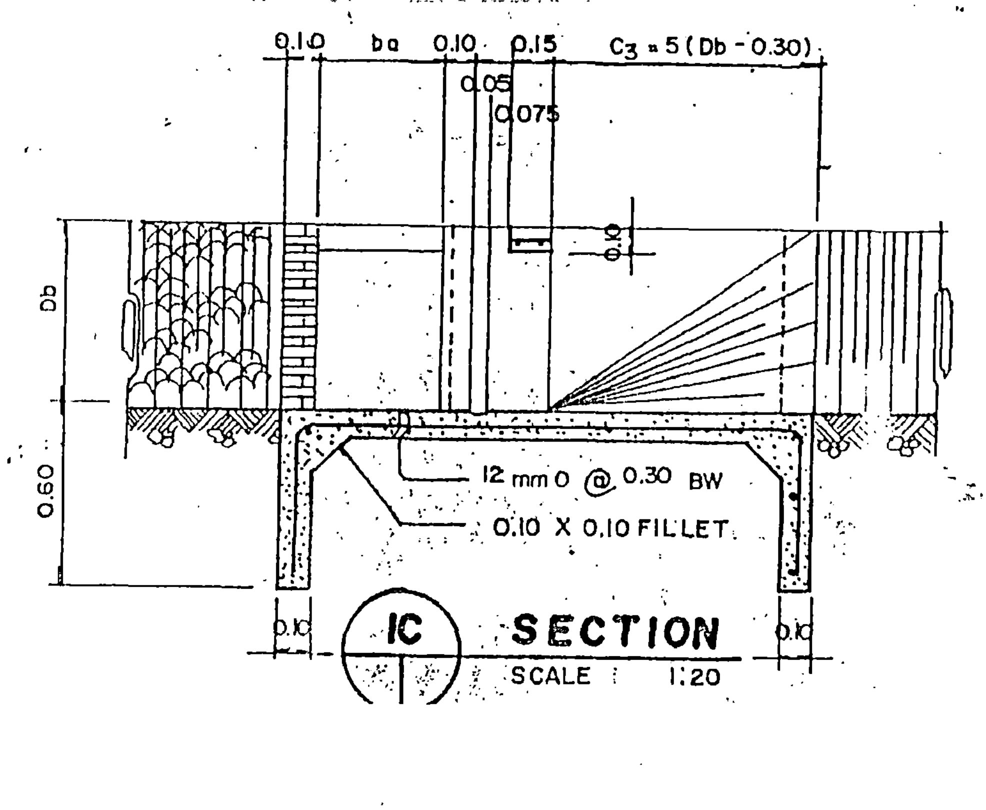
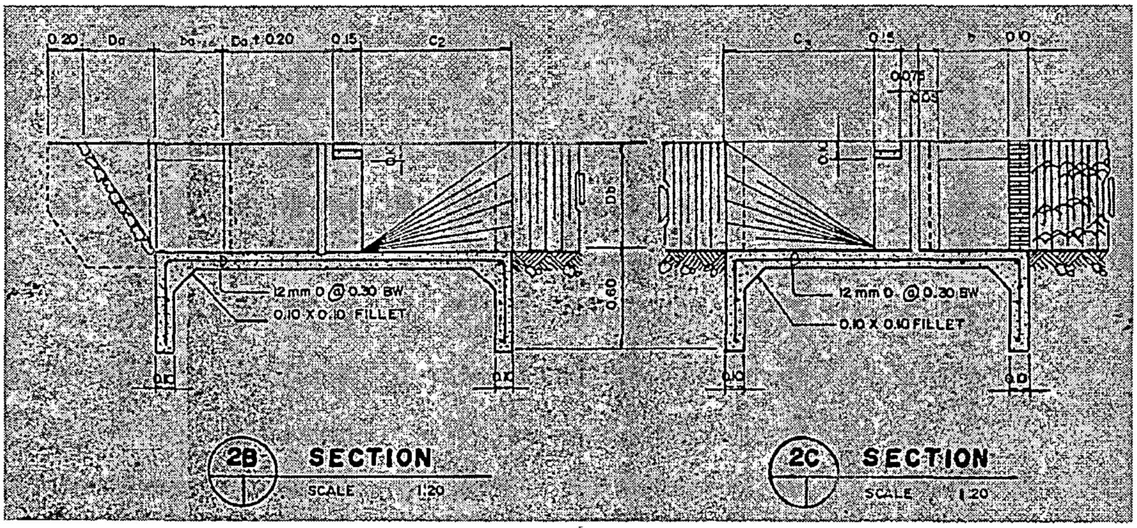


Figure 4-6b. DIVISION BOX RIGHT/LEFT



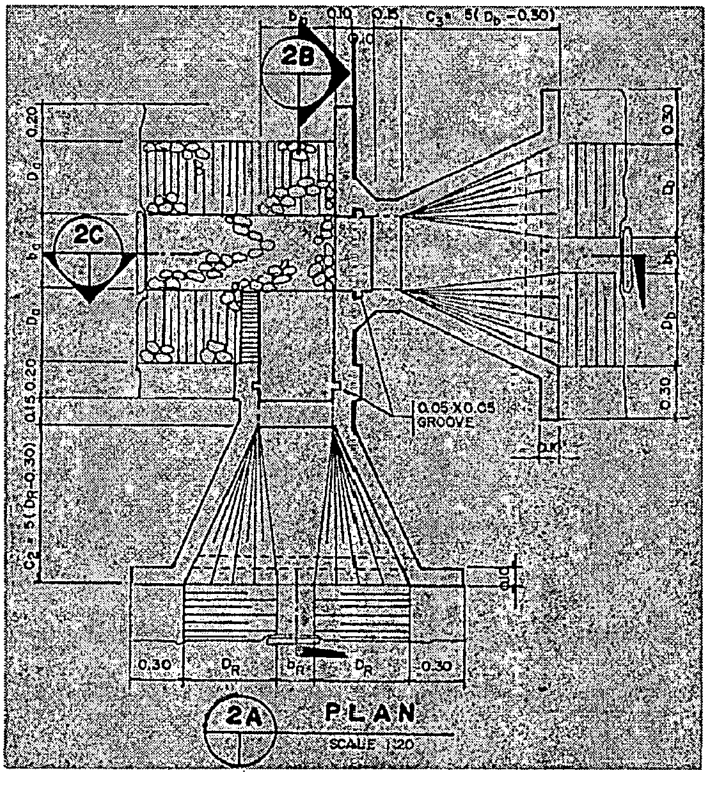


Figure 4-6c. DIVISION BOX RIGHT

Culvert – Thorough consideration should be given to the culvert alignment, profile, conduit, inlet, and outlet, with special attention given to the hydraulic design (see figure 4-8).

Alignment - A primary rule in locating a culvert is to utilize the natural channel with as little disturbance as possible to the natural runoff pattern.

Open drains paralleling the canal on the uphill side to intercept runoff water, should flow, if possible, to a natural channel, where conditions are best for locating a culvert. However, where natural channels are not available, such flow should be diverted across the canal at locations based upon economic culvert size and spacing.

Conduit – Culverts may be single or multibarreled as shown in figure 4-12, and may consists of any of the following types of conduit:

- Precast reinforced concrete pressure pipe (PCP)
- Precast reinforced concrete culvert pipe (RCCP)
- Asbestos-cement pressure pipe (AC)
- Reinforced plastic mortar pressure pipe (RPM)

The type of conduit selected for a particular site is dependent upon the project life, the life expectancy of the pipe, the loading conditions to be imposed upon the pipe, the relative cost of each type, and its availability at the site.

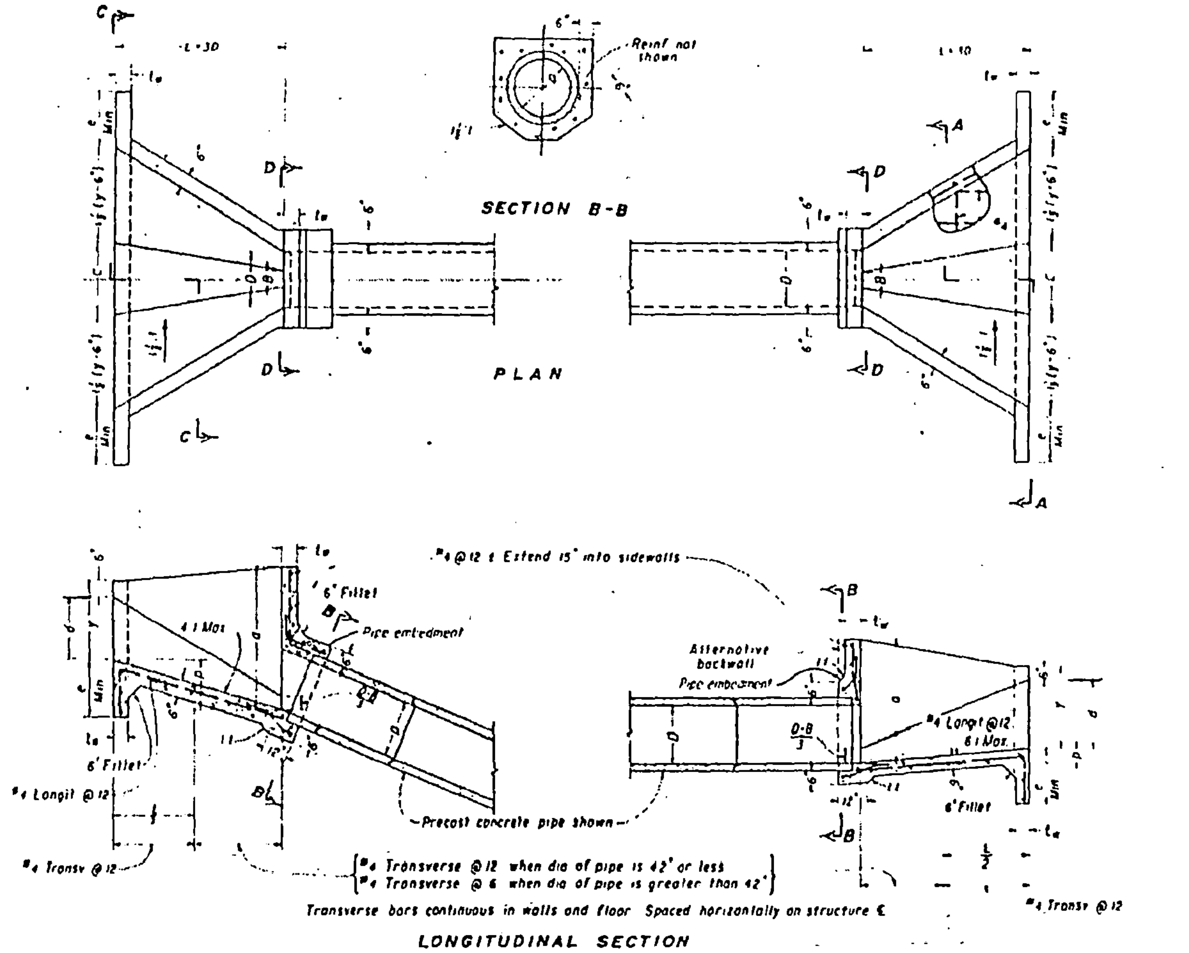
The type of conduit selected for a particular site is dependent upon the project life, the life expectancy of the pipe, the loading conditions to be imposed upon the pipe, the relative cost of each type, and its availability at the site.

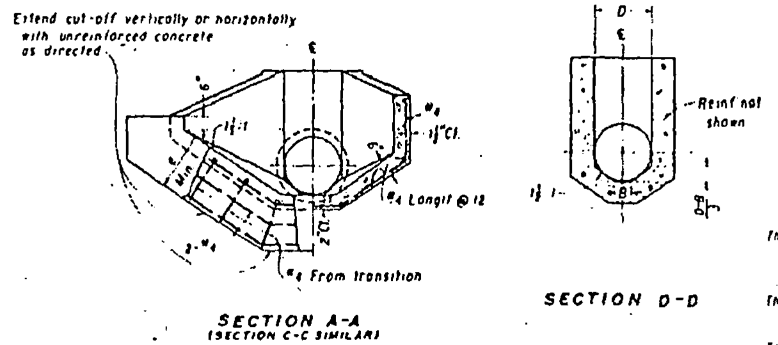
Considering the above factors, precast concrete pipe is the usual choice for culverts under canals, providing excellent strength, durability, watertightness, and flow characteristics. Rubber gasket joints are used to prevent leakage and to provide flexibility.

To avoid plugging with debris, the minimum diameter usually considered for culverts is 24 inches. However, this should not be considered inflexible, as the nature and quantity of debris in the drainage area, together with the extent of damage that could result from plugging, should be evaluated in establishing a minimum diameter.

Inlet – Several types of transitions are used as culvert inlet. The best choice for any particular situation is dependent upon the hydraulics, the topographic character of the site, and the relative elevations of the canal and drainage channel. Suitability of each of the basic types of transitions to use under various conditions is given as follows.

- Type 1- The broken back transition, as shown in figure 4-7, is best suited to a well defined inlet channel, where the channel banks can be shaped to conform to the side of the transition.
- Type 2- The type 2 transition is well suited to use in a wide, poorly defined channel, and combines the economy of simple lines with good flow characteristics (see figure 4-8).
- Type 3- The type 3 transition (see figure 4-9), like type 2, is suitable to use in a poorly defined channel. By extending the pool beyond the end of the sloping sidewalls, a longer crest results. By lowering the invert, the headwall opening is lowered, resulting in a lower water surface elevation for the inlet pool.
- Type 4- Except for its sloping floor, and the omission of the headwall cutoff, the type 4 transition, as shown in figure 4-10, is similar to type 3. The sloping floor permits a lower pipe invert at the inlet headwall the type 4 transition.
- Precast Concrete Transition- Precast concrete transition as shown in figure 4-11 are usually quite satisfactory, and may be more economical in some areas, particularly if a large number of transitions of the same size are required.
- Earth Transition- The designer may find that a particular culvert does not require a concrete transition due to the character of the earth or rock material in which it is constructed. An earth transition is permitted if the design flow can be carried with a maximum full pipe velocity of 5 feet per second with no encroachment on the freeboard requirement.





