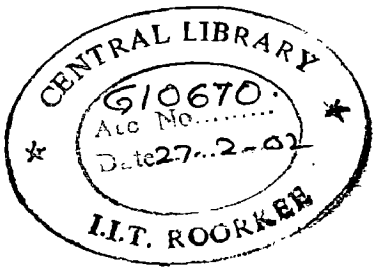
IMPACT ANALYSIS OF WATER COURSE LINING IN SONE COMMAND : A CASE STUDY OF MURKA DISTRIBUTARY

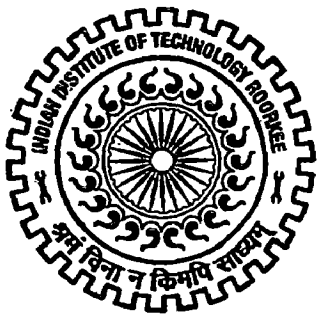
A DISSERTATION

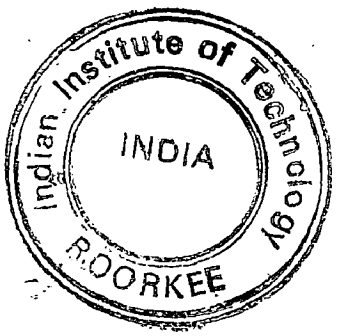
submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT

By

DEO NARAYAN PANDEY







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CANDIDATE'S DECLARATION

I hereby declare that the dissertation titled "**IMPACT ANALYSIS OF WATER COURSE LINING IN SONE COMMAND : A CASE STUDY OF MURKA DISTRIBUTARY**" which is being submitted in partial fulfilment of the requirements for the award of Master's Degree of Technology in Water Resources Development at Water Resources Development Training Centre (WRDTC), Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from 16th July 2001 to 18th January 2002 under the supervision and guidance of **Dr. S.K.Tripathi**, Professor, WRDTC, IIT, Roorkee.

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

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CONTENTS

Title		Page No.
CANDIDATE'S DECLARATION		i
ACKNOWLEDGEMENT		ii
LIST OF TABLES		vi
LIST OF FIGURES		viii
ABBREVIATIONS		ix
SYNOPSIS		x
CHAPTER – 1	**INTRODUCTION**	1
CHAPTER – 2	**PROJECT DESCRIPTION**	4
2.1	Sone Irrigation Project	4
2.1.1	Details of Barrage	5
2.1.2	Water Supplies	6
2.1.3	Old Sone canal System	6
2.1.4	Canal Modernisation	7
2.1.5	Water Quality	7
2.2	Resource Base	8
2.2.1	Location	8
2.2.2	Physiography and soils	8
2.2.3	Climate	10
2.2.4	Land Use Pattern	10
2.2.5	Demographic Features	11
2.2.6	Land Holding Pattern	11
2.3	Agriculture Situation	11
2.3.1	Cropping Pattern	11
2.3.2	Cropping Seasons	11
2.3.3	Crop Rotation	12
2.3.4	High Yielding Varieties	12
2.3.5	Irrigation	12
2.3.6	Agricultural Machinery	14
2.3.7	Horticulture	15

2.4	Infrastructure Support Facilities	15
	2.4.1 Input Supply Centres	15
	2.4.2 Marketing	15
	2.4.3 Processing	16
	2.4.4 Communication	16
2.5	Environmental Assessment	17
2.6	Sone Command Area Development Agency	18
CHAPTER – 3	**AREA OF STUDY**	20
3.1	Selection of Study Area	20
3.2	Eastern Sone Link Canal	22
3.3	Patna Main Canal	22
3.4	Murka Distributary	22
3.5	Outlet and Water Course	25
3.6	Lining of Water Course	26
3.7	Programme of Lining of Water Course	30
3.8	Land Holding Pattern in Study Area	30
3.9	Cropping Pattern in Study Area	30
3.10	Soil Texture	31
3.11	Bulk Density	32
3.12	Rainfall	33
3.13	Environment	33
	3.13.1 Afforestation	34
	3.13.2 Utilization of Cow dung as Fuel	34
CHAPTER – 4	**SEEPAGE LOSSES AND LINING IN WATER COURSE**	35
4.1	General	35
4.2	Review of Studies on Losses and Lining of Water courses - 19th Century (India)	40
4.3	Seepage Loss in Compacted Water Course	42
4.4	Measures for Reduction of Losses	43
4.5	Length of Lining of Water Course	47

4.6	Review of Evaluation Studies of Modernized Water Courses in Pilot Projects of Upper Ganga Canal in U.P.		49
4.7	Channel Renovation Alternatives		51
	4.7.1	Channel Cleaning and Repair	52
	4.7.2	Earthen Renovation	52
	4.7.3	Channel Lining	52
		4.7.3.1 Hard Surface and Exposed Membrane Linings	53
		4.7.3.2 Covered Membrane lining	62
		4.7.3.3 Earth lining	64
CHAPTER – 5	**IMPACT ANALYSIS OF LINING IN MURKA DISTRIBUTARY**		66
5.1	Condition of Lining		66
5.2	Cropping Practice		66
	5.2.1	Paddy	66
	5.2.2	Wheat	68
	5.2.3	Lentil, Gram, Pea & Khesari	69
5.3	Productivity of Crop		76
5.4	Irrigation Intensity		78
5.5	Crop water Requirement		80
	5.5.1	Computation of Reference Evapotranspiration (Eto) by Modified Penman Method	80
	5.5.2	Climatic Data	83
	5.5.3	Crop water Requirement for Rice	85
	5.5.4	Crop water Requirement for Wheat	87
5.6	Efficiency at Outlet Level		90
5.7	Irrigation management		95
5.8	Socio-economic Condition of Farmers		97
CHAPTER – 6	**SUMMARY AND CONCLUSION**		100
REFERENCES			102
ANNEXURES			104-113

LIST OF TABLES

Table No.	Title	Page No.
2.1	Details of Sone Canal System	5
2.2	Irrigation Potential Created in Sone Irrigation Project	13
2.3	Irrigated area in Old Sone Canal System	13
2.4	Irrigated Area in Sone High Level Canal System	14
2.5	Irrigated area in year 2000-2001	14
3.1	Reach wise and Village wise detail of selected outlet	20
3.2	Command Area of Selected Outlets	22
3.3	Texture of Soil	31
3.4	Bulk Density of Soil	32
3.5	Rainfall Variability of Paliganj Block	33
3.6	Tree Plantation along the Roads in Study Area	34
4.1	Coefficient of Permeability of Different Soils	38
4.2	Conveyance Loss in Earthen Channels made in Different Soils	39
4.3	Observed Seepage Losses in Water courses with Different period of Running.	44
4.4	Seepage Losses and Performance of Bitumen Linings	59
5.1	Cropping practice of Paddy in Murka Distributary Command Before and After Lining of Water course	71
5.2	Cropping practice of Wheat in Murka Distributary Command Before and After Lining of Water course	72
5.3	Cropping practice of Gram in Murka Distributary Command Before and After Lining of Water course	73
5.4	Cropping practice of Lentil in Murka Distributary Command Before and After Lining of Water course	75
5.5	Productivity of Main Crops in Murka Distributary Command Before and After Lining of Water course	76
5.6	Outlet wise Details of CCA (ha) Water Course length (m) & Area Irrigated (ha) during Kharif & Rabi	79

5.7	Area Irrigated in Kharif and Rabi in Head, Middle & Tail Reach of Murka Distributary Command	78
5.8	Irrigation Intensity in Head, Middle and Tail Reach of Murka Distributary Command	80
5.9	Crop Water Requirement Calculation Sheet for Rice	88
5.10	Crop Water Requirement Calculation Sheet for Wheat	89
5.11	Average Flow in Water courses below Outlet during Kharif 1991	90
5.12	Canal Running Days during Kharif 1991	90
5.13	Efficiency at Outlet Level in Command of Murka Distributary during Kharif	93
5.14	Average Flow in Water Courses below Outlet during Rabi 1991-92	93
5.15	Canal Running Days during Rabi 1991-92	94

LIST OF FIGURES

Fig. No.	Title	Page No.
2.1	Index Map Showing Command Area and Canal System under Sone Irrigation Project	9
3.1	Index Map of Paliganj Block, District Patna	21
3.2	Index Map of Patna Canal System	23
3.3	Index Map of Command Area of Murka Distributary	24
3.4	Section of Earthen Water Course	25
3.5	Section of Lined Water Course, Brick Lining with Cement Plaster (Year 1985)	27
3.6	Section of Lined Water Course, Brick Lining with Cement Plaster (Year 1987)	27
3.7	Details of Pre-Fabricated Channel	28
3.8	Section of Lined Water Course, Brick Lining with Cement Pointing	29
4.1	Seepage Losses in Clayey Soil (UPIRI, 1987)	45
4.2	Types of Small Channel Lining	54
5.1	Yield of Paddy (Q/ha) in different reaches of Murka Distributary of Sone command	77
5.2	Yield of Wheat (Q/ha) in different reaches of Murka Distributary of Sone command	77
5.3	Area irrigated (ha) in different reaches of Murka Distributary of Sone command	81
5.4	Irrigation Intensity (%) in different reaches of Murka Distributary of Sone command	81

ABBREVIATIONS

CAD	Command Area Development
CCA	Culturable Command Area
cm	centimetre
cumec	cubic metre per second
cusec	cubic feet per second
FCI	Fertilizer Corporation of India
FYM	Farm Yard Manure
GCA	Gross Command Area
ha	hectare
ha.m	hectare metre
HFC	Hindustan Fertilizer Corporation
HYV	High Yielding Varieties
ICID	International Commission of Irrigation & Drainage
IDUP	Irrigation Department, Uttar Pradesh
IMD	India Meteorological Department
IFFCO	Indian Farmers Fertilizer Corporation
kg/ha	kilogram per hectare
km	kilometre
m	metre
M acft	Million acre feet
OL	Outlet
PE	Polyethylene
PVC	Poly Venile Chloride
Q/ha	Quintal per hectare
RD	Reduced Distance
SCADA	Sone Command Area Development Agency
sq.km.	square kilometre
UPIRI	Uttar Pradesh Irrigation Research Institute
WAPCOS	Water and Power Consultancy Services
WRD	Water Resources Department

SYNOPSIS

India is an agrarian country. The livelihood of almost seventy percent of its population depends directly on agriculture or agro-industry.

To fulfil our need of food, it is necessary to increase the yield of the crops. Irrigation plays an important role in increasing the food production. Water is a precious commodity for human, animal and plant, therefore loss of water should be prevented.

It is observed that in major irrigation system about 45 percent of water is lost in seepage and percolation during conveyance from earthen channels. A major portion about 20 percent of this is lost in water course only. The conveyance loss can be minimise by lining the water courses.

Sone Irrigation Project, a run of the river scheme having a barrage (weir in past) on river Sone near Dehri on Sone in Rohtas district of Bihar state is about one and half century old. It provides irrigation to eight districts of Bihar state. Its G.C.A.is 8.66 lakhs ha & C.C.A. is 6.15 lakhs ha. For the development of command area of Sone Irrigation Project, Sone Command Area Development Agency was set up in 1973. Besides other activity, lining of water courses was started in 1982-83 by Sone Command Area Development Agency and is still continuing. The water courses selected for the study were lined by Sone Command Area Development Agency during 1987-88.

The study entitled "Impact Analysis of Water Course Lining in Sone Command : A Case Study of Murka Distributary" was undertaken with the objectives of evaluating changes brought by the lining of water courses on crop practice, crop productivity, irrigation intensity, irrigation efficiency, irrigation management and socio-economic condition. The observations revealed that the lining of water courses recorded only a marginal improvement in crop practice, crop productivity, irrigation intensity,irrigation efficiency and socio-economic condition.

INTRODUCTION

Water is nature's greatest gift to mankind. It is the water on which all human, animal and plant life thrive in this planet. The entire history of mankind is written in terms of water needed for life.

India occupies 2 percent of world's area but about 16 percent of its population and about 4 percent of its water resources. Geographical area of India is 329 mha out of which the present net cropped area is about 142.5 mha. The livelihood of almost two third of our population depends directly on agriculture or agro-industry.

Irrigation plays a vital role in augmentation of food production. To provide irrigation to crops, a few major irrigation projects were constructed in India in nineteenth century. One of them is Sone Irrigation Project. This project had been constructed in 1873-74. It is a run of the river scheme having a barrage (weir in past) on the river Sone at Indrapuri near Dehri on Sone in Rohtas district of Bihar state. Its GCA is 8.66 lakhs hectare and CCA is 6.15 lakhs hectare. In past the canals of this project were used for navigation also but now the navigation is stopped and the project is serving the purpose of irrigation.

For the development of command area of Sone Irrigation Project, Sone Command Area Development Authority was set up in 1973 and renamed as "Sone Command Area Development Agency" and abbreviated as SCADA in 1974. Beside other works of command area development, water course lining is one of its activity.

The water course is the link between field and conveyance network. A water course takes off from an outlet on a minor or a distributary or a branch canal. Responsibility of Irrigation Department to deliver water is suppose to end at outlet point and beyond outlet delivery and distribution of water is suppose to be farmer's responsibility. This results inefficient and inequitable distribution of water.

Therefore the efforts are to be made to ensure adequate supply at outlet head and make the water equitably available to farmers. This will encourage the farmers to manage the available water more efficiently.

It has been observed that in major irrigation systems about 45 percent of water is lost in seepage and percolation in unlined channels. A major portion about 20 percent of this is lost in the water course only. Certainly the loss of this valuable water cannot be allowed to occur indefinitely in a country that is to produce more food with decreased availability of water for irrigation.

The seepage loss in water courses are particularly high since ratio of wetted area to volume of water carried is high and they are mostly in filling reaches with poor maintenance. A major portion of the total seepage loss from a canal system can thus be controlled if the water courses are lined, which can be done at relatively low cost. Moreover the water saved by lining the water courses is a net gain whereas the saving by lining of main canals and distributaries are subjected to further losses in the water courses.

It has been estimated that the supply reaching the fields can be increased by 28 percent if water courses are lined. If main and branch canals are lined, water is saved by about 15 percent, whereas 15 percent increase in supply can be attained by lining only main water courses. If main canal along with its branches and distributaries are lined 25% water can be saved.

This clearly establishes the fact that in an old established irrigation system, lining may start from water courses.

The advantages of lining of earthen water courses are:

(i) Increase in efficiency of an irrigation system

(ii) Reduction of seepage & percolation losses

(iii) Prevention of water logging
(iv) Increase in discharge capacity for a given section
(v) Higher velocities permissible in lined channels.
(vi) Reduction in maintenance cost
(vii) More durable compared to earthen channel.

This will lead to better management of irrigation water and subsequently suppose to result in:

(i) increased yield per unit area
(ii) increased yield per unit volume of water use
(iii) increase in area irrigated
(iv) increase in net return from irrigated crops
(v) equitable distribution of water among the farmers
(vi) elimination of adverse environmental effect of irrigation

SCADA started lining of water courses in 1982–83 and is still continuing. Keeping this in view a study entitled "Impact Analysis of Water Course Lining in Sone Command: A Case Study of Murka Distributary" is proposed with the following objectives:

(i) effect of water course lining on cropping practice
(ii) effect of water course lining on crop productivity
(iii) effect of water course lining on irrigation intensity
(iv) effect of water course lining on irrigation efficiency
(v) effect of water course lining on irrigation management
(vi) effect of water course lining on socio-economic change.

PROJECT DESCRIPTION

2.1 SONE IRRIGATION PROJECT

The irrigation project comprising of an anicut (weir with drop shutters) at Dehri on Sone, district Rohtas, Bihar, the Western canal system for providing to parts of old Sahabad district and the Eastern canal system for providing irrigation to old Gaya and Patna districts was designed and constructed more than a century back in 1873-74 by Shri C.H. Dickens at the cost of Rs.2.68 crores. The project created an irrigation potential of 0.36 Mha, 0.24 Mha under Western canal system and 0.12 Mha under Eastern canal system mainly for Rabi crops.

Frequent operational difficulties and damages to the anicut prompted the Government of Bihar to go in for a new barrage to replace the old anicut. The increased demand for water to cater to the new HYV Kharif and Rabi crops induced the Govt. of Bihar to remodel the old canal system and constructed two high level canals, one each on either flank of the Sone river to provide irrigation to upper areas which were outside the command of the old canal system. With the construction of the Sone barrage, remodeling of the old canal system, construction of the High Level canals and availability of additional water from the Rihand reservoir even during dry season, the farmers of the Sone command who were earlier not very receptive to the new techniques of farming enthusiastically adopted the new High yielding varieties responsive to higher doses of fertilizers.

Taking off from either side of barrage are the western and eastern link canals from which the Sone western and eastern high level canals (new) take off. The Sone western and Eastern canals (old) have also been connected to the link canals. While the districts of Rohtas, Kaimur, Bhojpur and Buxar are served by western canals, parts of the districts of Aurangabad, Gaya, Jahanabad and Patna are served by the eastern canal.

Table 2.1 : Details of Sone canal system

Sl.No.	Name of canals	Design discharge in cumec	Length of canal in km.
1.	Western Link Canal	397.58	9.60
2.	Western High Level canal	44.46	86.40
3.	Ara Main canal	161.41	80.00
4.	Buxar Branch canal	97.24	72.00
5.	Chausa Branch canal	49.84	62.40
6.	Gara Chaube Branch canal	40.21	60.80
7.	Dumraon Branch canal	49.75	64.80
8.	Bihiya Branch canal	45.36	64.00
9.	Eastern Link Canal	124.59	9.60
10.	Eastern High Level canal	39.73	82.00
11.	Patna Main canal	84.95	125.00

Source : Daily discharge report , WRD Bihar, Patna dated 31.7.2001

Construction of Sone barrage had been started in year 1962 at Indrapuri on upstream of Sone river at a distance of 8 km from old Anicut & completed in year 1965.

2.1.1 Details of Barrage

Sl.No.	Particular	
1.	Length of Sone Barrage	1410 metre
2.	Pond level	R.L. 108.23 metre
3.	Flood Reservoir level	R.L. 110.94 metre
4.	Maximum discharge of river	0.40 lakh cumecs
5.	Number of Gates	60 Nos.(size18.29 mx4.42 m)
6.	Number of Undersluice	9 Nos. (size 18.29 mx1.98 m)
7.	Crest level of barrage	R.L. 103.96 metre
8.	Crest level of Under sluice	R.L. 103.35 metre
9.	Catchment area of barrage	6900 square km.

Source : WRD Bihar, Patna

2.1.2 Water Supplies

The total annual outflow of the river Sone has been estimated at 14.25 M acft. As per agreement between the riparian states Bihar, Uttar Pradesh and Madhya Pradesh the allocation of water is as follows :

Bihar	7.75 M acft (54.39%)
Uttar Pradesh	1.25 M acft (08.77%)
Madhya Pradesh	5.25 M acft (36.84%)

2.1.3 Old Sone Canal System

The canal was opened for irrigation in 1873-74, when an irrigation potential of 0.36 Mha was created. After remodeling of canal system and construction of the Barrage in 1965 the irrigation potential of the system increased to 0.584 Mha (Kharif 0.328 Mha, Rabi 0.243 M ha and Hot weather 0.013 M ha). The actual utilisation of irrigation water in the post remodeling period varied between 78.90% and 100.13% of the potential envisaged in 1965. After remodeling of Sone canals, the demand for irrigation water started rising. The advent of the HYVs and the new agricultural technology in the latter part of the sixties brought more areas under kharif than what was originally envisaged. This resulted in greater demand for water and led to encroachment of the freeboard in all the canals including the main and the branch canals. The canals were under heavy stress and damage took place due to the severe use.

However, Rabi irrigation utilisation which is dependent on the run of the river flow and release of water from Rihand reservoir, varied between 70 to 80%. What was suprprising was that from 1976-77 onwards, the hot weather irrigation was discontinued. After remodeling an area of 13000 ha was envisaged to be provided with hot weather irrigation but this irrigation has been totally stopped through a much larger area could have been provided with hot weather irrigation with the water available in the river during this period and the available dry weather discharge was allowed to go down the barrage.

Even after remodeling of the old Sone canals some deficiencies continued to persist. These are

(i) the designed parameters of the canal section (hydraulic mean depth, bed slope, coefficient of rugosity etc.) have deteriorated

(ii) critical velocity ratio of canal system is very low and varies been 0.5 to 0.85 due to flat bed slopes and reduction of cross sectional area of channels due to siltation

(iii) the old canal structures cause afflux on up stream leading to flatter hydraulic slope and reduced velocity

(iv) the number of cross regulator are inadequate

(v) most of field outlets are temporary; their sill levels are fixed arbitrarily.

2.1.4 Canal Modernization

With the signing of the Bansagar agreement the allocation of water from Sone River has been fixed at 7.75 M acft for Bihar. This would enable the Sone irrigation project to increase the irrigation intensity and bring additional area under irrigation. But the technical deficiencies continue to exist and these are likely to be rectified and corrected with the commencement of the Sone canal modernisation project. Major activities proposed for implementation include redesigning of the canal sections. Modification of design parameters of the canals, redesigning the canal structures to receive increased discharges, provision of more cross regulators, escapes, cross-drainage works and permanent outlets. The phase I programme are under implementation.

2.1.5 Water Quality

The Sone canal water is in general good quality with an average pH of 7.8 and an electrical conductivity of 3.15 micro mhos/cm at 25°C. The canal water carries heavy silt. It has been estimated that during the period of January to March the silt addition to the field was 73.6 kg per ha-cm of water whereas from July to September is was 175.2 kg per ha. cm of water. The canal water is, however, suitable for irrigation.

2.2 RESOURCE BASE

2.2.1 Location

The project area lies between latitude 24°25' and 25°45' N and longitude 83°00' and 85°15'E. An interstate river, the Sone has its origin in the plateau area of Amarkantak in Madhya Pradesh. The total catchment area of the river is about 70, 196 sq.km of which 15965 sq.km. (22.7%) lies in Bihar. The command area is bounded by river Ganges in the North, the Kaimur plateau of Rohtas and hilly areas of Aurangabad and Gaya to the South, the river Punpun in the east and river Karmnasa forming the UP and Bihar border in the west. The index map of command area is shown in Fig 2.1.

2.2.2 Physiography and Soils

The topography of the command in the old Sone canal system is fairly plain. The western and eastern high level canals which are contour canals cut across the general slope of the country which is from south to North. On the western side, the main rivers which originate from the plateau areas of Kaimur range are the Kao, the Kudra, the Suara, the Durgawati and the Karmnasa. These rivers form the main drainage system of the command area in Rohtas, Kaimur, Bhojpur and Buxar districts. On the eastern side also the main drainage is carried by the rivers, which originate on the northern slopes of the Palamu and Gaya hills. The main rivers are the Punpun, the Batane and the Adri. The countryside north of Grand Trunk Road is more or less flat with a few hills here and there. The lower reaches of the river Punpun in the district patna and of the Karmnasa in Buxar district often get submerged when these rivers are in high floods and the out fall conditions do not permit quick drainage when the flood level of the Ganges remains high.

Soils :

Broadly the soils in the command area are alluvial origin. They are medium to heavy textured, clay loam to clay and the neutral pH value. Soils of sedimentary origin are found in the southern parts. In some parts of Rohtas district, the soils are acidic, light textured, brown to reddish brown coloured.

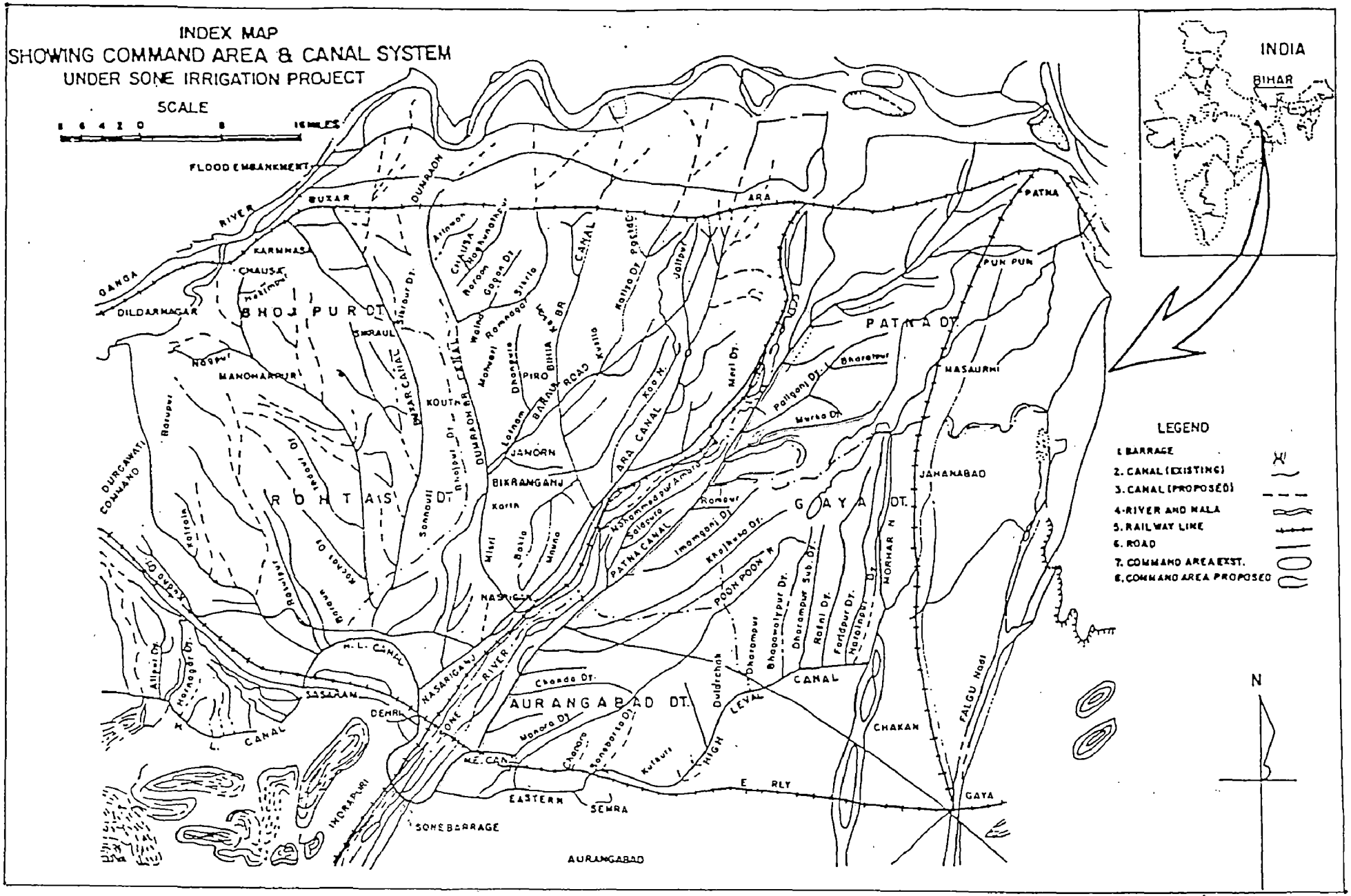

Fig. 2.1 Index Map Showing Command Area and Canal System under Sone Irrigation Project

2.2.3 Climate

The climate is subtropical monsoon characterised by hot summer, high humidity and dry winter. The three seasons are summer (March to Mid June), rainy season Kharif (mid June to mid October) and winter Rabi (mid October to February). The south west monsoon provides most of the rainfall, about 95% (June to September). Study of isoheytal map of Bihar indicates that rainfall decreases generally from East to West. The drought belt passes over the southern parts of the project area covering the districts of Gaya, Aurangabad, Rohtas and Kaimur where almost every year crops suffer totally or partially due to delayed erratic or scanty rainfall.

