A CRITICAL STUDY OF IRRIGATION MANAGEMENT PROBLEM IN BARNA COMMAND

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree
of
MASTER OF ENGINEERING
in
IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation titled **"A CRITICAL STUDY OF IRRIGATION MANAGEMENT PROBLEM IN BARNA COMMAND"** which is being submitted in partial fulfilment of the requirements for the award of Master's degree of Engineering in Irrigation Water Management at Water Resources Development Training Centre (WRDTC), University of Roorkee, Roorkee, is an authentic record of my own work carried out during the period of 16th July to 31st December 2000, under the supervision and guidance of **Dr. S. K. Tripathi**, Professor, WRDTC, University of Roorkee, Roorkee.

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

Roorkee

Dated : 31.12.2000

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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(A. K. SHENDE)

Trainee Officer

SYNOPSIS

Barna project is the first major river valley project of the Bhopal state *in* Madhya Pradesh. It is constructed in Raisen District of Madhya Pradesh. The project has been designed for annual irrigation of 60,500 ha with irrigated cropping intensity of 104% and 125% on right and left bank canals, respectively. The Rabi irrigation in the command has been achieved to the extent of 64% irrigation intensity against the design intensity of 57%. On the contrary, the use of Kharif irrigation is almost nil against the proposed irrigation intensity of 52%.

The designed annual irrigation has not been achieved in the project even after the 20 years of after irrigation development. The Kharif cropping pattern has been transformed by adoption of soybean as main crop of Kharif. Farmers of the command prefer only rainfed cultivation of Kharif crops as there is about 1000 mm rainfall during the monsoon. Only protective irrigation of Kharif is given by farmers in the time of failure of monsoon. The possibility of Kharif development in the command in general is limited to protective irrigation only. There is about 0.25 TMC live storage balance in Barna reservoir after Rabi irrigation almost every year. The under utilisation of reservoir storage is mainly due to non achievement of annual irrigation in the command.

After studying the project from the aspects of design, irrigation development, O.F.D. works, present cropping pattern, reservoir water balance, water logging, irrigation panchayat, WUA, irrigation distribution head to tail, recovery of irrigation revenue, etc., the following problems have been identified in the command :

(i) under utilisation of reservoir storage,

(ii) inequitable distribution of irrigation from head to tail,

(iii) water logging, and

(iv) poor recovery of irrigation revenue have been identified.

For full utilisation of reservoir storage and increase of annual irrigation the summer irrigation has fair scope for it's development in the command. A cropping pattern matching with the pattern of cultivators of the command including possible summer crops for irrigation has been proposed for full utilisation of created irrigation potential. The soybean, wheat/gram and summer moong are the main crops suggested for Kharif, Rabi and summer, respectively in both LBC and RBC system. The intensity of irrigation for Kharif, Rabi and summer for LBC system is possible to the extent of 42%, 85% and 44% respectively, while 52%, 70% and 32% for Kharif, Rabi and Summer respectively, possible for RBC system. While estimating this, the canal capacity has been considered same as project designed for both the system of LBC and RBC for the above proposed irrigation intensity. Crop water requirement has been assessed as per the present practices. The simulation study of the reservoir operation has also been carried out for the period of 1975-76 to 1990-91 as the actually observed inflow data for these period are available in project design. The annual dependability of irrigation for LBC and RBC system comes out to be 85% and 80% respectively which is quite satisfactory in order to adopt the above cropping pattern and particularly summer irrigation of 44% and 32% in LBC and RBC systems respectively.

The inequitable distribution of irrigation water from head to tail is very common in Barna command. The irrigation intensity of head, middle and tail reaches of D-1 distributary comes to 70%, 53% and 37% respectively.

Implementation of Warabandi, providing permanent structure to canal outlet system, promoting the use of ground water, disallowing lift irrigation from problematic distributaries of command, increase of maintenance norms, better communication facilities could be the remedial measures for equitable distribution of irrigation in the Barna command.

The water logging problem in the area of 555 ha has been reported in Barna command. Although it is not increasing at present but it requires proper attention for the control in future.

Promoting the ground water use by providing subsidy, proper maintenance of drainage system by weed control and silt removal, implementation of all the measures of equitable distribution of irrigation, joining the borrow pits of canal to nearby drains, promoting summer irrigation by lifting the groundwater are the suggested remedial measures to overcome the problem of water logging.

The irrigation revenue recovery position of Barna command is not satisfactory. There is a balance of Rs. 3.52 crore to be recovered from farmers in the Barna command. The remedial measures for improving the recovery is suggested below.

Following the procedure of state like U.P., where the recovery is relatively high. The responsibility of revenue department be fixed for recovery of water revenue.

Adopting the indirect measures, like disallowing the defaulters from taking loans and disallowing the defaulters from purchase and sale of immovable property, contesting the local body election, banning the defaulters from taking loans and making the panel rates on compound interest basis, instead of a fixed penalty. Time to time waving off the penal interest of defaulters by Government is not desirable for revenue recovery. co-operation of political leaders and influential farmers is necessary for irrigation revenue recovery. Proper training to officers and staff regarding M.P. irrigation rules and act for taking strong action against defaulters.

A periodical reviewal of the project is necessary for solving the various problem of irrigation management to achieve the desired output for betterment of people of the command.

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Chapter 1

INTRODUCTION

1.1 GENERAL

India has a land area of 3.27 million sq. kms. of which 49% is cultivable. Agriculture contributes 28% of gross national product, about 60% employment and is the primary source of livelihood in the rural area, which accounts for the 75% of India's population and 80% of it is poor. Madhya Pradesh which is situated in the heart of country is the largest state of Indian union having the area about 1/7th of that of the whole country. The state is bordered by the states of Maharashtra, Gujarat, Rajasthan, Uttar Pradesh, Bihar, Orissa and Andhra Pradesh. It's geographical area is 44.3 million hectares. The state is predominantly agriculturally oriented and 80% of its population is dependent on agriculture.

1.2 THE PROJECT LOCATION

Barna irrigation project is located in the Narmada basin and serves parts of Sehore and Raisen Districts of Madhya Pradesh. These Districts constituted the erstwhile Bhopal state (Before the reorganisation of states in Nov. 1956) and the project was originally envisaged in that state well before it came to be a part of the new state of Madhya Pradesh. The Barna project dam is located across Barna river (a tributary of Narmada in M.P.) near Bari village of Bareli Tehsil of Raisen District at 23°5' North and 78°7' East, approximately 105 kms from Bhopal city on national highway No. 12.

1.3 THE PROJECT AREA

The Barna irrigation project happens to be located in the heart of the state of Madhya Pradesh, which, in it's own turn, is known as the heartland of India. The state sprawls between 17°48′ and 26°52′ North and between 74°2' and 84°2′ East mainly on the central highlands, with 43% of its area being hilly and forested on heights varying from 460 m to 1220 m above sea level, and the residual area ranging in height from a little less than 180 m to 460 m above mean sea level.

Out of the state's geographical area (0.443 million sq. kms.) the area covered by different geological formations are Deccan Trap (1,66,537 sq. kms.), Vindhyans (50,028 sq. kms.), Gondwanas (47,280 sq. kms.), Cuddapah (37,257 sq. kms.), older alluvium and laterite (20,254 sq. kms.), unclassified crystalline gneiss etc. (70,028 sq. kms.), Granite (16,835 sq. kms.), Dharwars (11,849 sq. kms.), Bagh and Lameta beds (3,833 sq. kms.) and others (19,505 sq. kms.).

1.4 PROJECTS CATCHMENT AREA

The project has a designed irrigation potential of 60,500 ha. (Rabi 33,600 ha. and Kharif 26,900 ha.) and its reservoir has a catchment area of 1176 sq. km at the dam site. The project also intercepts the flow of Narsen river (apart from that of the Barna river). The reservoir's catchment is somewhat fan-shaped and spreads largely in the hilly and forested areas of the Bagaspur forest range in Raisen District.

1.5 GEOLOGY

The main geological formations occurring in the Barna command are alluvium deposited by Barna and Narmada rivers, Deccan traps and Bhander sandstone and shales of Vindhyan super system. Rocks of the Vindhyan system are present in the form of hills in the north and north western part of the area. They are exposed in the catchment and submergence areas of the Barna Project and are expected to occur below alluvium constitutes 60%, Deccan traps 30% and Vindhyan 10% of the geological formations in the area. The alluvium formations have good aquifers to sustain significant yields of ground water.

1.6 RAINFALL AND TEMPERATURE

The rainy season in the area generally spreads from mid June to October. Winter rains are received between November and February but are rather insignificant making it necessary to fall back on other sources of irrigation for Rabi cultivation. Prior to the coming up of the Barna irrigation Project its present command area was basically rain fed supported by ground water irrigation especially from dug wells with Rabi as the main crop season.

The climate of the Barna command area is generally dry and sub-humid. The temperature in Raisen District, in which a major part of Barna command area lies, range from 1°C to around 45°C. The mean daily temperature in the Districts of Raisen vary between 40°C in May and 10°C in January. The winter months are from November to February and summer extends from March to June.

1.7 TERRAIN, SLOPE AND DRAINAGE

The terrain in the Barna command area is gently undulating and mostly flat in the command areas of both LBC and RBC though interspersed with a number of nallas. The slope is mainly in the North-South direction towards the Narmada river and towards east in the direction of Tendon river. The slope vary from 0 to 5% - the highest elevational difference being 21.33 meter. Maximum Barna command cropped area of 33,000 ha. has 1% or less slope and only 5,100 ha has slopes in excess of 2%. The land slopes do not thus permit fast drainage despite a large number of deep and shallow Nallas.