DIMENSIONS e AND t_w

DEPTH (d) OF WATER IN CANAL	e	t_w
0' to 3'	24"	6"
3' to 6'	2'-6"	8"
Greater than 6'	[illegible]	8"

NOTES

The minimum freeboard of the transition cutoff of structures in earth lined or unlined canals should be 6 inches for depths of water at the cutoff of 0 to 1.25 feet, 9 inches for depths 1.26 to 2.00 feet, and 12 inches for depths 2.00 to 3.00 feet.
The freeboard of the transition cutoff of structures in hard surface lined canals should be the same as the freeboard of the lining.
The freeboard of transition headwalls should be equal to or greater than the freeboard of the cutoff, for 24 inch pipe and smaller and the freeboard should increase as the size of the structure increases.
B = 1.0 D
y = Depth (d) of cutoff plus freeboard of cutoff
The elevation of the invert of the headwall is determined from the required submergence of the headwall opening

DIMENSION C

RELATIONSHIP OF PIPE DIAMETER (D) TO DEPTH (d) IN CANAL	C WITH WATER SURFACE ANGLE OF 22 ½°	C WITH WATER SURFACE ANGLE OF 25°	C WITH WATER SURFACE ANGLE OF 27 ½°
D=d	.90	.80	1.10
D=1.25d	1.10	1.40	1.70
D=1.5d	1.50	1.80	2.10
D=2d	2.00	2.10	2.60

Figure 4-7. Concrete transitions- type 1.

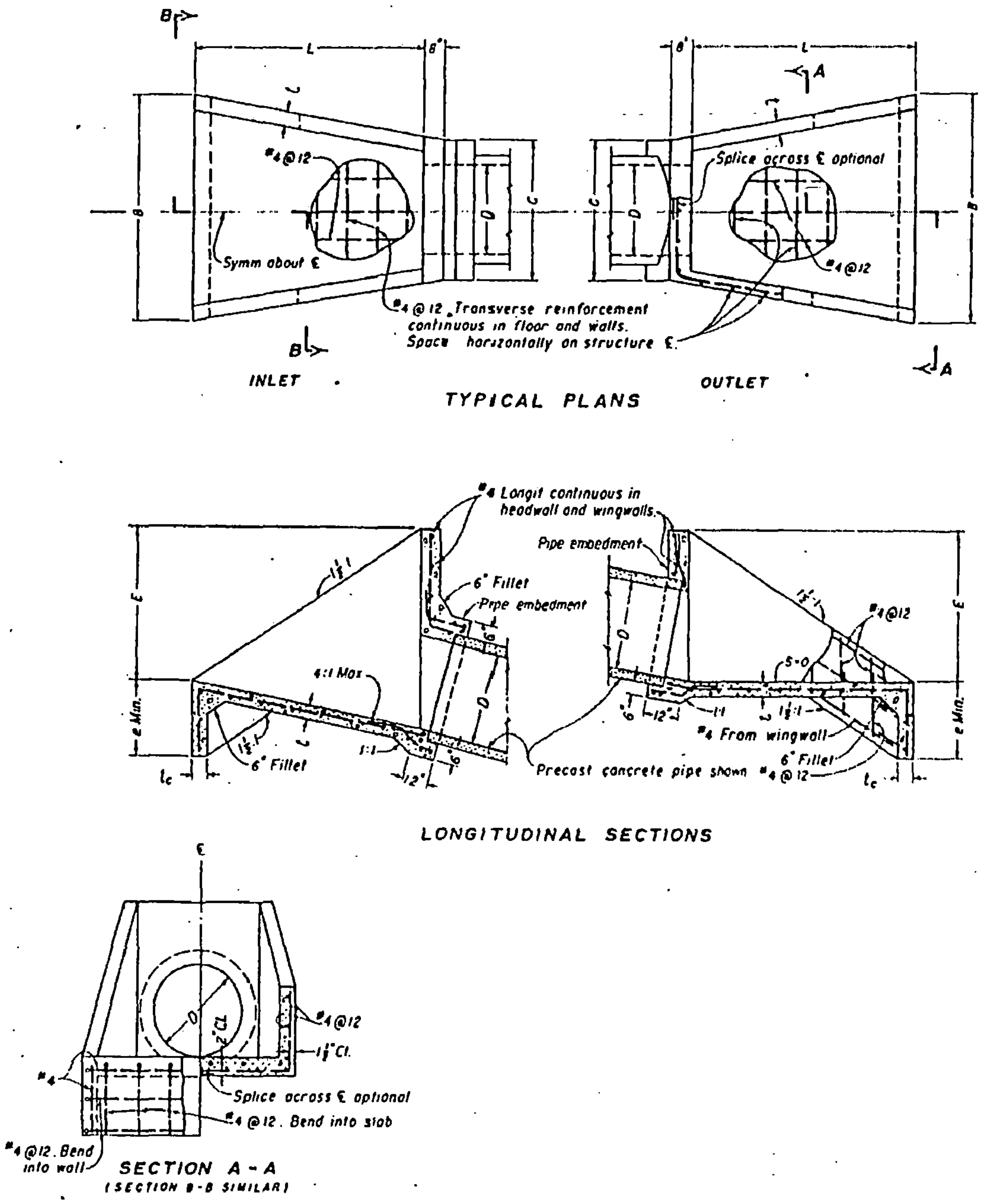
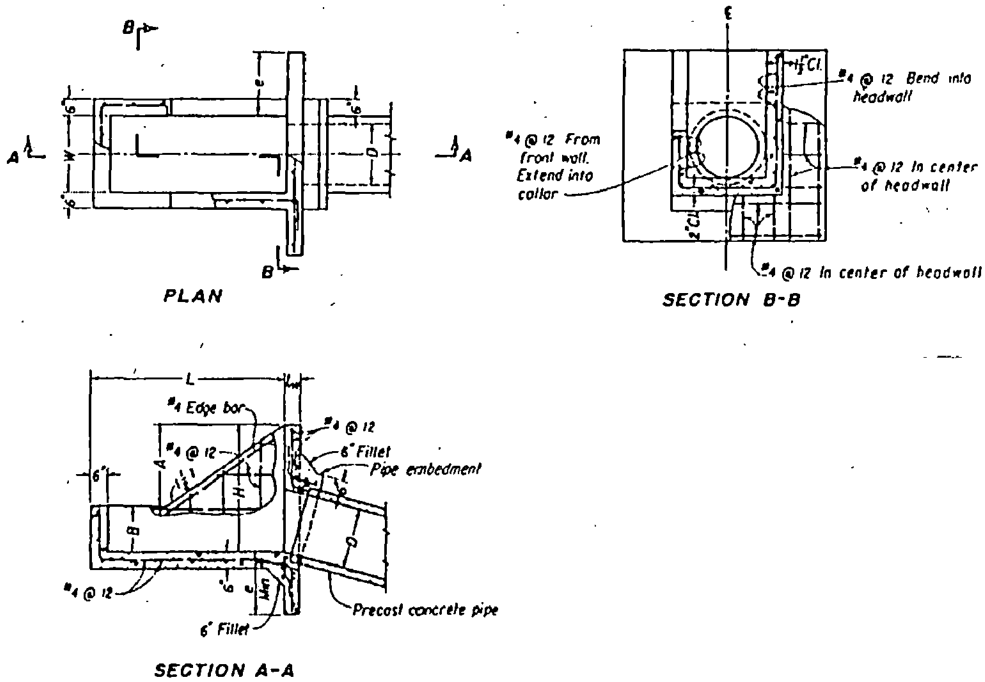


TABLE OF DIMENSIONS AND EST. QUANTITIES

D	E	e	L	B	C	t	t_c	CONC. (CU. YDS.)	REINF. (LBS.)
24"	4'-0"	24"	6'-0"	5'-6"	3'-6"	5"	6"	1.7	140
27"	4'-6"	24"	6'-9"	5'-6"	3'-9"	5"	6"	2.0	160
30"	4'-6"	24"	6'-9"	6'-6"	4'-2"	5"	6"	2.2	180
33"	5'-0"	2'-6"	7'-6"	7'-6"	4'-4"	5"	8"	2.4	200
36"	5'-0"	2'-6"	7'-6"	7'-6"	4'-8"	5"	8"	2.7	220
39"	5'-6"	2'-6"	8'-3"	9'-0"	5'-0"	6"	8"	3.5	280
42"	5'-6"	2'-6"	8'-3"	9'-0"	5'-3"	6"	8"	3.6	290
45"	6'-0"	2'-6"	9'-0"	10'-6"	5'-6"	7"	8"	4.7	370
48"	6'-0"	2'-6"	9'-0"	10'-6"	6'-0"	7"	8"	4.8	380

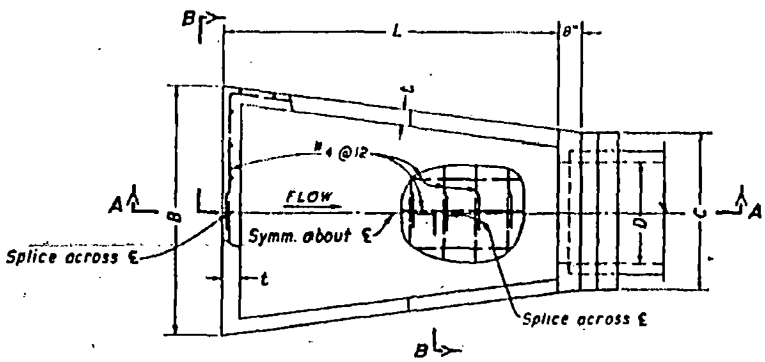
Figure 4-8. Concrete transitions- type 2.



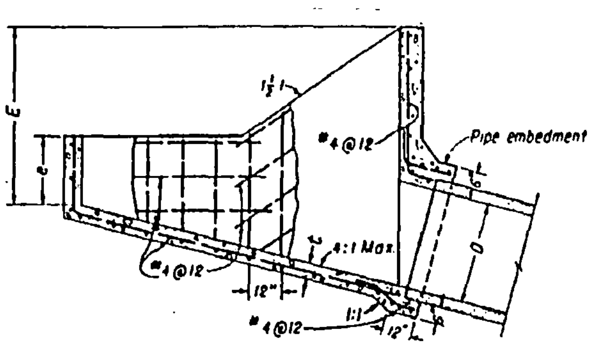
STR. No.	MAX. Q	DIMENSIONS								EST. QUANTITIES	
		D	L	W	H	A	B	t_w	e	CONCRETE CUBIC YDS.	REINF. STEEL LBS.
24-1	16	24"	6'-0"	2'-6"	4'-0"	2'-6"	18"	6"	24"	1.8	140
24-2	21	24"	6'-0"	2'-6"	4'-6"	2'-6"	24"	6"	24"	2.0	160
24-3	26	24"	6'-0"	2'-6"	5'-0"	2'-6"	2'-6"	6"	24"	2.2	180
24-4	31	24"	6'-0"	2'-6"	5'-8"	2'-6"	3'-2"	6"	24"	2.4	200
27-1	35	27"	6'-9"	2'-9"	5'-6"	2'-6"	3'-0"	6"	24"	2.6	210
27-2	40	27"	6'-9"	2'-9"	6'-0"	2'-6"	3'-6"	6"	24"	2.8	220
30-1	45	30"	7'-6"	3'-3"	6'-0"	3'-0"	3'-0"	6"	24"	3.0	240
30-2	50	30"	7'-6"	3'-3"	6'-6"	3'-0"	3'-6"	6"	24"	3.2	260
33-1	55	33"	9'-0"	3'-9"	6'-0"	3'-0"	3'-0"	8"	2'-6"	4.3	290
33-2	60	33"	9'-0"	3'-9"	6'-6"	3'-0"	3'-6"	8"	2'-6"	4.6	320
36-1	70	36"	9'-0"	3'-9"	7'-0"	3'-0"	4'-0"	8"	2'-6"	5.0	340

Tabulated dimensions and maximum Q's, provide freeboard at the headwall, with full-pipe velocities ranging up to 10 fps

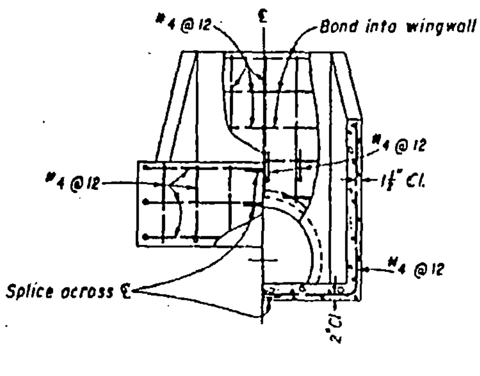
Figure 4-9. Concrete inlet transition-type 3.