The river Sone has its origin in the plateau of Amarkantak in the district of Sahdol in Madhya Pradesh, very near to the sources of the river Narmada and Mahanadi. Flowing in the northerly direction through Madhya Pradesh and Uttar Pradesh, its course mainly passes through hilly areas until it enters the Gangetic valley opposite Akbarpur in Rohtas district in Bihar. It then flows almost to the North through the plains of south Bihar till it joins the river Ganges about 32 Km west of Patna. The total catchment area of the river is about 70196 sq.km of which 15965 sq.km. lies in Bihar. The main tributaries of the Sone are the Rihand, Kanhar and North Koel.

2.2.4 Land Use Pattern

About 60 percent of the total geographical area is under cultivation in the project districts and about 71 percent land is under cultivation in the project area. The cultivable command area of the project is 615000 ha. The gross command area is 866000 ha.

In the project districts 11.16 percent land is covered under forests. Maximum forest area lies in Gaya, Aurangabad, Rohtas and Kaimur districts and minimum forest areas are in Buxar, Bhojpur, Patna and Jahanabad districts. The forest areas are mostly outside the project area.

2.2.5 Demographic Features

According to census 2001 (provisional) the total population of the project districts is estimated 19061414 of which about 85 percent reside in rural area. The sex ratio is 907 female per 1000 male. The literacy rate is about 57.9% (71.9% male, 42.5% female).

2.2.6 Land Holding Pattern

The average size of land holding in the project area is 1.0 ha. In general about 87 percent of land holders comprising marginal and small farmers hold about 50 percent of the total area in the project districts. Semi medium and medium farmers constituting about 13 percent of the landholders hold about 46 percent of total area. Large farmers (about 0.3 percent only) are holding about 4 percent of total area.

2.3 AGRICULTURE SITUATION

2.3.1 Cropping Pattern

In the project districts most of the cropped area is under food grains comprising predominant rice, wheat, pulses, barley, maize. Rice is the most predominant crop (48%) followed by wheat (27%), pulses (17.6%), barley and millets (0.8%), maize (1.2%), vegetable including potato (4.3%), oilseed crops (0.7%) and sugarcane (0.4%) of the cultivated area.

2.3.2 Cropping Seasons

There are three distinct cropping seasons. The maximum area is sown during the kharif season from June to October. Rabi crops are grown during November to April. Summer crops which cover the smallest area are grown during the last past of the dry season from March to May.

Rice is most dominant crop during kharif. It is mostly cultivated as canal irrigated crop other kharif crops are pulses (mostly Arhar or Red gram), maize and millets grown in the uplands.

During Rabi, crops are grown either with irrigation or on residual moisture. Wheat is the main crop in the irrigated areas. Dry areas are planted with drought resistant crops like barley or short cycle crops (pulses and oilseeds). Pulses are dominant after wheat. Oil seeds cover least area in Rabi.

Summer crops being negligible (7900 ha) are all irrigated by tubewells. The main crops are rice, maize, moong (green gram) and vegetables. Sugarcane as annual crop is grown in only 9000 ha land, which is negligible.

2.3.3 Crop Rotation

The important crop rotations followed in the project area are :

(i) In Irrigated Areas : Rice in kharif is followed by wheat. The rice-wheat rotation is expanding rapidly. Rice followed by pulse and oil seeds is also an important rotation followed in the area.

(ii) Rainfed low Lands : Rice in kharif followed by wheat, pulses or oilseeds.

(iii) Rainfed Uplands : Maize in kharif is followed by wheat, pulses or oilseeds.

2.3.4 High Yielding Varieties (HYV)

HYV seeds are mostly used in rice and wheat crops. In the project districts, about 68% in rice and 74% in wheat are under HYV. Districtwise HYV percentage in both rice and wheat crop are maximum in Bhojpur and Rohtas district which have a large network of canals (about 82 to 85 percent in rice and 81 to 85 percent in wheat).

2.3.5 Irrigation

After the construction of barrage at Indrapuri, it could be possible to construct Sone High Level canals namely Eastern Sone High Level canal and Western Sone High Level Canal. With the construction of these two canals in 1976-77 created irrigation potential increased. System wise detail is given in Table 2.2.

Table 2.2 : Irrigation Potential Created in Sone Irrigation Project

Sl. No.	Name of Canal system	G.C.A. (lakh ha)	C.C.A. (lakh ha)	Irrigation Potential Created (lakh ha)
1.	Sone Canal System (Eastern & Western Old Canal system)	6.81	4.86	5.84
2.	Sone High Level Canal System			
	(a) Eastern H.L. Canal system	1.00	0.70	0.87
	(b) Western H.L. Canal System	0.85	0.59	0.74
	Total	8.66	6.15	7.45

Source : SCADA Annual Report 1992-93

Details of trends in canal irrigation for the ten year period 1983 to 1992 in old and new Sone canal system are given in Table no. 2.3 & 2.4.

Table 2.3 : Irrigated Area in old Sone Canal System

Year	Kharif '000' ha	Rabi '000' ha	Total '000' ha
1983-84	360.85	186.18	547.03
1984-85	364.22	194.49	558.71
1985-86	369.89	190.01	559.90
1986-87	372.90	173.47	546.37
1987-88	365.65	185.00	550.65
1988-89	374.02	187.50	561.52
1989-90	381.15	188.10	569.25
1990-91	393.10	183.35	576.45
1991-92	312.20	188.51	500.71
1992-93	372.34	103.04	475.39

Source : SCADA Annual Report 1992-93

Table 2.4 : Irrigated Area in Sone High Level Canal System

Year	Kharif '000' ha	Rabi '000' ha	Total '000' ha
1983-84	79.81	19.64	99.45
1984-85	77.42	17.77	95.19
1985-86	80.09	31.09	111.18
1986-87	83.61	30.17	113.78
1987-88	81.44	35.02	116.46
1988-89	95.28	33.50	128.78
1989-90	109.65	35.57	145.22
1990-91	108.30	24.59	132.89
1991-92	90.99	26.78	117.77
1992-93	85.69	12.80	98.49

Source : SCADA Annual Report 1992-93

Table 2.5: Area Irrigated in year 2000-2001

Details	Kharif '000' ha	Rabi '000' ha	Total '000' ha
Old Sone Canal System	390.97	204.94	595.91
Sone High Level Canal	83.00	26.75	109.75
Total	473.97	231.69	705.66

Source : Irrigation Cell, WRD Patna

2.3.6 Agricultural Machinery

For ploughing the land mould board ploughs, desi ploughs, cultivators etc. are used by the majority of the farmers. Only a few big farmers use tractor with their accessories to plough their own land and also operate on hire. Sprayers are commonly

used in applying plant protection chemical in liquid farm. Threshers are used for threshing wheat crop. Seed drills are rarely used.

2.3.7 Horticulture

The population pressure and requirement of the people in the project districts very well justify the increase in production of fruits and vegetables. The agroclimatic condition of Sone Command is favorable for cultivation of fruit crops like mangoes, guava, banana etc. Mango is the most important fruit crop followed by guava and banana in the project area. In the project districts the area under mango is about 20115 ha under guava about 7680 ha, under banana about 616 ha and under other fruits about 2080 ha.

2.4 INFRASTRUCTURE SUPPORT FACILITIES

2.4.1 Input Supply Centers

The Bihar State Cooperative Marketing Union (BISCOMAUN) with Credit Agricole Deposts and Vyapar Mandals are responsible for the supply of seeds, fertilizers and pesticides. The Primary Agriculture Credit Societies (PACS) work as the agents of BISCOMAUN at the grass root level. Inputs are supplied in the form of short term credit. Seldom farmer procure them on cash payment.

In addition to BISCOMAUN, the various fertilizers corporations like HFC and FCI have their agents and dealers. IFFCO routes the sale of its products through cooperatives. Bihar state seeds Corporation and National Seeds Corporation supply seeds.

2.4.2 Marketing

The project area had practically no organised market till 1972 when Bihar State Agricultural Marketing Board (BSAMB) was established to enable the farmers to dispose of their produce at remunerative price, reduce the price difference between the producer and the consumer and ensure availability of agricultural inputs at reasonable prices. In the project districts, the following agricultural marketing yards have been established under Bihar Agricultural Produce Marketing Act where marketing rules and regulations are observed.

Districts	Market yards
Patna	Mussallapur, Patna, Danapur, Fatuha, Barh, Bihta, Mokamah, Masaurhi
Gaya	Gaya, Sherghati, Warsaliganj
Jehanabad	Jehanabad, Arwal
Aurangabad	Aurangabad, Daudnagar
Bojpur	Ara, Behia, Piro
Buxar	Buxar
Rohtas	Natwar, Sasaram, Nokha
Kaimur	Mohania

The market yards constructed with World Bank assistance have provided facilities of (a) drinking water for the users of the market and also for the cattle, (b) sheds for the accommodation of users, lavatories etc.

2.4.3 Processing

The area lacks in processing of the agricultural products of perishable nature like vegetables and fruits. However, there are number of Rice mills in Bhojpur and Rohtas districts, majority of them in private sector. Besides rice mills a number of small processing units for making wheat flour, pulses, extraction of oil from oil seeds are to be found in the form of cottage industry mainly due to shortage and erratic supply of power. A seed processing plant in public sector has been set up at Kudra by the Bihar State Seed Corporation. Other seed processing plant has been set up by Sone CADA in 1992 at Patna and now it has been shifted to Bihta. Both of them are running well. With no fruit processing unit available in the project area, the raw fruits are sold away at throwaway prices in the year of good harvest.

2.4.4 Communication

The district head quarters are connected with metalled roads to almost all the Block Headquarters. Most of the villages are still not connected by metalled roads.

There is a good network of earthen roads connecting villages. Though there used to be a good line of communication in the canal command through canal roads but these have gradually gone into disrepair due to poor maintenance. The total length of roads (1990) in the districts of the command area was 13222 km of which 4280 km was metalled. The National highway No.2 and 30 pass through the districts of command area and their total length is 486 kms.

The project area is served by the Main and Grand Chord lines of the eastern Railways which are the life line of communication between Kolkata and Delhi. Further all the coal traffic from Raniganj and Jharia coal field area pass through these trunk lines and thus the vital lines of communications.

Whereas the common mode of communication through the surfaced roads are the buses and trucks which reach the rural population to most of the block headquarters, the common mode of transport in the villages are the bullock carts, horse drawn carts, tractors, motor cycles and bicycles.

While there are concrete runways in the Airports with telecommunication facilities at Patna, Bihta and Gaya, there are landing strip at Ara, Buxar, Bhabhua, Dehri, Jehanabad and Aurangabad with facilities of landing of smaller aircrafts.

Telegraph facilities are available in 338 post offices in the districts of command. Telephone facilities are available at almost all block head quarters.

Canal telephone for operation of Sone canal system has been installed from Headworks to the tail reaches of system to Khagaul, Ara & Buxar.

2.5 ENVIRONMENTAL ASSESSMENT

Sone canal command area is dotted over with clumps of mango orchards, bamboo groves and date palms (*Phoenix dactylifera*). Numerous isolated species of tamarind (*Tamarindus indica*), Dina Sapindus and drum stick (*Moringa pierygosperma*) also occur. The Pipal (*Ficus religiosa*) and Banyan (*Ficus indica*) are common. The other

principal trees grown in this area are Bel (*Aegle marmelos*), Neem (*Azadiraeta indica*), Siris (*Mimosa siresa*), Shisham (*Dalbergia sisoo*), and Jack fruits (*Artocarpus integrifolia*). These trees are being cut to meet the requirement of fuel, fodder, agricultural implements and minor timber. The most notable change is the decline in large number of mango orchards, which have fallen to axe. There has been faulty large scale exploitation of the bamboo. Unending and wide spread tree felling has resulted in environmental deterioration and ecological disturbances.

Canal irrigation resulted in increased application of chemical fertilizers and pesticides. A portion of these chemicals is always drained off from land. This results in the concentration of certain undesirable elements in the water bodies with adverse effects on flora and fauna of the area. With the regulated flow of water and reduction of discharge in the Sone river below the barrage, many species of game birds and mainly the common strokes (Ganghill) which used to set up nests not very far from the river banks have been driven out of their favourite breeding places, a definite loss to agriculture as strokes used to eat away the insects and pests when they invaded crops and thus maintained ecological balance. With the unplanned and erratic use of canal water wild animals like hyena, black buck and Neelgai are rarely seen now in the area. Indiscriminate use of water has led to formation of local pockets of water logged areas with water hyacinth, obstructing development of fishery and encouraging mosquito breeding.

Except for local pockets like Dehri on Sone, Banjari, Dumraon, Guraru where cement, sugar, textile and paper mills and at a few other sites in command where rice mills are located, the area is mainly agricultural. Industrial waste effluent discharge in to the river Sone are not much and have yet not affected the aquatic lives.

2.6 SONE COMMAND AREA DEVELOPMENT AGENCY

In the Fifth Five year Plan to improve the utilisation of created irrigation potential and to take requisite steps for increasing agricultural production the concept of CAD programme for development of command areas in an integrated manner in selected major

and medium irrigation projects in the country was introduced. The old Sone canal system which was about a century old had poor field distribution system whereas in the new high level canals, the field distribution system had yet to be developed. Accordingly as per the directions of Government of India in respect of the Sone Irrigation Project, the Sone command Area Development Authority was set up in 1973. Subsequently under the Bihar Agricultural and Rural Area Development Agency Ordinance 1974 promulgated by Governor of Bihar the corporate body was renamed "Sone Command Area Development Agency". The ordinance was made into an Act in 1978.

In brief, the following functions were entrusted to the SCADA by Government of Bihar.

(i) Formulation of programmes and schemes for integrated rural and agricultural development with in its area of operation

(ii) Implementation of plans/programmes and schemes as necessary for the development of the area

(iii) Promotion and operation of schemes for irrigation, drainage, flood control, water supply, rural electrification, land leveling, land development, development of agriculture, animal husbandry, fishery and forestry within its area of operation; and

(iv) Undertaking such other activities from time to time as may be deemed necessary for attainment of aims and objects of the Bihar Agriculture and Rural Area Development Agency Act 1978.

The Executive Authority of the SCADA vests with a Board consisting of 24 members drawn from different offices of the State Government, Chairman of the Zilla Parishads, Legislators and representatives of farmers from the command area.

AREA OF STUDY

3.1 SELECTION OF STUDY AREA

In order to study the impact of water course lining in Sone canal command area, Murka distributary has been selected. It takes off from Patna canal on right at (41.18 mile) 66.26 km, of the eastern Sone canal system. Its design discharge is 4.53 cumec. This distributary has a total run of 27.94 km with only one sub-distributary Nagwan having a length 9.76 km, and water is discharged to water courses through hume pipe outlets located on both sides, of distributary. Neither the outlets are uniformly distributed nor have lining works been systematically executed. Therefore study is to be confined in the command of 14 outlets located in Head, Middle and Tail reach areas of the distributary in Paliganj Block of Patna District. Index Map of Paliganj Block is shown in Fig. 3.1

The outlets and the villages along the distributary are detailed in table 3.1.

Table 3.1 : Reach-wise and Village-wise detail of selected outlets

Reach	Village	No. of outlets
Head	Ajda	2 (One RHS & One LHS)
	Sikaria	5 (Two RHS and Three LHS)
Middle	Mankurha	3 (Two RHS & One LHS)
	Khanpura	1 (RHS)
Tail	Chandhaus	3 (One LHS & Two RHS)

The CCA and location of the outlet is given in Table 3.2.

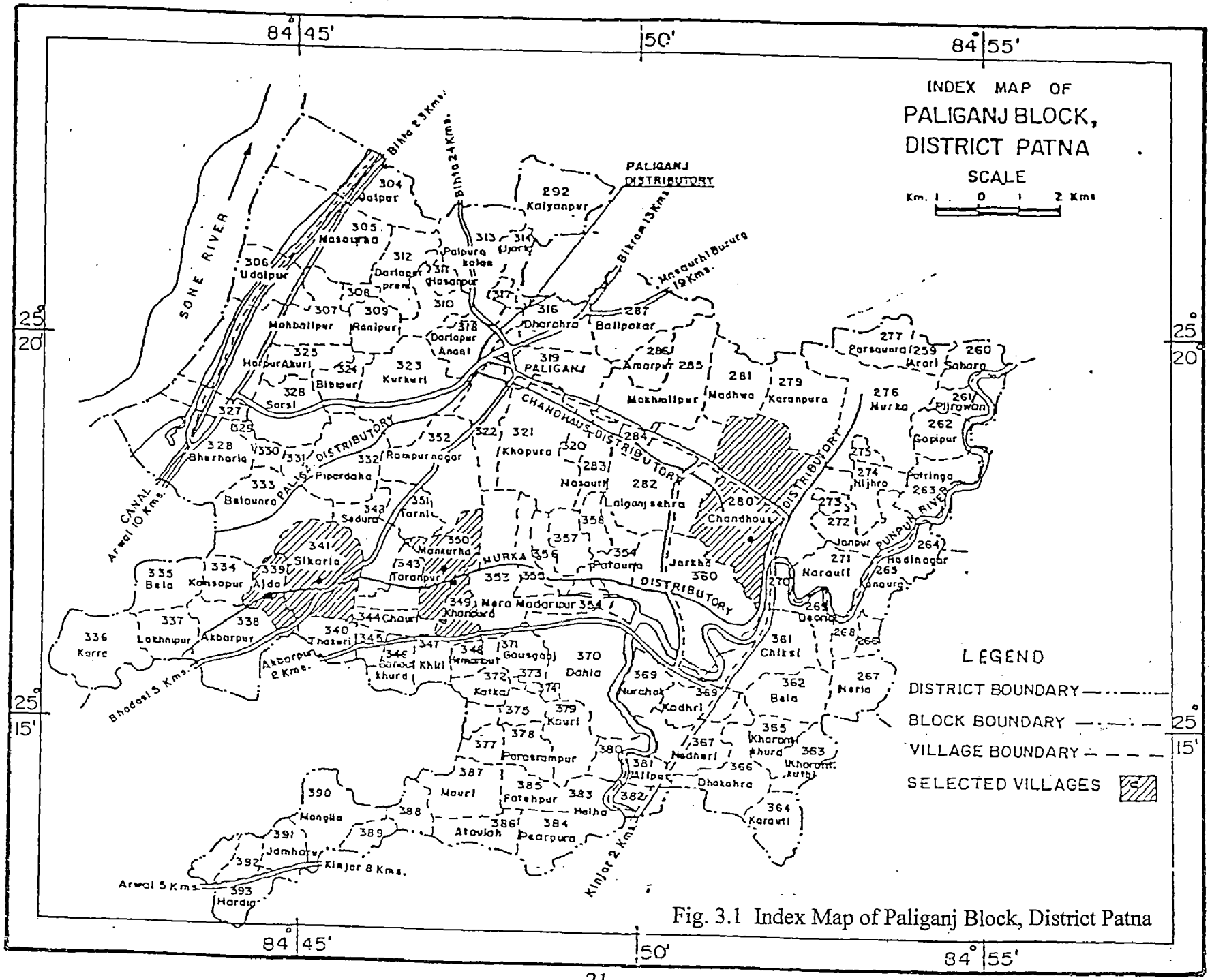

Fig. 3.1 Index Map of Paliganj Block, District Patna

Table 3.2 : Command Area of Selected Outlets

Sl. No.	Outlets	Location in RD (km)	CCA in ha	Sl.No.	Outlets	Location in RD (km)`	CCA in ha
1.	OL-1R	11.27	22.75	8.	OL-8R	14.42	27.50
2.	OL-2L	11.37	30.75	9.	OL-9L	14.49	19.00
3.	OL-3R	12.37	15.10	10.	OL-10R	14.65	14.70
4.	OL-4R	12.98	14.60	11.	OL-11R	15.09	23.75
5.	OL-5L	13.08	32.50	12.	OL-12L	22.54	33.25
6.	OL-6L	13.28	24.40	13.	OL-13R	23.59	9.70
7.	OL-7L	13.58	32.90	14.	OL-14R	23.77	4.00
						Total	304.90

Source : SCADA Patna

3.2 EASTERN SONE LINK CANAL

The eastern Sone Link Canal takes off from eastern side of barrage at Indrapuri. Its total length is 9.60 km and its design discharge is 124.59cumec. It feeds the eastern high level canal and Patna main canal.

3.3 PATNA MAIN CANAL

Patna main canal also known as canal takes off from eastern Sone link canal. Its design discharge is 84.95 cumec and its total length is 125 km. The index map of Patna canal is shown in Fig. 3.2.

3.4 MURKA DISTRIBUTARY

Murka distributary takes off from Patna canal on right at 66.26 km. Its design discharge is 4.53 cumec and CCA is 4300 ha. Its total length is 27.94 km. It has a sub-distributary Nagwa that takes off from distributary on right at 3.36 km whose length is 9.76 km. Index map of command area of Murka distributary is shown in Fig. 3.3.