1.8 SOILS

More than 47.5% of the soils in Madhya Pradesh are black, 36.5% are red and yellow and the remaining are broadly classified as alluvial, mixed red and black and skeletal. The soils in Raisen District in which Barna command area lies, are medium black cotton soils, which are the weathering product of Deccan trap basalts. These soils have 35% to 55% clay content, have a depth of up to 6 meter and are highly moisture retentive below surface. The parent material of these soils is augite, calcic plagio clases olivine and other ferromagnesium material, the colour of the soil is dark brown to dark grey and the pH is 6.8 to 7.8. These soils are low in nitrogen, medium in phosphorus and high in potassium content. The black cotton soils are very tricky in behaviour swelling with moisture and shrinking and cracking when dry, the cracks going down even to 5 m depth at places due to seasonal saturation, poor infiltration and poor drainage.

1.9 PROJECT COST AND COMPLETION TIME

The project proposed earlier in 1959 was approved for 5.56 crore. It was revised and approved for Rs. 15.27 crore in 1980 with little progress in between. Project was started in 1960 and about 92% completed by 1988 only at an estimated cost of Rs. 29.71 crore. The original proposals were for an earthen dam and unlined canals but changed later to masonry dam. The canal system is being now lined under a World Bank assistance programme under National Water Management Project.

The Socio-economic status of farmers of the command has improved after coming up of the Barna Project. They have adopted double cropping pattern of Rabi, while there was a single cropping pattern in general before the project. The yield of the crops has also increased from 125% to 175% in comparison to pre-project. The living standard and economic status of farmers can be further improved by achieving the full utilisation of irrigation and managing the various problems of irrigation management in the command.

1.10 SCOPE AND OBJECTIVE OF THE STUDY

The study entitled "A Critical Study of Irrigation Management Problem of Barna Command" is made for the entire command of the Barna project. The detailed study in the field of project design, irrigation development in different years, present adopted cropping pattern by the farmers of the command, irrigation distribution in different reaches of the canal network, position of water table, general maintenance status, role of non-government agencies in water distribution beyond the outlets, socio-economic status of the farmers, various reports and suggestions are necessary for knowing the achievement and problems of the project.

The objective of the study is to identify the major irrigation management problems in the Barna Command. On identification of the root causes of the problems, remedial measures could be suggested to overcome the problems. Irrigation management problems are more or less same in all the other projects of Madhya Pradesh also. The above study of identification of problems, their causes and remedial measures may be useful to other similar project also.

Chapter 2

REVIEW OF LITERATURE

2.1 IRRIGATION MANAGEMENT

Irrigation management has been defined as a process of manipulation of water resource to utilise it in the higher production of food and fibre. In actual sense of the word, it also includes the management of water in rainfed areas too besides that provided for perennial irrigated areas by man made irrigation system of different type and size. Irrigation management neither includes water resources, dams or reservoir to store water nor the water conveyance system, nor codes, laws or institutions to allocate water, nor farmers organisations nor soils or cropping system or drainage system, but it is the way by which certain skills and organisational approaches are used to manipulate physical, biological, chemical and social resources in order to bring the water to farms and crops for deriving more food and fibre production.

2.2 IRRIGATION MANAGEMENT – CONCEPT, RATIONALE AND PRACTICE

Irrigation is being practised for ages in India. But the need for irrigation management has never been more important than it is today. Therefore, it may be appropriate and also relevant to have an overview of the circumstances that have led to think about the need for management of irrigation. Before independence tanks, diversion weirs across perennial rivers and a few storage dams were the chief sources of irrigation. The service area, or command area as we call it today, of those projects used to be small, compact and above all largely homogeneous in terms of soil and terrain. Crops like paddy were domesticated depending upon the availability of water for irrigation and other environmental compulsions. Irrigation was essentially construed as merely delivering water from the source to the farmer's fields. The method of irrigation mostly used to be from field to field. Thus, water management appears to have not been considered as an important major issue.

The post independence period has, however, opened up new vistas for irrigation development. The expansion of irrigation has become a necessity not only to increase agricultural production to meet the food and fibre requirements of fast increasing population, but also to ensure balanced regional development. In spite of the fact that irrigation potential has increased substantially, the productivity of irrigated crops seems to have been much lesser than what it ought to have been. For instance, the average productivity of irrigated crops is around 1.6 tonnes per hectare as against 5 to 6 tonnes expected per hectare.

On the other hand, the mal distribution of water in major irrigation projects is believed to have affected adversely the environment – biological as well as social. Water related conflicts and litigation seem to have increased in irrigated areas. The benefits realised from irrigation and also potential benefits that could have been tapped with appropriate operational plans, appear to get completely camouflaged by the kind of environmental problems that crop up in major irrigation projects. Irrigation technology is a set of human activities which aim to augment and control the supply of water to the soil for the purpose of enhancing the production of crops. It is in this context that planners, designers, operators of irrigation systems and also the farmers seem to have felt the need for management of water to minimise adverse effects and increase positive gains.

2.3 OBJECTIVE OF IRRIGATION MANAGEMENT

The objective of the irrigation management in agriculture is to provide a suitable environment to the crops to obtain optimum crop yield with maximum economy in use of water. It is an inter-disciplinary system process with built in learning mechanisms to improve system performance by adjusting physical, technological and institutional inputs to achieve the desired level of output. It has been now realised that irrigation management includes the whole system. This is why the emphasis over the past has shifted from water management to on-farm water management, then to irrigation water management and now to irrigation management.

2.4 GOALS OF IRRIGATION MANAGEMENT

We need to be clear about the ultimate goals of irrigation management. Are these of a universal nature, that is, are they the same everywhere? At first thought, the answer is in the affirmative. After all, every community would unexceptionally subscribe to the following goals of irrigation management :

- Maximising farm production along a stable growth path.
- Realising full utilisation of created irrigation potential.
- Minimising over-irrigation and ecological degradation.
- Attaining cost-effectiveness and reliability in irrigation service.
- Achieving high water conveyance and storage efficiencies.
- Promoting sustainable irrigated farming.

At the stage of operationalising these goals, each community's larger goals of development have to be duly reckoned with. Since there is no universality about these developmental goals, the aforesaid goals of irrigation management get duly tempered with the community specific goals of development.

2.5 KEY ELEMENT OF IRRIGATION MANAGEMENT

Some of the key elements of management are as below :

- **Performance Monitoring :**

It is an activity to estimate performance of irrigation system. Monitoring requires the establishment of performance criteria.

- **Diagnostic Appraisal :**

It includes activities involved in identifying the interventions in the system and the consequences of such intervention in maximising the performance. Diagnostic appraisal should be viewed as opportunities for improving system performance and not as fault finding missions. There has been substantial research on appraisal methodologies and these may be effectively used in field.

- **Action Research :**

In action research interventions for making improvements in system performance are applied in a typical project area on experimental basis and are monitored to make purposeful evaluations.

- **People's Participation :**

Farmers are the ultimate water managers in the real sense and their active participation will increase project performance by inculcating a sense of participation in decision making. There is very little information available on the consequences of farmer's participation on system performance, though the need is well realized. There is need to document peoples behaviour in irrigation management and also for development of methodologies for more effective participation.

2.6 PROBLEM OF IRRIGATION MANAGEMENT

Irrigation plays an important role in the agriculture economy of the draught prone areas. However, it is still based largely on traditional methods which tend to waste water, nutrient and energy and may cause soil degradation by water logging and salinisation etc. The vital task before our irrigation system is to have stable and sustainable production over and above to make the system run profitable. Water and land therefore recognised as vital, precious and vulnerable resources and require to be managed properly to feed the growing population of this country.

The common problem of irrigation management could be summarised as follows :

- Water logging and soil salinisation.
- Disposal of drainage effluent.
- Low crop yields.
- Erosion and sedimentation.
- Socio-economic and institutional issues.
- Human health.
- Water recycling.
- Financial losses.
- Under utilisation of irrigation capacity.
- Dependability and inequity of irrigation.
- Sustainability of irrigated farming.

2.7 PRESENT STATUS OF IRRIGATION MANAGEMENT

With the traditional bureaucratic system of management purely run by the Govt. for more than 100 years and farmers developing a feeling that the system and water all belongs to the government and he has to use it to his maximum benefit. A complimentary question arises how to encourage farmers to assume more responsibility. Connected issues involved are regarding functions and responsibilities, motivations and incentives, costs and returns, rules and procedure, scale of operation location and identification of appropriate management units and linkage between irrigation administration which has mainly played the role of delivery of water and collection of revenue out of canal water supplied.

2.8 ROMAN PHILOSOPHY OF IRRIGATION MANAGEMENT

It is said that Rome once ruled all the countries of Southern Europe, Northern Africa and Western Asia, where irrigation had its birth and its greatest development in ancient time. Romans were among the most acute and logical thinkers the world has known to this day. It has been said in substance :

"Having ceased to rule the world by their arms, the Romans still control mankind by their reasons."

They believe that

"Like the air water was regarded as a necessity to human life of which everyone might use so much as was wanted for personal requirement, but which was not capable of appropriation to private ownership further than in this sufficient quantity."

My sole intention of reference to Roman laws was to emphasize that we shall have to frame appropriate and simple rules and legislative enactments, to assist the users in exercising in due controls and generate right traditions for use of water, before we hand over the responsibility to them.

2.9 ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACT OF IRRIGATION MANAGEMENT IN INDIA

Irrigation, hydropower and flood control remained major objectives of water resources development in India; with 14% of the total planned expenditures on dams and canals by 1979, India could increase her irrigation potential from mere 22.6 million hectares to 56.6 million hectares between 1970 to 1980. The cost of these projects becomes staggering if the environmental degradation and socio-economic consequences are also taken into account. Through various papers attempts to examine the way these irrigation works have played havoc to society, economy and environment and argues that such projects should be viewed in the total environmental and socio-economic perspective rather than being viewed as feats of engineering. Surface irrigation and ground water system contribute almost equal share in India's irrigation but of the two, former system not only costly and offers low returns, but gave rise to wide ranging socio-economic and environmental problems such as relatively low returns, regional and social inequalities, change in cropping pattern, water logging, salinity and loss of soil fertility, disruption of socio-economic life, deforestation, extinction of plant species, imbalance in eco system, destruction of wild life. It is because of some of such factors, the average yield of our irrigated area only about 1.7 tonnes of food grain per hectare as against expected average yield of 4 to 5 tonnes.