PLAN



SECTION A-A



SECTION B-B

TABLE OF DIMENSIONS AND QUANTITIES

DIA.	E	e	L	B	C	t	CONC. (CU.YDS.)	REINF. (LBS.)
24"	4'-0"	24"	8'-0"	5'-0"	3'-6"	5"	1.7	120
30"	4'-6"	24"	9'-0"	6'-6"	4'-2"	5"	2.2	150
36"	5'-0"	24"	10'-0"	7'-6"	4'-8"	5"	2.7	190
42"	5'-6"	2'-6"	11'-0"	9'-0"	5'-3"	6"	4.0	280
48"	6'-0"	2'-6"	12'-0"	10'-6"	6'-0"	7"	4.8	340
54"	6'-6"	2'-6"	13'-0"	12'-0"	6'-7"	7"	5.6	390
60"	7'-0"	2'-6"	14'-0"	13'-6"	7'-2"	7"	6.5	460

Tabulated dimensions provide for control at the headwall with a full pipe velocity of 12 fps

Figure 4-10. Concrete inlet transitions-type 4

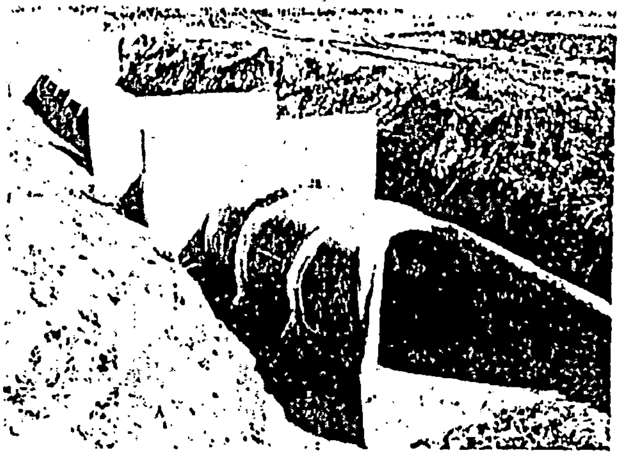


Figure 4-11. Precast concrete pipe culvert with precast concrete inlet transition.

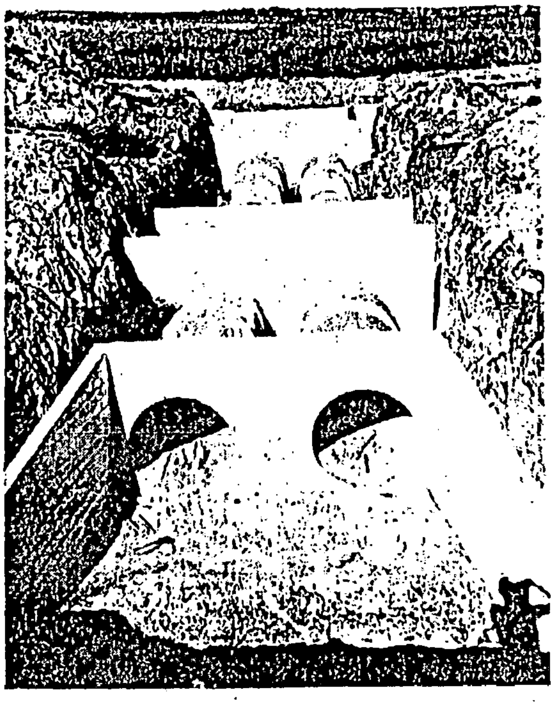


Figure 4-12. Double-barreled pipe culvert with concrete percolation collars.

Outlet- The culvert outlet performs the basic function of releasing water to the outlet channel without excessive erosion. Depending upon the amount of excess energy to be dissipated, this function may be performed by a concrete transition, baffled outlet, baffled apron drop or some other form of energy dissipator. The concrete transition should be used where possible in preference to most other types of outlets, which are more susceptible to problems with weeds, trash, and sediment.

- *Concrete Transition-* Concrete transitions may be used at culvert outlets provided: the conduit is sized on the basis of a maximum full pipe velocity of 10 feet per second; standard outlet protection is used if the pipe velocity at the outlet is equal to, or less than 15 feet per second; and the next higher class of protection is required if the pipe velocity at the outlet is greater than 15 feet per second.

  Two basic types of concrete outlet transitions are used are as follows:

  - Type 1 concrete transition- The type 1 concrete transition as shown in figure 4-13, is best suited to a well defined outlet channel, where the banks can be shaped to conform to the sides of the transition. Thus, it is generally used where it is necessary to construct a channel with its invert considerably below the original ground surface.
  - Type 2 concrete transition- The type 2 concrete transition as shown in figure 4-14 is well suited to use in a poorly defined channel. For this reason, it is the best choice where the outlet elevation is not appreciably lower than the original ground surface.

- Outlet Energy Dissipators- The need for energy dissipation structure at culvert outlets should be avoided if possible, by dissipating energy in the pipe. In addition to higher construction cost for energy dissipators, their maintenance cost is also greater. The pipe velocity may be reduced by diminishing the slope, but to not less than a slope of 0.005.

  Excess energy at culvert may be dissipated by the following structures:

- Baffled outlets- Baffled outlets performs well in dissipating excess energy, provided clogging by weeds or other debris can be avoided. When using a baffled outlet, the culvert pipe should be sized on the basis of a full pipe velocity of 12 feet per second. The theoretical velocity, $V_t = \sqrt{2gh}$, should not exceed 50 feet per second.
- Other types of energy dissipators- Drops and chutes with stilling pools have been used at culvert outlets, as have baffled apron drops. The stilling pool requires sufficient tailwater to produce a hydraulic jump whereas the effectiveness of the baffled apron drop is independent of the tailwater.

Hydraulic Design

- *Design Capacity* – Generally, for small irrigations cross-drainage structures are sized on the basis of storm runoff for a 25-year flood frequency.
- *Pipe Velocity* - The culvert should be designed for a maximum full pipe velocity of 10 feet per second if a concrete transition is used at the outlet, and for a full pipe velocity o0f 12 feet per second if an energy dissipator is used. In the rare cases that concrete inlets and outlets are not considered necessary, the pipe should be designed for a maximum full velocity of 5 feet per second.

  The actual full pipe velocity will usually be less than the maximum design velocity, due to the availability of pipe in 3-inch increment of diameter only. However the pipe will not necessarily flow full, and the actual velocity may be considerably faster than the full pipe velocity. If the exit velocity in the pipe exceeds 20 feet per second, an energy dissipator should be provided.
- *Pipe Diameter* – The diameter of the pipe is determined from the basic equation, Q = AV when related to pipe flowing full. This reduces to $D = 1.13\sqrt{Q/V}$. The minimum diameter usually permitted for culvert pipe is 24 inches. Precast concrete pipe is widely supplied in increment of 3 inches in diameter.

- *Hydraulic Control* – The upstream water surface will be controlled by the head that is required to satisfy: inlet conditions or outlet conditions (such as high tail water, or pipe losses). To insure the validity of other hydraulic computations, it must be determined whether the hydraulic control is located at the inlet or outlet.
    - *Inlet control* – If the upstream water surface is not influenced by flow conditions downstream from the inlet, it is said to have inlet control. Inlet control results from the following conditions.

      A downstream water surface that is low enough with respect to the inlet, that it does not influence the upstream water surface, combined with an upstream pipe slope that is steeper than the critical slope.
    - *Outlet control* – If the upstream water surface is influenced by downstream conditions, it is said to have outlet control. Outlet control results from the following conditions:

      A downstream water surface that is high enough with respect to the inlet that it influences the upstream water surface; or pipe losses that causes pipe flow at a depth greater than the critical depth.

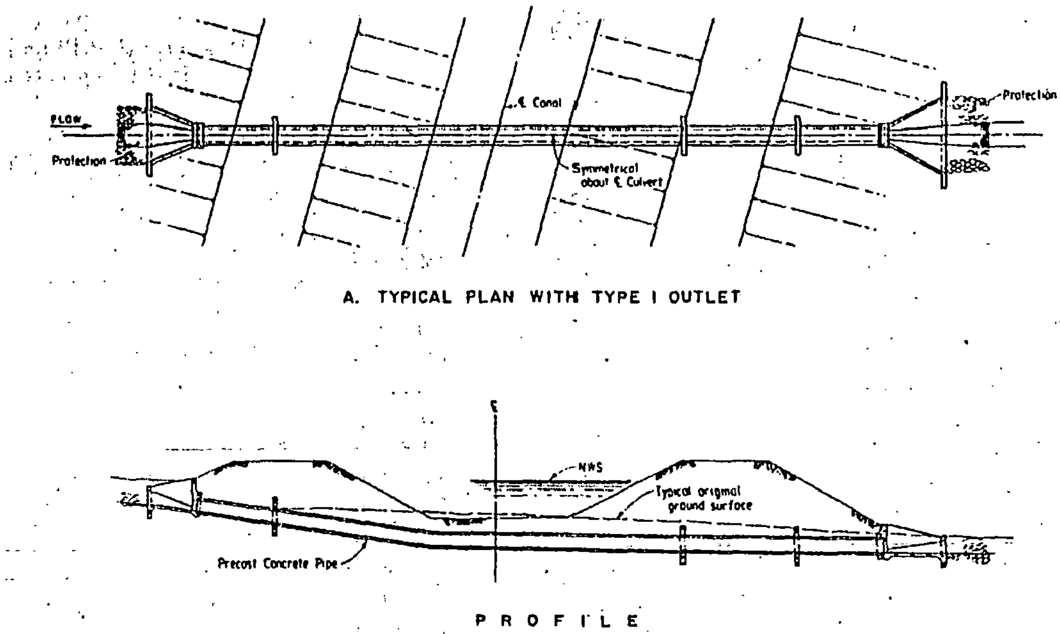


Figure 4-13. Plan and profile of typical culvert.

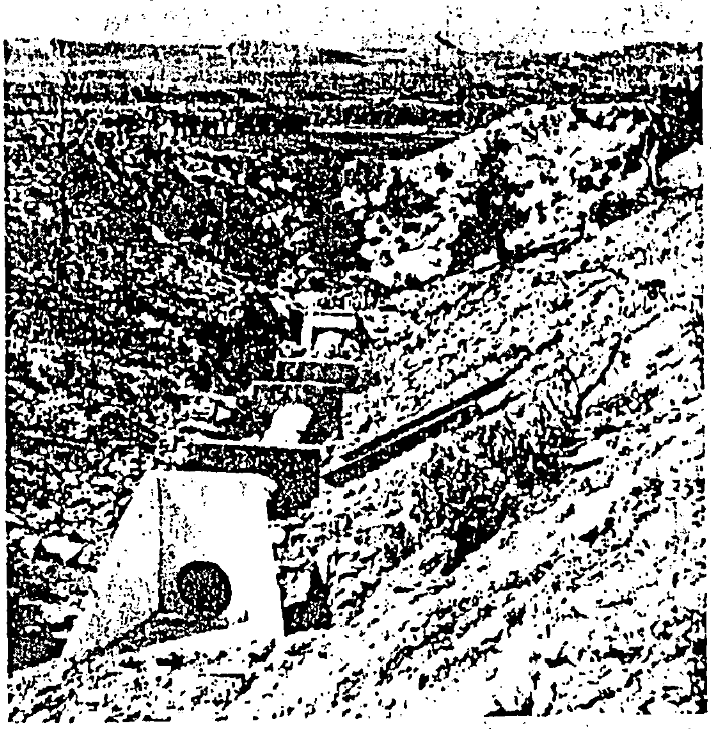


Figure 4-14. Culvert, constructed prior to construction of canal.

4.1.4 Construction Practice

Diversion Dam – is very important structure for any irrigation system. This should be designed such that they can provide the required flow throughout the year, it is robust and durable and that it needs as little maintenance as possible as lack of proper maintenance is often experienced in small-scale irrigation system. Mostly, it is concrete overflow dam of class "A" mixture.

Main Canal.- Though linings appear to be very simple from engineering point of view, yet it involves large investments of labour and materials. Because of these drawbacks, only portion of the main canal is lined. This varies from few meters to as high as 35% of the total Main Canal length if lesser concrete works is done in the irrigation works, such as flumes, road crossing, concrete drop and check structure, etc. Sometimes it is unlined at all.

Elevated Flumes.- These are rectangular concrete section of Class "A" mixture and sometimes these are constructed as rectangular conduit and performs as rectangular concrete overchute, so that it may serve other purposes. It may span from one bank of the canal to the other, but it is often jointed over piers to accommodate differential settlements on the piers without resulting in undue stress in the flume. As flumes are fairly short, the most economical section is not necessarily the most desirable. A wider and shallower section will permit a shallower inlet depth, resulting less inundation of the channel. Thus the freeboard requirement can more easily be satisfied without excessively raising the uphill bank of the canal. The wider shallow flume section is particularly applicable to a shallow or poorly defined natural channel.

Road Crossings.- Precast reinforced concrete culvert pipe (RCCP) is commonly used for these purpose (see figure 4-5).

Division Box – Division box may be a separate structure or it may be the outlet of the drop, a siphon or a turnout from which further division is required. If measurement is not required at the point of division, the flow through the structure may be directed through the various outlets with gates or stoplogs (see figure-4a and 4b). If the flow must be measured and the head is available, weirs may be used to proportion the flow. These are reinforced concrete structure of class "A" mixture.

Culvert – Precast reinforced concrete culvert pipe is the usual choice for culvert canals, providing excellent strength, durability watertightness, and flow characteristics. Rubber gasket joints are used to prevent leakage and to provide flexibility. Concrete transitions are used as culvert inlets and outlets (see figure 4-13).

4.1.5 OPERATION AND MAINTENANCE OF THE SYSTEM

After the completion of construction of irrigation system, the whole part of the system is completely turned-over to the Farmers Cooperative, witnessed by the Local Government Units (LGU's) and the Department of Agriculture- RFU.

4.1.5.1 Operation and Maintenance Organization

Responsibilities of the Local Government Unit (LGU).

(1) Undertake the organizational and institutional activities for the project.
(2) Provide for terms and guidelines for the safeguard and upkeep of the project.
(3) Shall be responsible in the repair and maintenance of the ordinary tear and wear of the project.
(4) Shall conduct watershed development of the project site.
(5) Shall directly provide agricultural support and services to the farmers' beneficiaries.
(6) Close supervision is also extended to develop or maintain this association to avoid failure.

Responsibilities of the Department of Agriculture

(1) Conduct inspection/assessment of the project.
(2) Request for funding as needed for the rehabilitation/ expansion of the project.

Responsibilities of the Farmers Cooperative

(1) To take over the entire Operation and Maintenance of the system.

4.1.5.2 Farmers Cooperative/ Irrigators Association

(1) **Farmers Cooperative/Irrigators Association** is an organization of farmers' beneficiaries within an irrigation system that serves for the effective channeling of assistance program and for the implementation of proper water management.

(2) **Objectives**

(i) Operate and maintain the system.

(ii) Equitably distribute water among farmers.