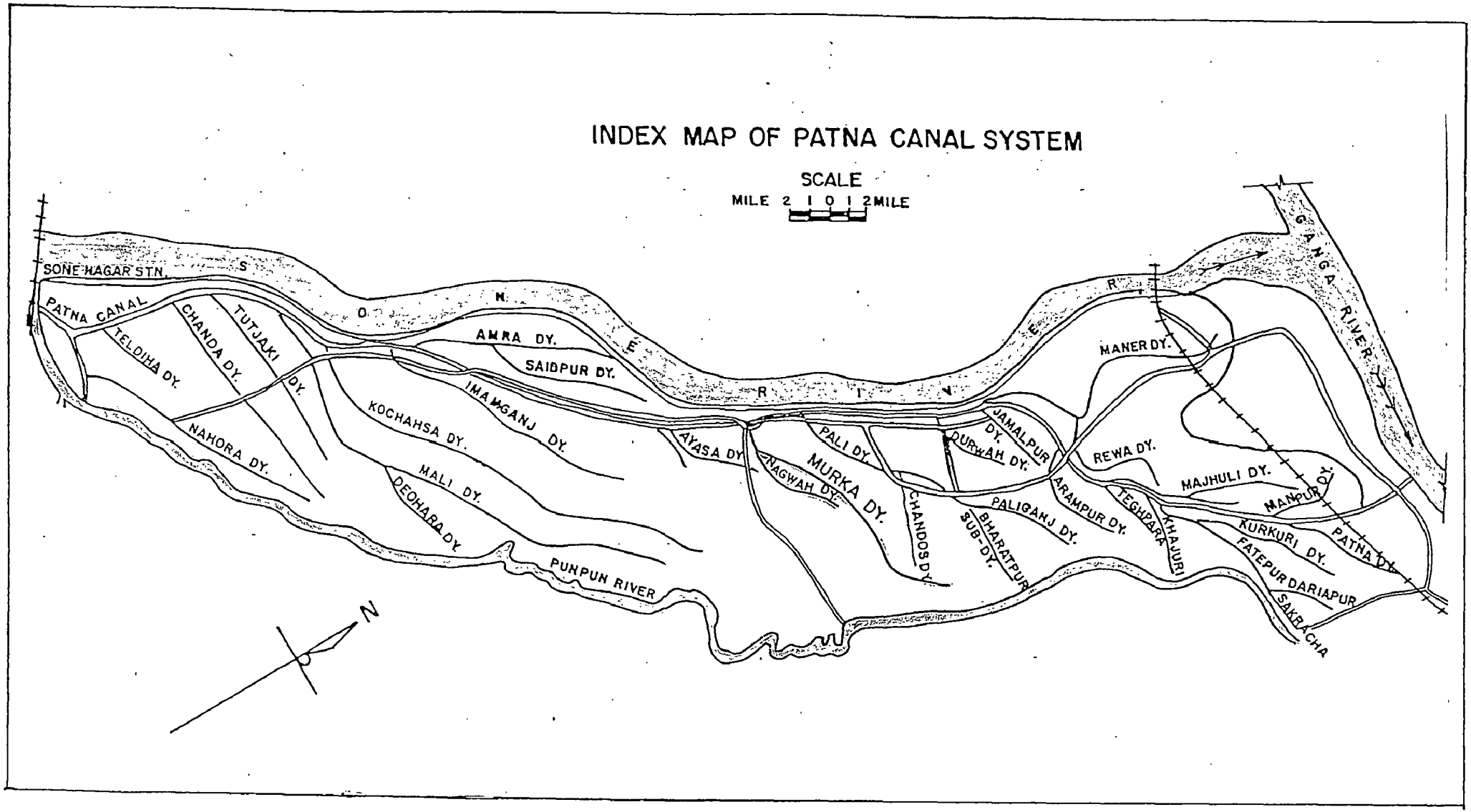

Fig. 3.2 Index Map of Patna Canal System

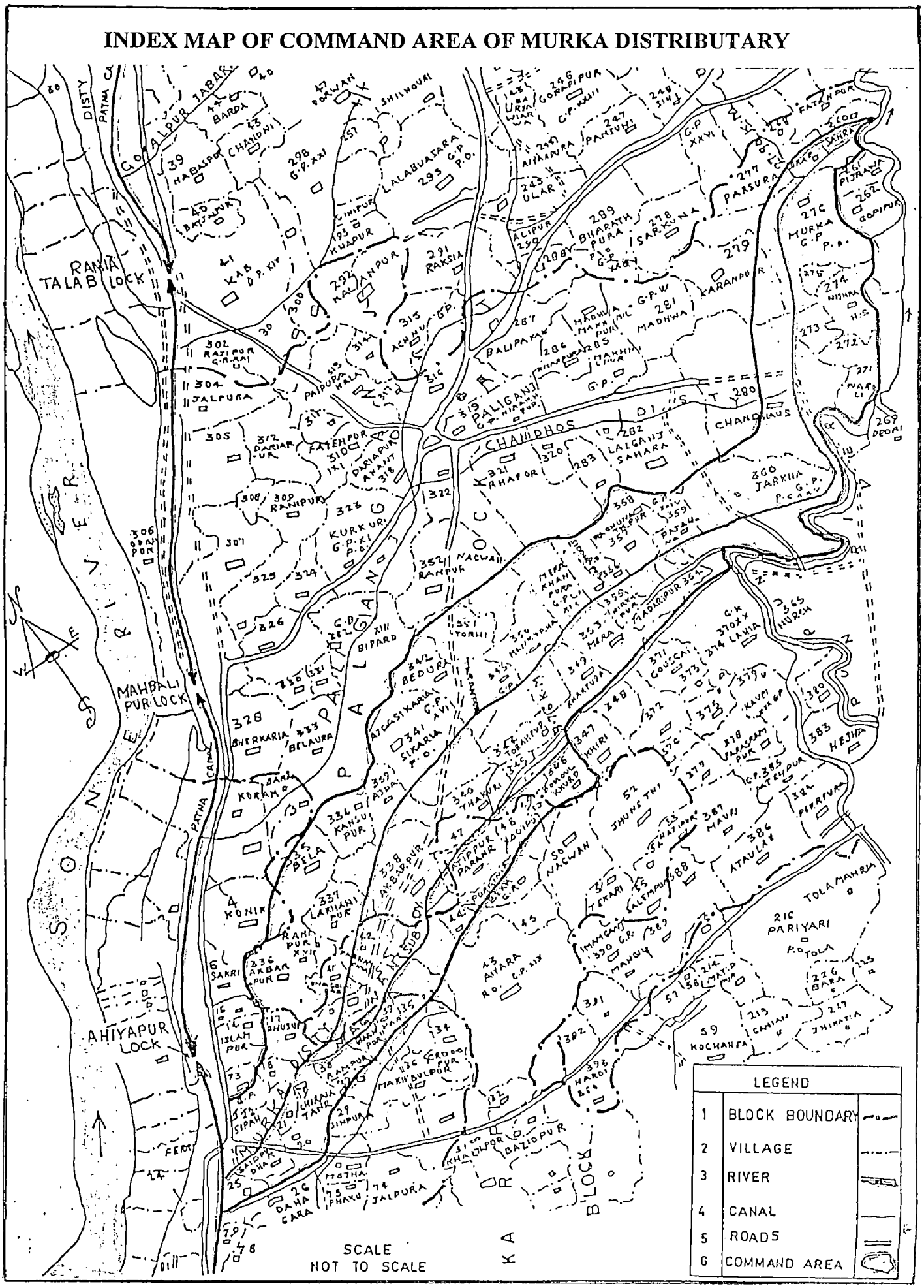

Fig. 3.3 Index Map of Command Area of Murka Distributary

There are 192 outlets of 6" ϕ each in Murka distributary and 60 outlets of 6" ϕ each in Nagwan sub distributary.

3.5 OUTLET AND WATER COURSE

Outlets :

Outlets allow the irrigation water to flow from distributary into water course. In old canal projects outlet is the point where the responsibility of Irrigation Department ends. In different parts of country different type of outlets have been provided but in Sone Irrigation project particularly in Murka distributary all of them are pipe outlets. A concrete pipe embedded in head wall (face wall) is taken across the bank from where the farmers carry water to their field through water courses.

All outlets in selected villages are 6" (15.0 cm) dia concrete pipe embedded in the head wall.

Water Course

Water course is the link between the conveyance system and farmer's field. It takes off water from outlet and delivers to field. Usually their discharge capacity is one cusec. Section of earthen water course is shown in Fig. 3.4.

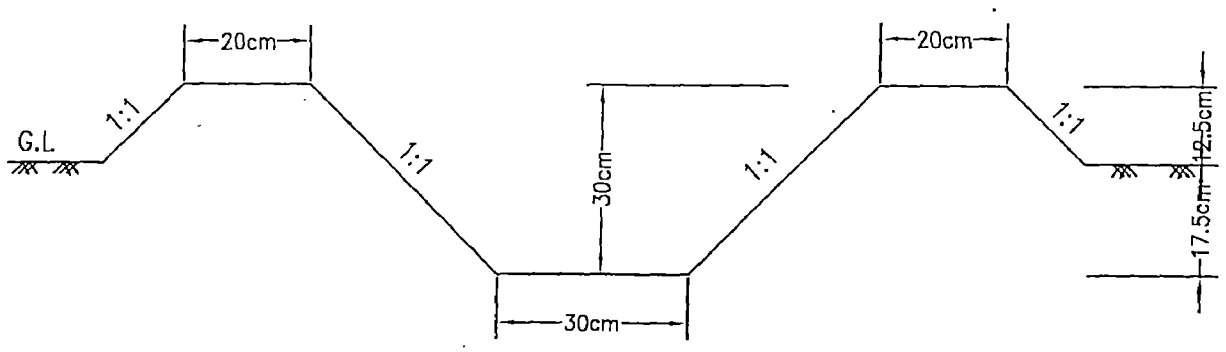

Fig 3.4: SECTION OF EARTHEN WATER COURSE

Lateral Channels :

The farmers do not consider the need for lateral channels in kharif season as they traditionally practice field to field irrigation. In their opinion excess water in paddy fields has no harmful effect on the crop unless the crop is completely drowned. No farmer therefore objects to carrying water through his field to the adjoining fields but in Rabi the condition is altogether different. The farmers are well aware that excess water does more harm to wheat and other Rabi crops. Accordingly they construct temporary earthen channels along the boundary line of the transit field to carry water to the adjoining fields. Such channels are ploughed back at the start of next crop season.

3.6 LINING OF WATER COURSES

As per recommendation of Govt. of India, first 20% of the total length of the water course was lined by Sone CADA in selected outlet command. This is based on the results of experiments conducted in other parts of the country that lining first 20% length of the earthen water course reduces considerable seepage loss in the water course. Theoretically, to what length the channel should be lined is guided by the saving in water losses in a channel and the cost involved in lining that is benefit cost ratio of successive length of lining. Brick lining was done in the water courses selected for the study .

Type of Lining Used :

Type of lining in water courses changed time to time in Sone command.

1. Brick Lining with Cement Plaster :

Brick lining were used for lining of water course in Sone command upto 1988. The section of lining is shown in Fig. 3.5 & 3.6.

2. Pre-Fabricated Channel :

Pre fabricated channels had been used in Sone command from year 1990 for the lining of water courses. These channels were casted in casting yards under vigilant supervision and then channels were transported to field for laying. These precast

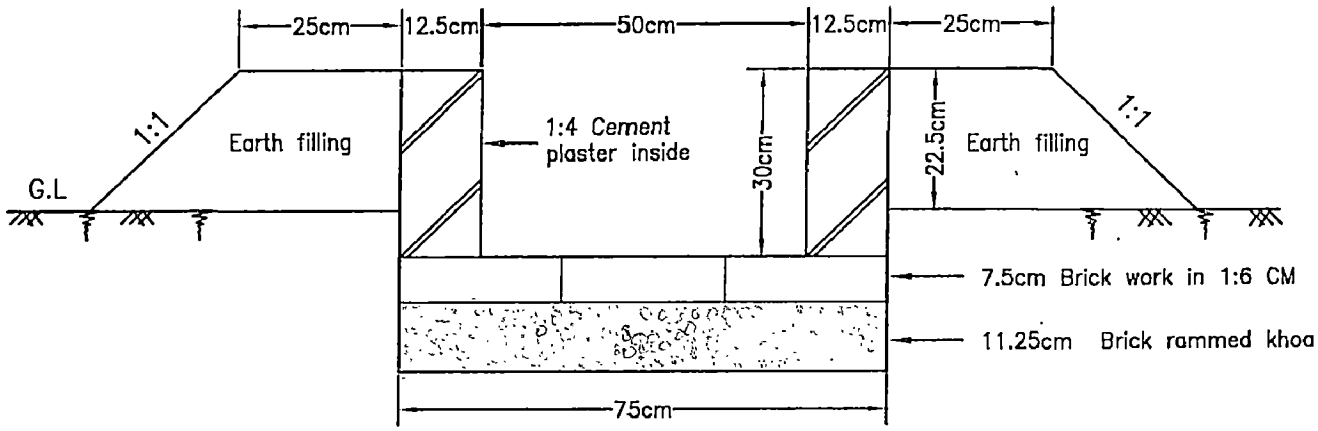

Fig 3.5: SECTION OF LINED WATER COURSE
BRICK LINING WITH CEMENT PLASTER
(YEAR 1985)

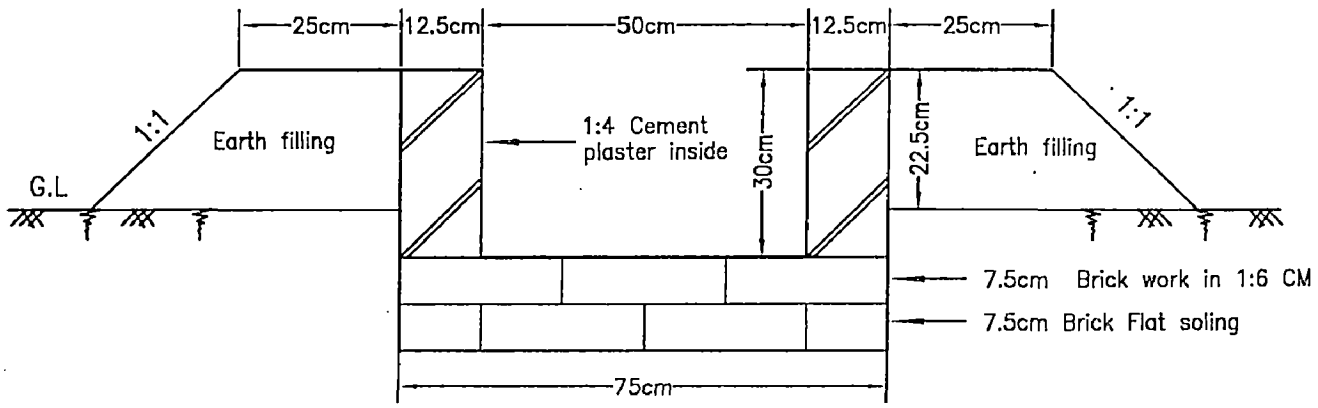

Fig 3.6: SECTION OF LINED WATER COURSE
BRICK LINING WITH CEMENT PLASTER
(YEAR 1987)

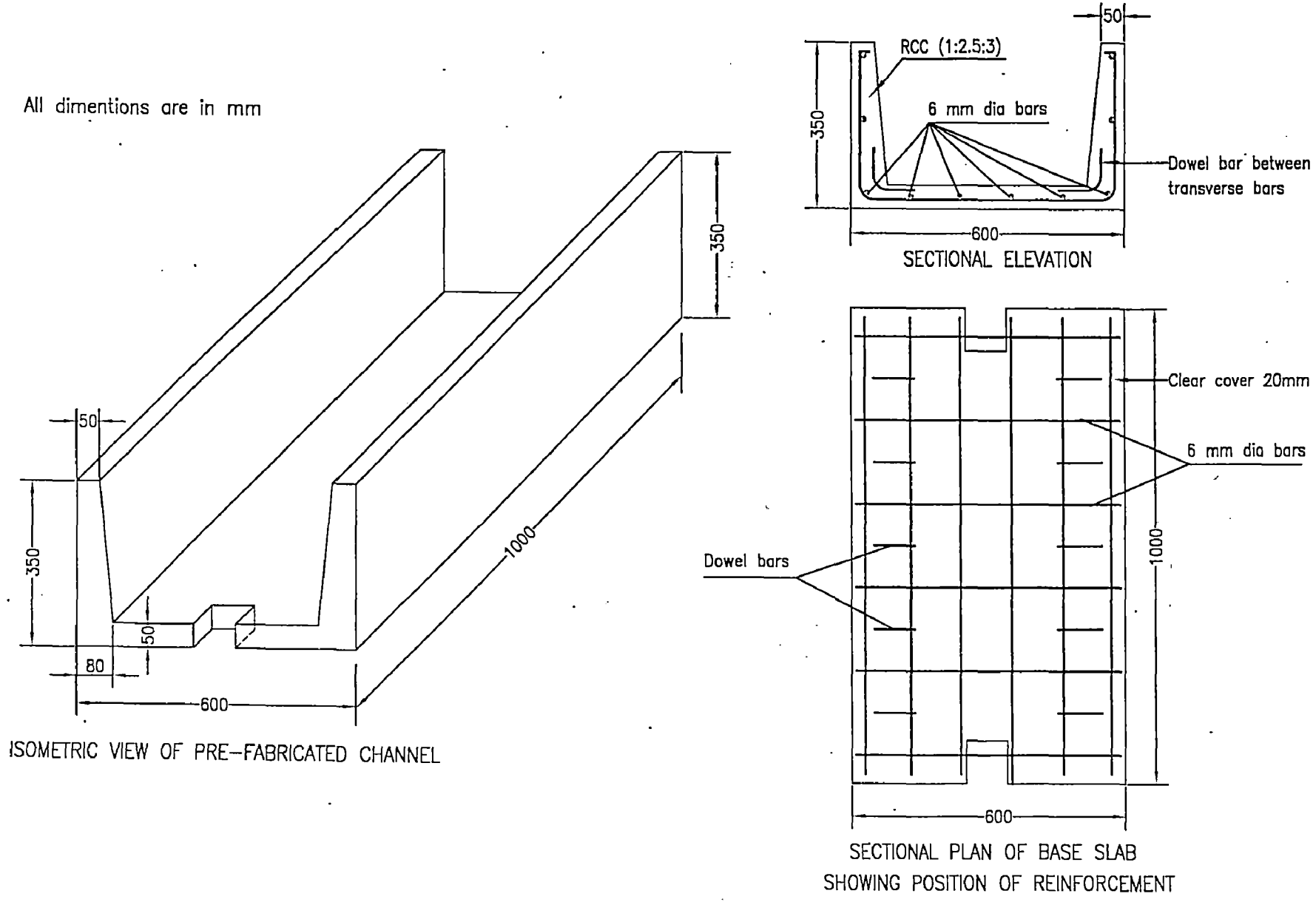

Fig 3.7: DETAILS OF PRE-FABRICATED CHANNEL

channels were 1000 mm long with section 600 mm x 350 mm. Isometric view, sectional elevation and sectional plan are shown in Fig. 3.7.

3. Brick Lining with cement pointing :

Use of pre-fabricated channel has been stopped and now brick lining with cement pointing is being used for the lining of water courses from year 2000. Section of such lined water course is shown in Fig. 3.8.

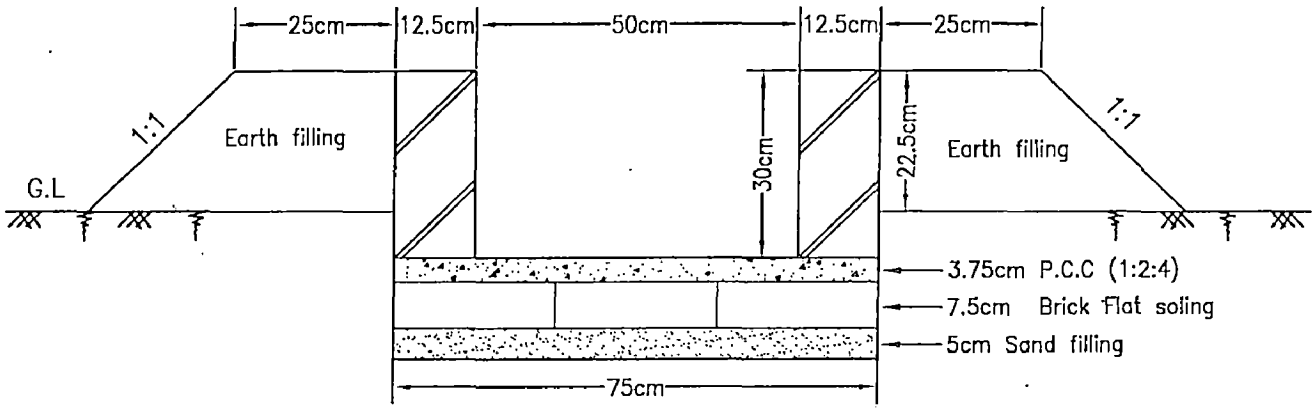

Fig 3.8: SECTION OF LINED WATER COURSE BRICK LINING WITH CEMENT POINTING

3.7 PROGRAMME OF LINING OF WATER COURSES

Lining of water course in Sone command was done randomly. There are five field divisions in Sone CADA at Patna, Ara, Aurangabad, Dehri on Sone and Mohania. Whenever fund obtained in head of lining it was distributed in all five field divisions and lining of water courses were done on different distributaries command of Sone Irrigation Project. Recently in year 2000-2001, distributaries have been selected for water course lining.

3.8 LAND HOLDING PATTERN IN STUDY AREA

The land holding in the study area can be categorised as :

	Percentage	land holding
Marginal farmers	35%	upto 1 ha
Small farmers	41%	1 ha to 2 ha
Medium farmers	20%	2 ha to 4 ha
Large farmers	4%	4 ha to 10 ha
Other farmers	nil	above 10 ha

3.9 CROPPING PATTERN IN STUDY AREA

Paddy	90%
Wheat	31%
Barley	3.5%
Lentils	25%
Gram	5%
Khesari & Pea	24%
Vegetables	1.5%
Fodder	1.5%
Total	181.5%

3.10 SOIL TEXTURE

Soil textures at varying depths upto 75 cm depth in outlet command of outlet No. 2, 6, 8 and 13 is shown in the Table 3.3.

Table 3.3 : Texture of Soil

A1 – Head Reach

Sl. No.	Village	Out let	Texture at the depth of				Remarks
			7.5 cm	22.5 cm	45cm	75 cm	
1.	Ajda	2	Loam	Clay	Clay	Clay loam	
2.	Ajda	2	-	Clay	Clay	Clay	
3.	Ajda	2	Clay	Clay	Clay	Clay	
A2 – Head Reach							
1.	Sikaria	6	Clay	Clay loam	Clay loam	Clay	With gravels
2.	Sikaria	6	-	Clay	Clay	Clay	
3.	Sikaria	6	Clay	Silt loam	Clay	Clay	
B – Mid Reach							
1.	Mankurha	8	Clay loam	Loam	Clay loam	Sandy clay loam	With gravels
2.	Mankurha	8	-	Sandy clay loam	Sandy clay loam	Clay	
C – Tail Reach							
1.	Chandhous	13	Clay loam	Silty clay	Clay	Clay	With gravels
2.	Chandhaus	13	Silt	Clay loam	Clay loam	Sandy clay	
3.	Chandhaus	13	-	Clay	Clay	Clay	

Source:AFC,Report (1993)

The above data for the surface soils indicate that by and large, heavy texture dominates in the area irrespective of head, mid and tail reach sections of Murka Distributary. The variation of texture with respect to depth also reveals the same fact in all the reaches of the distributary.

3.11 BULK DENSITY

The bulk density or moist density is the total mass M of the soil per unit of its total volume

Thus $\rho = \frac{M}{V}$

Where,

ρ = bulk density

M = total mass

V = total volume

It is expressed in terms of gm/cm^3 or kg/m^3

The values of bulk density in different village are shown in Table 3.4.

Table 3.4 : Bulk Density of Soil (gms/cm^3)

Sl. No.	Village	B.D. of surface soil	Location
1.	Ajda	1.40	Head Reach
2.	Sikaria	1.58	Head Reach
3.	Khanpura	1.47	Mid Reach
4.	Chandhaus	1.60	Tail reach

Source :AFC,Report (1993)

The respective values of bulk density have been found to be on the higher side from the normal values. This indicates that comparatively more compact surface soils are dominant in the area and they require special attention regarding the improvement of their physical conditions through organic amendments. This practice will not only help to improve the crop stand in early growth stages but also increase the yield of crop in the long run.

3.12 RAINFALL

For the study of rainfall variability, the rainfall data of Paliganj Block situated at 5 to 8 km from study area were obtained for the period of 1985 to 1992 and has been presented in annexure II. A summary of rainfall is given below :

Table 3.5 : Rainfall Variability of Paliganj Block

Year	Total Rainfall (mm)	No. of rainy days
1985	1164.0	60
1986	945.7	45
1987	1450.8	48
1988	993.7	47
1989	881.0	50
1990	960.2	58
1991	780.8	56
1992	632.9	34

Source :Block office record, Paliganj, Patna

3.13 ENVIRONMENT

Environment plays a very important role in development and sustenance of healthy life but it is less realised in man's relationship with nature. Man has been exploiting nature to his advantage without paying much attention to the balance that should be maintained. Indiscriminate felling of trees and discharging harmful affluent into streams is a common problem. Such practices have disturbed the ecological balance to the extent that its harmful effects are being felt in several ways. The solution to the problem lies in the economic growth with due respect to the environment. The past era has taught us that man in spite of great scientific achievement cannot command nature i.e. wind and rain. The surroundings, we line in is made up of an immensely complex and mysterious issues about which we know very little. We must therefore be careful in exploitation of natural resource so as not to disturb the desirable balance between man ecology and the environment.

3.13.1 Afforestation

Increasing pressure of population on land has led to unending widespread felling of trees for converting more and more land into cultivated area. The statistics available indicate non-existence of forest in the study area. Visual observation also confirms that no significant area is under forest plantation. The tree plantation along the road in study area is given in Table3.6

Table 3.6 : Tree Plantation along the roads in study area

Location	Village & their distance from Paliganj	Connecting Road	Tree plantation along the road
Head Reach	Ajda-Sikaria – 7 km	Paliganj to Akbarpur	No tree plantation except one mango orchard adjacent to road
Mid reach	Mankurha-Khanpura – 5 kms	Paliganj to Kheri Morh	No tree plantation and orchard
Tail Reach	Chandhaus – 8 km	Paliganj to Sigori	Big trees exits along the road

Plantation have also been done on the canal banks except where Murka Distributary which passes through villages. Social forestry has not been established in any of the above mentioned five villages. Trees besides supplying fuel wood, fodder, timber, fruits, manure, it moderates the micro climate, maintain atmospheric equilibrium and environmental stability.

3.13.2 Utilisation of Cowdung as Fuel

Due to decreasing supply of firewood, the farming community depends largely on cowdung cakes for cooking. This leads to nominal or no supply of FYM to the cultivated land. House hold survey indicated that very few farmers use FYM and thus the fertility of land is adversely affected. Canal irrigation results in increased application of fertilizers and pesticides for achieving higher production. A portion of these chemicals is always drained of the land, which leads to concentration of certain undesirable elements in the water having adverse effect on man, flora and fauna of the area.

SEEPAGE LOSSES AND LINING IN WATER COURSE

4.1 GENERAL

In the past, the stress was mainly on the extension of irrigation not only in India but also in many other countries in the world to meet out the demands of fast growing population and also to achieve self sufficiency in agriculture production as much as could be possible. Efficient use of water did not receive the requisite attention and this trend has been mainly responsible for poor returns from Irrigation projects. Improper use of irrigation water not only results in poor returns but also induces water logging and salinity in due course. Improper and inefficient use of water in 12^{th} and 13^{th} century has converted one of the most fertile and green land on this planet (Mossopotamia) in to deserts and sand heaps with in a period of nearly 100 years. Similar carelessness in Pakistan in recent times has rendered 40,000 ha of fertile land into water logged areas every year, while at the mid of 15^{th} century the water table in these areas was nearly 25 to 30 m below the ground surface. Similar situation is likely to arise in many part of our country say Punjab, Haryana, Uttar Pradesh, Rajasthan, Bihar, Bengal and Gujarat in the areas where surface irrigation is a well established practice over a long period. The combined wisdom of Irrigation Engineer, Agricultural Engineer and Agronomist has to be pooled for formulating a suitable strategy to utilise optimum quantity of water efficiently for maximum production, without waste of soil, water or any input concurred with production.