The above situation calls for proper planning and management of irrigation projects, fuller utilisation of the benefits offered by them, thorough investigation of the likely effects on environment and society, use of alternative systematic gigantic projects, development of ground water resources, proper lining of canals, distributaries, field channels and drains based on natural drainage units and the like.

2.10 IRRIGATION MANAGEMENT IN INDIA

Irrigation is an old practice in India. With growth in population and demand for food the pressure on irrigation has increased. Irrigation potential has been developed on large scale, but its utilisation is not satisfactory. The situation needs improvement. Efficient irrigation management including the whole system is required to be practised. prevention of losses in conveyance and improvement in field application efficiency are necessary for which the involved personnel are to be suitably trained. A cadre of water managers, equipped with the necessary knowledge and expertise, should be established. Efforts should be made to practice scientific management of irrigation rather than increasing potential.

2.11 TASK OF IRRIGATION MANAGEMENT AHEAD

There are some of the task summarised below to be achieved ahead are as under :

- Food production is to be raised to 240 mt by the turn of the century.
- Problem of water logging and soil salinity is spreading fast leading to degradation of good agricultural land.

- Increasing the availability of irrigation water under the condition of the share of water for agriculture is gradually decreasing.
- Preservation of quality of environment and ecological balance.
- Extension of benefits of irrigation to a large number of farm families ensuring social and equitable distribution of water.
- Reducing the gap between the irrigation potential created and utilised.

2.12 TRAINING IN IRRIGATION MANAGEMENT

The objective of any training in irrigation management is to remove the functional deficiencies of the concerned personnel (Irrigation and CAD officials, agriculture officers, farmer leaders and farmers) affecting the performance of their assigned tasks, and improve their capabilities in irrigation management. Assessment of "training needs" and "appropriate design" of the training programmes are the two most important prerequisites to have effective irrigation management training.

2.13 ROLE OF MEDIA IN IRRIGATION MANAGEMENT

The role of media in disbursing information to the people is crucial. This does not only help shape the making of future policy makers but also those who are actually involved in implementing policies. In case of irrigation management, the Indian media has played less than an useful role. Crucial issues such as over use of water by the farmers, continuing land erosion because of destruction of grass cover, among other issues, have been virtually ignored. Instead, sensational journalism, often siding with disruptive environmentalists, has stymied the media impact on these vital issues.

2.14 CONCLUSIONS AND RECOMMENDATIONS

The present quality of irrigation management (water management) in India varies from system to system – on some established and well managed systems, the scope for improvement is limited. Major deficiencies exist on many new systems, particularly where the command area needs extensive land preparation due to its undulating nature, and farmers as well as irrigation engineers, lack experience of system operation and irrigated agriculture.

The recommendations may be summarised as below :

I. Planning

All new projects, and renovation of existing systems should be planned for annual irrigation intensities of 100% and above.

A system study should be carried out for cropping pattern and optimum use of canal and well water.

II. Design

Design of canal capacities on basis of E.T. requirement.

Provision of adequate regulation points and escapes.

Provision of sub-proportional semi module outlets on branches, and upstream of raised crest falls and regulators.

III. Operation of Main System

Regulation of main system in accordance with rationally computed water demand of crops, subject to constraints of available supplies.

Ensuring minimum head on tail end outlets.

IV. Outlet Command

On new projects construction of trunk water courses down to 8 ha (20 acre) areas. Lining about half upstream length of main water courses; where unlined ensuring cleaning and compaction of water course section.

On Warabandi system taking water losses into account, and providing allotment of a minimum time for small farm holdings.

Chapter 3

DESCRIPTION OF BARNA PROJECT

3.1 HISTORICAL BACKGROUND

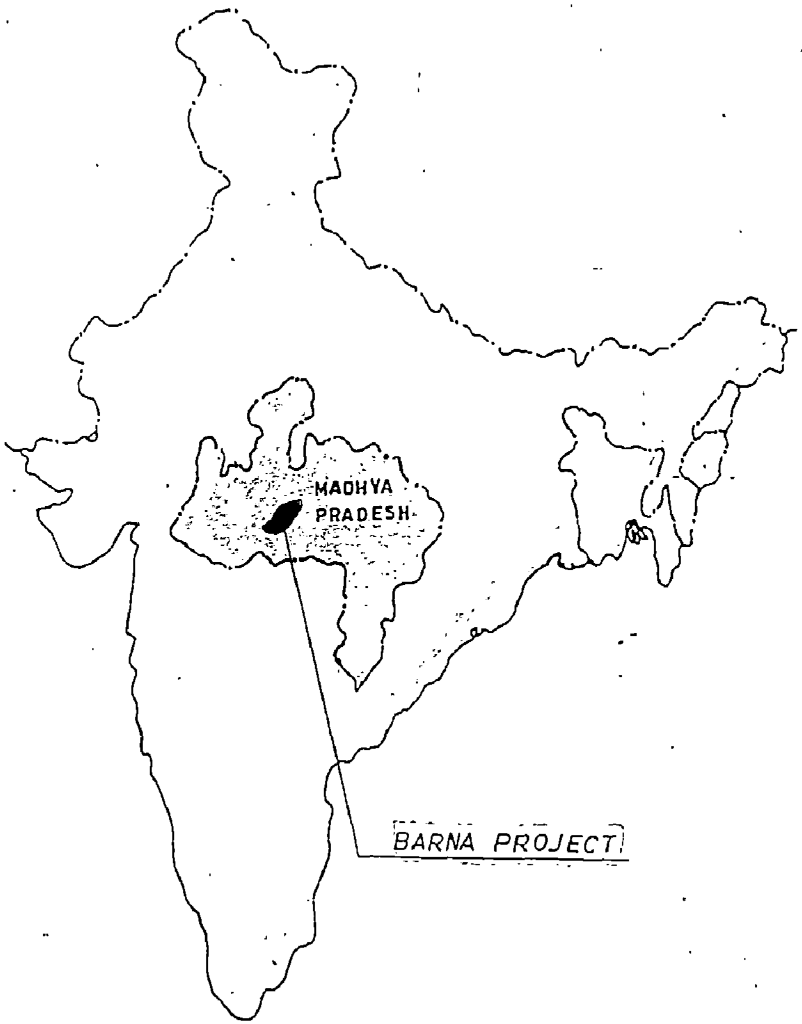
The Barna project, located in the Raisen District of Madhya Pradesh is the first major river valley project of the Bhopa State and taken up in the second five year plan. Location of Barna project and Index Map of Barna command could be seen in Fig. 1 and Fig. 2 respectively.

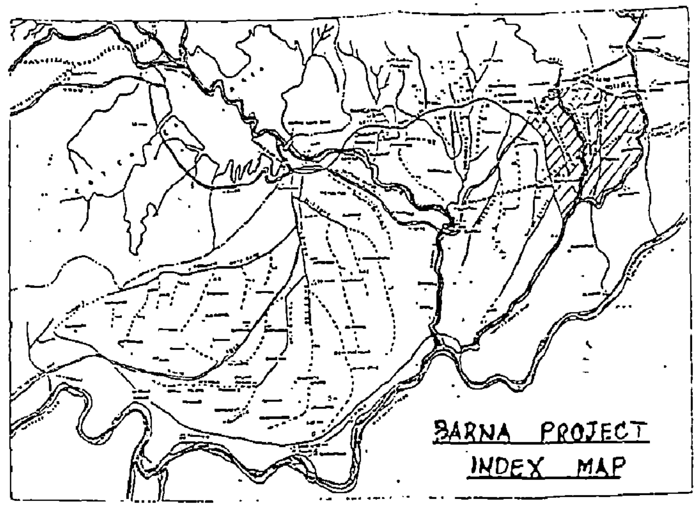
The Barna river originates in the Vindhyan range of hills and after flowing north-east for about 56 km, it passes through a narrow gorge of about a 2 km in length near Bari village. At the downstream end of this gorge the dam has been constructed. Barna dam site is about 105 km away from Bhopal city on National Highway No. 12.

The project comprises of a straight gravity stone masonry concrete dam, with centrally located spillway across the river Barna. There are two canal system and a carrier water course from the saddle dam, out of which left bank canal is designed for a CCA of 19826 ha and right bank canal for a CCA of 35048 ha. The left bank canal and right bank canal takes off from carrier water canal which is about 600 m in length and gets water from saddle through three barrels.