(iii) Assure each individual member to avail of essential services geared toward increased crop production and maximum benefits from irrigation.

(iv) Strengthen group action through efficient coordination between and among irrigation irrigation and users and the irrigation personnel as well.

(3) **Benefits**

(i) Equitable distribution of irrigation water to members farm lots.

(ii) Proper maintenance and speedy repair of irrigation facilities and structures.

(iii) Better cooperation among members in the prevention and control of pest disease infestations.

(iv) Serve or channel for essential services provided by government and private agencies.

(v) Lessen conflicts among farmers in the distribution of irrigation water.

(vi) Closer coordination and more effective communication between end users and irrigation personnel.

(4) **Farmers involvement and participation**

(i) Participate in the O&M of irrigation system.

(i) Construct and maintain internal farm ditches in their area to facilitate delivery and distribution of irrigation water in each farm lot.

(iii) Participate in the election of officers and other activities of the association.

(iv) Cooperate with other group members for the attainment of the goals of the association.

(v) Obey the rules and Regulations of the association and strictly observe policies governing operation and maintenance of irrigation system.

(5) **Advantages of the Farmers Organization Set-up**

(i) The irrigation office will deal or coordinate only with the officers of the association.

(ii) The farmers are provided with continuous training ang assistance to ensure increased crop production and farm income thereby uplifting their living standards.

(iii) Through the associations, discipline among farmers could be fostered and as an organizers, government and private lending institutions engage in providing credit assistance to farmers could make use of organizations to expand their loaning schemes with assured repayment collection from the individual farmers members.

4.1.6 Performance of the System

Main Canal runs continuously except for a short maintenance and repair. During the start of irrigation season, the flashboards are installed so that the water level rises in the Diversion Dam. The water is then diverted to the conveyance canals (e.g. Main canals, laterals and farm ditch) to supply the requirement of the areas served. Excess rivers flows spillover the dam and discharges to their waterways. The length of the canal is 1134m; the effect of head regulation reaches the tail end the same hour.

4.2 BOHE-PAHU DIVERSION DAM PROJECT

4.2.1 Salient Features

(i) Location	:	Barangay Bohe-Pahu, Tipo-Tipo, Basilan Province
(ii) Diversion Dam		
a) Height	:	1.00 m
b) Width	:	20.0 m
c) Length	:	20.50 m
(iii) Service Area	:	70.00 ha.
(iv) Canal		
a) Bed Width	:	0.20 m
b) Water depth	:	0.25 m
c) Bed Slope	:	0.002 to 0.073
d) Side Slope	:	1:1
Main Canal	:	980.00 m (950.60 m lined)
Laterals	:	4,500.00 m (1,156.00 m lined)
Sub laterals	:	4,336.00 m
(ii) Canal Structures		
a) Division Box	:	14 units
b) Concrete Drop	:	68 units
c) Concrete Chute	:	2 units
d) Road Crossing	:	11 units
e) Drainage Structure	:	3 units
f) Turn-out and Check	:	14 units
g) Turn-out	:	6 units
(vi) Total Project Cost	:	P 10,000,000.00

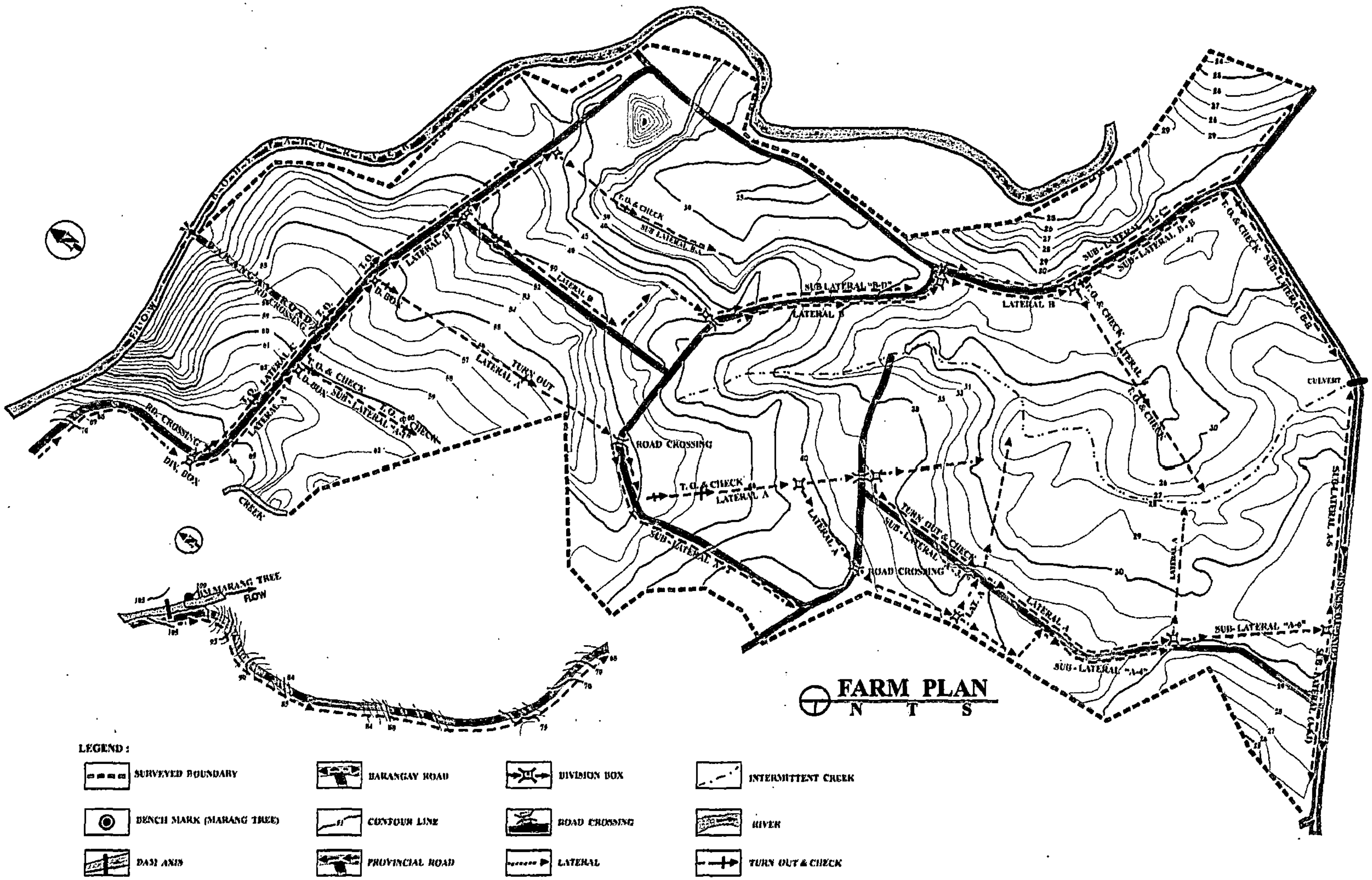


Figure 4-15. Farm Plan of Bohe-Pahu DD

The **Bohe-Pahu Diversion Dam Project** has been entirely investigated, designed and implemented by the **Agricultural and Infrastructure Development Division of the Department of Agriculture - Regional Field Unit-9,** the lead agency mandated to implement the components of **Ginintuang Ani Program** (GAP) in the region with a **Project Cost of P 10,000,000.00**. This was implemented in the late 1990's and all works were satisfactorily completed.

The Planning and Design of the canal system was based on the method of continuous flow as in many rice-growing areas.

In line with the implementation of the **Republic Act 8435- Agriculture and Food Modernization Act (AFMA) of 1997** which declares food security and self sufficiency to be a paramount goal of the state, in the year 2000, this project was rehabilitated and an amount of P5, 000,000.00 was provided under the "Ginintuang Masaganang Ani" (GMA) program for rice for the terracing of some service areas.

Rice is the most significant commodity in the Philippines agriculture, being the staple food of the Filipinos and a major source of income. Ensuring enough rice for the public and the stability of the rice industry are used as measurement of political economy of the Philippines. That is why the Philippines government strongly supports program of food (particularly rice) and agriculture.

The unique feature about the planning for the rehabilitation of this project was the employment of maximum manpower and minimum machinery together with the achievement of economy and speed in construction. The implementation of the project was planned in such a manner in order to reduce poverty incidence in the rural areas which is one of the "Goals and Objectives" of the GMA for rice program.

OPERATION AND MAINTENANCE OF LAKNAUTA MINOR, UPPER GANGA CANAL (UGC) SYSTEM

5.1 DESCRIPTION OF UPPER GANGA CANAL (UGC) SYSTEM

The severe famine of 1837 in Ganga Yamuna Doab drew the attention of British Canal Engineers to protect the agriculture land from recurring drought. Captain P. Thomas Cautley, a Royal artillery Officer, came forward and first of all prepared the project of UGC in 1838 with a proposal to take out a canal from Ganga River near Hardwar, and feasibility report was approved in 1841.

Captain Cautley was a visionary person. He used his engineering skill in producing simple and bold design with locally available materials (brick, lime and surkhi) at the time when there was no established soil mechanics and knowledge of hydraulic engineering too was in primitive stage. In spite of several constraints, the project was ultimately taken up with full swing in 1848 and canal was commissioned on 8th April 1854.

5.1.1 Upper Ganga Canal Modernization Project

Upper Ganga Canal is the oldest irrigation system in India (figure 5-1). All the works have become 150 years old and thus have outlived their useful life. Since those times, no major change has been carried out in these structures. The canal was built for a design discharge of 190 cumecs (6750cusecs), which was subsequently increased to 295 cumecs (10500 cusecs) in the year 1951 due to the increase in the irrigation demand.

From its Headworks at Hardwar to up to Roorkee in a stretch of nearly 30 kms, Upper Ganga Canal is intercepted by four mighty wild torrents, descending from Shivaliks, on which four major cross-drainage works namely, Ranipur siphon, Pathri super passage, Dhanauri level crossing and Solani aqueduct were constructed.

Any mishap to these structures would cause disruption in the supply of irrigation water to the whole of Western Uttar Pradesh. The construction of any one of them would take at least 4 to 5 years. In this period, irrigation of agricultural land of the areas would have suffered. Therefore a decision was taken to construct a

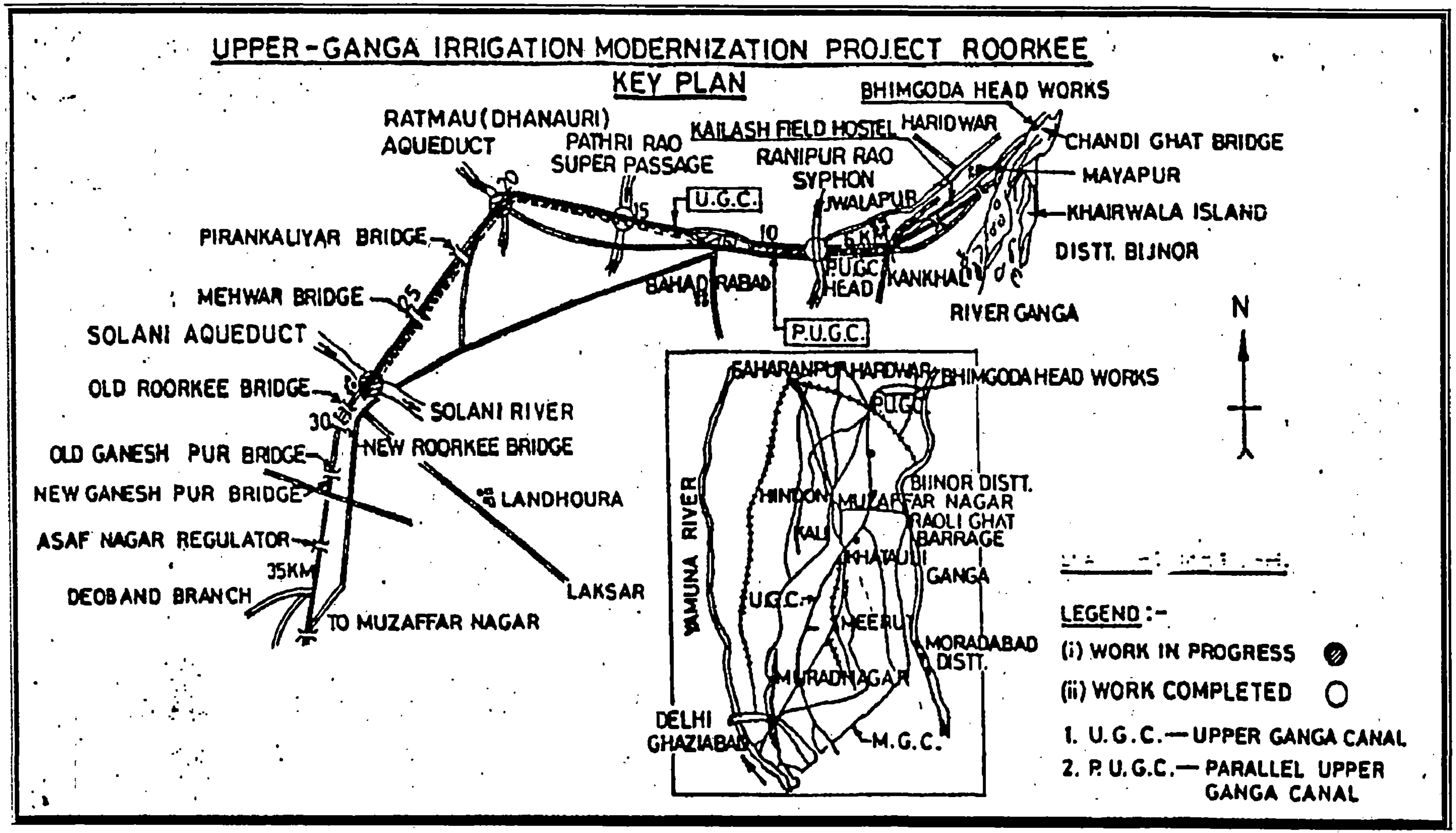


Figure 5-1. UPPER – GANGA CANAL MODERNIZATION PROJECT

parallel Upper Ganga Canal so that during the construction period irrigation was not to be affected. To save the seepage losses, the new canal has been lined.