It is estimated that in major irrigation system 45 percent of water diverted for irrigation is lost in transit in various links connecting the source of water to the field. The order of magnitude of the breakup of this loss for situations existing in Indo-Gangetic plain is given by ICID as below :

Transit losses in main canal	17 percent
Transit losses in branches and distributaries	8 percent
Transit losses in water courses and field channels	20 percent

It is, therefore, obviously advantageous to improve the water course and field channels network to minimise this loss. Now a days the water course are usually of less than 28 lps (one cusec) serving a group of farmers and consist of branch water course and field channels, whereas in past specially in Punjab and Sindh the water courses existed with capacity of 3 to 5 cusecs. Main water courses and Branch water courses run continuously or intermittently for specified timings according to water distribution practices while field channels normally run more intermittently to meet out irrigation requirements of only adjoining fields. Selection and application of water course improvement technique in their modernization and rehabilitation will, therefore depend upon cost of the improvement, alternatives weighed against benefits derived from it.

Earthen channel sections have considerably low initial cost as compared to lined sections. But these sections besides having excessive water loss by way of seepage, also have many other serious problems, such as frequent breaches when running in heavy filling, weed growth, water logging and heavy maintenance costs etc.

Seepage Losses :

In earthen sections, following are the important factors effecting seepage losses.

1. The type of the surface of the canal i.e. the material of which the banks are made, its permeability and nature of the lining, if any, applied to its wetted perimeter.
2. The type of surrounding soil of the canal more particularly permeability of adjoining soil
3. The surrounding vegetation of the canal – trees, bushes and other vegetation bordering the canal, as they tend to increase the rate of seepage.
4. The wetted area of the canal bed and banks – the larger the wetted area, the greater the seepage.
5. Frequencies of the canal usage – the more often the canal is used, the less is the rate of seepage, for the soil pores tend to become saturated and then with time get partially sealed. On the other hand, in a canal, which is used only for short duration or intermittently with long intervals, the dry surface has to undergo the cycle of saturation over again affecting the seepage. Seepage losses in water

courses are much more as the water course is subject to intermittent wetting and drying.

6. Age of the canal system – on a larger number of canals, particularly from rivers in alluvial plains, it is observed that seepage losses reduce with the canal's age. This is due to natural sealing of the wetted area by fine silt brought by the flowing water from the parent river.
7. The weather conditions under which the canal operates – the temperature of flowing water and of the soil affects the rate of seepage. In dry months, the rate of seepage should be more because the moisture in the surrounding soil evaporates easily and the rate of seepage from the canal increases to replace this moisture.
8. The amount of sediment contained in the water and its grade – the larger the quantity and finer the grade of the sediment, the greater is the sealing of the soil pores and consequently lowering of the seepage rate.
9. The depth of water flow in the canal – the greater the depth the higher the seepage rate.
10. The ground water level in the locality relative to the canal – the ground water level controls the hydraulic gradient through the soil and the hydraulic gradient affects the rate of seepage loss.
11. Other factors – percentage of entrained air in the soil, capillary tension in the soil, barometric pressure, the chemistry of the soil and water, intensity of artificial drainage and relative location of drainage channels and irrigation canals, and location of canals within the radius of influence of tube wells and wells are some of the other factors which affects the permeability of soil and, therefore, the seepage losses.

Since water course sections are small with low depth of flow, generally constructed above ground level and have intermittent flow, the permeability of soil mass is the important factor in the seepage loss and other factors have little or negligible influence.

An idea about the order of percolation in different nature of soils can be had from the range of permeability coefficients for various soils given in Table 4.1.

Table 4.1 : Coefficient of Permeability of Different soils

Sl.No.	Soil Type	Coefficient of permeability (cm/sec)
1.	Clean gravel	1.0 and greater
2.	Clean sand (coarse)	1.0 to $1x10^{-2}$
3.	Sand (mixture)	$1x10^{-2}$ to $5x10^{-2}$
4.	Fine sand	$5x10^{-2}$ to $1x10^{-3}$
5.	Silty sand	$2x10^{-3}$ to $1x10^{-4}$
6.	Silt	$5x10^{-4}$ to $1x10^{-5}$
7.	Clay	$1x10^{-6}$ and smaller

Source : Punmia, B.C. (1983)

In addition to above Alawn Early (1980) found many or all of the following factors significant in heavy seepage losses on Pakistan water courses.

1. Dead storage :
   (a) Watercourse channels are deeper than the fields. This is especially true within the village area (abadi) where the people remove mud from the channel for construction purposes.
   (b) Buffalo wallows ..... areas where the animals walk and cool themselves in the muddy water course
   (c) Wide, shallow sections used by animals and people as crossing areas
   (d) Negative gradient areas within the channels itself .... usually created when the channel is cleaned without proper leveling equipment.
2. Infiltration :

   The rate of infiltration into the ditch bank is at its highest when the soil is dry, when the water is first turned on. This rate may exceed that of field soil by as much as 500 percent, due to the regularity of the capillary system within the compact bank soil.

3. Rodent holes :

Inspection and excavation of the banks reveals many holes created by insects, rodents, and plant roots. The highly porous nature of these banks is one reason for accelerated infiltration. Most of these holes originate in the sides of the channels and do not penetrate the entire ditch bank. They may penetrate downward end into the subsoil. Coarse textured subsoil then will further increase water loss.

4. Nakka leaks :

Most of the water wasted is through kachha nakkas due to less soil compaction in the newly cut field outlets. Water is absorbed in the watercourse bunds as well as wasted through leakage of the nakkas. Every irrigation evaluator is cautioned to estimate this kind of loss before doing steady state flow measurements.

Losses from channels are through seepage and evaporation. The observed data on water losses are usually this combined figure. The later being comparatively very small the observed losses are considered as a measure of the seepage losses.

Etchevery and Harding (1933) have given the amount of water lost in conveyance in different types of soils is given in Table 4.2.

Table 4.2 : Conveyance losses in earthen channels made in different soils

Character of material	Losses (cumecs/M sq.meters of wetted perimeter)
Impervious clay loam soil	0.9 to 1.2
Medium clay loam soil under laid with hard pan at depth of not over 0.60 to 0.90 m below bed	1.2 to 1.8
Ordinary clay loam soil ,silty soil, or lava ash loam	1.8 to 2.7
Gravelly or sandy clay loam soil , cemented gravel ,sand and clay	2.7 to 3.6
Sandy loam soil	3.6 to 5.2
Loose sandy soil	5.2 to 6.1
Gravelly sandy soils	7.0 to 8.8
Porous gravelly soils	8.8 to 10.6
Very gravelly soils	10.6 to 21.2

4.2 REVIEW OF STUDIES ON LOSSES AND LINING OF WATER COURSES – 19TH CENTURY (INDIA)

4.2.1 U.P. Irrigation Branch circular collection No. 1 on Puddling of irrigation water course gives lot of information on losses observed and measures taken by experienced canal engineers in Punjab and U.P. in the last two decades of 19th century. The problem of losses was quite serious in Punjab and Sindh specially due to large capacity water course extending over large length and passing through sandy soils with large seepage and percolation losses. Some of the relevant important observations are recorded as below.

4.2.2 Mr. Kennedy, Executive Engineer Bari Doab canal irrigation works, Punjab (1890) laid down that average loss of water in a water course was 21 percent of head discharge of canal or nearly 43 percent of outlet head.

Another Engineer Mr. Dempster who had made a number of experiments commented that the loss in possibly well over 30 percent of head discharge.

Length of water course with branches measured on an average 10,000 rft with capacity of 0.5 cusec with average Rabi duty 120 acres.

4.2.3 In another observation on chenab canal on a representative water course with capacity of 5 cusecs (2 ft bed width), main water course for a representative village with 1712 acres commended area was on an average 12000 rft long, with eight branch water courses aggregate 37,500 feet in length.

The field channels were found in length of 63 x 9270 = 584,010 feet. This gives over 100 miles of channel in a single village. Thus on chenab canal main water course were equivalent to a minor and branch water course to a water course (nearly 0.60 cusecs). We can very well imagine the quantum of loss over these three set of channels.

Attempts were also made for comparative study of water losses on the above set of channels

The wetted area of main water course = 12,000 x 8 = 96,000 square feet
Wetted area of branch water course = 37,500 x 4 = 1,50,000 square feet
Wetted area of field channels = 584,010 x 2 = 1,168,020 square feet

Main water course normally run constantly, the branch water course might possibly run constantly or by turns.

Say they run half time.

The field channel may only run at time, say one twelfth of them running always.

The proportionate losses (based on wetted perimeters) would be as

96 : 150/2 : 1168/12
or 96 : 75 : 97

or roughly the loss in equal in each of these cases.

Of course as the loss is only on the amount which enters at the head of channel, then with the same percentage of loss the final set of channels would have the least losses.

4.2.4 Mr. Kennedy in his memorandum also gave the rate of absorption in different kind of channels. He reported that one cusec water is lost from surface areas of irrigation system as below :

Branch canal	45 ft^2
Constant distributaries	30 ft^2
Tatiled distributaries	17 ft^2
Water course	8 ft^2

This shows that proportionate loss is greatest on water courses, less on distributaries and least on canals.

If the wetted surfaces is taken instead of surface areas (this seem to be fair method) the differences would not have been so great, but still the order could not be effected.

Normally, the greater the depth of water the greater the absorption, we might have expected the absorption per square foot of wetted surface to be greatest in canals, next on distributaries and least on water courses.

If the reverse is the case, it must be due to the lower velocities in the smaller channels and their greater rugosity` which increases the wetted area without adding to the calculated length or breadth.

This would be specially the case in the water courses, which are so often irregular and eroded.

On another recent studies on losses in field channels the losses in kachha guls during running period were observed as 4 percent per 100 metre length.

4.3 SEEPAGE LOSS IN COMPACTED WATER COURSE

In order to test the suitability of mechanically compacted water course over that of manually compacted water course, a study has been conduced in 1987 by U.P. Irrigation Research Institute, Roorkee (UNDP Project IND/84/006). The rate of seepage loss was observed at the end of each week in both the water courses. The result indicate that the rate of seepage loss reduces to about half in both the water courses in about four weeks time. It was also found that rate of seepage loss is inversely proportional to the running period. The rate of seepage at the end of six weeks was observed as 0.812 and 0.67 cumecs per million square metre in manually and mechanically compacted clayey

soil respectively, meaning thereby that good amount of water approximately 21% could be saved by way of mechanical compaction.

50 metre long water course having a trapezoidal section was dug in the mechanically compacted clayey embankment. The compaction of the embankment was done by crawler tractor with sheep foot roller. The bed and top widths of the dug section were kept as 30 cm and 100 cm while the depth was 35 cm.

Similar water course with same dimensions was dug in the manually compacted clayey embankment. The parameters of both the water courses were kept in consonance with each other as to avoid any discrepancy in the experimental results.

Ponding method has been adopted for measuring seepage loss. The seepage loss observed in these water courses are given in Table 4.3.

A graph between the rate of seepage loss and period of ponding has been plotted and a best fit curve has been drawn and is shown in Fig. No. 4.1.

A perusal of results contained in table 4.3 and in fig. 4.1 indicate that :

(a) The rate of seepage through water courses is inversely proportional to the period of ponding.

(b) The seepage loss reduces to about half after four weeks running over the first week in manually and mechanically compacted clayey soil.

(c) The rate of seepage loss at end of six weeks is of the order of 0.812 and 0.67 cumecs per million square metre respectively.

(d) Mechanically compacted water course conserves more water say about 21% over manually compacted water courses in six weeks ponding.

4.4 MEASURES FOR REDUCTION OF LOSSES

4.4.1 It was also observed that in a water course with poor maintenance seepage loss was double to that of the well maintained water course.

Table 4.3 : OBSERVED SEEPAGE LOSSES IN WATER COURSES WITH DIFFERENT PERIOD OF RUNNING
(Cumec · per million square metre of wetted surface area)

Time in hours	Seepage losses observed in manually compacted unlined water course					Seepage losses observed in mechanically compacted unlined water course				
	(Clayey Soil) Period of running					(Clayey soil) Period of running				
	One week	Two week	Three week	Four week	Six week	One week	Two week	Three week	Four week	Six week
1.	2.763	2.139	1.508	1.072	0.980	2.143	1.368	1.234	0.855	0.806
2.	2.272	2.031	1.391	1.067	0.978	2.032	1.325	1.148	0.828	0.792
3.	2.092	1.990	1.203	0.990	0.876	1.995	1.215	1.036	0.812	0.784
4.	1.957	1.529	1.130	0.950	0.840	1.932	1.176	1.061	0.795	0.706
5.	1.839	1.498	1.181	0.948	0.823	1.815	1.162	0.996	0.771	0.663
6.	1.728	1.435	1.124	0.947	0.815	1.750	1.124	0.978	0.749	0.637
7.	-	1.409	1.111	0.943	0.805	1.710	1.111	0.934	0.745	0.619
8.	-	1.400	1.111	0.943	0.711	1.693	1.116	0.934	0.695	0.613
*	**1.904**	**1.544**	**1.143**	**0.953**	**0.812**	**1.816**	**1.151**	**0.990**	**0.761**	**0.670**

* Average seepage losses after two hours during observation period

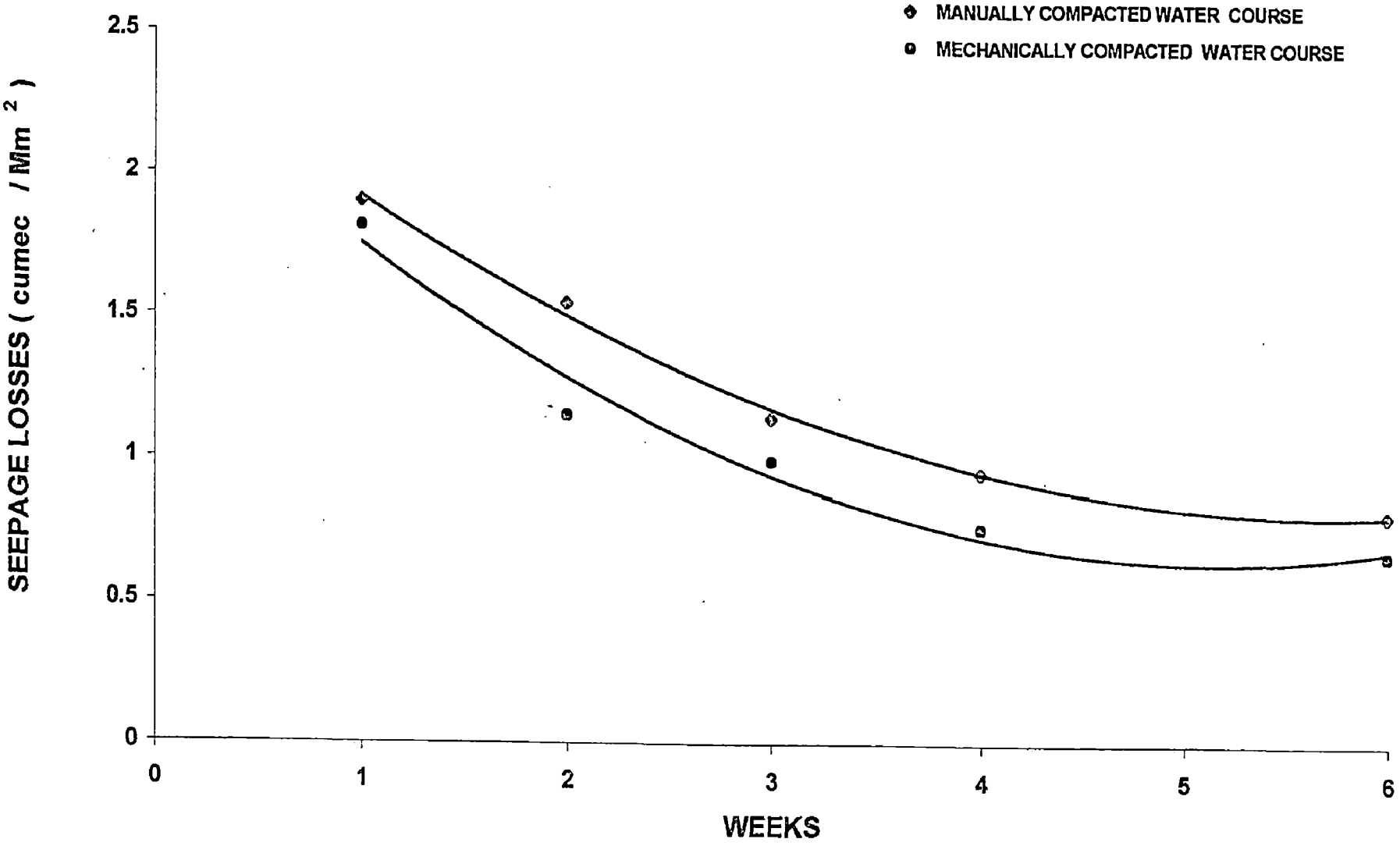

FIG 4.1 SEEPAGE LOSSES IN CLAYEY SOIL (UPIRI,1987)

There was a practice in 19th century on water courses in Punjab that if farmers did not take care for proper maintenance of his water course , supplies were cut off.

4.4.2 It has also been observed during recent studies on Pakistan canal system that cleaning and compaction of unlined water course gives best returns on investment in view of substantial reduction in losses, specially if the water course is thoroughly cleaned of vegetation growth and is well compacted after proper clearance.

4.4.3 Various measures were tried in Punjab and Sindh canals to reduce the water loss on water courses especially passing in sandy soils and with large lengths, the most common and cheapest practice was of plastering the water course with mud (clay), cowdung and bhusa or puddle lining but this needed the good clays for puddling. Normally the puddling was in 3" depth and covered by 4" to 6" good soil to keep it moist.

Since maintenance of water courses and field channels was the primary responsibilities of farmers, British Engineers did not venture to invest on this work and left it to farmers to take adequate measures as considered necessary in sandy soils.

In U.P. specially in irrigated command of eastern Yamuna canal, Upper Ganga canal and lower Ganga canal, the soils in general were heavy and clayey loam, the water courses were of comparatively small capacity and lesser lengths, the lining of water course was not seriously considered.

4.4.4 The greater difficulty with lined water course was to secure the subsequent maintenance. Although loss in water course is no doubt greater than that of minors, but for many reasons it was conceivable that cost per cft of water saved may be less on the minors than in water course. Subsequent supervision and maintenance will also be much easier and there is a great probability of Govt. being able to utilise the water saved carefully than the farmers, where the saving occurs in channels under its own control. This also discouraged the engineers to take up lining on water courses on a large scale.

4.4.5 Mr. Kennedy, based on his observations projected the following figures of losses : Out of 100 cubic ft entering head of canal 80 cubic ft enter the distributary, 74 cubic ft enter the water course 53 cubic ft are taken out of water courses of which 24 are dissipated by waste full application and 28 are actually consumed in maturing the crops.

Thus lining the water course will not stop excessive watering or wasteful application but if we could stop all losses in a water course the quantity of water placed for irrigating field would be increased in the ratio of 53 to 74 or nearly 40 percent. Mr. Dempeter's Estimate was 30 percent. However from practical consideration it could not be considered possible to stop all losses in water courses, the most practical estimate for reduction was limited to nearly 50%.

4.5 LENGTH OF LINING OF WATER COURSE

4.5.1 The available supplies both from surface and ground water resources are much in scarcity comparing with the irrigation requirement in Haryana state in northern India.

A massive programme of lining the canal water course has been under way since 1973. When the water course lining programme was started the inevitable question was whether the katchha water course should be lined in 100 percent length or part of length can be left unlined. Serious thought was given by engineers to this aspect and the ideas have progressively improved on lot of experience gained in the field.

4.5.2 The seepage losses in an unlined water course go on increasing as the distance of delivery point from the outlet on irrigation canal increases. Apart from the wastage of precious irrigation waters, it entails a grossly inequitable system of water distribution because the present warabandi system does not take into account the progressive loss of water due to seepage. Therefore, one of the main purpose of lining water course was to achieve the social objective of equitable distribution of water on major surface irrigation system by minimising the seepage losses.

4.5.3 The steady state losses in a kachha water course have been observed to be 20 to 30 cusecs per million square feet of wetted area. During the first 24 hours of running, after usual 7 day closure, the losses have been found to be as high as 50 to 100 cusecs per million square feet depending on nature of soil and seasonal temperature. In a lined water course, on the other hand, losses during first 24 hours of running after a 7-day closure were observed to be between 4 to 8 cusecs per million square feet of wetted area and steady state losses dropped to about 3 to 6 cusecs per million square feet.

Further the perimeter of a kachha water course is about 1.5 to 2 times that of a lined one for the same discharge. Hence saving in losses is tremendous.

4.5.4 Lining of water course has greatly contributed to the equitable distribution of water, which is the primary objective of any efficient and proper water management. In the traditional water course only those share holders whose land happened to be near the head of outlet or at the most in the middle of chak used to get the benefit of irrigation waters. This was so because most of water was lost in breaches and frequent cuts frustrated the efforts of tail share holders. The lined water course on the other hand is not so valuable and each farmer is assured of his shared.

Evaluation study of lining water courses in Haryana has found that :

(a) beneficiaries having fields at the tail of water courses had benefited the most as compared to those located at the head or in the middle

(b) due to convenience of bridging the depression by lined water course and also in view of flatter slopes possible on lined section there has been an overall improvement in command in saving the human energy and cost involved in lifting waters to cover high lands.

(c) There has been substantial increase in irrigation intensities on lined water courses and also increase in irrigated areas by 15 to 25 percent.

4.5.5 It was realised from very early stages of the water course lining programme that lining 100% length was not desirable because the benefits derived were not

commensurate with the cost. There is a cut of point beyond which the benefits declined sharply compared to the additional length of lining.

Sri S.P. Malhotra, Engineer-in-Chief, Haryana introduced the concept of feet hours considering that the head reaches were required to run for longer periods than the middle and tail reaches during 7-day running programme. He concluded that the lining of about 50 percent length of water course was equivalent to the lining of about 85 percent feet hours. In other words 50 percent lined length would lead to the reduction of 85 percent seepage losses. It may be seen from the curve developed on the above concept that 60 percent lined length gives about 94 percent reduction in seepage losses.

It is, therefore, stipulated that lined length should be between 50 to 60 percent.

4.6 REVIEW OF EVALUATION STUDIES OF MODERNIZED WATER COURSES IN PILOT PROJECTS OF UPPER GANGA CANAL IN U.P.

During implementation of Ist phase of agreement on modernization of U.G.C. between Govt. of India, Govt. of U.P. & World Bank (1984-90) the distributaries block in lower command, Bulandshahar and Harduaganj distributaries were modernised as Pilot projects. In this process the distribution main channel, all the minors and water courses were to be lined besides the rehabilitation and updating of water courses and outlets for distribution and better use of water.

The above pilot projects were executed by IDUP in consultation with experts and engineers from World Bank and also expert Advisory Planning Group of the project provided by WAPCOS (Govt. of India) to carry out necessary studies and provide necessary technical advice specially for these projects from time to time as considered necessary.

The APG (WAPCOS – Govt. of India) has carried out the evaluation studies of the modernisation of water courses on both distribution system, the main relevant observations are recorded as below :

(i) the proposal of reorganisation and regrouping of large water courses and converting them into minors could not be finalised and executed in view of many related problems in the old establised irrigation practices.

(ii) On Bulandshahar distributary system, the average percentage seepage losses in unlined water courses during kharif and Rabi were found to be of the order of 28%. This is based on the analysis of observed data of 24 Nos. unlined water courses in kharif and 20 nos. in Rabi.

On lined water courses of above distributary based on analysis of a lined water courses the average percentage loss works out to 12%.

Based on above data saving in seepage loss between unlined and lined water courses works out to nearly 53%. The percentage of length lined varied from 69 to 80% in case of 4 out of 9 outlets while in others, it was varying from 38 to 53% while suggested lengths for lining water courses were 50 to 60%. The quality of lining was also found to be lacking in thorough control and specially in jointing of precost lined through sections and at outlet locations.

(iii) On Harduaganj distributary system, the average losses in unlined water courses during kharif have been assessed as 32% and during Rabi as 28%.

On lined water courses, based on data of 29 observations during kharif, the average loss works out as 16% and based on 9 observations the average loss during Rabi works out as 14%.

Thus saving of losses on water courses in this system has been nearly 50% during kharif and Rabi.

Out of 30 water courses lined, only 16 were lined from 61%to 100% length while on 5 outlet the length of lining ranges from 14 to 38% and on remaining water courses length of lining varied from 45 to 60%, the recommended length to be lined was 50 to 60%, depending upon conditions and layout of water courses.

It had also been observed that mild variations in permeability of soil through which the water courses passes does not play important role in seepage as the fine silt carried by canal water gets deposited over the time, on inner surface of unlined water courses and makes it less pervious in due course of time.

The variation in losses on unlined water courses on a particular channel in the same area, normally depend on the quality of maintenance of water course, culverts and other structures and water management by farmers.

Thus it could be summarised that although the modernisation works lead to substantial saving in seepage losses and satisfaction to the farmers but the advantages were not found as per expectations and could not be sustained over a period due to neglect in maintenance and misuse by users.

4.7 CHANNEL RENOVATION ALTERNATIVES

Where water table is high, with the introduction of canal irrigation, the land is likely to become water logged if water losses are not prevented. Hence channel renovation is essential.

Possible alternatives to reduce water losses from small conveyance system range from the cleaning of vegetation from the banks to complete channel lining. Three alternatives are as follows :

1. Cleaning and repair
2. Earthen renovation and
3. Channel lining

Which alternatives is chosen for a given section will depend upon the amount and type of losses, cost of programme and the benefits from the saved water. The resources (personnel, material and financial) available, and the time available.