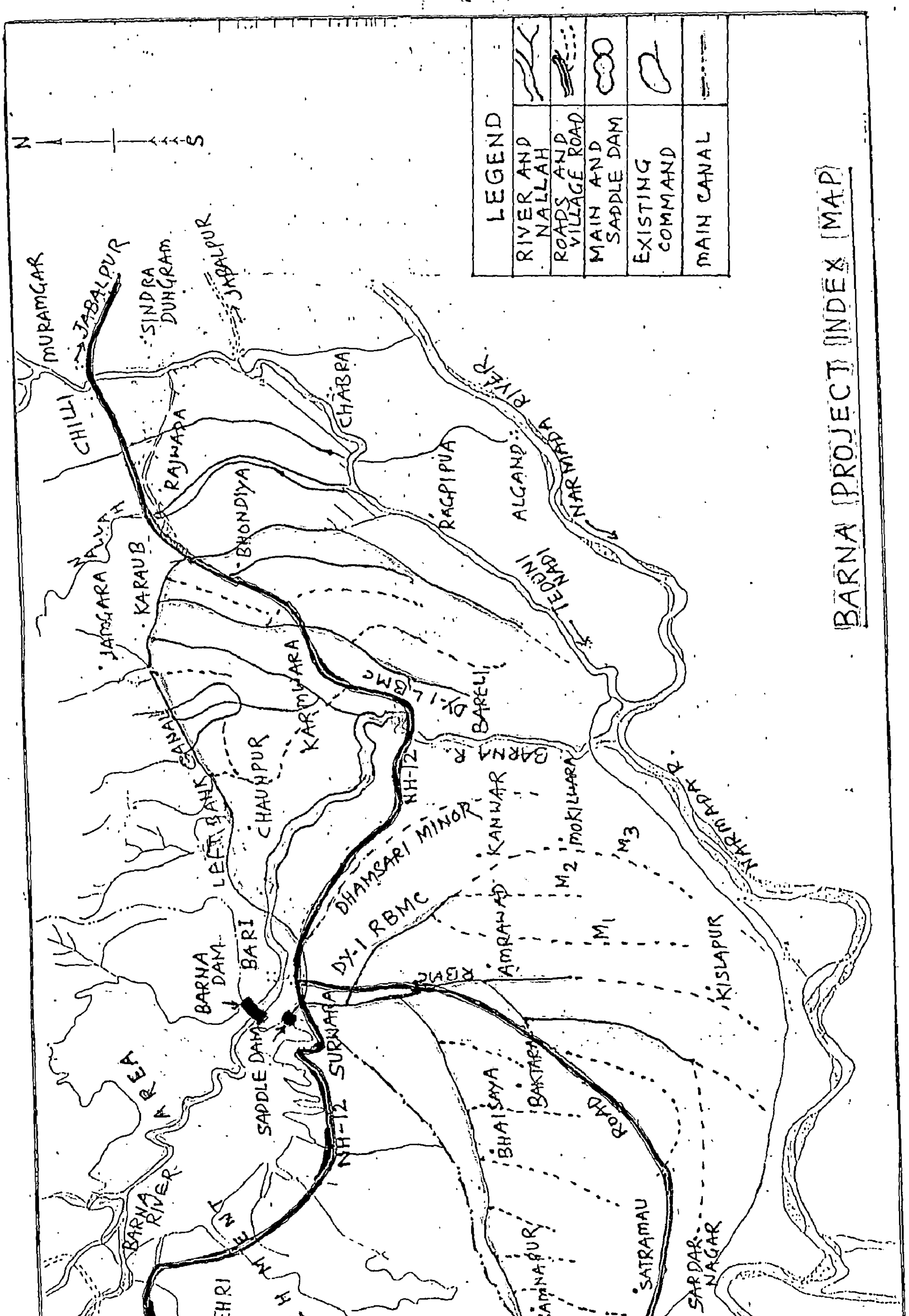
The total estimated cost of the project was 15.27 crore (as per project report of the year 1980). It is designed to irrigate about 55000 ha of land to serve annually 60500 ha of cropped area by multiple cropping and irrigation intensity of 125% and 104% in left bank canal and right bank canal commands respectively.

The cost of the project was revised for Administrative sanction by Government from time to time as per details given in Table 3.1.





BARNA LOCATION MAP



BARNA PROJECT INDEX MAP

SCHEMATIC DIAGRAM OF BARNA PROJECT

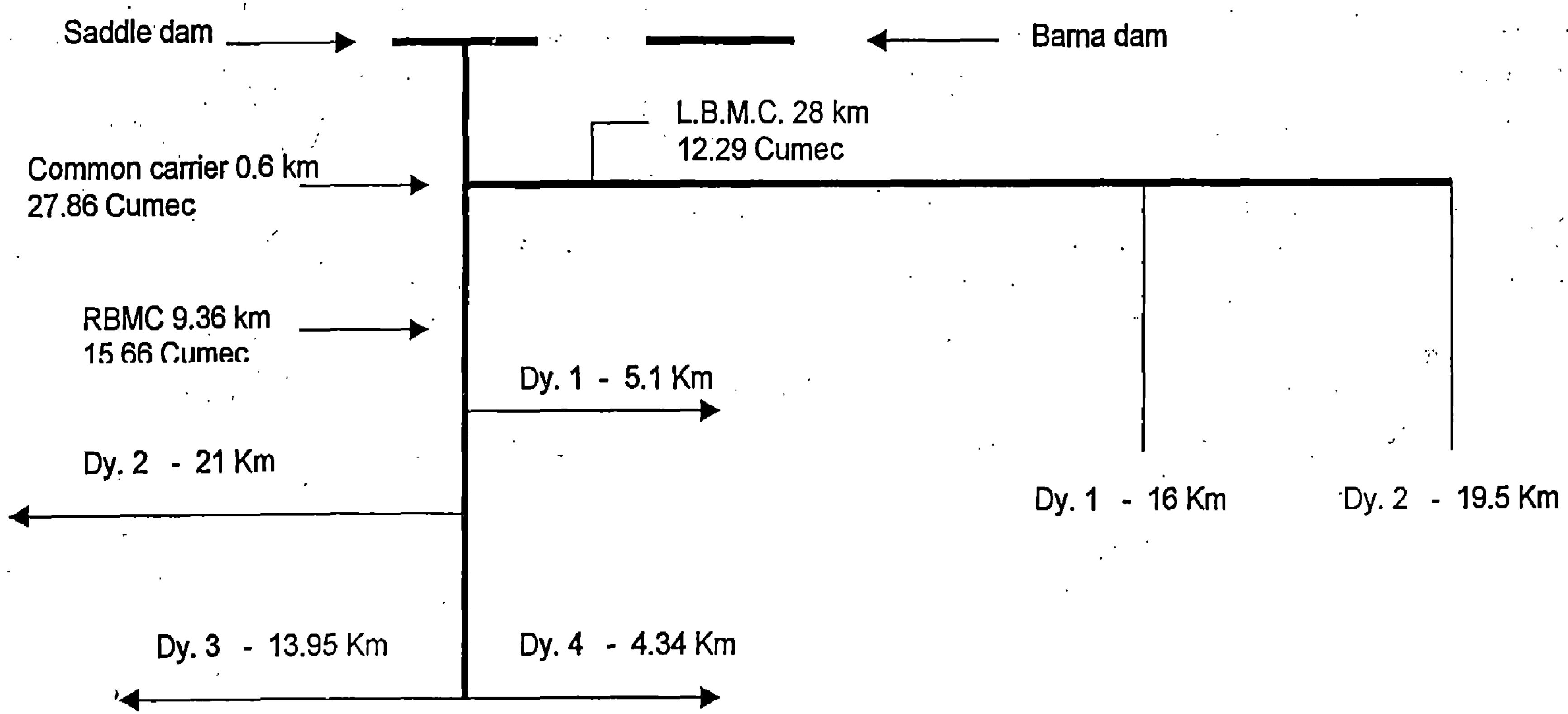


Table 3.1 : Administrative Approval of Barna Project

S. No.	Administrative Approval Year	Amount of A.A. in Rs. Crore
1	7th June 1959	5.56
2.	3rd Dec. 1975	12.97
3	6th Nov. 1980	15.27

Barna project was started in the year of 1959 under second five year plan. However, a little work was done till 1968. Firstly because of the emphasis was on medium and minor irrigation works. Secondly there was scarcity of funds. Thirdly there was dislocation due to Chinese war in 1962 and Pakistan war in 1965.

The total expenditure up to 1968 was only Rs. 90.6 lakhs which is about 5.85% of the anticipated estimated cost of Rs. 15.27 crores. The expenditure was mostly on purchase of T & P and construction of buildings and roads etc.

The actual work on the project started from 1969 and by July 1975, the first phase, i.e., completion of the dam up to crest level (excluding erection of spillway crest gates and spillway bridge), completion of saddle dam and completion of parts of RBC system to create irrigation potential of 13,355 ha. was completed.

The erection of crest gates and main works on canal has been completed in 1977. By 1980 main works of canal system were completed and full irrigation potential 60,500 ha. was created.

3.2 SALIENT FEATURES OF BARNA PROJECT

3.2.1 Location

1.	State	-	Madhya Pradesh
2.	District	-	Raisen
3.	Site of Dam	-	Longitude 78°7′ E Latitude 23°5′ N (Topo sheet No. 55-$^{I}/_{4}$)

3.2.2 Hydrology

1.	Drainage area of the river above dam site	-	1176 sq. km.
2.	Average annual rainfall	-	1132 mm
3.	Max. annual rainfall	-	2068 mm (year 1973)
4.	Min. annual rainfall	-	535 mm (year 1920)
5.	Mean annual run-off at the dam site	-	56,500 hect. meter
6.	Observed max. flood at the dam site	-	11,480 cumec (year 1965)
7.	Designed flood	-	13,557 cumec
8.	Moderated flood	-	6825 cumec

3.2.3 Reservoir

1.	Gross storage capacity at FRL 348.55 m	-	53,900 hect. m
2.	Dead storage at LSL 338.10 m	-	8320 hect. m
3.	Live storage at FRL 348.55 m	-	45,580 hect. m
4.	Area submerged at FRL 348.55 m	-	7,700 hect.
5.	(i) Area under cultivation	-	2,430 hect.
	(ii) Area not under cultivation	-	2,190 hect.
	(iii) Forest area	-	3,080 hect.
6.	Villages affected	-	25 Nos.

3.2.4 A- Main Dam

1.	Type of dam	-	Straight gravity stone masonry concrete
2.	Normal pondage level	-	348.55 m
3.	Max. water level	-	351.45 m

4.	Dead storage level	-	338.10 m
5.	Top level of dam	-	460 m
6.	Deepest river bed level	-	315.60 m
7.	Length of dam	-	432.00 m
8.	Top width of dam	-	4.60 m
9.	Max. height	-	47.70 m

3.2.5 Central Spillway

1.	Crest level of the spillway	-	341.70 m
2.	Length of the spillway	-	115.10 m
3.	Types of crest gates	-	Radial crest gates
4.	No. and size of gates	-	8 Nos. (12.2 m x 6.85 m)
5.	Top level of crest gates	-	348.55 m

3.2.6 B – Saddle Dam

1.	Type of dam	-	Straight gravity stone masonry concrete
2.	Length of dam	-	94.50 m
3.	Top width of dam	-	4.60 m
4.	Max. height	-	20 m

3.2.7 Canal System

1.	Gross command area	-	72000 ha.
2.	Culturable command area	-	55000 ha.
3.	Annual irrigation	-	60500 ha.
4.	Rabi	-	33600 ha.
5.	Kharif	-	26900 ha.