In addition to irrigation water supply round the year, following consumptive use requirements have to be met on priority basis.

(i.) 5.67 cumecs to Delhi for drinking water supplies

(ii.) Drinking water supply to Meerut city in Ganga-Yamuna inter basin

(iii.) 2.83 cumecs to Kasimpur thermal power station

(iv.) 2.83 cumecs to Kampur thermal power station.

5.2 SALIENT FEATURES OF THE SYSTEM

This canal has become the lifeline for the prosperity of Uttaranchal and Western Uttar Pradesh. The UGC irrigates a CCA of about 9.31-lakh hectare.

Deoband branch with designed discharge of 24.77 cumecs takes off at 35.5 km of UGC. Sidhauli Distributary takes off at 9.707 km of Deoband Branch Canal having authorized designed discharge of 1.9 cumecs.

The salient features of the Upper Ganga Canal project are as follows:

Discharge	:	325 cumecs
Bed Width	:	69 m
Depth of flow	:	3.32 m
Velocity of flow	:	0.92 m/sec
Year of commission	:	1854

5.2.1 Layout and Salient Features of Laknauta Minor

A layout of Laknauta Minor is given in figure 5-2. This minor takes off from Sidhauli Distributary.

The salient features of Laknauta Minor are as follows:

Discharge	:	0.311 cumecs
Bed Width	:	0.915 m
Side Slope	:	½ : 1 (H:V)
Full Supply Depth	:	0.67 m
Unlined Canal Length	:	4.780 km
Rugosity Coefficient (n)	:	0.0225

Culturable Command Area	:	657 ha
Number of Outlets	:	22
Pipe outlets (non-modular)		

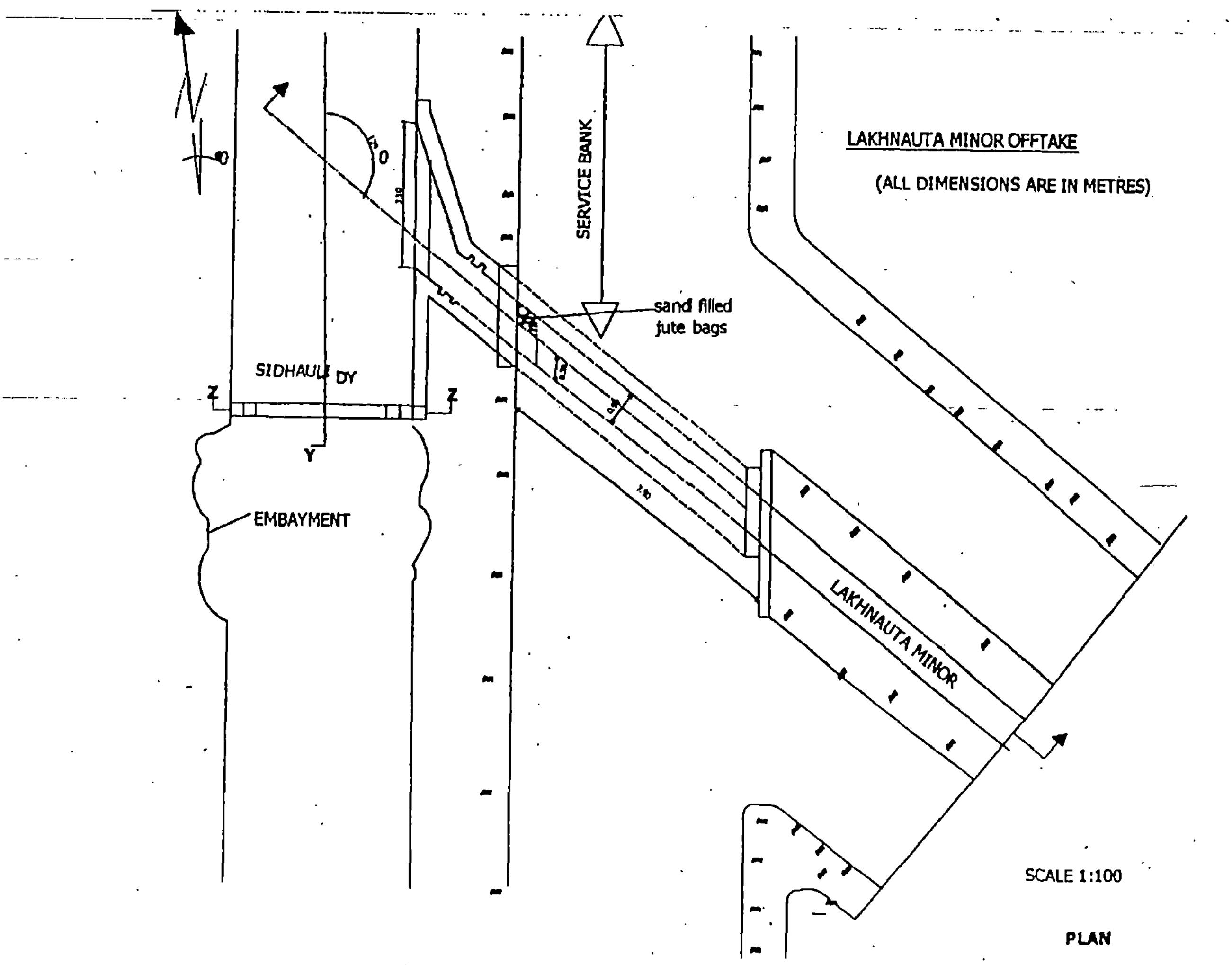


Figure 5-2. Layout of Laknauta Minor

5.3 ENGINEERING DETAILS OF LAKNAUTA MINOR

The engineering details of Laknauta Minor are as follows:

5.3.1 Bridges

The Laknauta Minor consists of four Village Road Bridge (VRB) one Foot Bridge (FB) and head regulator off taking from Sidhauli Distributary. VRB are at RD 500 m, 950 m, 1965 m, and 4600 m. The Foot Bridge is situated at RD 300 m.

5.3.2 Outlets

There are 22 non-modular pipe outlets located along the 4783 m long Laknauta Minor.

5.3.3 Tube Wells

There are 7 numbers of private tube wells in the command of Laknauta Minor. Farmers are using ground water conjunctively with canal water by their own tube wells and shallow bore wells worked by diesel pumping sets.

5.4 OPERATING PRACTICES OF LAKNAUTA MINOR

Operating practices of Laknauta Minor are based on the proposed area and also the operating schedule of Deoband Branch, which draws supplies from Upper Ganga Canal (UGC) as per allocation to this branch, depending upon the availability in the UGC. The available water in the main canal is distributed depending upon the proposed area under cultivation under each division. As the demand is always higher than the available supply at the head, the branches and their canal network runs on rotation.

The Main Canal runs continuously except for a short closure for maintenance and repairs. During rabi season, the Branches, Distributaries and Minors are run in rotation. The period of rotation is usually in multiples of week. In rabi, one week "ON" and two weeks "OFF" are being followed. I.e. the total period of rotation is 21 days. But sometimes the schedule is not followed strictly and closure period may have to be extended.

The water is distributed proportionally among all the outlets depending on the area proposed to be cultivated under different outlets. Thus depending on the allotment of water to various outlets, their discharge requirements are worked out taking the time of 168 hours and pipe sizes are fixed. The regulation is carried out at the head of the distributary, and normally the minor runs when the distributary is running. Even otherwise this is a common practice that when a distributary is running all the minors run. Also all the outlets on the distributary or minors are normally running simultaneously with fall discharges when the channel is running.

5.4.1 System Operation below Outlets

The watercourse is constructed and maintained by the farmers. Irrigation Department responsibility ceases with handing over water at the outlet. The schedule of channel are printed and distributed to farmers. Thus the farmers are well acquainted with running of channels and availability of water to them.

5.4.2 Operation of Osrabandi

1. In Osrabandi system of water distribution, farmers irrigate their land as per their turn fixed in osrabandi. In this case no actual crop water requirement is considered. When the minor is in operation, all the outlets run simultaneously. Farmers may plug some of the outlets when water is not needed.
2. In this method, roster of 168 hours (1 week) is allocated to individual cultivators in proportion to their land holding. Thus the farmers are entitled to use the water during the fixed allotted time slot only. The farmers themselves decide about the cropping pattern, assessing the availability of water and the land holding and supplement irrigation requirement by use of ground water to meet out their demands.
3. The chakwise osrabandi is in operation.
4. The osrabandi start from head to tail and changed alternate years to share the distress and problems in night irrigation.

Osrabandi is a very well established practice on Upper Ganga Canal system for the last nearly 100 years. Most of the channels on UGC systems are covered by osrabandi.

Osrabandi is also quite popular on other canal systems in other states of North Western India, and also the canal system of Pakistan.

Management of distribution of water by farmers through osrabandi on Upper UGC system is a time tested successful practice for equitable distribution of water.

By this practice the farmers are motivated for better use of water and to keep the losses in control by careful watch during irrigation of their fields.

5.4.3 Methods of Irrigation

The crops grown in the area are: wheat, sugarcane, berseem and mustard. Method of irrigation with the crop is only wild flooding or may be basin or border according to size of the plot and slope. Furrow irrigation and basin irrigation are followed in sugarcane. In case of berseem it is only border irrigation or basin irrigation depending on the size of plot and slope. The irrigation interval varies from 5-21 days depending upon cropping system and water supply.

5.4.4 Discharge Measurement

Discharge measurements are carried out by the Irrigation Department staff normally at the beginning of each crop but certainly after annual clearance. The discharge tables renewed as above are normally used to regulate the channel with allocated water. As the channel normally run full capacity in each running the entire outlet draw full discharges. The outlets are pipe outlets (non-modular) with average head varying from 30 to 45 cm.

5.5 GROUNDWATER USE IN LAKNAUTA MINOR

There are large reservoirs of ground water in this area. Farmers are using groundwater conjunctively with canal water through their own tube wells and pumping sets. The water table in the area is about 5 meters from the average ground level. This generally goes down during summer and rises by about one meter during rainy season. The conjunctive use of ground and surface water has created favorable conditions for large area under sugarcane crop. In the area commanded by outlet number 16 alone there are 7 numbers of tube wells. Farmers, whose chaks are not commanded by the outlet or who do not get timely water from channel, depend solely on the ground water alone. This conjunctive use could be one of the reasons for the water table not rising alarmingly in spite of high irrigation intensity.

5.6 WATER AVAILABILITY TO WATER USERS

Since the farmers are free to choose the crops of their preference without regard for their water requirement and availability of water, the demand normally exceed the supply. This is taken care by rotational running of channels and by support of ground water, conveniently available.

The farmers manage by themselves the distribution of water below outlet as per the schedules fixed and notified earlier to them covered by osrabandi as explained earlier.

5.7 MAINTENANCE PRACTICES ON LAKNAUTA MINOR

Irrigation system are subjected to high intensity storm floods, drought conditions, burrowing animals, cattle encroachments, inadequate and unreliable supplies, which cause recurring damage, erosion, vegetation and a variety of losses. Since water flowing in the canal carries a lot of silt quantity it is deposited in the bed canal. In addition human interference in the form of cutting of banks, putting obstruction in the bed, unauthorized/oversized outlets also create operation and maintenance problem and disturb the design parameters and impair the operation efficiency of the system. As reported by the Irrigation Authorities U.P. Irrigation Department the maintenance including silt clearance is being done normally manual by laborers, now on longer channels machines are also being used frequently where these are considered necessary and economical.

5.8 · OPERATION, MAINTENANCE BUDGET ON LAKNAUTA MINOR

There has been a constraint in availability of adequate financial resource causing a gradual but definite and substantial deficiency in the standard of maintenance and ultimately the overall deterioration of conditions of the conveyance system. Also with the increasing pressure on the system to meet-out ever increasing and round the year demands of irrigation water, the maintenance of carrying capacity of distribution channels has got the priority over the other maintenance requirements. This gradually affected the condition of main canal, branch canal and major masonry works.

Irrigation rates in India are normally heavily subsidized on canal system. This established practice has generated a philosophy to continue with the least and insufficient maintenance grant.

Central Water Commission, Government of India, recommended a policy to work out the maintenance grants of canal systems on the basis of area actually irrigated in different crops of Rabi and Kharif in the year. In the states proposed irrigation intensities are quite different for different systems. With these considerations, the proposed came forward that maintenance budget for different system be work out on the basis of area commanded rather than actually irrigated for proposed crops still there is no common practice in India covering all the states for formulating the maintenance budget proposal of irrigation systems.

5.8.1 Conventional Budget

The budgetary system in India, as in many other countries, has been designed and developed mainly to facilitate financial and legal accountability of the executive of the legislature, and within the executive, observance of similar accountability on the part of each subordinate agency. The main objective is to ensure that funds are raised and money is spent by the Executive in accordance with and within the limits of legislative sanctions and authorizations. Accordingly, the budget emphasize the financial aspects and do not inter-relate financial outlays with physical targets and achievements. Present "conventional budget" (also referred to as administrative budget) has a strong bias towards organizations and objects of expenditure. The budget shows item wise details of provisions toward salaries, cost of material under each administrative unit. In this form, it has a number of shortcomings, of which four arise out of the system of classification.

(i) The classification does not permit a proper analysis of the impact of government transaction on the total economy

(ii) It is difficult to see for what broad purposes and objectives, resources are being allocated

(iii)It is not helpful as a basis for judging the progress towards the attainment of long and short term objectives as envisaged in the development plans and

(iv)It does not serve as an adequate base for informed decision-making.

5.8.2 Performance Budget

The technique of performance budgeting seeks to remedy the defects by highlighting management considerations in budgeting as outlined in the earlier paragraph. The emphasis in performance budgeting is on the accomplishments rather than on the means of accomplishments, on the precise definition of work to be done or service to be rendered rather than on the money spent on the several objects.