4.7.1 Channel Cleaning and Repair

Channel cleaning and repair involves minimum amount of initial capital inputs. Channel repair includes plugging holes to stop visible leaks, raising banks to stop overtopping, strengthening thin banks to prevent washouts, improving deteriorated junction areas to strengthen banks, smoothing out channel bottom fluctuations, removing vegetation from banks, maintenance and monitoring operations.

4.7.2 Earthen Renovation

Earthen renovation of small channels involves the complete destruction of old channel banks and reconstruction to specifications based upon hydraulic design and the installation of permanent structures at junctions and major outlets. This requires significantly more time to complete than the cleaning and repair, because of more extensive earth work.

Earthen renovation will save all the losses, which cleaning and repair can save, plus additional losses associated with porous vegetation covered banks and uneven, irregular channels.

4.7.3 Channel Lining

Lining for small channels should be practically water tight to prevent seepage loss, resulting water logging and rise of alkali. Its cost should not be excessive, it should prevent the growth of weeds, resist burrowing animals, be strong and durable, preferably not affected by the tramping of cattle, adaptable for the construction of proper shape of the channel section permitting higher velocities.

The following are the types of lining generally adopted for small channels in field:

A. Hard surface and exposed membrane linings.

(i) Portland cement concrete lining

(ii) Shotcrete lining

(iii) Soil cement lining

(iv) Precast concrete slab lining

(v) Asphaltic concrete lining

(vi) Prefabricated asphaltic lining

(vii) Brick lining

(viii) Stone lining

(ix) Exposed asphaltic membrane lining

B. Covered membrane lining or Buried membrane lining

(i) Buried sprayed in place asphaltic membranes

(ii) Prefabricated buried asphaltic membranes

(iii) Plastic and synthetic rubber membrane

C. Thick compacted earth lining

(i) Thick compacted earth lining

(ii) Thin compacted earth lining

(iii) Clay or bentonite – soil lining

4.7.3.1 Hard surface and exposed membrane linings

This category includes all hard surface linings constructed of asphaltic materials, portland cement concrete and mortars, soil cement, brick and stone and lining consisting of relatively thin membranes of asphaltic materials, plastics and synthetic rubber placed directly on the channel bed without protected cover.

(i) Portland cement concrete lining :

Cement concrete linings are generally costlier than all other hard surface linings and probably also constitute the best type. These linings when properly design constructed and maintained, have average serviceable life of over 40 years. Some linings, still in good condition are 50 to 60 years old.

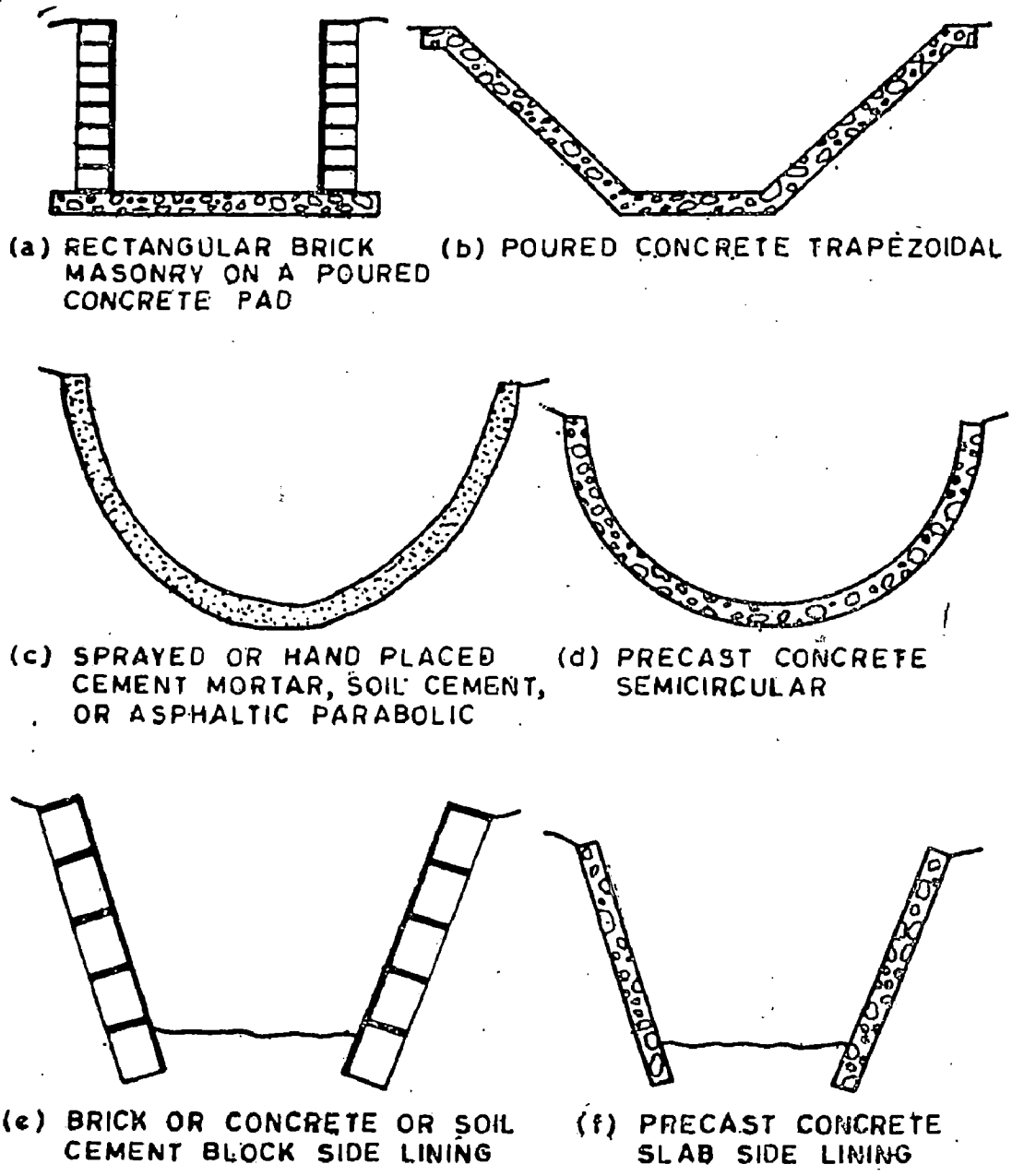

Fig. 4.2 Types of Small Channel Lining

Cement concrete linings are adopted where good quality of stone aggregates and coarse sand (Bajri) are easily available in the nearby locations and the work is generally mechanised.

Cement concrete also have the advantage of adopting precast concrete slabs.

These linings are subject to some cracking. Any appreciable cracks are avoided by suitable joints in concrete and minor cracks, which permit leakage/seepage, can be sealed with asphaltic compounds. With cement concrete linings, all type of sections such as circular trapezoidal, and rectangular sections can be constructed.

It is preferable for higher water velocities. It eliminate weed growth and reduction in maintenance costs. Burrowing animal can not penetrate concrete.

Since the cost of hard linings is usually high, the section with the smallest perimeter for a given area is the most economical.

(ii) Shotcrete lining :

Shotcrete is a term adopted to designate pneumatically applied portland cement mortar (mortar which is shot into place by pneumatic pressure). Pneumatic application is accomplished by the use of special equipment available from several manufacturers who have adopted trade names such as 'Gunite' and 'Jot-crete' for mortar placed by their equipment.

Shotcrete has been widely used for many years and has given satisfactory service, particularly in mild climates. Because of the small amount of construction equipment required and its mobility, this process is well suited to construction or repair work on small or widely scattered canal lining jobs, and also on minor and water courses having frequent sharp curves and structures.

These linings are constructed by shooting a mortar consisting of a thorough mixture of cement, sand and water into place by means of compressed air. The usual mix is 1:4.5 (cement, sand). The thickness varies from about 2.5 to 7.5 cm and wire mesh reinforcing is some times used. It is more easily placed over a rougher subgrade and so is adopted to use in rock cuts where trimming would be very expensive.

It is not economical for the thickness more than 5 cm so its use should be limited to small canals. Being thin they are damaged by hydrostatic pressures and settlement and shrinkage of the subgrade.

(iii) Soil cement lining :

Soil cement offers possibilities for use as a canal lining material where subgrade or adjacent soils are of a sandy nature and other suitable lining materials are not readily available.

As the name implies, soil cement lining are made up of a mixture of port land cement and natural soil. Soils, well graded with a maximum size of 2 cm and containing fines passing No.200 (0.074 mm) sieve, between 10 to 35 percent, gives best results.

Soil cement is commonly mixed in place and compacted with optimum moisture content. Compaction must be sufficient to obtain specified density. After compaction curing should start immediately. Proper curing is as important as it with concrete.

(iv) Precast concrete slab lining :

Precast slabs are usually made 5 to 7 cm thick, width and length are varied to suit channel dimensions and to provide weights that can be conveniently handled. Following sizes have been used extensively in India – 50 cm x 25 cm x 6.5 cm, USA – 61 cm x 20 cm x 5 cm. Pakistan 38 cm x 38 cm x 5 cm. Tongue and groove joints are provided along the edges. The joints should be sealed with mortar or bitumen. Contraction joints at 4 to 5 m spacing are required if slabs are joined with cement mortar. Channel beds are often lined with in-situ concrete while prefabricated slabs are chosen to line the side slopes.

The main advantage of precast concrete lining is that it is possible to exercise close and continuous quality control over the selection and proportioning of concrete materials, mixing, compaction and curing operations. The surface is rendered more smooth than in case of lining with portland cement concrete.

(v) Asphaltic concrete lining :

Asphalt is a petroleum product which, when mixed with sand and gravel is used as a liner in the same way as concrete made from portland cement.

Asphaltic concrete may be an economical substitute for unreinfroced portland cement concrete in water courses where the cost of asphalt is low.

Velocity in such type of lining must be limited to a maximum of about 1.5 m per second and there is danger of weed growth. This type of lining have insufficient resistance to external hydrostatic or soil pressures. Type of asphaltic concrete lining :

(i) Hot mixed asphalt concrete

(ii) Cold mixed asphalt concrete

Hot mixed asphalt concrete

This is a carefully controlled mixture of asphalt and graded aggregate similar to mixed for highway surface. The concrete is mixed, placed and compacted at high temperatures. Generally 1" & 1.5" thick asphalt concrete is used in lining.

A binder having a penetration of 60 to 70 is preferred for lining as hard penetration grade produces lining that are more resistant to the destructive action of water, extremes of weather penetration by vegetation, and stable on side slopes.

Placement of asphalt concrete lining is accomplished by subgrade guided slip forms, similar to those used for cement concrete lining. Concrete is mixed on or near the job and hauled to the point of application.

Water tightness of lining depends on the degree of compaction. Compaction is done either by tamping or rolling or by vibratory rollers or weighted and heated ironing screeds.

Placement of hot mixed asphalt concrete requires heavy skill and is generally costly.

Cold-mixed asphalt concrete

The mix is similar to hot mixed asphalt concrete, but the mixing and tamping are done at a relatively low temperature, generally at prevailing atmospheric temperature (18^{o} to $40^{o}C$). Suitable emulsions are used to make the asphalt workable.

The draw back of this type of lining, however is that it takes a long time in curing before the lining acquires a certain degree of cohesion. Also some cold mixes tend to remain soft indefinitely while others contract in curing and develop cracks which must be filled in some manner, generally with a slurry of sand and asphalt emulsions.

(vi) Prefabricated asphaltic lining :

Materials similar to asphaltic concrete have been prefabricated to avoid the use of hot materials on the job.

Prefabricated asphalt sheets are manufactured in standard width of 90 to 120 cm and are available in rolls of varying lengths.

Thickness varies from 3 to 12 mm. Reinforcing materials such as jute, hemp, glass fibre, asbestos or synthetic fibres of plastics are used.

Thick panels are used without cover or protection. Thin sheets are used as a burried membrane with a protective cover. All joints of adjacent panels are usually overlapped at least 5 cm, and joined with hot asphalt, cold mastics, or special cut backs.

Although the jointing creates roughness in the surface considerably, yet it is smooth enough for easy cleaning.

Seepage losses and performance observed for some different specifications of bitumen linings studied by Research Institutes in India are given in table 4.4

Table 4.4 : Seepage losses and performance of bitumen linings

Description of lining of water course	Seepage losses		Behavior
	In cc/24 hrs./sq.cm of wetted area	In cusec/10^6 sq.ft. of wetted area	
1	2	3	4
1. Shalimar P.B.S. lining without primer-1/8 in. prefabricated bitumen sheet cut and placed with 3 in. overlap at joints, slopes 1.5:1	0.7	0.264	Excessive weed growth deteriorated within nine months and joints opened out
2. Shalimar Tarfelt lining without primer – Base of tough grade hessian saturated with coaltar pitch with coat of asbestos felt, slopes 1:1	1.2	0.455	Excessive weed growth deteriorated soon and joints opened out
3. Shalimar tarfelt lining with primer – ½" in. layer of primer with coat of hot tar mastic no. 1, slopes 1½ :1	0.55	0.210	Excessive weed growth deteriorated soon and joints were opened.
4. 1 in. thick cut back stablised mudplaster lining prepared with 80/100 bitumen. 9 in. base, 12 in. height, slope 1½ :1	0.85	0.324	Excessive weed growth surface was swollen and deteriorated soon
5. Bituminous (30/40 grade) 1 in. thick lining, 9 in. base, 12 in., height, slopes 1½ : 1	1.64	0.621	No weed growth, cracks occurred due to slip of the bituminous material on the slopes towards the bottom

Source : CBI & P Publication No. 82 (1967)

(vii) Brick lining :

Brick linings have many of the advantages and disadvantages inherent in linings constructed to precast concrete slabs. Brick linings, however can be used to advantages in areas where

- an abundance of inexpensive manual labour is available
- materials for brick are available near the channel sites
- materials and machinery for other suitable types of lining are not available at a competitive price

Lining with bricks or tiles in different mortars are extensively used due to their low cost, easiness is in construction and local availability.

Brick and tiles are generally quite porous and therefore, it hardly plays any part in preventing seepage losses. The water tightness in brick lining is solely due to plaster which may be on the exposed surface or on the under side. The bricks only form a skeleton to hold plaster or function as a protective cover.

However, in order to reduce the cost of lining, numerous research has been carried out to render them less permeable by suitable treatments.

The various treatments are :

1. Deposition of Moss on the brick surface :

Bricks in continuous presence of water result in the deposition of moss on the brick surface. This layer of moss gets thicker with time and reduces the amount of water seeping through bricks. This method is neither practical nor very effective.

2. Treatment with soap solution :

Soap is a sodium salt of fatty acids and this sodium salt precipitates over the brick surface and fills the interstices of the bricks making it less pervious. Performance of this treatment observed at U.P. Irrigation Research Institute. Seepage losses vary from 1.7 to 1.5 cusecs per million sq. ft. of wetted perimeter.

Effect of soap solution appears to stay for about one year after which fresh treatment is required.

3. Painting brick surface :

Painting the brick surface is also found to reduce the porosity and permeability of bricks. Painting with lime cement and sand slurry has been attempted at U.P. irrigation Research Institute and found to give good results. Seepage losses with such treatment varies from 0.7 to 2.0 cusecs per million sq. ft. of wetted perimeter. The life of this treatment can be taken as two years.

4. Treatment with silicon solution :

Silicon possesses water repellant properties. The sprayed solution of silicon forms a thin film over the brick surface by ;which the water is not able to enter into small pores of bricks and thus reduces seepage.

Seepage losses with such treatment varies from 1.6 to 5.2 cusecs per million sq. ft of wetted perimeter. Though losses increase with time, this treatment appears to be comparatively little more effective and durable than other treatments given above.

(viii) Stone Lining

Stone or rubble masonry linings have been employed in areas where suitable materials, such as sand stone or basalt are available. The construction of stone lining are relatively slow and labour is the major expense as the stones are placed by hand.

Stone masonry walls are used as lining. Generally random stone masonry is used for lining purposes and cement is plastered from inside (water contact surface) to reduce seepage and rugosity coefficient.

Where good lime is available masonry may be done in lime mortar otherwise masonry may be done in cement mortar 1:5 or 1:6.

Generally minimum thickness of masonry wall is 9" to 1'. Because of the thickness of wall and small size of water course section, trapezoidal and circular sections

are not practical. Therefore, stone masonry is generally used for rectangular sections, and is also easy in construction.

Stone lining has little resistance and slightest settlement of the subgrade may case distress. Such lining is not satisfactory in filling. Expansion and contraction of clay subgrade have consequently caused frequent failure of these linings.

(ix) Exposed Asphaltic membrane lining :

Exposed membranes include their membranes of asphalt, plastics and synthetic rubber. Their low permeability, when combined with strength of soil or other base materials, will prevent seepage of water. Plastic materials placed as exposed membranes get deteriorated from sun, weather and erosion after two to four years. Damage is also caused by weed puncture and weed burning, live stock traffic, maintenance equipment and rodent. Even theft has been a problem in some areas.

4.7.3.2 Covered membrane lining

Experiments and practice show that membranes such as placed asphalts prefabricated asphaltic materials, plastics, synthetic rubber, clay and bentonite effectively control seepage over a considerable period of time when covered.

A buried or covered membrane lining consists of a relatively thin and impervious water barrier covered by a protective layer. Generally earth and gravel are used as the covered material.

The commonly used burried membranes are :

(i) Burried sprayed in place asphaltic membranes

It is composed of a special high softening point asphalt sprayed in place at high temperature and is laid on a prepared subgrade to form approximately 6 mm thick water proof barrier. It is covered by protective layer of earth and gravel. It provides an effective and cheap means of seepage control.

(ii) Prefabricated Burried asphaltic membranes

This category of membrane comprises all thin asphalt coated felts or fibre, mats. Reinforcing materials used are jute, hemp, floss fibre and asbestos. The membranes have a thickness of approx. 4 to 5 mm and are made up in rolls of standard size.

Prefabricated asphaltic membranes have been developed for use on small channels by USBR.

(iii) Plastic and synthetic membranes

Extensive use is being made of a variety of plastic and some rubber prefabricated membranes for canal lining. The most commonly used materials are P.V.C., polyethylene (P.E.) and butyl rubber. These membranes or film are flexible, have no rigidity and can not withstand external forces. Considering both performance and cost, in the majority of practical applications PE may be the most economical material for covered flexible membrane canal lining.

The film may be directly placed on the dressed subgrade and anchored on the banks or may be burried. When used as a exposed membrane these are disturbed by flowing water, grazing animals, and gets punctured by weeds, and irregularities of the subgrade such as clay lumps, pebble etc. The film is also susceptible to sun and wind damage and therefore do not last much.

The lining works more effectively when properly burried, as the film is not subjected to much external forces. On the side slopes, the earth cover on the film slips down due to its smooth surface and the film is exposed. To avoid this the film is placed vertically in the sides. However this involves two times rehandling of earth work, and some extra film. The films are available in large pieces, generally in folded rolls of various width to reduce the amount of field joining. All membranes need to be joined in the field rather than only overlapped, to produce water tightness.

Joining in the field is not difficult and also does not require highly trained labour. PVC linings are quickly sealed to give rapid setting, by injecting a small amount of adhesive between two pieces which are over lapped 5-10 cm and by gently smoothing the adhesive covered area to effect a bond. Special adhesives that develop strength more slowly are used with PE and Butyl. Some times joints are soldered with hot iron.

When the film remains dry for a few months, it is damaged by rats, insects, mice, white ants, and also by the roots of the weeds.

This type of lining is not recommended when weed growth is a problem because of the likely damage to the flexible lining by the weed roots.

4.7.3.3. Earth Lining

The lining of an irrigation channel with natural soil is termed as earth lining. The most important prerequisites of an earth lining material are that it should be impervious, non erodible, should not crack or disintegrate under weathering action.

(i) Thick compacted earth lining :

Where suitable earth material is available near the site, a lining of thick compacted earth is a cheap and efficient means of seepage control.

A thick compacted earth lining is constructed of selected soils, both the bottom and side slopes being compacted in successive horizontal layer not more than 15 cm thick after compaction. The soil must be homogeneous when placed of proper thickness and compacted at proper moisture content to the prescribed density.

The final selection of material is done on the basis of gradation, plasticity, compaction and permeability.

(ii) Thin compacted earth lining :

Thin compacted earth lining have same characteristic as the thick lining. This type of lining may be considered where :

(a) Highly suitable earth material is available providing relative water tightness with thickness of only 15 to 30 cm.

(b) Suitable earth material has to be hauled from considerable distance.

(c) Lower velocities can be economically permitted to prevent any scour on the thin lining, or coarse soils or gravel is available near the site for a protective cover.

Extra precaution must be taken to protect the relatively thin lining and additional cost of maintenance may be greater than the difference in the initial cost of thin and thick compacted earth lining.

(iii) Clay or bentonite – soil lining :

Bentonite, which is a clay material containing a large percentage of sodium type manmorillonite clay is characterised by high water absorption accompanied by swelling, imperviousness and slipperiness (low stability). The fact that bentonite does swell and does become impervious on wetting makes it a very useful material in the control of seepage from canals, provided it can be obtained from local deposits at low cost.

Bentonite and other clays are premixed with sandy soils and spread over the channel perimeter or mixed in place and compacted to from 5 to 7.5 cm thick layer.

The optimum amount of bentonite for the soil- mix type of lining usually ranges from 5 to 25 percent. A protective cover of stable earth or gravel is also recommended over the thin mixed or combination lining.

The bentonite lining have proved better than the ordinary brick lining as far as the seepage loss is concerned. This type of lining show decrease in seepage loss with lapse of time.

There is a great difference in seepage losses of 20 percent and 30 percent mix linings than that in 30 percent and 40 percent linings. It shows that by increasing the quantity of bentonite reduction in seepage is not attained proportionately. Difference of seepage losses in 30 percent and 40 percent mix linings tends to reduce with lapse of time. Weeds grow in the lining and cannot be totally removed without disturbing the lining.

IMPACT ANALYSIS OF LINING IN MURKA DISTRIBUTARY

5.1 CONDITION OF LINING

Under CAD programme the water course emanating from outlets have been lined by SCADA in the selected outlet commands. The water courses are lined with bricks and plastered with cement plasters. The section of lined channels are 50 cm x 30 cm.

The lined channels in selected outlet command were in good condition Besides outlets provided in the wall of lined channel, the farmers have made additional cuts for irrigating fields quickly. Wherever the tractors cross the water course, the side walls being only 12.5 cm get damaged as no channel crossing had been constructed in the entire selected outlet command.

5.2 CROPPING PRACTICE

The cropping practices being followed in the study area are based on the information collected from the farmers of study area. A brief description of the cropping practices followed for different crops in the study area is given below :

5.2.1 Paddy

IN NURSERY

(a) Land preparation :

For one hectare transplanting of paddy about $1/20^{th}$ of land is used for nursery. About three ploughings are done by bullocks using deshi plough. The plots with standing water are puddled to receive seed.

(b) Seeds and sowing :

About 60 to 70 kg of paddy seeds are required for transplanting one hectare area. The plots with standing water are puddled and then seed is broadcasted on 1/20 hectare of land for growing seedlings for 1 hectare planting area. The seeds are generally sown in the second week to third week of June depending upon

availability of canal water and rainfall condition. The common varieties are Sita and Mansoori, but other varieties like Pankaj, Jayshree, Radha, Sujata and Padmini are also grown. A few farmer grow some local varieties like Indrasan, Gauri, Rajhans. Basmati, a fine paddy is most commonly grown by the farmers for the ceremonial uses.

(c) Fertilizer application ;

At the time of sowing of seed fertilizers are not applied but after about a fortnight Urea is applied as top dressing. Compost is used as basal does instead of chemical fertilizer.

(d) Plant protection measures :

No plant protection measures are adopted in seedling plots.

(e) Irrigation :

In case of failure of rain, paddy seedling are saved by canal water in the head and middle reaches and by tubewell water in tail reach.

IN FIELD

(a) Land preparation :

Summer ploughing is not practiced at all. During the month of June after the on set of monsoon two to three ploughings are done for preparing land. At the time of transplantation, the fields are puddled and prepared to receive the seedlings.

(b) Manure and fertilizers :

Almost all the farmers use compost during field preparation for transplantation. Di-Ammonium Phosphate (DAP)/SSP are applied as basal dose. After about 3 to 4 weeks, first top dressing is done, with Urea. Again after 3 to 4 weeks, second top dressing with Urea is carried out. Potas is not used at all by the farmers.

(c) Transplantation :

The transplantation starts from second week of July and generally finishes by the end of July. Under normal circumstances, the age of seedling is about 30 days old but in delayed transplantation due to abnormal circumstances the age of seeding goes upto 40 to 45 days also. The distance of 6 to 9 inches apart is kept and 5 to 6

seedlings are put per hill. Transplantation work is done manually by female labourers.

(d) Irrigation :

In head and middle reaches canal irrigations are given when ever required. But in tail reach canal water is not available during peak demand and most of farmers are based on rain water. A few farmer also use tubewell water to save the crop.

(e) Intercultural operations :

Weeding operations are carried out after about three to four weeks of transplantation and before first top dressing. Weeding work is done manually with the help of male and female labourers. Labour required for weeding depends on the intensity of weeds in the plots.

(f) Plant protection measures :

As preventive measures, nothing is done. No seed treatment is adopted before sowing. Soil treatment is also not practiced. Under crop treatment, it is only done by a few farmers whenever there is an attack of pests and disease.