3.2.8 Total Length of Canal

(a)	Main canal	-	38.56 km

(b)	Distributaries	-	86.30 km.
(c)	Minors	-	193 km.
6.	No. of villages benefitted and proposed irrigation		
(a)	In Raisen District	-	156 Nos. (48,600 ha.)
(b)	In Sehore District	-	42 Nos. (12000 ha.)

3.2.9 Revised Estimates of Cost

1.	Cost of unit-I dam and appurtenent work	-	Rs. 9.29 crore
2.	Cost of unit-II main canal distributaries and minors	-	Rs. 5.98 crore
3.	Total cost	-	Rs. 15.27 crore
4.	Cost per ha. (to annual irrigation)	-	Rs. 2525
5.	Cost per ha. (to CCA)	-	Rs. 2780

3.2.10 Benefits

1.	Agricultural increased yield	-	Rs. 1.82 lakh tonnes
2.	Benefits @ 1990 price level	-	Rs. 54 crore
3.	Benefit cost ratio		
	@ 5% interest	-	10.75
	@ 10% interest	-	6.23

3.3 SALIENT FEATURE OF BARNA COMMAND

3.3.1 Location

The project provides for bringing under irrigation the rich valley of Narmada lying between arm of Vindhyan range on the north and Narmada river on the south.

The area under the command of the left bank canal is bounded by river Barna on the west, river Narmada on the south, river Khand and its tributaries on the east, Vindhyan hill range and the left bank canal on the north.

The area under the command of the right bank canal is bounded by river Barna on the east, river Narmada on the south, main canal and its tail distributaries on the north and Dobi river on the west.

Latitude : 22°48′ to 23°5′ N

Longitude : 77°50′ to 78°18′ E

The systemwise details of gross command area, irrigated command area, annual irrigated area and irrigation intensities as per project design is given in the table below :

System wise Command Area, Design Irrigation Intensity

Description	GCA Ha.	ICA Ha.	Annual Irrigation Ha.	Irrigation Intensity, %		
				Kharif	Rabi	Total
LBC command	26000	19830	20500	42	83	125
RBC command	46000	35050	40000	52	52	104
Total project	72000	54880	60500	52	57	112

3.3.2 Canals

(i) Left Bank Canal

Left bank main canal is a contour canal and 28 km long. It traverses 7 big nallas by means of aqueducts and small nallas by means of drainage culverts. There are 12 cross communication structures (DRBs, VRBs). The canal crosses national highway by syphon. One of the major structures is Barna Aqueduct, where canal crosses Barna river. 65% of length of the canal is in heavy filling. In cutting reach it passes through porous soils. The head discharge is 12.20 cumecs. Because of contour canal, the bed gradient of the canal can not be steepened from 1 in 10000 to 1 in 7000. This canal is almost a carrier canal up to km 27 from where the first distributary takes off. The other distributary take off from the tail.

(ii) Right Bank Main Canal

This is a ridge canal and is 9.86 km long. It has a head discharge of 15.66 cumecs. There are 1 aqueduct, 6 falls and 7 VRBs lying on this canal. This canal deliver/diverted distributaries D1, D2 and D3 from the CH2.97, 5.79 and 9.84.

(iii) Combined Main Canal

It is a common carrier canal and is about 0.60 km in length and has earthen section. It's maximum discharging capacity is 27.95 m^3/sec. It has taken off from a saddle dam and gets water from it through three barrels.

3.3.3 Design Irrigated Cropping Intensity

The designed irrigated cropping intensity as per project report for LBC and RBC command in different season is given in the enclosed Table No. 3.3.3.

Designed Cropping Pattern and Crop Water Requirement

The cropping pattern as per project report for different crops in Kharif and Rabi for left bank canal command and right bank canal command is given in the Table No. 3.3.3 and designed crop water requirement as per project report is given in Annexure No. 1.

Table 3.3.3 : Designed Cropping Pattern

S. No.	Crops	Area in Hectare		Total	Assumed water requirement at outlet in mm
		Right command	Left command		
KHARIF					
1	Paddy	11545	1639	13184	585
2	Maize	2694	1147	3841	155
3	Pulses	3848	-	3848	100
4	Vegetable	385	820	1205	410

5	Fodder	770	-	770	100
6	Groundnut	770	-	770	100
7	Soybean	-	3278	3278	255
	TOTAL	20012	6884	26896	
RABI					
8	Hy wheat	5773	13604	19377	560
9	Local wheat	11545	-	11545	410
10	Gram	1924	-	1924	155
11	Vegetable	770	-	770	810
	TOTAL	20012	13604	33616	
	GRAND TOTAL	40024	20488	60512	

3.3.4 Climate, Topography and Soil

There is no meteorological observatory in the command area. There is one observatory at Sultanpur in the catchment area, 6.25 km to 7.5 km north-west of the command area and the other at Hoshangabad about 5 to 6 km south-west of the command area. Data for Sultanpur observatory is available for year 1955-56 only, while that for Hoshangabad for 1918 to 1954. Hence data for Hoshangabad has been used. At Hoshangabad, the annual mean max. temperature is 33°C and mean min temperature is 13°C.

In the command area of left bank main canal the rainfall varies from 1143 mm to 1270 mm. In the command of the right bank main canal the rainfall varies from 1016 mm to 1093 mm.

The general prevailing direction of winds during the month of June to October is west-south and from November to January north-west and February to April is north-west. The average velocity during the month of June-August is 6.20 km/hr and from Sept to April 3.10 km/hr. The maximum velocity is about 50 km/hr.

The humidity surcharge in weather is very low in dry weather and is maximum in monsoon season. It is as low as 4% to 8% in driest months of April and May.

The major part of the area has black clay soil known as "Superior Kalawat". When dry becomes very hard and cracks easily, but when wet, it is soft and clayey. On account of its power of absorbing water, it remains moist for considerable period. This soil is specially suited to wheat, masur and gram. If irrigation is possible, it will grow sugarcane, gardens, rice, etc.

On the basis of field and laboratory tests at CWPRS, Poona, it has been found that :

- The soil of the command area is fairly deep and falls under black cotton soil.
- 5.2% of the area have soluble salts above 0.5% in at least one layer.
- 34.1% of the area have soluble salts above 0.25% atleast one layer.
- The soils in the area are natural to alkaline.
- The soils are clayey.
- The average sodium saturation is only 4%.
- The amount of exchangeable potassium is fairly high.
- The amount of organic matter and nitrogen are poor.

The command area is drained by the large number of nallas and streams in the Narmada river and provide a good drainage for the whole area.

3.3.5 Ground Water Table

As per the project report the ground water table position in the command area is as under

Ground water table depth	Percentage area
Upto 2 m	2.85
Between 2 to 5 m	40.00
6 m and above	57.15

3.3.6 Benefits of the Project

The benefits as per project report on full development of irrigation would be as below :

(A) Direct Benefits

(i) Increase of 0.196 M. tonnes of agriculture production annually of value about 2.27 crore.

(B) Indirect Benefits

(i) The area commanded by the project is now sparsely populated. The irrigation will increase the population as people from unirrigated areas will migrate to this area.

(ii) The purchasing power and wealth of the people will increase.

(iii) The value of property will increase and the people will realise more rents from the land and buildings.

(iv) The growth of fruits, vegetable and sugarcane will improve the health of the people.

(v) There will be no occurrence of the famine at all.

(vi) the town and village will get better water supply.

3.3.7 Benefit Cost Ratio

(a) 10.75 @ 5% interest

(b) 6.23 @ 10% interest.

Prior to project, percentage of irrigation in the District was 4% only but with development of full irrigation the intensity of irrigation will jump to about 58%.

3.4 SITE DESCRIPTION AND INDEX MAP

Barna irrigation project is one of the major project in the Narmada valley and is situated in Raisen District of Madhya Pradesh (India). The catchment area, dam location, canal networks, major rivers, command area etc., are shown in Index Map (Fig. 2).

3.5 ORGANISATIONAL SET UP OF BARNA COMMAND

The Barna project and command have the following major department for its management.

(i) Water resources department

(ii) Agriculture department

(iii) Barna CAD Authority

The organisational chart of water resources department, agriculture department and CAD is given in the Table 3.5(a), 3.5(b) and 3.5(c), respectively.

3.6 COMMAND AREA DEVELOPMENT AUTHORITY

Though the Barna project was identified as one of the to be CAD projects as early as 1975-76, the Barna command area development Authority came to be set up in 1980 only, in compliance of Govt. of M.P. resolution No. 1-9-76-2-CAD-XIV dated the 3rd of June, 1979, and became functional in 1981. As its first tasks, it undertook to prepare a project report, which was brought out in 1985, detailing the work to be done by it over a period of ten years extending to 1994-95.

The tasks entrusted to Barna CADA by the government of M.P. resolution of 3rd June 1979 were for too many and covered all activities which were originally envisaged by the Government of India to be performed by CADAs.

The command area development activities, as came to be envisaged subsequently, were arranging the full package of inputs like credit, seeds, fertilisers and pesticides, providing subsidies for on farm development mainly construction of W/C, field channels and drains, training of officials and farmers, motivating adoption of latest technology for optimising yields of crops, constituting farmers' societies for water distribution and management and introducing Warabandi for equitable distribution of water.