The performance approach to budgeting is based principally on the use, in budget management of three inter-related considerations. Firstly, a meaningful classification structure in terms of programs and activities is established under each function entrusted to an organization in order to show precisely the objectives of various agencies, the work done by them and the organizational responsibility. Secondly, the system of accounts and financial management is brought in line with this classification. Thirdly, under each program and activity, action is taken to establish work, unit, norms, standard and other performance indicators for appraisal and evaluation of performance. The above constitute the three basic steps in the introduction of performance budgeting, each serving the management needs in part and together forming an important tool for review and analysis.

The main purposes of performance budgeting are:

(i.) To correlate the physical and financial aspects of programs and activities.

(ii.) To improve budget formulation, review and decision-making at all levels of management in the government machinery.

(iii.) To facilitate better appreciation and review of management of a project.

(iv.) To make possible more effective performance audit.

(v.) To measure progress towards long term objectives as envisaged in the plan

(vi.) To bring annual budget and development plans closely together through a common language.

5.8.3 Operation and Maintenance Budget for a Canal- A Case Study For Lakhnauta Minor

There are prescribed norms for maintenance grant on canal system in India, which vary from state to state. A case study of annual maintenance grant for a canal division in Upper Ganga Canal (UGC) has been carried out.

In U.P. at present, maintenance grants on canal system are normally worked out on the following basis.

(i.) Rs. 100/ per ha (approx.) on actual irrigated areas

(ii.) Rs. 45/ per ha (approx.) on unirrigated area in the command

(iii.) On the basis of normal sanctioned estimate of division/system

The overall maintenance grant was up to Rs. 133/ (approx.) per ha on rabi and kharif during 1996-1997.

The normal estimates of different divisions are sanctioned on the basis of norms issued vide E-in C office Memo. 6738-IB/83B-100-A/grant dated 30.11.1959, revised from time to time, as estimates are revised and sanctioned by Chief Engineers with administrative control.

Chief Engineer allots the fund form annual maintenance including special repairs on the basis of sanctioned normal estimates of a particular Division. At present the total funds available to the Division are generally limited to 80 % of the sanctioned normal estimate on an average.

In addition Engineer-in-Chief, U.P. Irrigation Department has issued specific instruction for utilization of maintenance funds on different parts and elements of a canal system (Ref. Office Memo. No. 2884/18/108B/aa/March-77/Section-Revenue/87-88 dated 30.5.1987). The prescribe percentage are as below:

(i.)	Silt clearance on channel	25 %
(ii.)	Repairs to masonry Works	35 %
(iii.)	Strengthening of banks	10 %
(iv.)	Escapes and connected drains	10 %
(v.)	Head works	10 %
(vi.)	Miscellaneous and vehicle maintenance	5 %
(vii.)	Inspection houses & other buildings	5 %
		100 %

These days, in view of persistent inadequate maintenance grant and continuous rising pressures in feeding the maximum number of tail of channels, quite high percentage of share is utilized on silt clearance and strengthening of channels with nominal expenditure on masonry work.

Besides the above, Chief engineer controlling the administration of different canal system, also exercise necessary control from time to time for better and more useful utilization of available grants on various items by issuing specific orders for each system with detailed instructions to S.E. and E.Es. The Superintending Engineer in U.P. Irrigation is the primary competent officer to exercise and maintain proper financial controls over the Executive Engineer and other staff, they carryout frequent inspections in the field in every crop season. Executive Engineer sends the comments on a prescribed format to Chief Engineer. In addition monthly monitoring is also carried out on the progress / achievements and expenditures in all the division at the

Monitoring Cell established in the office of Engineer-in-Chief, and headed by a Chief Engineer.

Thus, on the basis of recommended norms, the total Operation and Maintenance Budget of Lakhnauta Minor work out as discussed herein for Irrigated area at Rs. 100/ha and for unirrigated area at Rs. 45/ha. However, overall maintenance grant on rabi and kharif area would be Rs. 133/. Therefore, total Operation and Maintenance = Rs. 133/ x 657.2 ha (CCA) = Rs. 87,408/, whereas expenditure incurred by the government for maintenance is approximately Rs. 8,000/ per km /year.

The total maintenance for Lakhnauta Minor (4.780 km) incurred by the government is Rs. 8,000/ x 4.780 = Rs. 38,240/ year only which on per ha of CCA works out to just Rs. 58/.

DISCUSSIONS AND PROPOSALS FOR MODIFICATION

6.1 PROPOSED SERIES OF PIPE DROPS

In Pasingkalan DD, looking closely at the Profile of Main Canal and its Hydraulic Properties, the velocities in some sections are very high which are beyond the allowable velocity for unlined canal. The canal along this same terrain would ordinarily be steep enough to cause severe erosion in earth canals, frequent and costly maintenance to keep it in use or disruptive flow in hard surface lined canal. The water must therefore be conveyed with a drop structure designed to safely dissipate the excess energy.

Pipe Drops- A pipe drop conveys water from a higher elevation to a lower elevation. The drop may be any amount between 3 and 15 feet. A pipe drop not only conveys water but it must also dissipate the excess energy and still the water after it has reached the lower elevation.

Type 1 pipe drop (fig. 6-1) is a practical and economical drop and is used as an inline canal structure where the possibility of clogging is minimal. Another type of drop structure should be used for cross drainage.

Pipe drops are easily designed, built and operated. Pipe drops are economical, especially for small discharges and require very little maintenance, provided they are constructed of durable pipe having good rubber gasket joints and provided the bends are properly made.

On figure 6-1 type 1 pipe drops have been standardized so the entire pipe profile can be designed using this figure and accompanying table 6-1. There are standard designs for type 1 pipe drops with a concrete downstream transition for capacities up to 50 cfs and standard design for type 1-pipe drops with an earth outlet transition with capacities up to 22 cfs.

6.2 PROPOSED STEPPED OR CASCADE-TYPE FALL

In the same project, Pasingkalan DD, as shown in figure 6-3, this unlined canal section on a steep slope has an erosive velocity. A suitable conveyance structure must be provided in order to convey the water, but it must also stills the water after it has reached the lower elevation resulting in excess energy being dissipated. The proposed arrangement needs to be technically sound and economically viable.

Stepped or cascade-type fall – this conveyance structure is suitable for the above canal section.

The decision as to whether to use a stepped or a cascade-type fall, series of pipe drops or a chute has been based upon a hydraulic and economic study of the three alternatives.

The economic study was based on comparing the cost of each alternative taking into account the advantages and disadvantages pertinent to the specific condition.

If the above proposals for modification were done, a lot of water could be saved, maintenance would be economical and an additional area could be served adequately. Also, there will be sustainable supply of water, for the safety of the system and the system as a whole would be more stable and sustainable in use.

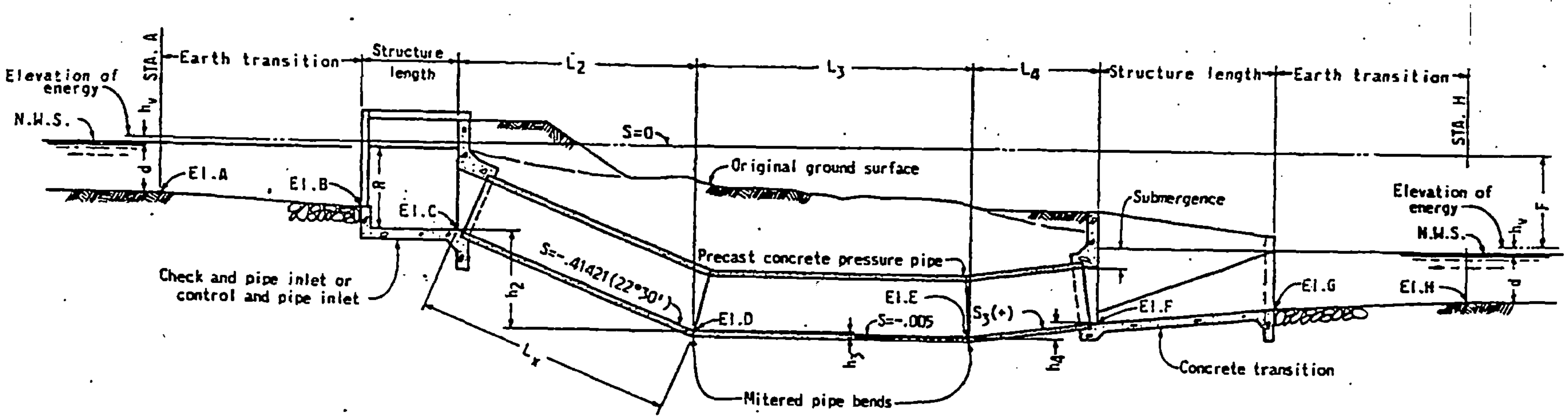
6.3 WARABANDI SYSTEM

In Indian irrigation system, the practice of "Warabandi System" has been introduced to serve million of farmers way back in 1880 to ensure equitable distribution of water.

Protective irrigation for many rather than intensive irrigation for the few, has been the central theme, on which the warabandi system has been planned and designed, and also serve equitable distribution of water.

Above all, it is a management system and its principle management objective is to simultaneously achieve high efficiency of water by imposing water scarcity on each and every user. This acts as a deterrent to wasteful practice and results in maximum production per unit of available water, though it may not be the maximum per unit of land irrigated.

In my study, which is mostly for rice growing areas, warabandi system is not so relevant although it has been successful in the states like Punjab and Haryana. In most of the small canal systems in the Philippines the water supply is adequate. However, this system is very effective and efficient, so maybe useful in the future in the Philippines also.



LONGITUDINAL SECTION

NOTES

The pipe slopes used will allow the substitution of $7^0 30'$ precast concrete elbows for the mitered pipe bends.
The maximum velocity in the pipe at the outlet equals 5 feet per second for pipe flowing full.
Hydraulic head losses due to entrance, friction, bends and exit have been neglected.
Precast concrete pressure pipe with mitered pipe bends shown. AC or RPM may be substituted.
These standard designs are for flows less than 50 cubic feet per second. For flows greater than 49 cubic feet per second it is more economical to use a rectangular inclined drop. If it should be desirable to have a pipe drop with a flow greater than 49 cubic feet per second, it will be necessary to actually design the pipe drop.
Ordinarily the maximum water surface drop for a pipe drop structure is 15 feet. However, standard design tables extend slightly beyond this maximum.

Figure 6-1. Type 1 Pipe Drop with concrete outlet transition-explanation sheet for table 6-1.
Adapted from Design of Small Canal Structures, USBR, 1974

Table 6-1. Type 1 Pipe Drop with concrete outlet transition (to be used with figure 6-1).

All values are in feet unless otherwise noted

F	2.28	2.9	3.2	3.82	4.15	4.79	5.1	5.75	6.08	6.73	7.04	7.7	8.04	8.7	9.03
h2	2.1	2.87	3.25	4.02	4.4	5.17	5.55	6.31	6.7	7.46	7.84	8.61	8.99	9.76	10.14
h3	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
h4	0.53	0.53	0.53	1.07	1.07	1.07	1.34	1.34	1.34	1.34	1.66	1.66	1.66	1.66	1.66
L2	5.1	7	7.9	9.7	10.6	12.5	13.4	15.2	16.2	18	19	20.8	21.7	23.6	24.5
L3	5	5	5	5	5	7	7	7	7	7	7	7	6.5	6.5	6.5
L4	4	4	4	5	5	4	4	4	4	5	5	5	6.5	6.5	6.5
S3	7°.30'					15°									
Submergence	0.56	0.72	0.79	0.81	0.86	0.56	0.63	0.74	0.80	0.64	0.71	0.82	0.45	0.56	0.61
d2	2.01	2.15	2.22	2.35	2.4	2.52	2.58	2.68	2.74	2.84	2.9	3	3.04	3.14	3.18
Lx	5.5	7.5	8.5	10.5	11.5	13.5	14.5	16.5	17.5	19.5	20.5	22.5	23.5	25.5	26.5
d1 + hVI	4.66	5.43	5.81	6.58	6.96	7.73	8.11	8.87	9.26	10.02	10.4	11.17	11.55	12.32	12.7

Q = 4 cfs **Dimeter of Pipe = 15 inches** **Vp = 3.26 fps** **$h_v p$ = 0.17 fps** **Inlet R = 2.50 ft.**

Check and Pipe Inlet **Control and Pipe Inlet**

F	9.7	10.04	10.71	11.06	11.74	12.08	12.76	13.09	13.79	14.12	14.81	15.15	15.85	16.54	17.22
h2	10.91	11.29	12.05	12.44	13.2	13.58	14.35	14.73	15.5	15.88	16.64	17.03	17.79	18.56	19.32
h3	0.04	0.04	0.04	0.04	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.05	0.05
h4	1.88	2.07	2.07	2.07	2.01	2.07	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.69	2.69
L2	26.3	27.3	29.1	30	31.9	32.8	34.7	35.6	37.4	38.4	40.2	4J.J0	43	44.8	46.7
L3	7	7	7	7	7	10	10	10	10	10	10	10	10	10.5	10.5
L4	7	7	7	7	7	5	5	5	5	6	6	6	6	6.5	6.5
S3	15°					22°30							22°-30'		
Submergence	0.58	0.62	0.59	0.63	0.71	0.75	0.42	0.47	0.55	0.6	0.67	0.72	0.78	0.53	0.61
d2	3.27	3.31	3.39	3.43	3.5	3.54	3.62	3.66	3.73	3.77	3.84	3.88	3.94	4.01	4.08
Lx	28.5	29.5	31.5	32.5	34.5	35.5	37.5	38.5	40.5	41.5	43.5	44.5	46.5	48.5	50.5
dl + hVI	13.4 7	13.85	14.61	15	15.76	16.14	16.91	17.29	18.06	18.44	19.2	19.59	20.35	21.12	21.88