(g) Harvesting and threshing :

Harvesting of paddy crop is done manually with the help of sickle. Both male and female labourers do the work of harvesting. Harvested paddy is kept in the field for three to four days for drying the plants. Then bundles are made in the field and transported to threshing floor. Threshing work is done manually with the help of bullocks on the kuchha threshing floor. Some farmer do the threshing work with tractor.

5.2.2 Wheat

(a) Land preparation

Wheat is mostly sown after about a week or two weeks of paddy harvest. When the land becomes suitable for ploughing the field is cultivated two times by bullock ploughs. A few farmers also get their fields prepared by tractor ploughing.

(b) Seed and sowing :

Seed rate of 150 kg to 160 kg per hectare is normally used. UP-262, HUW-234, HD-2285 and Sonalika are most popular varieties. Sowing is generally done by

broadcasting. Most of the farmer use same seed two to three years. Seed treatment is not in practice.

(c) Fertilizer application :

Compost is not used in wheat cultivation. During sowing time DAP/SSP is broadcasted as basal dose. Top dressing is done two times by Urea after first and second irrigation or at rainfall when plots have sufficient moisture. Potas is not used by the farmers.

(d) Irrigation :

Wheat crop is irrigated two to three times. First irrigation is given on about 21st to 25th day from date of sowing and is very important from point of view of yield. Second & third irrigation is given at an interval of 20 –25 days.

(e) Intercultural operations :

No weeding is done by the farmers in the wheat crop. Though weeding of undesirable plants from wheat field is beneficial for better yield.

(f) Plant protection measures :

Plant protection measures are not common.

(g) Harvesting and threshing :

Wheat crop is manually harvested with sickle. Harvested crop is transported in three four days to threshing floor in bundles according to convenience of farmer. But bundles of harvested crop is made same day in the field. After about a fortnight of harvest, it is threshed with the help of threshers and in some cases with the help of bullocks.

5.2.3 Lentil, Gram, Pea & Khesari

(a) Land preparation :

For lentil, gram and Khesari as paira crop no land preparation is required. For sown crops of Lentil, Gram and Pea, 2 ploughing are done.

(b) Seed and sowing :

Local improved varieties of seed are used at the following rate :

Lentil	80 kg to 100 kg per ha
Gram	80 kg to 100 kg per ha

Khesari	80 kg to 120 kg per ha
Pea	80 kg to 120 kg per ha

Seeds are broadcasted after first ploughing in case of sown crops and is mixed in soil by doing other one or two ploughing and planking. No seed treatment is in practice. Khesari is taken as paira crop and seeds are broadcasted in standing paddy crop.

(c) Manure and fertilizers :

Generally no fertilizer and compost are used in these crop but some farmer use DAP as basal dose in sown crops – Gram, Pea and Lentil. In case of winter rain farmers use Urea as top dressing in gram crop after the rain.

(d) Irrigation :

No irrigation is applied to all of these crops because heavy soil is there in study area and irrigation will damage the crops.

(e) Intercultural operations :

No weeding is done in any of these crops. Nipping is done in gram crop after 30-35 days from date of sowing. This helps in the branching of the plants of gram.

(f) Plant protection measures :

Plant protection measures are not applied except in case of gram that also in few cases. Pesticides are used on gram crop in case of pest (pod borer) attack. Dose of pesticide is decided as per intensity of pest attack and pesticide used.

(g) Harvesting :

All pulse crops are harvested manually in the last week of March.

(h) Threshing :

Threshing is completed manually after harvesting.

A comparative practice pre and post lining for rice, wheat, gram & lentil is presented in Table 5.1 to 5.4.

Table 5.1 : Cropping practice of paddy in Murka distributary command before and after lining of water course

Distributary – Murka Distributary Crop : Paddy

Particulars	Before Lining 1986	After lining 1991
Head Reach		
- Nursery	Third week of June	Second week of June
- Transplantation	35 days	30 days
- Seed rate	60-70 kg/ha	60-70 kg/ha
- Seed treatment	No	No
- Fertilizer use	80 : 20 : 0	100 : 40 : 0
-		
Middle Reach		
- Nursery	Third week of June	Second week of June
- Transplantation	35 days	30 days
- Seed rate	60-70 kg/ha	60-70 kg/ha
- Seed treatment	No	No
- Fertilizer use	80 : 20 : 0	100 : 40 : 0
Tail Reach		
- Nursery	Third week	Second week of June
- Transplantation	35 days to 40 days	35 days
- Seed rate	60-70 kg/ha	60-70 kg/ha
- Seed treatment	No	No
- Fertilizer use	80 : 20 : 0	90 : 30 : 0

Source : Farmers Interview

1. Nursery sowing date has advanced in all reaches after lining of water courses.
   Sowing time has shifted
   In head reach from third week of June to second week of June
   In middle reach from third week of June to second week of June
   In tail reach from third week of June to second week of June
2. Transplantation date of paddy has advanced in all reaches after lining of water course.

In head reach from 35 days to 30 days. In middle reach from 35 days to 30 days In tail reach from 35-40 days to 30 days

3. Seed rate in all reaches is same as before lining
4. Seed treatment was not done before lining and is not being done after lining.
5. Use of fertilizer has been increased in all reaches.
   In head reach from 80:20:0 to 100:40:0. In middle reach from 80:20:0 to 100:40:0. In tail reach from 80:20:0 to 90:30:0

Table 5.2 : Cropping practice of wheat in Murka distributary command before and after lining of water course

Distributary : Murka distributary Crop : Wheat

Particulars	Before lining 1986-87	After lining 1991-92
Head reach		
- Sowing date	December 10-15	November 20-30
- Seed rate	160 kg/ha	150 kg/ha
- Seed treatment	No	No
- Fertilizer use	60:30:0	90:40:0
- Irrigation	2	3
Middle reach		
- Sowing date	December 15-20	December 1-10
- Seed rate	160 kg/ha	160 kg/ha
- Seed treatment	No	No
- Fertilizer use	60:30:0	90:40:0
- Irrigation	1	2
Tail reach		
- Sowing date	December 10-15	December 1-5
- Seed rate	160 kg/ha	160 kg/ha
- Seed treatment	No	No
- Fertilizer use	60:30:0	80:40:0
- Irrigation	1	2

Source : Farmers Interview

1. Sowing of wheat was late before lining. Sowing has been advanced and timely sowing is being done. Sowing time has shifted
   In head reach from Dec. 10-15 to November 20-30. In Middle reach from Dec. 15-20 to Dec. 1-10. In Tail reach from Dec. 10-15 to Dec. 1-5
2. Seed rate has been reduced due to timely sowing from 160 kg/ha to 150 kg/ha
   In head reach from 160 kg/ha to 150 kg/ha. In middle and tail reach no change in seed rate
3. Use of fertilizer has increased in all reaches
   In head reach from 60:30:0 to 90:40:0. In middle reach from 60:30:0 to 90:40:0
   In tail reach from 60:30:0 to 80:40:0
4. Seed treatment was not done before lining and is not being done after lining.
5. Number of irrigation has increased
   In head reach from 2 irrigation to 3 irrigation. In middle reach from 1 irrigation to 2 irrigation. In tail reach from 1 irrigation to 2 irrigation

Table 5.3 : Cropping practice of gram in Murka Distributary command before and after lining of water course

Distributary – Murka distributary Crop : Gram

Particulars	Before lining 1986-87	After lining 1991-92
Head reach		
- Sowing date	November 1	October 20
- Seed rate	80-100 kg/ha	80-100 kg/ha
- Seed treatment	No	Rizobium culture
- Fertilizer use	No	DAP 60 kg/ha
- Irrigation	No	No
Middle reach		
- Sowing date	November 1	October 20
- Seed rate	80-100 kg/ha	80-100 kg/ha
- Seed treatment	No	Rizobium culture
- Fertilizer use	No	DAP 60 kg/ha
- Irrigation	No	No

Tail reach		
- Sowing date	November 1	October 25
- Seed rate	80-100 kg/ha	80-100 kg/ha
- Seed treatment	No	No
- Fertilizer use	No	DAP 40 kg/ha
- Irrigation	No	No

Source : Farmers interview

1. Sowing of gram was late before lining
   Sowing has advanced in all reaches
   Sowing time has advanced
   In head reach from November 1 to October 20
   In middle reach from November 1 to October 20
   In tail reach from November 1 to October 25
2. Seed rate in all reaches is same as it was before lining
3. Seed treatment was not done before lining
   Rizobium culture is mixed in seed for treatment in head and middle reach after lining
4. No fertilizer was used before lining
   After lining fertilizer is used at following rate :
   In head reach DAP 60 kg/ha
   In middle reach DAP 60 kg/ha
   In tail reach DAP 40 kg/ha
5. Irrigation was not done before lining and is not being done after lining.

Table 5.4 : Cropping practice of Lentil in Murka distributary command before and after lining of water course

Distributary – Murka Distributary Crop : Lentil

Particulars	Before lining 1986-87	After lining 1991-92
Head reach		
- Sowing date	November 20	November 10
- Seed rate	80-100 kg/ha	80-100 kg/ha
- Seed treatment	No	No
- Fertilizer use	No	DAP 40 kg/ha
- Irrigation	No	No
Middle reach		
- Sowing date	November 15	November 10
- Seed rate	80-100 kg/ha	80-100 kg/ha
- Seed treatment	No	No
- Fertilizer use	No	DAP 40 kg/ha
- Irrigation	No	No
Tail reach		
- Sowing date	November 10	November 5
- Seed rate	80-100 kg/ha	80-100 kg/ha
- Seed treatment	No	No
- Fertilizer use	No	No
- Irrigation	No	No

Source : Farmers interview

1. Sowing of Lentil has advanced after lining in all reaches. Sowing time has shifted
   In head reach from November 20 to November 10
   In middle reach from November 15 to November 10
   In tail reach from November 10 to November 5
2. Seed rate in all reaches is same as it was before lining

3. Seed treatment was neither done before lining nor being done after lining

4. No fertilizer was used before lining

After lining fertilizer is used at following rate in sown crops

In head reach DAP 40 kg/ha. In Middle reach DAP 40 kg/ha. In tail reach no fertilizer is used

5.3 PRODUCTIVITY OF CROP

Reach wise productivity of Paddy and Wheat is presented in Table 5.5. and reach wise comparison of productivity is shown in Fig. 5.1. & 5.2.

Table 5.5.: Productivity of Paddy and Wheat crops in Murka distributary command before and after lining of water course

Crops	Yield (Q/ha) Before lining 1986-87	Yield (Q/ha) After lining 1991-92
Head Reach		
- Paddy	28.00	35.60
- Wheat	19.00	27.78
Middle Reach		
- Paddy	27.50	38.35
- Wheat	15.00	18.77
Tail Reach		
- Paddy	20.00	27.20
- Wheat	12.00	15.14

Source : 1991-92- Report, "An Indpeth Evaluation Study of Agricultural and Irrigation Situation of Sone Command Area (Murka distributary)"

1986-87- Farmer's Interview

1. Production of paddy has increased in all reaches after lining of water course.

In head reach from 28.00 Q/ha to 35.6 Q/ha

In middle reach form 27.50 Q/ha to 38.55 Q/ha

In tail reach from 20.00 Q/ha to 27.20 Q/ha

2. Production of wheat has increased in all reaches after lining of water course.

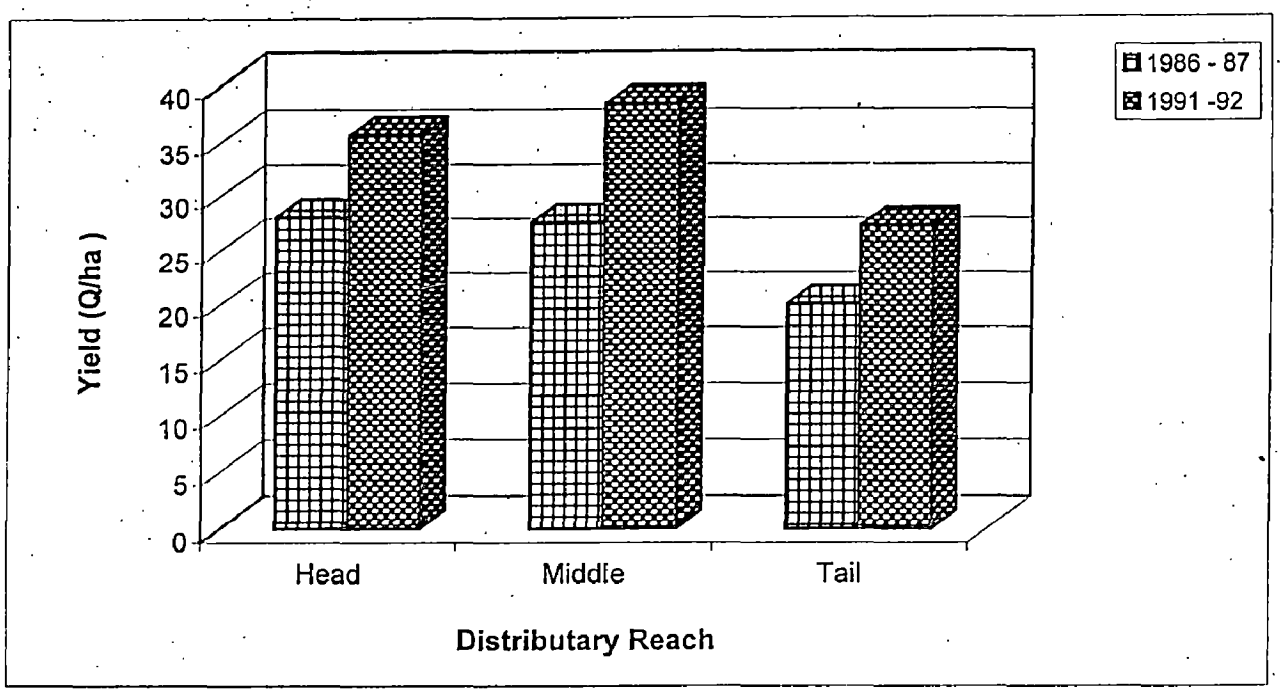

Fig :5.1 Yield of Paddy (Q/ha) in different reaches of Murka Distributary of Sone Command

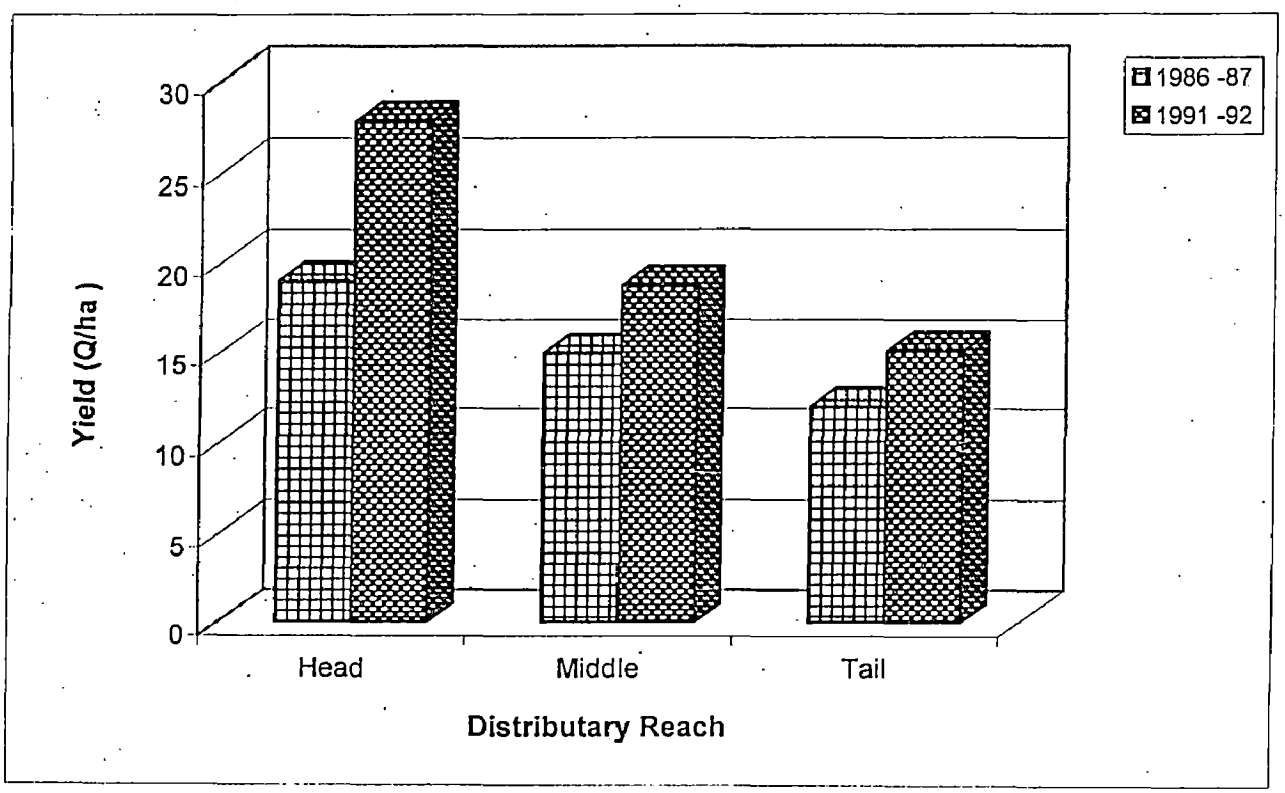

Fig :5.2 Yield of Wheat (Q/ha) in different reaches of Murka Distributary of Sone Command

In head reach from 19.00 Q/ha to 27.78 Q./ha

In middle reach from 15.00 Q/ha to 18.77 Q./ha

In tail reach from 12.00 Q/ha to 15.14 Q/ha

5.4 IRRIGATIONS INTENSITY

Outlet wise details of CCA (ha), water course length (m), area irrigated (ha) during kharif & rabi are given in Table 5.6. Reach wise area irrigated (ha) and irrigation intensity (%) is presented in Table 5.7 & 5.8. Comparison of reach wise area irrigated (ha) and irrigation intensity (%) is shown in Fig. 5.3 & 5.4.

Table 5.7: Area irrigated in Kharif and Rabi in head, middle & tail reach of Murka distributary command

Particulars	**Head reach**	**Middle reach**	**Tail reach**	**Total**
No. of outlet	1-7	8-11	12-14	14
C.C.A. (ha)	173	84.95	46.95	304.90
Area Irrigated (ha)				
86 Kharif	101.00	59.40	25.50	185.90
86-87 Rabi	44.20	32.40	9.30	85.90
Total (ha)	145.20	91.80	34.80	271.80
Area Irrigation (ha)				
91 Kharif	109.17	63.57	26.79	199.53
91-92 Rabi	48.64	34.01	9.78	92.43
Total (ha)	157.81	97.58	36.57	291.96

Source: 91-92- Report, An Indepth Evaluation study of Agricultural and Irrigation Situation of Sone Command (Murka distributary)

86-87 – farmers interview

Table 5.6 : Outletwise details of CCA (ha), water course length (m) & area irrigated (ha)

Outlet No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
CCA (ha)	22.75	30.75	15.10	14.60	32.50	24.40	32.90	27.50	19.00	14.70	23.75	33.25	9.70	4.00	304.90
Length of water course (m)	742.38	1204.27	487.80	365.85	884.15	579.28	823.17	426.83	457.32	396.34	728.66	1021.34	217.37	243.90	
Irr.Area kharif 86 (ha)	14.20	18.30	9.30	7.50	16.30	16.90	18.50	11.50	16.10	12.60	19.20	19.80	2.80	2.90	185.90
Rabi 86-87 (ha)	10.90	9.00	2.90	4.00	5.10	4.30	8.00	7.80	11.90	10.50	2.20	4.40	3.00	1.90	85.90
Total (ha)	25.10	27.30	12.20	11.50	21.40	21.20	26.50	19.30	28.00	23.10	21.40	24.20	5.80	4.80	271.80
Irr.Area Kharif 91 (ha)	15.32	19.83	10.07	8.15	17.53	18.27	20.00	12.29	17.26	13.52	20.50	20.72	3.00	3.07	199.53
Rabi 91-92 (ha)	12.05	9.95	3.25	4.46	5.55	4.70	8.68	8.22	12.45	11.05	2.29	4.58	3.19	2.01	92.43
Total (ha)	27.37	29.78	13.32	12.61	23.08	22.97	28.68	20.51	29.71	24.57	22.79	25.30	6.19	5.08	291.96

Note : At Outlet No.12, irrigated area in kharif 90 has been taken for kharif 1991

Source : 1991-92, Report, An Indepth Evaluation Study of Agricultural and irrigation Situation of Sone Command (Murka Distributary)
1986-87 : Farmers Interview

Table 5.8 : Irrigation Intensity in head, middle and tail reach of Murka distributary command

Particulars	Head reach	Middle reach	Tail reach	Total
CCA (ha)	173	84.95	46.95	304.90
Irrigation Intensity (%) 86-87 %	83.93	108.06	74.12	89.14
Irrigation Intensity (%) 91-92 %	91.22	114.87	77.89	95.75

Irrigation intensity has increased in all three reaches of distributary. It has increased

In head reach from 83.93% to 91.22%

In middle reach from 108.06% to 114.87%

In tail reach from 74.12% to 77.89%

And total intensity from 89.14% to 95.75%

Maximum irrigation intensity is in the middle reach followed by head reach and least is in tail reach.

5.5 CROP WATER REQUIREMENT

For the calculation of crop water requirement computation of Reference Evapotranspiration (Eto) is required for which climatic data is needed.

5.5.1 Computation of Refernce Evapotranspiration (Eto) by Modified Penman Method

Climatic data required are

Mean temperature (T in ^{o}C)

Mean Relative Humidity (R_h in %)

Total wind run (U in Km/day at 2m height)

Mean actual sunshine duration (n in hours /day)

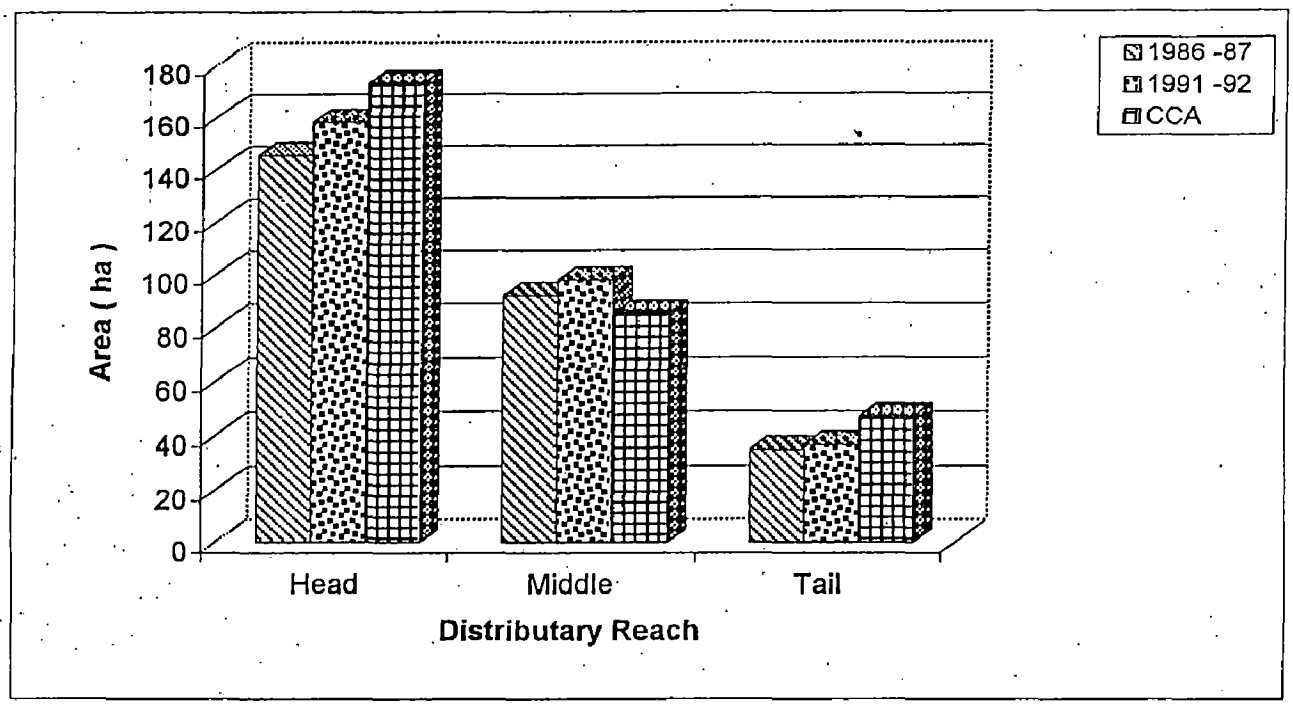

Fig.5.3 Area irrigated (ha) in different reaches of Murka Distributary of Sone Command

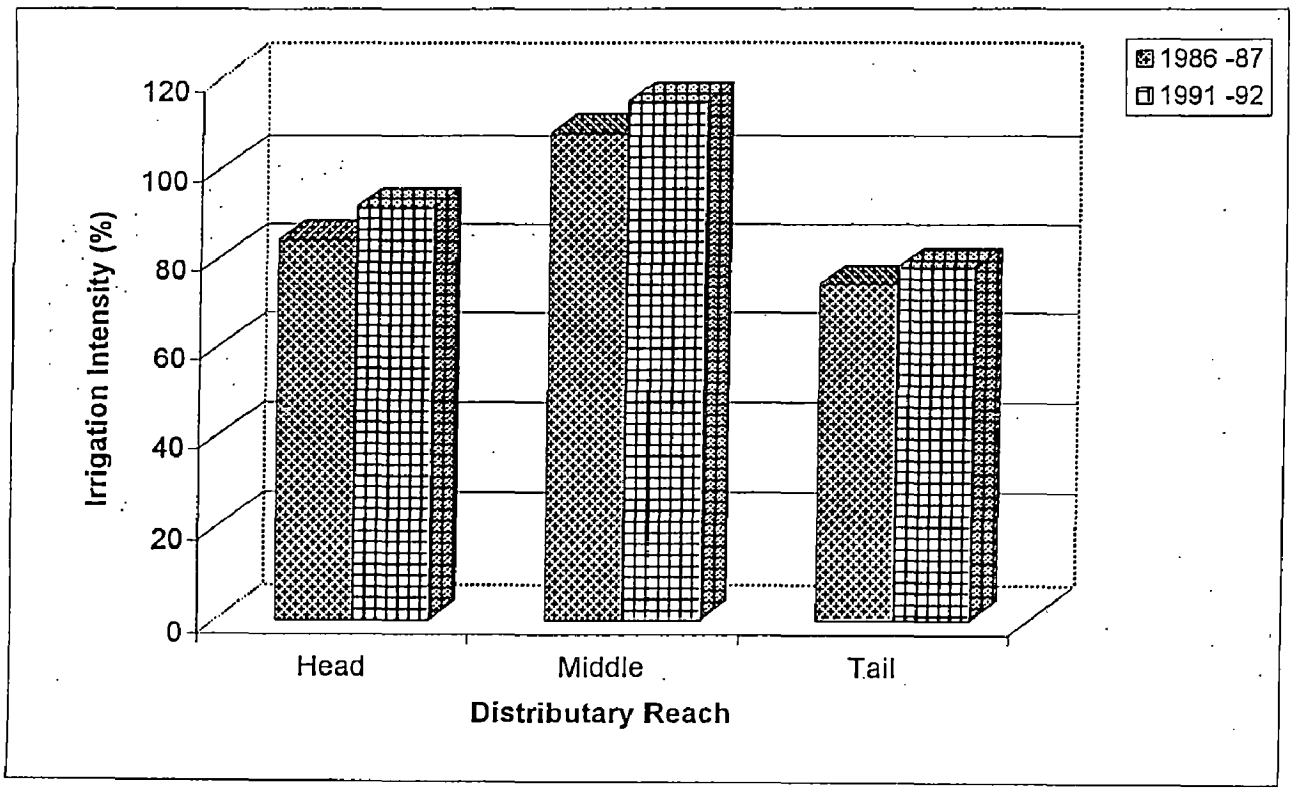

Fig.5.4 Irrigation Intensity (%) in different reaches of Murka distributary of Sone Command

Mean maximum relative humidity (R_h max in %)

Mean day time wind speed (U day in m/sec at 2m height)

Reference crop evapotranspiration (Eto) representing the mean value in mm/day, over the period considered is obtained by

$$Eto = C\,[W.Rn + (1-W).f(U).(e_a - e_d)]$$

$e_a - e_d$ = vapour pressure deficit i.e. the difference between saturation vapour pressure (e_a) at Tmean in mbar (Table 9 of FAO-33) and actual vapour pressure (e_d) in mbar where $e_d = e_d$. Rh/100

f(U) wind function f(U) = 0.27 (1+U/100) with U in km/day measured at 2m height

Rn total net radiation in mm/day or Rn = 0.75 Rs – Rnl where

Rs is incoming short-wave radiation in mm/day either measured or obtained from Rs = (0.25 + 0.50 n/N) Ra where

Ra = extra terrestrial radiation in mm/day (Table 10 of FAO – 33)

n = mean actual sunshine duration in hours/day

N = maximum possible sunshine duration in hours/day (Table 11 of FAO – 33)

Rnl = Net longwave radiation in mm/day and is a function of temperature f(T), of actual vapour pressure f(ed) and sunshine duration f(n/N).