Table 3.5(a) : Organisation Chart of Water Resources Department in the Barna Command

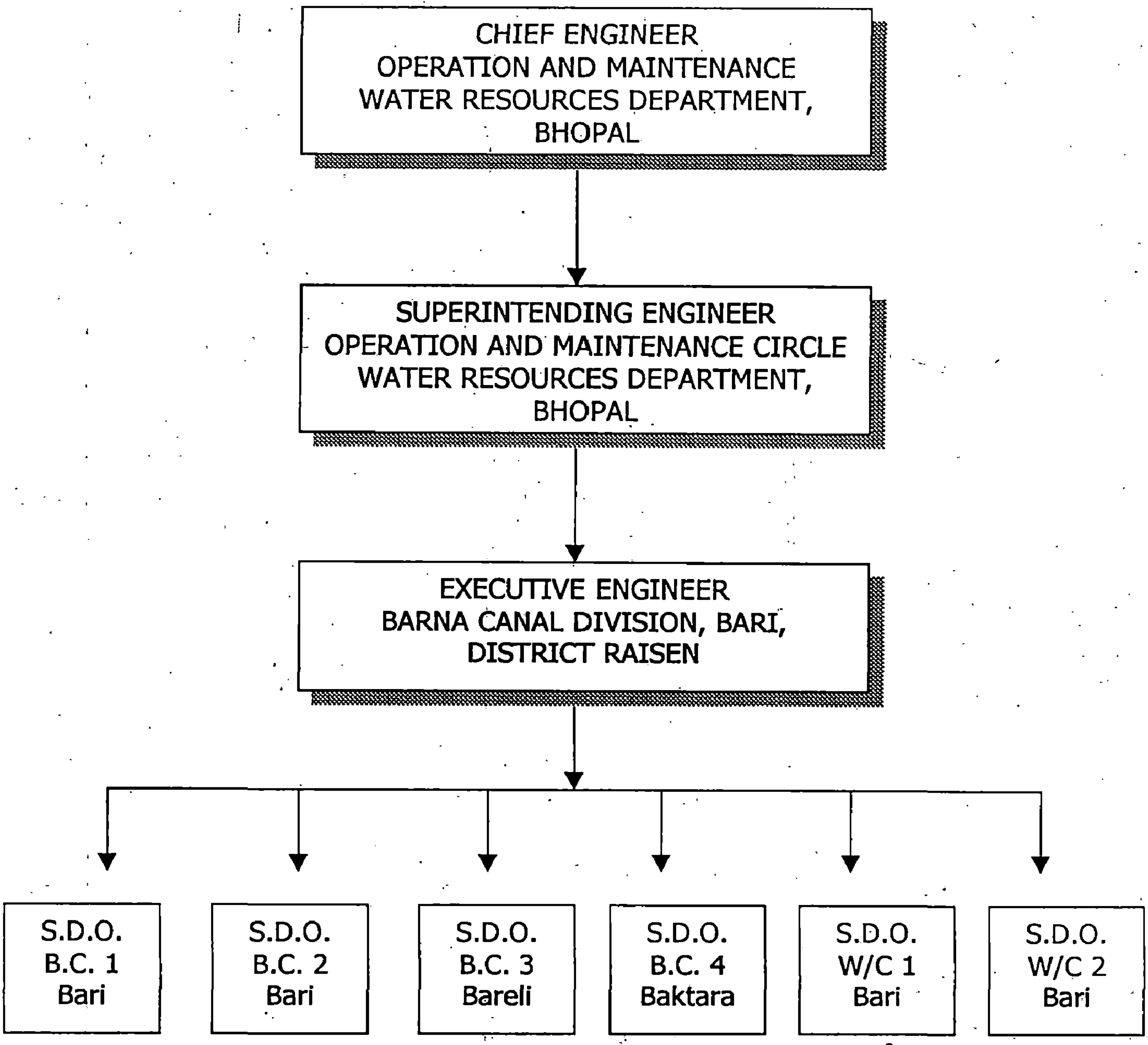


Table 3.5(b) : Organization Chart of Agriculture Department

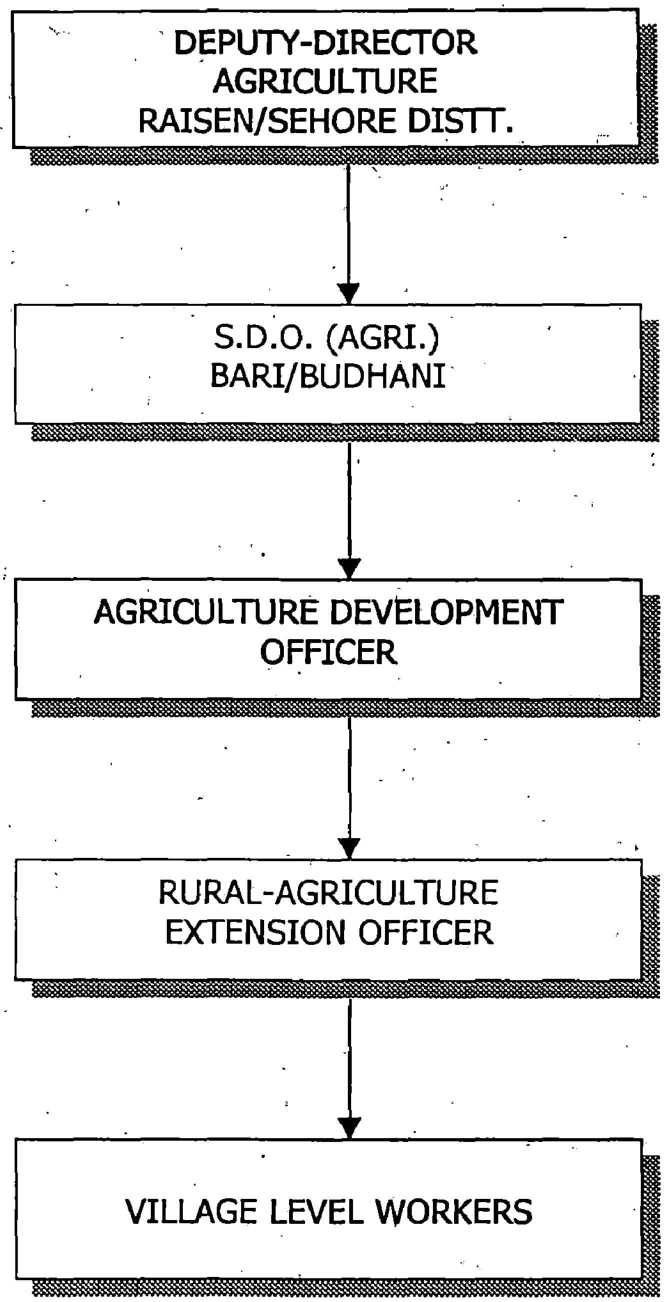
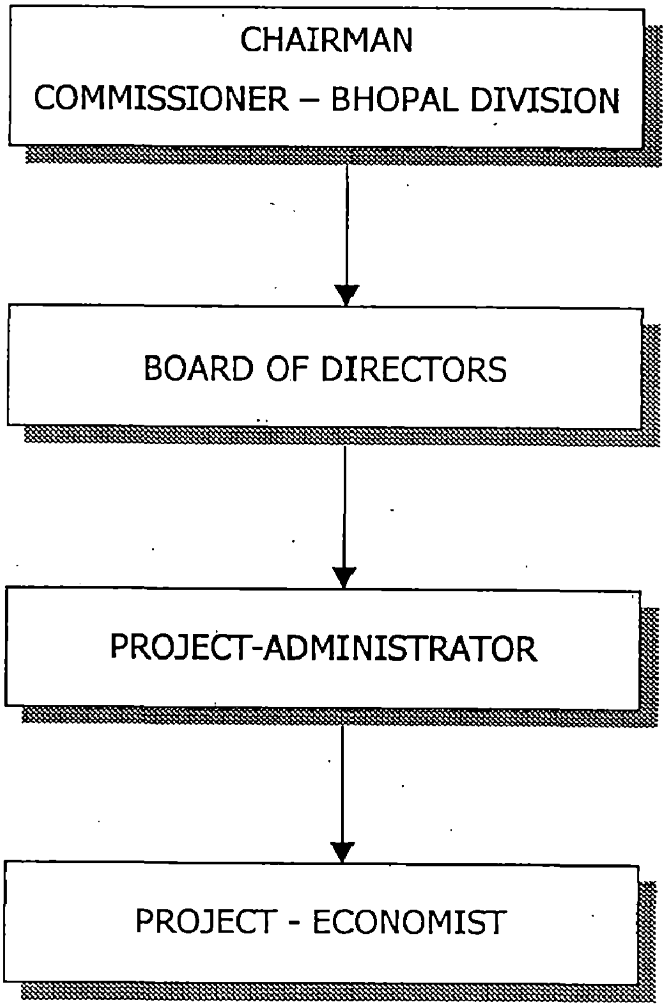


Table 3.5(C) : Organization Chart of Command Area Development Authority (CADA)



Even though Barna CADA was set up in 1980, it could not become operational straight away as there was no CAD programme readily available for implementation other than the project report which dealt more with irrigation and cropping pattern which too was running into a controversy as being impracticable as far as Kharif cropping was concerned. As has been seen earlier, the first irrigation was given from the Barna system as far back as 1975-76 but the irrigation achievement was rather low as is evident from the Table No. 3.6.

3.6.1 CADA Objective

The main objective is to optimise utilisation of irrigation potential for optimum agricultural production coordinated to area development. These essentially call for bridging the gap between potential created and utilisation there of by proper water management and provision of adequate infrastructure for water distribution down to the last field.

3.6.2 CADA Activities for Utilisation of Irrigation Potential

Some of the main activities of CADA which have an important bearing on the utilisation of irrigation in Barna command are discussed in the following paragraphs.

3.6.3 Construction of W/C and Field Channels

This is very important component of the CAD programme. Full utilisation of the potential created can be possible only if water reaches all farmers' fields. For this well designed, durable, lined water courses equipped with all necessary structures are necessary.

In the Barna command area, water courses and field channels have so far been constructed in 45,542 ha and 26,712 ha respectively. Considerable more area remains to be covered yet.