Adapted from Design of Small Canal Structures, USBR, 1974

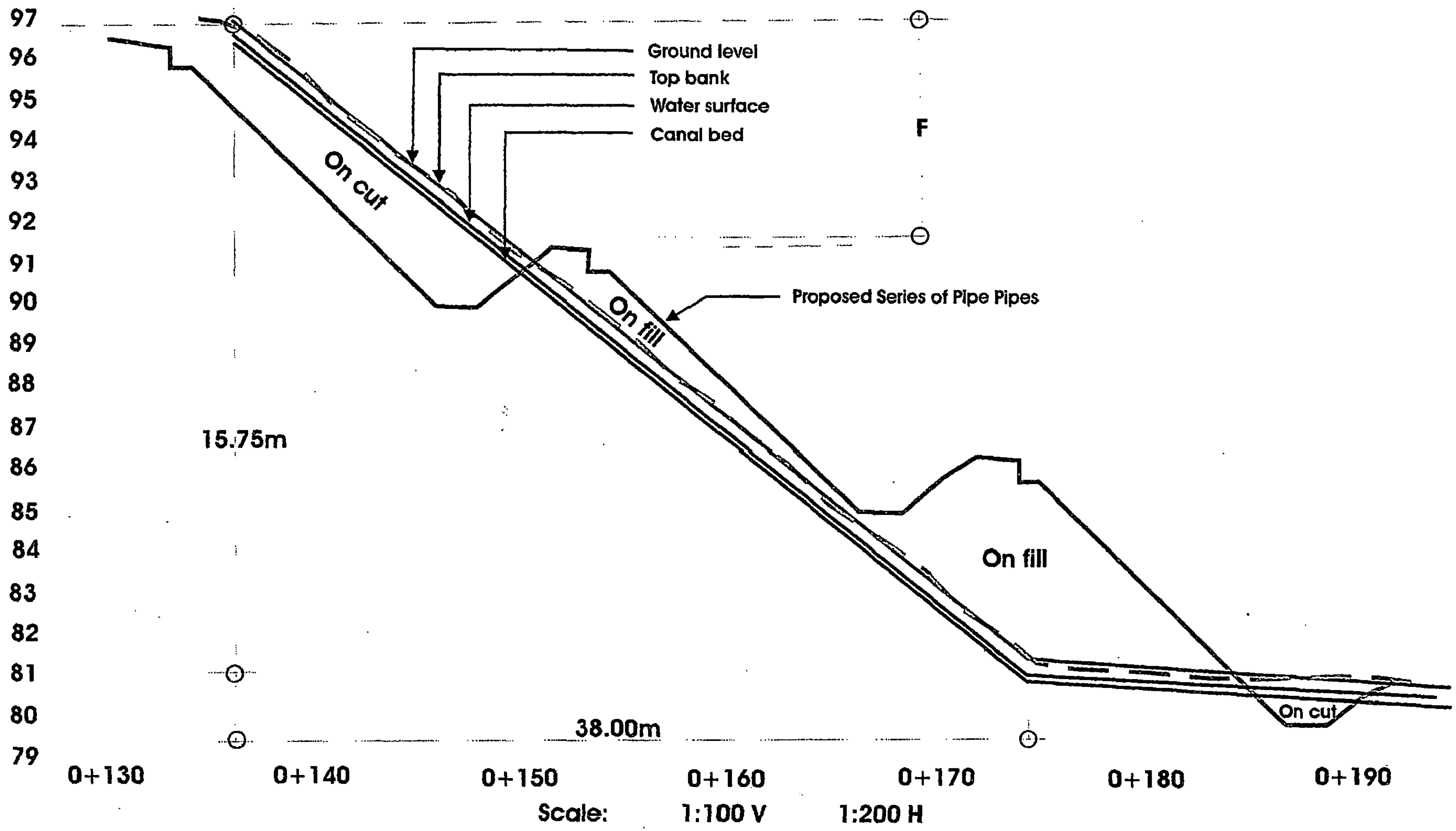


Figure 6-2a. Existing Unlined Canal and Proposed Series of Pipe Drops

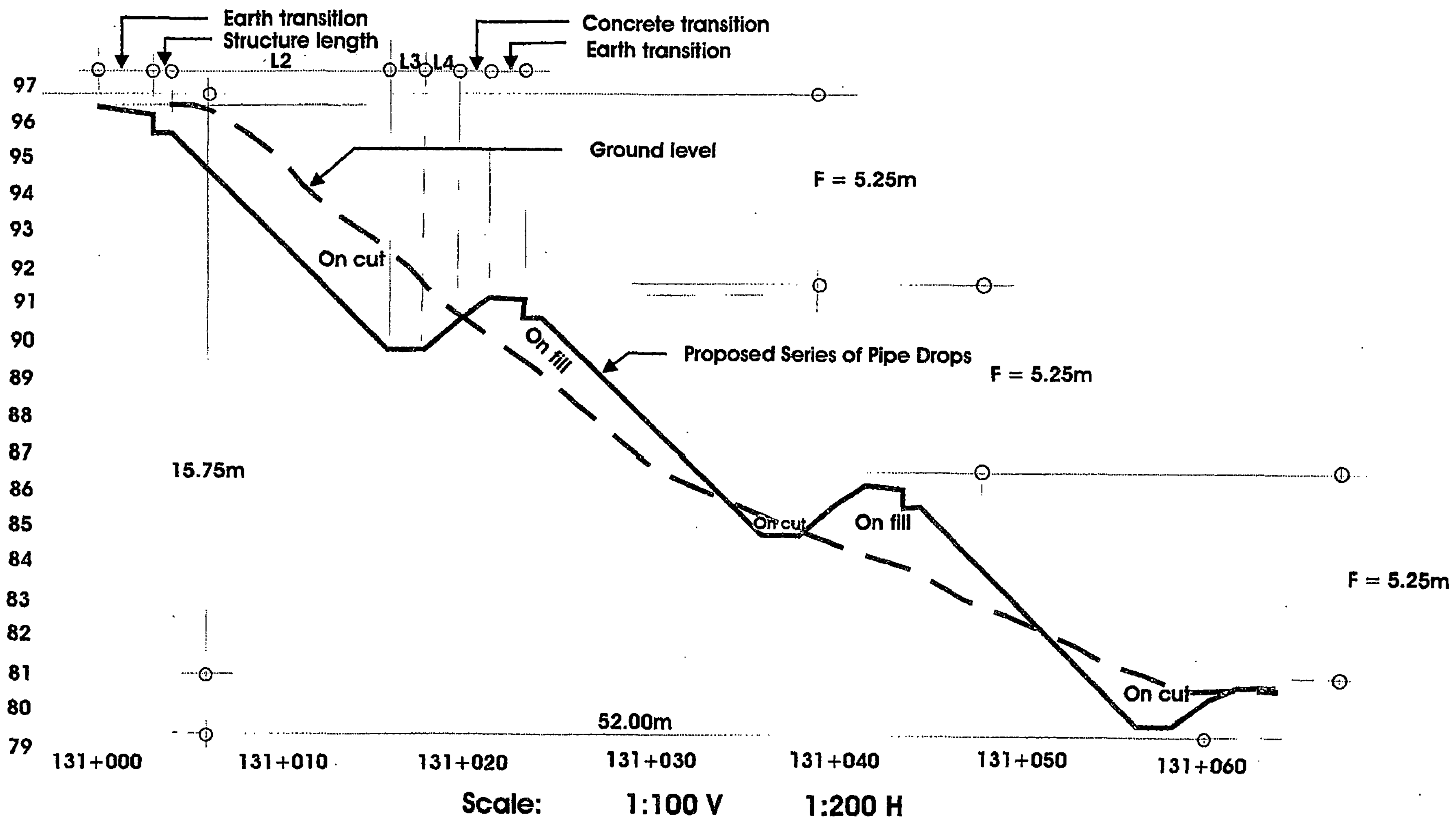


Figure 6-2b. Proposed Series of Pipe Drops Alignment

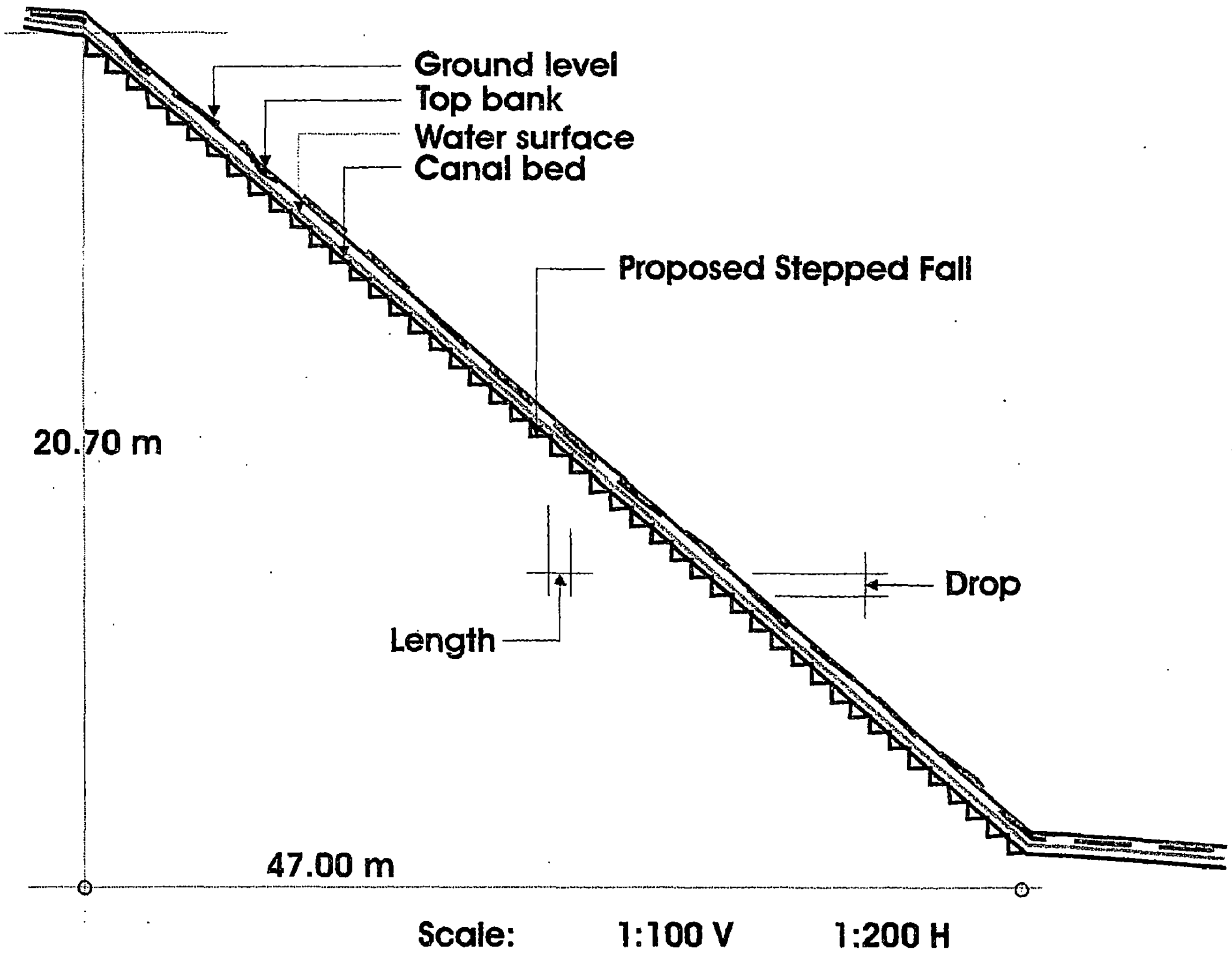


Figure 6-3a. Existing Unlined Canal and Proposed Stepped or Cascade-Type Fall

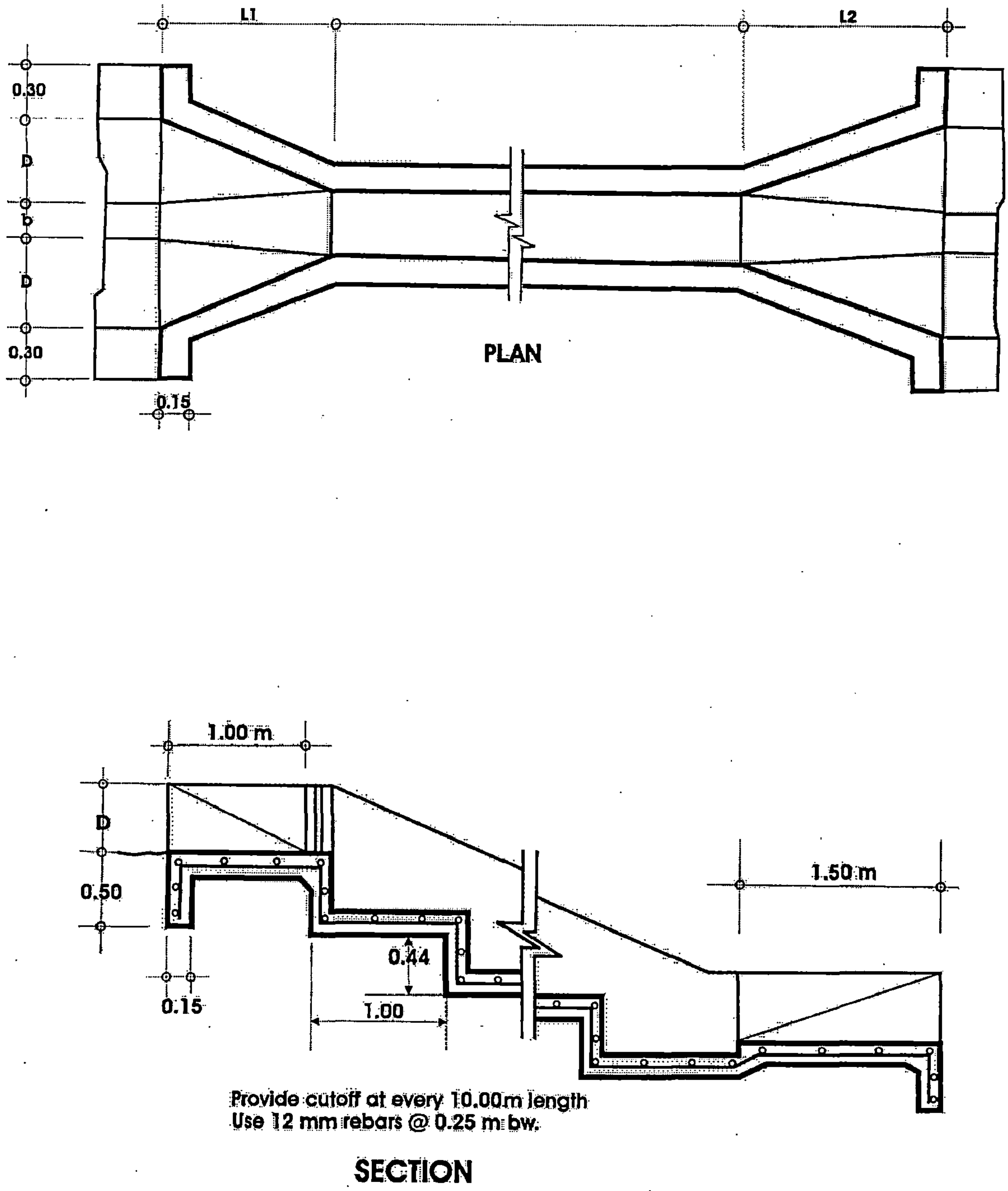


Figure 6-3b. Plan and Section of Stepped or Cascade-Type Fall

SEARCH STRATEGIES TO IMPROVE OPERATION AND MAINTENANCE IN BOHE-PAHU IRRIGATION SYSYEM

7.1 ADAPTABLE STRATEGIES ON GROUNDWATER USE FROM LAKNAUTA MINOR/ OTHER PLACES IN THE PHILIPPINES

Water quality of groundwater in Bohe-Pahu command area is good, which can be used for irrigation. Rice is the main crop for the farmers in the command area for which they wish to cultivate the whole area throughout the year. Although water is sufficient for the first cropping i.e. May-August but during the second cropping and especially in the third cropping water is not sufficient, considering the crops planted are "High Yield Varieties" which requires more water.

From the above situation, it can be seen that additional water is required. The potential of ground water is high in this area, thus ground water can be augmented to canal and use for irrigation. Keeping in view also that high yield varieties are more susceptible to flood damage than most traditional rice.

This strategy is being practiced in many projects in India and specifically in Laknauta Minor, Deoband Branch of Upper Ganga Canal. Such type of conjunctive use has been practiced where water is not sufficient from canal. In the Philippines, this practice is widely used by individual farmers in Zamboanga del Sur, Zamboanga del Norte and in many other areas where rainfall is insufficient and rivers as well as stream flow is not available. Similarly, the same strategy may be adapted in Bohe-Pahu command area by providing sufficient number of tubewells to irrigate areas during dry season. The number of tubewells depends on the discharge, which has to be studied in detail.

7.2 ADAPTABLE STRATEGIES FROM USBR (USA) FOR BOHE-PAHU SMALL-IRRIGATION SYSTEM

7.2.1 Operation and Maintenance Cost Estimate

Each year Operation and Maintenance Cost Estimate should be made based on developed procedures and past experience. The system should have at least a reserve fund to provide for unseen condition. If no regular maintenance, it will lead to the deterioration of the system and inefficiency in serving its purpose.

7.2.2 Transfer of Facilities

Essentially all distribution facilities are transferred to the Farmers Association and to be operated by them. The Farmers Association is required to function effectively to utilize water resources at their disposal.

7.2.3 Operation

Written Regulations and Instructions are essential to the effective operation of an irrigation system. Without written and approved instructions, essential procedure are easily forgotten or never known by operation personnel, resulting to premature breakdown, use of improper procedures, unsafe practices and discontinuity in operation especially during changes of personnel. These are essentially required in Bohe-Pahu command area.

A system scheduling for use in routing the water through the distribution system may be used. After identifying quantities of water needed at each turn-out (by on-farm scheduling procedures), the system-scheduling programme assists in efficiently routing the water as needed.

The purpose of an Irrigation system is to deliver water in a specific quantity at a proper place and time for development of land resources and assure increased yield in the command. The purpose can be accomplished by proper and timely regular measurement of water in transient through the system including farm outlets. ***Water Measurement*** is more important in shortage situations and for equitable distribution on large number of users.

7.2.4 Maintenance

The main objective of any irrigation system should be to attain a high level of operation and maintenance and maintain it on sustained basis. One of the most reliable ways to reach this objective is through the use of ***Periodic Review of the Operation and Maintenance of the System***. The purpose of the review is to evaluate, discuss and identify deficiencies in the operation and maintenance of the system. Such review has to be carried out in Bohe-Pahu to improve its performance. In USBR (USA) someone from outside the organization of the project and who is really experienced in such System Operation and Maintenance and Evaluation carries out such periodic review regularly at 3 to 5 years interval. The purpose of this is to attain an unbiased evaluation of past system operation, maintenance and management activities. Factual data should, however be available to the reviewer.

The number and type of personnel required to efficiently operate and maintain an irrigation system varies with country philosophy, crops grown and type of system.

Maintenance of Facilities and Equipment is obviously one of the most critical aspects related to the efficient delivery of water and maintenance cost may account for at least 50 % of total Operation and Maintenance Budget as per experience by USBR.

The facilities and equipment requiring maintenance in the operation of an irrigation system is quite complex and require specialized knowledge to accomplish efficiently. Some of the areas, which require training, are weed control, dam maintenance, concrete repair, ditch maintenance, generator maintenance, etc. Procedure for maintenance of irrigation system facilities and equipment are often unique to on-site condition. The Bohe-Pahu condition warrants appropriate action to maintain the facilities available in the system.

Vegetation Control is another important aspect of maintenance of irrigation system specially unlined channels, suitable grown plants helps in stability of the slopes but uncontrolled plantation and vegetation growth is a cause of serious trouble and constant nuisance to channels and embankments. Lack of Operation and Maintenance Budget is the real problem but growing carelessness in personnel and neglect of control at the level of senior professionals, is the main cause of poor maintenance standards on these aspects.

7.2.5 Training

Training of personnel is often one of the most important but neglected aspects of the operation of irrigation systems. Often the day-to-day work and pressures take priority over training needs and unless it is scheduled and followed through on, it is often delayed or never takes place. Training program for all types of personnel should be developed and implemented and documented similar to other operating instructions.

Workshops, seminars, Farmers Association meetings, and study tours provide training through technical sessions, exchange of ideas, and observation and study of other systems and ideas. Some of these sessions include Farmers Association meetings, special sessions, Water System Management Workshop, dissemination of information through the Water Operation and Maintenance Bulletin and other current literature. Most of these sessions are held annually to maintain current knowledge.

The farmers in the Bohe-Pahu irrigation system are required to be imparted adequate training as above to improve their knowledge and skill that in turn will help in the performance of the system.

7.3 ADAPTABLE STRATEGIES IN THE PHILIPPINES FROM HUERTA OF VALENCIA

7.3.1 Operating Procedures

The procedures recognize three conditions of water availability-abundance (abundancia), seasonal low water (estiaje ordinario or mitjania in Valencian), and extraordinary drought (sequia extraordinario or nacesitat gran in Valencian)-and they prescribe different rules for each.

7.3.1.1 Periods of Ordinary Low Water

In periods of ordinary low water all farmers share water shortage in proportion to the number of hectares with right to water that they irrigate. This is accomplished by lengthening the time between deliveries of water. When the water reaches a farmer, he takes what he needs, but he will have to wait longer than in periods of abundance for the water to return for the next irrigation of his fields.

7.3.1.2 Periods of Extraordinary Drought