Or Rnl = f(T).f(e_d).f(n/N)

(Table 12, 13 and 14 of FAO-33)

W temperature and altitude dependent weighting factor (Table15 of FAO-33)

C adjustment factor for ratio Uday/Unight, for $R_H$max and Rs (Table 16 of FAO-33) to compensate the day and night weather conditions.

Description of variables

(a) Vapour pressure ($e_a - e_d$)

Air humidity affects Eto. Humidity is expressed as saturation vapour pressure deficit ($e_a - e_d$).

Air humidity data are reported as relative humidity (Rh max and Rh min in %). In our case relative humidity measured at 0649 is considered as Rh max and the same measured at 1349 is considered as Rh min.

(b) Wind Function f(u)

The effect of wind on Eto has been studied for different climates resulting in a wind function f(u) given by an expression as

F(u) = 0.27 (1+ U/100) where U is 24 hr wind run in km/day at 2m height.

Where wind data is not collected at 2m height then appropriate corrections to be applied.

(c) Weighting factor (1-W)

(1-W) is a weighting factor for the effect of wind and humidity on Eto.

(d) Weighing Factor (W)

W is the weighting factor for the effect of radiation on Eto.

(e) Net Radiation (Rn)

Net radiation (Rn) is the difference between all incoming and outgoing radiation.

(f) Adjustment Factor (C)

The Penman equation given assumes the most common conditions where radiation is medium to high, maximum relative humidity is medium to high and moderate day time wind about double the night time wind. However, these conditions are not always met.

Therefore, correction to Penman equation is required. This correction is made by applying adjustment factor (c) to the Penman equation.

5.5.2 Climatic data

The nearest station from where climatic data such as Temperature, relative humidity, wind velocity, sunshine hour etc. could be collected is the Agricultural

Research farm of Rajendra Agriculture University at Patna, which is about 75 kms from the study area. In strict sense these data cannot be accepted for Paliganj Block but there is no alternative. Therefore climatic data has been collected from Rajendra Agriculture University, Patna. The rainfall data has been collected from Paliganj Block Office of Patna district. Data of wind speed is not being recorded at Rajendra Agriculture University due to broken wind speed meter therefore data of wind speed has been collected from India Meteorological Department Patna climatic data is appended in Annexure III.

Procedure of computation of Eto and sample calculation

The procedure laid down in "yield response to water" FAO irrigation and drainage paper No.33 (1979) for the modified Penman method to compute evapotranspiration Eto is followed for calculation. The tables given in the FAO-33 are used in the calculation. A sample calculation is illustrated below for the month of August 1991.

Steps of Calculation :

1. Maximum air temperature in °C = 31.9 (from climatic data)
2. Minimum air temperature in °C = 24.9 (from climatic data)
3. Mean air temperature in °C = (31.9 + 24.9)/2 = 28.4 (calculated)
4. Maximum relative humidity (Rh max %) = 90 (from climatic data)
5. Minimum relative humidity (Rh min %) = 76 (from climatic data)
6. Mean relative humidity (Rh mean %) = (90+76)/2 = 83 (calculated)
7. Average wind speed in km/hr = 5.661 (from climatic data)
8. Average wind speed in km/day = 135.86 (calculated)
9. Wind speed (day) in m/sec = 1.57 (calculated)
10. Sunshine hours (n) in hours = 4.6 (from climatic data)
11. Maximum possible sunshine hours (N) = 13 (from Table No.11)
12. Saturation vapour pressure e_a in mbar corresponding to mean temperature of 28.4°C = 38.72 from Table No. 9
13. Actual vapour pressure e_d = (e_a x Rh mean)/100 = (38.72 x 83)/100 = 32.14 (calculated)

14. Vapour pressure deficit ($e_a - e_d$) = 38.72-32.14 = 6.58 (calculated)
15. Wind function f(u) = 0.27(1+U/100) = 0.64 (calculated)
16. Extra terrestrial radiation (R_a) corresponding to latitude 25°37'N and month August in northern hemisphere = 15.75 (from table No.10)
17. Ratio n/N corresponding to sunshine hour 4.6 = 4.6/13 = 0.3538 (calculated)
18. Short wave radiation $R_s = (0.25 + 0.5\ n/N)R_a$ = 6.7 (calculated)
19. Function of temperature f(T) corresponding to mean temperature 28.4°C = 16.4 (from Table No.12)
20. Function of vapour pressure f(ed) corresponding to e_d = 32.14, = 0.09 (from Table 13)
21. Function of sunshine duration f(n/N) corresponding to n/N = 0.3538 = 0.42 (from Table no. 14)
22. Net longwave radiation Rnl = f(T) x f(e_d) x f(n/N) =0.62(calculated)
23. Net radiation Rn = 0.75 Rs – Rnl = 0.75 x 6.7 – 0.62 = 4.41 (calculated)
24. Weighting factor W corresponding to mean temperature 28.4°C and altitude 53m = 0.772 (from table no.15)
25. Adjustment factor corresponding to ratio Uday/Unight = 1 for study area conditions Rs= 6.7 mm/day), Rhmax 90% wind velocity, U = 1.57 m/sec, C = 1.00 (from table No.16)
26. Eto = C[W Rn + (1-W).f(U). ($e_a - e_d$) in mm/day = 4.36 (calculated)

Eto calculation sheet is attached in Annexure I.

5.5.3 Crop Water Requirement for Rice

Soil type – caly (in study area)

Bulk density = 1.5 T/m^3

Assumptions on the basis of book, Irrigation theory and practice by A.M. Michael for the clay soil

Moisture content at saturation = 40%

Soil moisture available = 15% to 30%

Root zone depth = 0.5 m

Seepage & percolation for clay 3mm/day to 5mm/day

Steps of Calculation

1. Find water requirement for field preparation for nursery and for transplantation :

   FOR NURSERY – June 5-9, 1991

(a)	Depth of water (40-15)/100x1.5x500	= 187.50
(b)	Seepage & percolation @ 5mm per day	= 25.00
(c)	Ponding water	= 100.00
(d)	Eto for 5 day 5.74x5	= 28.70

	Total	= 341.20 mm

   $1/20^{th}$ of 341.20 = 17.06

   FOR TRANSPLANTATION – July 5-10, 1991

(a)	Depth of water (40-30)/100x1.5x500	= 150.00
(b)	Seepage & percolation @ 3mm per day	= 18.00
(c)	Ponding water	= 100.00
(d)	Eto for 5 day 5.04x6	= 30.24

	Total	= 223.24 mm

2. Divide crop duration into five equal stages.
3. Take average values of crop coefficients (Kc) of Rice for all five crop development stages namely initial, crop development, mid season, late season, at harvest from Table No.18, FAO-33. These values will be used for five stages as divided in step 2.
4. Calculate Eto for the corresponding month taking the value of Eto for corresponding month from Eto calculation sheet and multiplying it by number of days in that month
5. Calculate Etc

   Etc = Eto for month (mm) x Kc for corresponding month
6. Calculate seepage and percolation (S&P) for full month taking seepage & percolation in mm/day and multiplying it by number of days in the month
7. Add Etc and S&P to get Etc + S&P
8. Calculate effective rainfall Pe (mm)

Pe = 0.8P – 25 if P≥ 75 mm/month

Pe = 0.6P – 10 if P≤ 75 mm/month

Where P = rainfall in mm for corresponding month

9. Calculate Net irrigation requirement NIR for month

NIR = Etc + S&P – Pe (mm) all values for corresponding month

10. Net irrigation requirement for crop (mm)

Add NIR of all months to get Net irrigation requirement for the crop in mm per hectare

Crop water requirement for Rice is shown in Table 5.9

5.5.4 Crop Water Requirement for Wheat

Steps of Calculation

1. Divide crop duration into five equal stages.
2. Take average values of Crop coefficients Kc of wheat for all five crop development stages from Table No. 18 FAO-33. These values will be used for five stages as divided in step (1).
3. Calculate Eto for the corresponding month taking the values of corresponding month mm/day from ETo calculation sheet and multiplying it by number days in that month.
4. Calculate Etc

   Etc = Eto for month (mm) x Kc for corresponding month
5. Calculate effective rainfall Pe (mm) from Table 34 (USDA SCS 1969). Average monthly effective rainfall as related to average monthly ETcrop and mean monthly rainfall.
6. Calculate Net irrigation requirement NIR for month NIR = Etc – Pe
7. Add NIR of all corresponding months to get NIR for crop mm/ha

   Crop water requirement for wheat is shown in Table 5.10.

Table : 5.9 Crop Water Requirement Calculation Sheet for Rice

Crop:Rice Soil Type: Clay YEAR-1991

Period	Eto (mm/day)	Eto(mm)	Kc	Etc	S&P(mm)	Etc +S&P	Rain(mm)	Pe(mm)	NIR(mm)
June 5-9	Field prepration for nursery								17.06
June10-30	5.74	120.54	1.125	135.608	105.00	240.61	83.00	41.40	9.96
July 5-10	Field prepration for transplantation								223.24
July 1-31	5.04	156.24	1.266	197.8	93.00	290.80	61.00	23.80	185.18
Aug 1-31	4.36	135.16	1.193	161.246	93.00	254.25	285.00	203.00	51.25
Sept 1-30	4.03	120.9	1.000	120.9	90.00	210.90	263.00	185.40	25.50
Oct 1-22	3.81	83.82	1.000	83.82	66.00	149.82	0.00	0.00	149.82
TOTAL						**1146.37**			**662.01**

CROP STAGE- I-June10-July 6 II-July 7-Aug 2 III-Aug 3-Aug 29 IV-Aug 30- Sept 25 V-Sept 26 -Oct 22

S&P=Seepage&percolation (mm), for clay 3mm/day to 5mm/day

Pe=Effective Rainfall (mm),Pe=0.8P-25 if P>75 mm/month, Pe=0.6Pe-10 ifP<75 mm/month

Eto=Evapotranspiration of a refrence crop (mm)

Kc=Crop coefficient for evapotranspiration

Etc=Evapotranspiration of crop(mm)

NIR=Net Irrigation requirment(Etc+S&P-Pe)

FIR=Field Irrigation requirment(NIR/AE)

AE= Application efficiency rangingbetween 50-75%

Table : 5.10 Crop Water Requirement Calculation Sheet for Wheat

Crop : Wheat Soil Type: Clay YEAR: 1991-92

Period	Eto(mm/day)	Eto(mm)	Kc	Etc	Rain(mm)	Pe(mm)	NIR(mm)
	(days)						
Dec 1-31	2.13	66.03	0.4	26.41	19.00	12.00	14.41
Jan 1-31	2.15	66.65	0.846	56.39	0.00	0.00	56.39
Feb 1-29	3.24	93.96	0.99	93.02	24.00	19.00	74.02
Mar 1-31	5.73	177.63	0.52	92.37	0.00	0.00	92.37
April 1-10	7.70	77.00	0.23	17.71	0.00	0.00	17.71
TOTAL				**285.90**			**254.90**

CROP STAGE: I-Dec 1-27 II-Dec28-Jan23 III-Jan24-Feb-19 IV-Feb20-Mar19 V-Mar20-April10
Eto=Evapotranspiration of a refrence crop (mm)
Kc=Crop coefficient for evapotranspiration (Etc/Eto)
Etc=Evapotranspiration of crop(mm)
NIR=Net Irrigation requirment(Etc-Pe)
FIR=Field Irrigation requirment(NIR/AE)
AE= Application efficiency rangingbetween 50-75%

5.6 EFFICIENCY AT OUTLET LEVEL

Efficiency at Outlet level in Kharif 1991

Table 5.11 : Average flow in Water course measured below the outlet during Kharif 1991

Village	Outlet number	Flow in cumec				
		June 1991 (Assumed)	July 1991	August 1991	Sept. 1991	Oct. 1991
Ajda	OL-1	0.005	0.01	0.016	0.014	0.020
	OL-2	0.009	0.015	0.029	0.028	0.037
Mankurha	OL-8	0.006	-	0.020	0.028	0.018

Source : Report, An Indepth Evaluation study of Agricultural and Irrigation Situation of Sone Command Area (Murka distributary)

Canal running days in different month counted from canal running schedule attached in Annexure IV.

Table 5.12 : Canal running days during Kharif 1991

Month	June 1991	July 1991	Aug. 1991	Sept. 1991	Oct. 1991
Canal running days	15	31	27	20	28

Water Delivered in ha.m

At outlet No.1

= 0.005 x 8.64 x 15 + 0.010 x 8.64 x 31 + 0.016 x 8.64 x 27 + 0.014 x 8.64 x 20 + 0.020 x 8.64 x 28 = 14.32 ha.m

At Outlet No.2

= 0.009 x 8.64 x 15 + 0.015 x 8.64 x 31 + 0.029 x 8.64 x 27 + 0.028 x 8.64 x 20 + 0.037 x 8.64 x 28 = 25.75 ha.m

Water Required

Crop water requirement for Rice as calculated

Net irrigation requirement for Rice for the year 1991 = 662.01 mm

Water required = NIR x Area irrigated

At Outlet No.1

$$\text{Water required} = \frac{662.01x15.32}{1000}$$

$$= 10.14 \text{ ha.m}$$

At outlet No. 2

$$\text{Water required} = \frac{662.01x19.83}{1000}$$

$$= 13.12 \text{ ha.m}$$

$$\text{Efficiency at outlet No. 1} = \frac{Water\ required}{waterdelivered} x100$$

$$= \frac{10.14}{14.32} x100 = 70.81\%$$

$$\text{Efficiency at outlet No.2} = \frac{13.12}{25.75} x100 = 50.95\%$$

Water Delivered at outlet No. 8

0.006 x 8.64 x 15 + 0.02 x 8.64 x 27 + 0.0282 x 8.64 x 20 + 0.018 x 8.64 x 28 = 14.67 ha m

Water required = NIR x Area irrigated

$$= \frac{662.01x12.29}{1000} = 8.13$$

$$\text{Efficiency at outlet No. 8} = \frac{Water\ required}{water\ delivered} x100$$

$$= \frac{8.13}{14.67} x100 = 55.42\%$$

Efficiency in head reach at outlet No.1 is calculated as 70.81% and at outlet No.2 as 50.95% where as efficiency in middle reach at outlet No.8 as 55.42%.

Efficiency at Outlet level before lining :

Kharif Season :

As only irrigated area in outlet commands is known. Discharge data and climatic data are not available. As there has not been any major change in climatic conditions in the study area. Cropping pattern in kharif season has not changed. Therefore following assumptions can be made for the calculation of efficiency at outlet level :

1. same discharge would have passed from outlet
2. same water requirement for the crop
3. same crop i.e. paddy was grown.

Area irrigated in outlet command in kharif season before lining :

OL –1	14.20 ha
OL – 2	18.30 ha
OL – 8	11.50 ha

Water delivered at outlet No. 1 14.32 ha.m.

Outlet No.2 25.75 ha.m.

Outlet No.8 14.67 ha.m.

Water required at OL No.1 $\frac{662.01 x 14.20}{1000} = 9.40 ha..m.$

OL No. 2 $\frac{662.01 x 18.30}{1000} = 12.11 ha.m.$

OL No.8 $\frac{662.01 x 11.50}{1000} = 7.61 ha.m.$

Efficiency at

OL No.1 $\frac{9.40}{14.32} = 65.64\%$

OL No. 2 $\frac{12.11}{25.75} = 47.02\%$

OL No.8 $\frac{7.61}{14.67} = 51.87\%$

After lining of water courses efficiency at outlet level has increased in head reach and middle reach, it has increased at

OL – 1 from 65.64% to 70.81%

OL – 2 from 47.02% to 50.95%

OL – 8 from 51.87% to 55.42%

Table 5.13 : Efficiency at outlet level in command of Murka distributary during kharif

Particulars	Before lining 1986 Efficiency (%)	After lining 1991 Efficiency (%)
Head Reach		
OL – 1	65.64%	70.81%
OL – 2	47.02%	50.95%
Middle Reach		
OL – 8	51.87%	55.42%

Efficiency at Outlet level in Rabi 1991-92

Table 5.14: Average flow in water course measured below the outlet during Rabi 1991-92

Village	Outlet number	Flow in cumec			
		Dec. 1991	Jan. 1992	Feb. 1992	March 92
Ajda	OL – 1	0.0167	0.0178	0.0228	0.0203
	OL –2	0.029	0.036	0.023	0.024
Mankurha	OL – 8	-	0.029	0.021	-

Source : Report, An Indepth Evaluation study of Agricultural and Irrigation Situation of Sone Command Area (Murka distributary)

Canal running days in different months calculated from canal operation schedule attached in Annexure IV

Table 5.15 : Canal running days during Rabi 1991-92

Months	Dec. 1991	Jan. 1992	Feb. 1992	March 1992
Canal running days	3	16	20	24

Water Delivered

At OL No.1 = 0.0167 x 8.64 x 3 + 0.0178 x 8.64 x 16 + 0.0228 x 8.64 x 20 + 0.0203 x 8.64 x 24 = 11.04 ha.m.

At OL No.2 = 0.029 x 8.64 x 3 + 0.036 x 8.64 x 16 + 0.023 x 8.64 x 20 + 0.024 x 8.64 x 24 = 14.68 ha.m.

At OL No.8 = 0.029 x 8.64 x 16 + 0.021 x 8.64 x 20 = 7.64 ha.m.

Water required :

At outlet = NIR x Area NIR for wheat 91-92 = 254.90 mm

$$\text{At OL} - 1 = \frac{254.90 x 12.05}{1000} = 3.07 ham$$

$$\text{At OL} - 2 = \frac{254.90 x 9.95}{1000} = 2.54 ham$$

$$\text{At OL} - 8 = \frac{254.90 x 8.22}{1000} = 2.09 ha.m$$

$$\text{Efficiency at outlet} = \frac{water\ required}{water\ delivered}$$

$$\text{Efficiency at OL} - 1 = \frac{3.07}{11.04} = 27.80\%$$

$$OL-2 \quad = \frac{2.54}{14.68} = 17.30\%$$

$$OL-8 \quad = \frac{2.09}{7.64} = 27.35\%$$

The efficiency in head reach at all three outlets is very low in Rabi 1991-92.

5.7 IRRIGATION MANAGEMENT

Distribution of Water

Water distribution to the command area of a canal, distributary or minor is done in following ways.

(a) Rotational delivery method

(b) Delivery on demand method

(c) Continuous flow method

(a) Rotational Delivery Method :

This method of irrigation (also known as warabandi or osrabandi) involves the delivery of water to all the farmers with in an outlet command according to their entitlement. It leads to the increase in irrigation efficiency as the beneficiary farmers cooperate and wait for their turn. In this system control over the stream size that passes through the outlet is essential but is difficult to be maintained in Murka distributary due to poor physical condition of the distributary and the absence of discipline in the distribution of water.

(b) Delivery on Demand Method

This method allows each farmer to receive the supply of water according to the need but is limited by the capacity of distribution network. When water rates are charged on volumetric basis and the cost of water is high, demand method is most suitable as it involves the use of water most economically and according to crop requirement at critical

stages of growth. This system is not easily adaptable in our country because it needs well maintained systems and trained staff for operation.

(c) Continuous Delivery Method

To large consolidated areas or the areas belonging to a corporation or trust delivery of water can be done continuously instead of by rotation. This method is not suited to conditions where size of holding is small and irrigation water is to be supplied to a large number of plots with in an outlet command.

Despite the facts that land holding is small in the Murka distributary command and also the consolidation of land has not been done since long back, the continuous delivery method was in practice in Murka distributary command before lining of water courses and is also prevailing after the lining of water courses. Because operation of canal on continuous basis is simpler for canal authorities. This is why this system is used in Murka Distributary despite the fact that it involves wastage of water and makes the farmers in lower reaches of distributary and water courses to suffer.

Method of Irrigation

The method of irrigation was surface flooding in general. In paddy fields, which are almost level border, flooding is done and in wheat check basis flooding is practiced.

Water Application :

Whenever the water flowed in the distributary the farmers started irrigating their fields if in their opinion the irrigation at that time would proved beneficial. The fields lying along the water course received the water directly through the inlet and other fields situated away from water course received field to field irrigation. Since laterals and sub laterals have not been constructed in general and large number of plots oriented in zig-zag manner were to irrigated, field to field irrigation was the most common practice.

This practice of water application was followed in the command area before lining of water course and the same is being followed after the lining of water courses.

Therefore there is no improvement in water management in Murka distributary command.

5.8 SOCIO-ECONOMIC CONDITION OF FARMERS

Socio-economic condition of farmer in Murka distributary command

Sl. No.	Particulars	Before lining	After lining
1.	Input supply centre	Paliganj CD block at a distance of about 5 to 8 km from study area where seed, fertilizer and pesticides were sold. Few shops were there	Paliganj CD block seed, fertilizer and pesticide are easily available in many shops at competitive rates
2.	Plant protection centre	There was a plant protection centre at Paliganj from where pesticides and machines for using it were available	In addition of P.P. centre there are many shops from where spray machines can be taken on rent at very cheap rates
3.	Seed multiplication farm	Seed multiplication farm under agriculture department at Paliganj where activities were limited	This farm transferred to Sone CADA in 1992 and a lot of agricultural activities are going on. Farmers of near by area are taking the advantages from this farm
4.	Agricultural implements	Bullocks were used for ploughing, wheat thresher were less in practice and threshing was done by bullocks	Tractors are being used for ploughing wheat thresher are very common among most of farmers.

5.	Institution credit centre	Branches of Patliputra Central Cooperative Bank Punjab National Bank & State Bank of India at Paliganj. Allahabad Bank at Chandhaus. Few farmers were taking short term loan	Patliputra Gramin Bank opened in Khanpura in 1988 and in Sikaria in year 1990 Number of farmers are taking short term loan from bank
6.	Communication	Paliganj – Akbarpur Road connecting Sikaria and Ajda village of head reach Paliganj – Ataula road connecting Khanpura & Mankurha villages of mid reach Paliganj – Chandhaus Road Vehicles operation was rare	Though the roads are in dilapidated condition but Jeeps, three wheelers and Mini-buses ply over these roads
7.	Marketing facilities	Shops were at Paliganj and farmers have to come to Paliganj even for small items	Many shops have been added at Paliganj and a few shops are available in villages which are satisfying the daily needs of farmers
8.	Health facilities	Hospital at Paliganj CD Block where medical facilities were available. But private clinics were rare	In addition to hospital there are many private clinic with prompt services at Paliganj
9.	Education facilities	Educational facilities upto higher secondary standard at Paliganj	Strength of students has increased as many students come from near by villages.