Table 3.6

Barna Project : Development of Irrigation in Canals Command Areas

S. No.	Year	Kharif			Rabi		
		LBMC (ha)	RBMC (ha)	Total (ha)	LBMC (ha)	RBMC (ha)	Total (ha)
1	1975-76				2388	3167	5555
2	1976-77				2880	6583	9463
3	1977-78				206	7288	7494
4	1978-79	8	245	253	77	11306	11383
5	1979-80	49	261	310	609	1075	1684
6	1980-81	28	243	271	3078	11091	14169
7	1981-82	11	33	44	4340	11447	15787
8	1982-83	299	531	830	7879	14833	22672
9	1983-84		50	50	9340	18110	27450
10	1984-85	170	186	356	9116	15384	24500
11	1985-86				8681	15849	24530
12	1986-87		178	178	8783	15754	24537
13	1987-88				10383	11544	21927
14	1988-89				10720	16881	27601
15	1989-90				11505	20360	31865
16	1990-91				11542	21084	32626
17	1991-92						33775
18	1992-93				11229	21511	32740
19	1993-94				12482	22000	34482

An idea of annual progress and cumulative progress of construction of water courses can be had from Figs. 4 & 5 and of field channels from Fig. 6. It was noticed that the structures required for these channels were not constructed as per requirement. Since these channels were only made up of earth and were kutcha in nature, and no effort for their maintenance was made a good of many of them have been severely damaged and some have even been brought under the plough by the farmers who felt that these interfered with their farm planning or tractors operations. The amount invested in the construction of such channel upto 1990-91 was Rs. 2.50 crore and 30% of it has already been lost. Construction of field channels in less than 50% of the area for which water cources have been constructed is not a satisfactory development especially when water courses have been constructed in 83% of the project C.C. area. Thus, even if water is available in the reservoir, agreements have been entered for supplying water for a crop season, actual utilisation is much less and its effect on productivity not as expected.

3.6.4 Field Drains and Drainage Network

An important requisite in systematic irrigation is to prevent excessive pondage in the fields by providing field drains and carrier drains, for draining out excessive moisture as and when necessary.

In Barna command area, the topography in a large percentage of the RBC command is flat and gently sloping but in the LBC command there is a marked need for field drainage. The expenditure so far incurred on drainage is about Rs. 21.10 lakh which is much below requirement.

3.6.5 Land Levelling and Land Shaping

Surface irrigation requires even lands with proper slopes for flow of water and drainage for which land levelling and shaping is being required. Such land levelling and shaping is important for multiple cropping, water management and irrigation practices like border strip method, basin and chak method of irrigation.