For periods of extraordinary drought the water users of Valencia have devised ingenious steps to enable the canal communities to continue distributing water according to the basic principle of the ***huerta*** (intensively irrigated areas that surround or adjoin town): that water is supplied to each farmer in proportion to the area of the land he irrigates. As drought becomes more and more extreme, however, the effective discretion of the individual farmer to define his requirement becomes more limited, and ultimately the rule that water in proportion to land has to be abandoned.

Distribution to the canal of proportionate share of river water, initiated in the regimen of ordinary drought, additional steps are taken, however. It is designed to increase the utility of the limited water available in the river channel. It requires that the canals on the right and those on the left banks of the river alternate in taking water, each bank irrigating two days at a time. This measure does not increase the increase the volume of water that otherwise be abstracted by each canal, for a while it doubles the water in the canal at anytime it halves the time it is available. It does insure, however, that farmers will receive more of this volume in usable irrigation water than it would otherwise. Without this measure it would be difficult to raise the canal's water to the level of farm turnouts and to reach turnouts at the end of delivery routes. This measure is applied, the Valencian say, to double the water *(doblar el agua)*. To initiate *la dobla*, the syndics flip a coin to determine which canals-those of the right or of the left bank-are to receive water for the first two days.

The canals that practiced rotations among their laterals during ordinary low water continue to do so in extraordinary drought, but they may need to alter their procedure because the canals will receive water only on alternate two-day periods.

As the water diminishes, the time between successive irrigations may become so long that the normal procedure, allowing each farmer to take all that he needs when the water reaches him, will have to be modified if all or most farmers are not to lose their crops.

7.3.1.3 Period of Water Abundance

Basically when water is abundant all principal canals, all their laterals, and all irrigators on each lateral take the water they need approximately when they need it. And since abundant water is likely to be an excess of the needs of land with rights, fields without right can also be supplied.

Even where water is abundant, however, the distribution network may not be sufficiently large or elaborate to serve all farms that demand water at the same time. Some form of operating procedure, or scheduling, is required because of the mechanics, or more properly the hydraulics, of distribution. Thus in some canals the procedure of rotation and repartitions among laterals that is common during ordinary low water is continued when water is abundant; in other canals this procedure is relaxed. In most cases farmers along a lateral will continue to take water in turn, but the waiting period between successive turns will be short. Thus operating procedures for periods of water abundance may be complex, but this should not obscure the basic characteristic of water distribution in this season, namely that farmer gets the water they want approximately when they want it.

7.3.2 Conflict Resolution

Principal objective of Valencia's farmers in determining procedures for allocating and distributing irrigation water and in establishing institutions to operate these procedures has been to mute conflicts among neighbours- that is, among users of the same canal, among the several canal communities of the huerta, and between huerta and upstream users.

The objective then, is to provide order and predictability so that water users can realize their other goals related to increased income, popular control, and social justice. To this end irrigators will adopt operating procedures and institutions that discourage conflicts and settle those that arise. Potential and actual conflicts among members of a community are resolved within the community itself on the basis of principles, rules or regulations to which all members have consented.

7.3.1 People's Participation and Local Control

All landowners have an equal vote in a canal community's general assembly and this assembly approves the canal's operating procedures, elects the executive committee whose members represent the principal service areas of the distribution network, and chooses directly or indirectly the canal's administrative officers. Furthermore the farmers of each lateral constitute a limited community, with equal votes, to choose ditch riders and special guards.

Community members should participate in determining procedures for operating their distribution systems and for ordering relations between these systems and authorities. They should be free from arbitrary authority of their own officers and from control by outside organizations. These related objectives have been pursued with remarkable intensity by irrigators in the United States, Spain, and probably throughout the world.

CONCLUSIONS

Based on the study carried out in this paper the following conclusions could be drawn.

1. The Planning, Design, Execution, Operation, Maintenance and Management of the Irrigation Systems should be strictly based on the criteria of the water use concept and the availability of water and on the experience based approved guidelines and regulation manuals. The irrigation supplies should normally be based on actual water requirements, but may be cross-checked by prevalent duty system, evolved over long experience in the nearby areas. Net irrigation requirements can be estimated conveniently and accurately using FAO Ready Reckoner/ FAO CROPWAT program.

2. Water Management; Water Measurements is not practiced throughout a project, and the efficiency of irrigation system varies, measuring devices should be installed on various suitable control points to assess the delivery and use of water. The distribution of water among farmers to be improved to ensure better use of water and equity in water distribution by simple suitable measures as evolved on Indian Canal Systems, by rotational running and "Warabandi" involving active role of farmers for efficient use of available water from the system.

3. In many areas, planned for irrigation for Small Irrigation Projects, very little attention is given for conjunctive use of surface and ground water. Though, there are some irrigated areas where augmentation of surface water with ground water has been practiced, they have come up mainly because of shear necessity and not as a part of an integral plan. Indian experience does indicate that the farmers initiative and management in using ground water to supplement the surface water from canals, has been very encouraging, simple and economical.

4. It is clearly seen that our Water Development Planning for irrigation, need to be planned and designed with emphasis on the infrastructure to be provided in the canal system for efficient Operation and economical Maintenance. The canal system has to be planned and executed to the level of the farmer's field. In fact, at the planning and

design stage, operation of the system for management of water, including ground water for conjunctive use, should be considered as an important input to optimize the production. The irrigated field and farmer's response and initiative should be the focal point from where the design for the canal system, be initiated.

5. Periodic review and regular monitoring of the system and the review of the benefits as planned, should be an important feature for better and improved performance. Much can be learned from well-established successful practice of Periodic Review of Operation and Maintenance by USBR (USA) and prescribed regular monitoring practice inbuilt in management of Northern Indian Canal Systems.

6. The planning and design practice should involve the experience and requirement of particular areas involving simple and bold designs utilizing local resources and materials. Recent and Modern technology should only be used in case of small systems, where it can economically be maintained and operated and high order of durability is needed. Simple and bold designs with more practical Engineering skills may give better results, as indicated on existing old Indian Irrigation Systems, but the regular examinations and careful maintenance is certainly needed, which can be provided economically and conveniently, with lot of skilled labor force available.

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