10.	Living standard of farmers	Most of houses were kachha, cycles and bullock carts was mode of transportation	Many pucca houses have been constructed. Motor cycles and Jeeps are used for transportation
11.	Connection with State capital	Patna the state capital of Bihar at 75 km was connected to Paliganj by road and a few buses were plying on Paliganj Patna road	Frequent bus service is available and road condition has also improved.
12.	Participatory Irrigation Management	There was no farmers association for participatory irrigation management in the command of Murka distributary and adjoining areas	Water user association has been formed in adjoining Paliganj distributary and management has been handed over to WUA in year 1997. This will certainly motivate the farmers of Murka distributary to adopt PIM

SUMMARY AND CONCLUSION

Sone Irrigation project is more than a century old. It is a run of the river scheme. Canals on both sides takes off from a barrage on Sone river, a tributary of Ganges, at Indrapuri near Dehri on Sone in Rohtas district of Bihar state. Its gross command area is 8.66 lakhs hectare and culturable command area is 6.15 lakhs hectare. Its command lies in Rohtas, Kaimur, Bhojpur, Buxar, Aurangabad, Jahanabad, Gaya and Patna districts of Bihar state.

Sone Command Area Development Authority was set up in 1973 and subsequently renamed "Sone Command Area Development Agency" and abbreviated as SCADA. Sone Command Area Development Agency performs several activities for the development of command area of Sone Irrigation Project. Water course lining is one of the activities of Sone CADA.

Murka distributary takes off from Patna Main canal on right side at 66.26 km and Patna main canal takes off from eastern Sone link canal. The design discharge of Murka distributary is 4.53 cumec and C.C.A. is 4300 ha. There are 192 outlets in Murka distributary. Fourteen outlets have been selected for the study of which 7 are situated in head reach, 4 are situated in middle reach and 3 are situated in tail reach of Murka distributary. Selected water course were lined during 1987-88 .

The study entitled "Impact Analysis of Water Course Lining in Sone Command : A Case Study of Murka Distributary" was undertaken with the objective of analysing impact with respect to :

- Cropping practice
- Productivity of crop
- Irrigation intensity
- Irrigation efficiency

- Irrigation management and
- Socio-economic condition of farmers.

The analysis was made from the data collected from farmers interview about pre and post lining status. The observations are summarised as follows :

(i) Cropping practice has improved in the command of Murka distributary and major changes have been in the head reach as compared to middle and tail reach of distributary. Timely sowing of the crops have been insured and use of fertilizer also increased as compared to pre lining period.

(ii) Productivity of crop also increased in head, middle and tail reaches of distributary. The production of main crops paddy & wheat increased in all reaches of distributary after lining.

(iii) Irrigation intensity in lined water courses increased from 83.93% to 91.22% in the head reach; 108.06% to 114.89% in the middle reach and 74.12% to 77.89% in tail reach of distributary.

(iv) Irrigation efficiency in lined water courses also increased. The irrigation efficiency during kharif increased from 56.33% to 60.88% in head reach and from 51.87% to 55.42% in middle reach.

The efficiency during Rabi was only 27.80% in the head reach and 27.35% in the middle reach.

(v) Warabandi in water distribution practice could not be introduced in the command even after lining.

(vi) Socio-economic condition of the farmers improved slightly but not appreciable.

Based on the aforesaid findings it can be concluded that the lining of water courses of selected outlets in Murka Distributary of Sone command recorded only marginal improvement on account of cropping practice, crop productivity, irrigation intensity, irrigation efficiency and socio-economic condition.

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ANNEXURE - I

CALCULATION OF REFERENCE CROP EVAPOTRANSPIRATION (Eto)

STATION:Patna LATITUDE : 25^0 37' N LONGITUDE : 85 ^{0} 10' E ALTITUDE :53m

Year	Month	Temprature °C			Relative Humidity Rh %			Wind	n hrs	N hrs	e_a	e_d	e_a-e_d	f(u)	Ra	Rs	f(T)	f(ed)	f(n/N)	Rnl	Rn	w	c	Eto
		Max °C	Min °C	Mean °C	Max %	Min %	Mean %	Speed																(mm)
								Km/day																
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1991	Jan	22.3	7.6	14.95	88	49	68.5	16.94	6.7	10.7	16.95	11.61	5.34	0.32	10	5.63	13.64	0.19	0.66	1.72	2.50	0.624	1.04	2.28
	Feb	27.9	11.6	19.75	83	39	61	101.11	8.7	11.3	23.05	14.06	8.99	0.54	11.7	7.43	14.55	0.18	0.79	2.02	3.55	0.689	1.03	4.08
	March	32.6	15.7	24.15	74	33	53.5	126.19	9.0	12.0	30.08	16.09	13.99	0.61	13.8	8.63	15.44	0.16	0.78	1.96	4.51	0.731	1.05	5.88
	April	36.5	20.5	28.5	66	31	48.5	88.39	8.8	12.7	38.95	18.89	20.06	0.51	15.3	9.13	16.40	0.15	0.72	1.77	5.08	0.772	1.07	6.68
	May	37.5	24.1	30.8	80	45	62.5	140.50	8.7	13.3	44.40	27.75	16.65	0.65	16.4	9.46	16.90	0.11	0.69	1.26	5.84	0.788	1.05	7.24
	June	35.3	25.7	30.5	82	59	70.5	130.39	5.6	13.7	44.65	31.48	13.17	0.62	16.6	7.54	16.82	0.09	0.47	0.73	4.92	0.786	1.02	5.74
	July	32.6	25.3	28.95	87	69	78	110.71	5.6	13.5	39.98	31.18	8.80	0.57	16.5	7.55	16.50	0.09	0.47	0.74	4.92	0.775	1.02	5.04
	Aug	31.9	24.9	28.4	90	76	83	135.86	4.6	13.0	38.72	32.14	6.58	0.64	15.7	6.70	16.40	0.09	0.42	0.62	4.41	0.772	1.00	4.36
	Sept	31.9	24.1	28	90	73	81.5	18.79	5.3	12.3	37.80	30.81	6.99	0.32	14.4	6.70	16.30	0.10	0.49	0.76	4.27	0.77	1.06	4.03
	Oct	31.9	19.8	25.85	87	51	69	7.75	7.3	11.6	33.32	22.99	10.33	0.29	12.4	7.00	15.86	0.13	0.67	1.36	3.89	0.748	1.04	3.81
	Nov	28	12.1	20.05	86	42	64	13.58	6.8	10.9	23.40	14.98	8.42	0.31	10.5	5.90	14.60	0.17	0.66	1.64	2.79	0.691	1.05	2.86
	Dec	23.8	9.7	16.75	87	50	68.5	15.58	4.8	10.6	19.10	13.08	6.02	0.31	9.5	4.53	13.95	0.18	0.51	1.28	2.11	0.647	1.05	2.13

ANNEXURE - I

CALCULATION OF REFERENCE CROP EVAPOTRANSPIRATION (Eto)

STATION:Patna LATITUDE: 25° 37' N LONGITUDE : 85° 10' E ALTITUDE :53m

Year	Month	Temprature °C			Relative Humidity Rh %			Wind.	n hrs	Nhrs	e_a	e_d	e_a-e_d	f(u)	Ra	Rs	f(T)	f(ed)	f(n/N)	Rnl	Rn	w	c	Eto
		Max °C	Min °C	Mean °C	Max %	Min %	Mean %	Speed																(mm)
								Km/day																
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1992	Jan	22.7	7.7	15.2	88	47	67.5	14.30	4.9	10.7	17.24	11.64	5.60	0.31	10	4.79	13.68	0.19	0.51	1.33	2.26	0.628	1.04	2.15
	Feb	24.6	8.6	16.6	82	39	60.5	27.72	7.9	11.3	18.92	11.45	7.47	0.34	11.7	7.01	13.92	0.19	0.73	1.94	3.32	0.646	1.06	3.24
	March	33.4	15.5	24.45	65	32	48.5	94.45	8.7	12.0	30.75	14.91	15.84	0.53	13.8	8.45	15.51	0.17	0.75	1.99	4.35	0.734	1.06	5.73
	April	38.5	20.7	29.6	55	29	42.0	130.00	9.2	12.7	41.48	17.42	24.06	0.62	15.3	9.37	16.62	0.16	0.75	1.95	5.07	0.778	1.06	7.70
	May	36.5	22.1	29.3	72	43	57.5	100.64	9.5	13.3	40.79	23.45	17.34	0.54	16.4	9.96	16.56	0.13	0.74	1.56	5.91	0.776	1.07	7.16
	June	36.7	25.3	31.0	76	52	64.0	79.60	7.2	13.7	44.90	28.74	16.16	0.48	16.6	8.51	16.95	0.10	0.57	1.01	5.37	0.79	1.06	6.24
	July	33.5	24.5	29.0	84	65	74.5	130.00	4.6	13.5	40.10	29.87	10.23	0.62	16.5	6.94	16.50	0.10	0.41	0.67	4.53	0.775	1.01	4.99
	Aug	32.7	25.1	28.9	89	72	80.5	136.60	5.2	13.0	39.87	32.10	7.77	0.64	15.7	7.07	16.48	0.09	0.46	0.69	4.61	0.774	1.00	4.69
	Sept	31.8	24.2	28.0	88	67	77.5	107.60	6.2	12.3	37.80	29.30	8.51	0.56	14.4	7.23	16.30	0.10	0.55	0.92	4.50	0.77	1.03	4.70
	Oct	31.1	20.6	25.85	89	57	73.0	38.30	7.8	11.6	33.20	24.24	8.96	0.37	12.4	7.27	15.63	0.12	0.71	1.36	4.09	0.748	1.06	4.14
	Nov	29.5	13.9	21.7	81	48	64.5	11.60	8.4	10.9	25.95	16.74	9.21	0.30	10.5	6.67	14.94	0.16	0.79	1.90	3.11	0.707	1.06	3.19
	Dec	25.2	9.3	17.25	76	52	64.0	20.90	5.2	10.6	19.70	12.61	7.09	0.33	9.5	4.71	14.05	0.18	0.54	1.40	2.13	0.652	1.03	2.26

ANNEXURE- II

RAINFALL DATA AT STATION PALIGANJ

Monthwise rainfall(mm)

Months	1985	1986	1987	1988	1989	1990	1991	1992
January	5.0(1)*	0	0	0	4.2(1)	0	19.3(3)	0
February	0	0	0	0	0	34.3(3)	5.5(2)	24.0(1)
March	0	0	0	35.7(2)	0	1.0(1)	19.0(1)	0
April	10.0(1)	0	0	0	0	10.6(1)	26.0(1)	0
May	29.0(1)	0	0	4.2(1)	10.4(1)	33.8(4)	0	26.0(3)
June	109.5(2)	282.6(7)	40.0(2)	207.8(11)	145.2(8)	131.7(10)	83.0(7)	21.5(2)
July	418.7(23)	403.1(18)	497.6(19)	148.6(10)	447.2(16)	506.8(22)	61.0(9)	294.3(14)
August	181.3(15)	153.0(8)	448.8(14)	367.4(15)	150.2(6)	119.0(7)	285.0(19)	187.0(8)
September	234.6(10)	35.0(35)	435.4(11)	150.0(6)	206.0(13)	88.0(7)	263.0(10)	78.0(3)
October	166.5(5)	72.0(7)	11.0(2)	65.0(1)	6.6(2)	35.0(3)	0	2.1(3)
November	0	0	0	0	0	0	0	0
December	9.4(2)	0	0	5.0(1)	11.2(3)	0	19.0(4)	0
Total	**1164.0(60)**	**945.7(45)**	**1450.8(48)**	**993.7(47)**	**981.0(50)**	**960.2(58)**	**780.8(56)**	**632.9(34)**

Note : * Values shown in parenthesis are number of rainy days

Source: Block Office Paliganj Block ,District Patna ,Bihar

ANNEXURE -III

CLIMATIC DATA AT STATION PATNA

Year	Month	Temprature °C		Relative Humidity		Wind	n hrs
		Max °C	Min °C	Max %	Min %	Speed	
						Km/day	
1	2	3	4	5	6	7	8
1989	Jan	21.8	7.3	88	45	28.26	8.8
	Feb	25.9	9.8	74	34	60.00	9.3
	March	30.6	13.8	77	36	67.74	8.1
	April	37.9	19.5	51	23	111.99	10.4
	May	36.3	24.5	69	48	143.22	9.4
	June	34.4	25.7	84	62	103.61	7.4
	July	31.4	24.8	90	78	65.42	4.2
	Aug	32.4	25.3	88	71	108.37	6.8
	Sept	32.1	25.0	89	72	74.79	6
	Oct	31.6	21.5	87	59	7.36	9.1
	Nov	28.7	13.6	85	42	13.60	8.7
	Dec	23.2	9.8	90	51	5.42	7

Year	Month	Temprature °C		Relative Humidity		Wind	n hrs
		Max °C	Min °C	Max %	Min %	Speed	
						Km/day	
1	2	3	4	5	6	7	8
1990	Jan	23.6	9.3	89	47	37.93	7.4
	Feb	27.1	12.7	81	45	74.47	8.7
	March	30.9	16.3	72	38	136.26	9.1
	April	36.2	21.5	64	36	175.2	9.6
	May	36.0	25.1	76	49	119.62	8.8
	June	33.8	26.1	83	64	90.40	6.6
	July	32.3	25.7	91	77	71.60	4.9
	Aug	32.0	25.3	89	76	64.26	4.5
	Sept	32.8	25.2	91	70	51.60	7.4
	Oct	31.7	20.6	87	54	13.55	9.1
	Nov	29.4	14.5	85	40	8.00	9
	Dec	25.5	11.1	88	48	10.07	8

Source : Rajendra Agricultural University Patna , & IMD Patna

ANNEXURE -III

CLIMATIC DATA AT STATION PATNA

Year	Month	Temprature °C		Relative Humidity		Wind	n hrs
		Max °C	Min °C	Max %	Min %	Speed	
						Km/day	
1	2	3	4	5	6	7	8
1991	Jan	22.3	7.6	88	49	16.94	6.7
	Feb	27.9	11.6	83	39	101.11	8.7
	March	32.6	15.7	74	33	126.19	9.0
	April	36.5	20.5	66	31	88.39	8.8
	May	37.5	24.1	80	45	140.50	8.7
	June	35.3	25.7	82	59	130.39	5.6
	July	32.6	25.3	87	69	110.71	5.6
	Aug	31.9	24.9	90	76	135.86	4.6
	Sept	31.9	24.1	90	73	18.79	5.3
	Oct	31.9	19.8	87	51	7.75	7.3
	Nov	28.0	12.1	86	42	13.58	6.8
	Dec	23.8	9.7	87	50	15.58	4.8

Year	Month	Temprature °C		Relative Humidity		Wind	n hrs
		Max °C	Min °C	Max %	Min %	Speed	
						Km/day	
1	2	3	4	5	6	7	8
1992	Jan	22.7	7.7	88	47	14.30	4.9
	Feb	24.6	8.6	82	39	27.72	7.9
	March	33.4	15.5	65	32	94.45	8.7
	April	38.5	20.7	55	29	130.00	9.2
	May	36.5	22.1	72	43	100.64	9.5
	June	36.7	25.3	76	52	79.60	7.2
	July	33.5	24.5	84	65	130.00	4.6
	Aug	32.7	25.1	89	72	136.60	5.2
	Sept	31.8	24.2	88	67	107.60	6.2
	Oct	31.1	20.6	89	57	38.30	7.8
	Nov	29.5	13.9	81	48	11.60	8.4
	Dec	25.2	9.3	76	52	20.90	5.2

Source : Rajendra Agricultural University Patna , & IMD Patna

DISCHRAGE IN MURKA DISTRIBUTARY AT ARWAL

	JUNE			JULY		
Date	Discharge in Cumec			Discharge in Cumec		
	1990	1991	1992	1990	1991	1992
1	C	1.274	C	3.398	4.248	1.274
2	C	1.699	C	3.398	3.398	1.274
3	C	1.699	C	3.398	4.248	1.274
4	0.850	C	C	3.398	4.248	1.274
5	0.850	1.841	C	3.398	4.248	1.274
6	0.850	1.841	C	3.398	2.265	1.274
7	1.274	C	C	3.398	4.531	1.274
8	C	1.699	C	2.549	4.248	1.274
9	C	1.699	C	C	5.097	3.398
10	C	1.699	C	C	5.097	3.398
11	2.549	1.699	C	1.699	5.097	2.265
12	3.398	1.699	1.699	1.699	4.672	3.398
13	3.398	C	1.133	1.699	4.672	3.398
14	3.398	C	1.133	1.699	4.248	3.398
15	C	C	1.133	2.549	4.248	3.398
16	C	C	1.699	3.398	1.699	3.398
17	C	C	C	3.398	1.699	3.398
18	1.699	C	1.274	3.398	1.699	3.398
19	1.699	C	1.274	3.398	1.699	3.398
20	1.699	C	1.274	3.398	4.531	3.398
21	1.699	C	1.274	3.398	4.531	4.248
22	1.699	C	1.274	C	4.531	4.248
23	3.398	C	0.850	C	4.531	4.248
24	3.398	0.850	0.085	C	4.531	C
25	3.398	C	0.850	3.398	4.531	C
26	3.398	C	0.425	3.398	4.531	C
27	3.398	4.248	0.283	3.398	4.531	C
28	3.398	4.248	0.283	3.398	4.531	C
29	3.398	4.248	C	3.398	4.531	4.248
30	3.398	4.248	C	2.549	4.531	4.248
31	-	-	-	1.699	4.531	4.248

Note: C indicates closure of distributary

Source:Office of SDO Arwal, WRD,Bihar

DISCHRAGE IN MURKA DISTRIBUTARY AT ARWAL

	AUGUST			SEPTEMBER		
Date	Discharge in Cumec			Discharge in Cumec		
	1990	1991	1992	1990	1991	1992
1	1.699	4.531	4.248	4.248	2.832	4.248
2	1.699	4.531	4.248	4.248	2.549	4.248
3	1.699	4.531	4.248	4.248	4.531	4.248
4	1.699	4.531	4.248	4.248	4.531	4.248
5	1.699	4.531	2.832	4.248	2.265	4.531
6	1.699	4.531	2.832	4.531	4.531	4.531
7	1.699	4.531	1.133	4.814	3.398	4.531
8	1.699	4.531	2.832	2.265	C	4.531
9	1.699	C	C	2.265	C	4.531
10	C	C	C	1.982	C	4.531
11	C	C	C	4.248	C	C
12	C	C	4.531	4.248	C	1.274
13	C	4.531	C	4.248	2.832	4.531
14	3.398	4.531	4.248	5.663	2.832	4.531
15	3.398	4.531	4.248	5.663	2.832	2.832
16	2.549	4.531	4.531	5.663	2.832	4.531
17	3.398	4.531	4.531	4.248	1.274	4.531
18	4.531	4.531	4.531	5.663	1.274	4.531
19	4.531	4.531	4.531	4.531	4.531	4.531
20	5.663	4.531	1.133	4.531	4.531	4.531
21	5.663	4.531	3.964	4.531	4.531	4.531
22	5.663	4.531	3.964	5.663	4.531	4.531
23	4.248	4.531	3.964	5.663	C	4.531
24	C	4.531	C	4.248	C	1.812
25	C	2.832	C	4.248	C	1.812
26	4.248	2.832	C	4.248	C	1.812
27	4.248	2.832	C	5.663	C	1.812
28	4.248	4.531	C	5.663	4.531	4.531
29	4.248	4.531	2.549	5.663	4.531	4.531
30	4.248	4.531	2.549	5.663	4.531	4.531
31	4.248	2.832	2.549	-	-	-

Note: C indicates closure of distributary

Source:Office of SDO Arwal, WRD,Bihar

ANNEXURE -IV

DISCHRAGE IN MURKA DISTRIBUTARY AT ARWAL

	OCTOBER			NOVEMBER		
Date	Discharge in Cumec			Discharge in Cumec		
	1990	1991	1992	1989	1990	1991
1	5.663	4.531	4.531	4.248	2.832	4.531
2	4.248	4.531	4.531	3.398	2.832	4.531
3	4.248	4.531	4.531	3.398	5.663	4.248
4	4.248	4.531	4.531	1.841	4.248	2.832
5	4.248	4.531	3.398	1.841	5.663	2.832
6	5.663	4.531	2.832	1.841	4.531	2.832
7	4.248	4.531	2.832	1.841	1.699	2.832
8	4.248	C	0.850	C	1.699	1.133
9	4.248	1.699	C	C	1.699	2.832
10	4.248	1.699	C	1.841	C	2.832
11	4.248	1.699	2.265	C	C	1.133
12	2.832	1.699	C	C	C	1.133
13	4.248	4.531	2.265	C	C	1.133
14	4.248	4.531	2.265	C	C	2.265
15	4.248	4.531	2.265	C	C	1.699
16	4.248	4.531	2.265	C	C	1.699
17	2.832	4.531	2.265	C	C	1.699
18	2.832	4.531	1.699	C	C	2.549
19	2.832	4.531	1.699	C	C	1.699
20	2.832	4.531	1.699	C	C	1.699
21	2.832	4.531	1.699	C	C	2.549
22	2.832	4.531	2.832	C	C	2.549
23	2.832	4.531	C	C	C	2.549
24	2.832	4.531	C	C	0.850	2.549
25	2.832	4.531	C	C	0.850	2.549
26	2.832	C	C	C	0.425	2.549
27	2.832	C	C	C	0.425	2.549
28	4.248	4.531	C	C	0.425	2.549
29	4.248	4.531	C	C	0.425	C
30	4.248	4.531	1.133	C	C	C
31	4.248	2.832	2.265	-	-	-

Note: C indicates closure of distributary

Source:Office of SDO Arwal, WRD,Bihar

ANNEXURE -IV

DISCHRAGE IN MURKA DISTRIBUTARY AT ARWAL

	DECEMBER			JANUARY		
Date	Discharge in Cumec			Discharge in Cumec		
	1989	1990	1991	1990	1991	1992
1	C	C	C	C	C	C
2	C	C	C	C	C	C
3	C	C	C	C	C	C
4	C	0.850	C	C	C	C
5	C	C	C	C	C	C
6	C	C	C	C	C	C
7	C	0.850	C	C	C	C
8	C	C	C	C	0.425	C
9	C	1.274	C	C	C	C
10	C	0.850	C	C	C	0.850
11	C	0.850	C	C	C	0.850
12	C	0.850	C	C	C	0.850
13	C	0.850	C	1.274	C	0.850
14	C	0.850	C	1.699	C	1.133
15	C	1.274	C	1.699	C	1.133
16	C	1.274	C	1.699	C	1.133
17	C	1.274	C	1.699	C	1.133
18	C	C	C	1.699	1.274	0.566
19	C	C	C	C	1.274	0.566
20	0.850	C	0.850	C	1.274	0.850
21	1.699	C	0.850	C	1.274	1.133
22	1.699	C	0.850	C	1.699	1.133
23	C	C	C	1.699	1.699	1.699
24	1.699	C	C	1.699	1.699	1.699
25	1.699	C	C	1.699	1.699	0.850
26	1.699	1.699	C	1.699	1.699	C
27	C	1.699	C	1.699	1.699	C
28	C	1.699	C	1.699	2.549	C
29	0.425	1.699	C	1.699	2.549	C
30	1.274	1.699	C	C	2.549	C
31	C	1.699	C	C	2.549	C

Note: C indicates closure of distributary

Source:Office of SDO Arwal, WRD,Bihar

DISCHRAGE IN MURKA DISTRIBUTARY AT ARWAL

	FEBRUARY			MARCH		
Date	Discharge in Cumec			Discharge in Cumec		
	1990	1991	1992	1990	1991	1992
1	C	2.549	2.549	C	2.124	2.549
2	C	2.549	C	C	2.124	1.274
3	C	2.549	C	C	0.850	1.274
4	C	2.549	C	C	0.850	1.699
5	1.699	2.549	C	C	0.850	1.699
6	C	0.850	C	C	0.850	1.699
7	C	0.850	C	C	0.850	1.699
8	2.549	0.850	C	C	0.850	1.699
9	2.549	0.850	C	C	0.850	1.699
10	2.549	1.274	1.699	C	0.850	0.850
11	C	C	1.699	C	0.850	1.699
12	C	C	1.699	C	C	1.133
13	C	C	1.699	C	0.850	1.699
14	0.850	C	1.274	C	0.850	1.133
15	0.850	C	1.274	1.133	0.850	1.133
16	0.850	C	1.133	1.133	0.850	1.133
17	0.850	C	1.133	1.133	0.850	C
18	0.850	C	1.133	1.133	0.850	C
19	0.850	0.850	1.133	1.699	0.850	C
20	1.699	0.850	C	1.699	0.850	C
21	C	0.850	1.133	1.699	0.850	C
22	C	2.124	2.549	2.549	0.850	C
23	C	2.124	2.549	2.549	0.850	1.274
24	C	2.124	1.699	2.549	0.850	1.274
25	C	2.549	3.398	C	0.850	1.274
26	C	2.549	3.398	C	0.566	C
27	C	2.549	2.832	C	0.566	1.699
28	C	2.549	2.832	C	0.566	2.549
29	-	-	1.274	2.124	0.425	2.832
30	-	-	-	1.699	C	2.832
31	-	-	-	1.274	C	1.699

Note: C indicates closure of distributary

Source:Office of SDO Arwal, WRD,Bihar