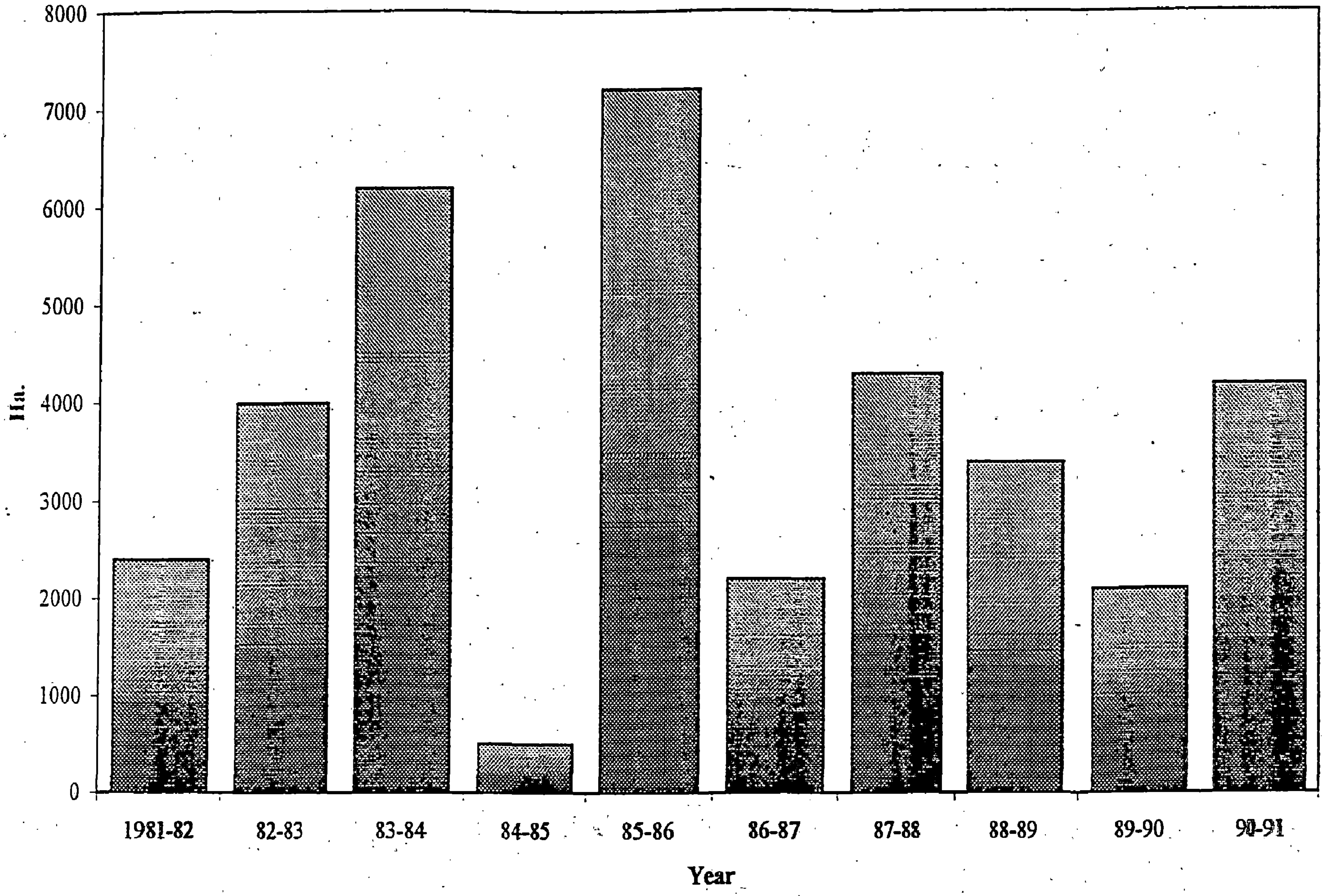


Fig. 4 : BARNA CAD PROJECT

Construction of Water Courses

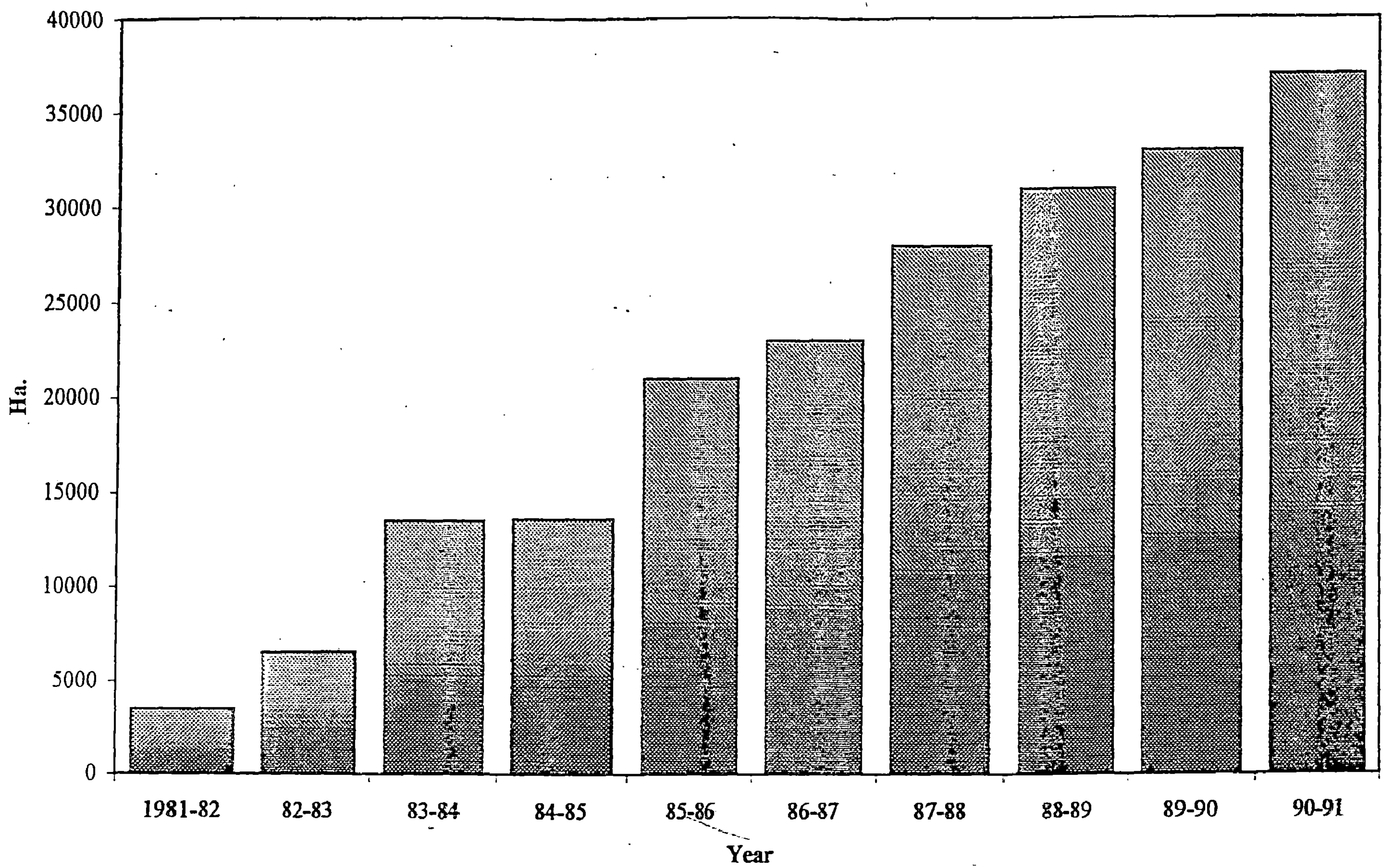


Fig. 5 : BARNA CAD PROJECT

Construction of Water Courses – Cumulative Progress

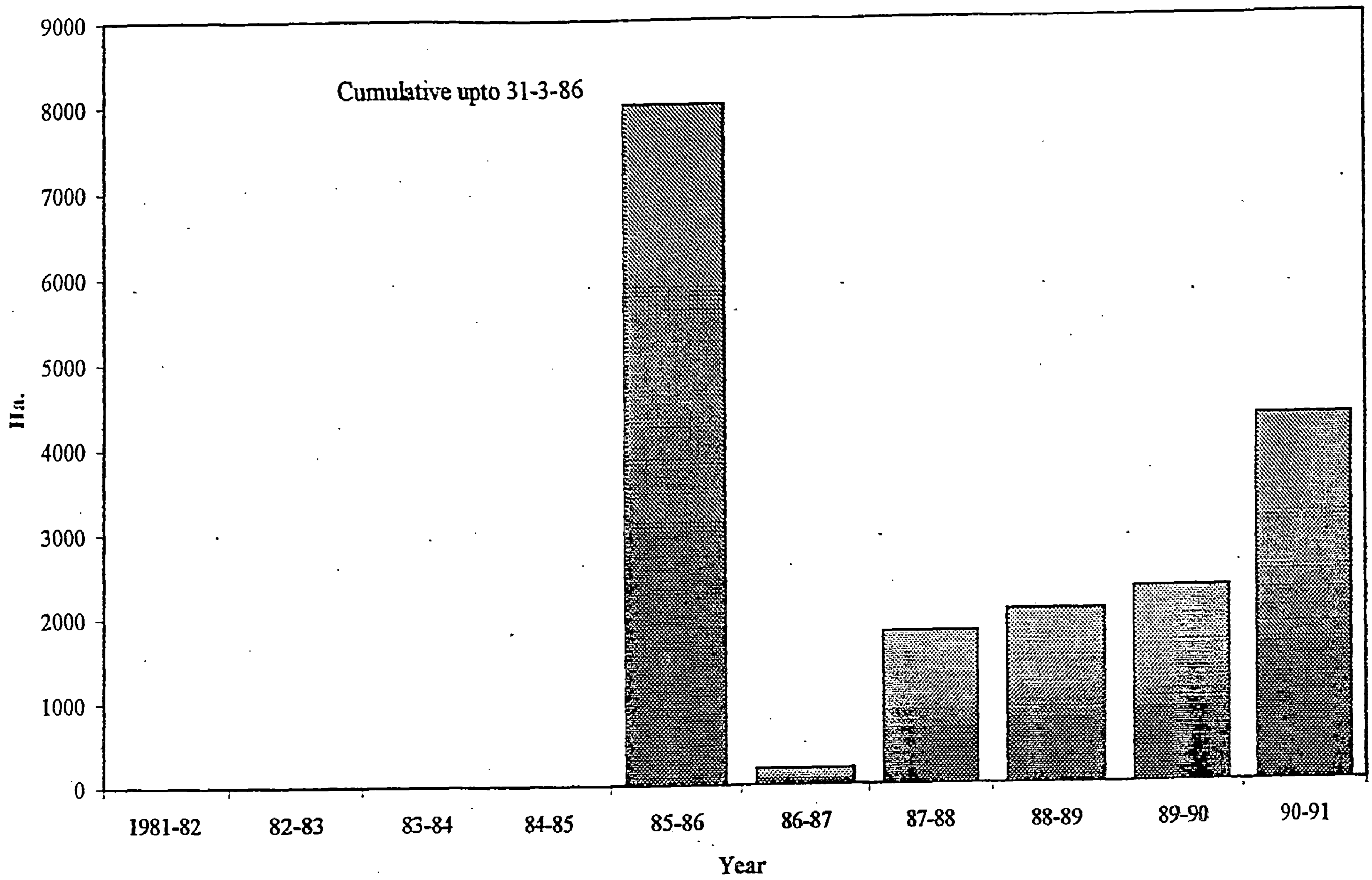


Fig. 6. : BARNA CAD PROJECT

Construction of Field Channels

The Barna command area is largely a flat terrain not requiring much land levelling except in an area of 2200 ha. Incidentally, this activity has not been taken up in Barna command by CADA though farmers do it on their own.

3.6.6 Consolidation of Holdings

No serious attempts have been made in the Barna command area to do full on farm development. There is practically no enthusiasm amongst any section of the farming community in the Barna command for consolidation of holdings despite the realization in all the quarters that is grossly uneconomic, cumbersome and greatly inconvenient to do farming in widely dispersed, fragmented, small and uneconomic patch holdings.

3.6.7 Warabandi

Although it is farmers' right to get full irrigation supplies for the crops proportionate to the size of his holding, as agreemented, but, in practice, the farmers in the head reaches manage to get larger share of water supply.

In the Barna command area the rotational system of water supply, i.e., Warabandi, has in effect, not been implemented for which the farmers as a whole are as much responsible as the staff for the preparation of irrigation operation plans and enforcing Warabandi. Efforts of CADA to introduce Warabandi and to induce irrigation Panchayats to motivate their members to agree to Warabandi were equally ineffective.

3.6.8 Farmer's Participation

Since farmer is the end user and beneficiary of all activities related to command area development, his involvement and whole-hearted cooperation is a must for CADA's success in all the fields. In many progressive states like Maharashtra, Gujarat, Haryana and U.P., there are water users' associations for management and distribution of irrigation water. The M.P. Irrigation Act, 1931, which was enforced all over new M.P., after reorganisation of the states in 1956, envisages setting up of Irrigation Panchayats for managing irrigation and collection of water charges.

In the Barna irrigation project command area also, 55 irrigation panchayats were duly constituted covering an area of 23,500 ha. These were not active and presently they stood superceded as their term had ended. The members of the superceded Panchayats feel that the remuneration fixed for the recovery of water charges is too inadequate. There are 870 "Chak Samitis" with a membership of 4350 farmers but these Samitis too are not working satisfactorily in the Barna command area. Water rates recovery is hardly 10% of the annual demand.

3.7 STATUS OF POTENTIAL CREATED AND IRRIGATION UTILISED

In Barna project head work portion is completed in all respect in the year of 1978-79 while the construction of canal was in progress. The first irrigation from the project was started in the year of 1975-76 for Rabi irrigation for an area of 5555 ha. and for Kharif irrigation in the year of 1978-79 for an area of 253 ha.

The progress of potential created and irrigation utilised from 1975-76 to 1998-99 period has been shown in Table 3.7. From the table, it is very much clear that the potential created and utilisation has a big gap.

Table 3.7 : Barna Irrigation Project : Potential Created and Utilised

Year	Potential Created (Ha.)			Potential Utilised (Ha.)		
	Kharif	Rabi	Total	Kharif	Rabi	Total
1975-76	3200	4900	8100		5554.75	5554.75
1976-77	6380	9800	16180		9463.11	9463.11
1977-78	6930	10650	17580		7494.04	7494.04
1978-79	7320	11230	18550	253	11383.25	11636.25
1979-80	8130	12450	20580	309.85	1683.50	1993.35

1980-81	8700	13350	22050	271.14	14169.56	14440.70
1981-82	10540	16200	26740	44.11	15787	15831.11
1982-83	16950	26030	42980	830.50	22672	23502.50
1983-84	25140	33263	58403	50.18	27449	27499.18
1984-85	26700	33623	60323	356	24500	24856
1985-86	26887	33623	60510		24530	24530
1986-87	26887	33623	60510	178	24537	24715
1987-88	26887	33623	60510		21927	21929
1988-89	26887	33623	60510		27601	27601
1989-90	26887	33623	60510		31865	31865
1990-91	26887	33623	60510		32626	32626
1991-92	26887	33623	60510		33775	33775
1992-93	26887	33623	60510		32740	32740
1993-94	26887	33623	60510		34482	34482
1994-95	26887	33623	60510		33378	33378
1995-96	26887	33623	60510		34172	34172
1996-97	26887	33623	60510		35007	35007
1997-98	26887	33623	60510		34949	34949
1998-99	26887	33623	60510		33178	33178

3.8 DESIGN CROPPING PATTERN

The designed cropping pattern of project for left bank canal command and right bank command is shown in Table 3.8. The cropping pattern in Kharif has changed almost totally which cover about 70% of irrigated command area. The development of Kharif irrigation in both the canal system is almost nil even after tremendous increase in soybean cultivation. The summer irrigation is also nil in the command.

Table 3.8 : Designed Cropping Pattern for LBC and RBC Command

S. No.	Name of Cops	RBC (% of ICA)	LBC (% of ICA)
KHARIF :			
1	Paddy	30	10
2	Maize	7	7
3	Pulses	10	-
4	Vegetables	1	5
5	Fodder	2	-
6	Groundnut	2	-
7	Soybean	-	20
	TOTAL	52%	42%
RABI :			
8	Hyv Wheat	15	83
9	Local Wheat	30	-
10	Gram	5	-
11	Vegetable	2	-
	TOTAL	52%	83%

3.8.1 Kharif Cropping Pattern

The major emphasis was given to paddy crop of Kharif while designing the project. There was a provision of 30% paddy in the project design. On development of irrigation from Barna project, it is experienced that during Kharif the farmers have not come forwarded for paddy crop. The soybean which was not in existence at the time of preparation of project, has covered the area extensively. In fact for paddy cultivation, a particular type of table top level fields are needed where water can be stagnated to equal depth. The area of command is not of that type. Secondly for paddy cultivation, it needs very heavy machinery to prepare the heavy black soil fields for paddy crops. The soils are very much sticky and normally they can not be operated with any type of bullock drawn implements at one set of rows. Even the tractor drawn implements cannot work easily in these soils. Again after harvest of paddy, soil gets so hard that the bullock cannot break the soil tilh for Rabi cultivation.

It is also a point to consider that the farmers holding in Barna command are too big. There is acute shortage of labour at the time of sowing, weeding and harvest of crops. These may be the major reason for not coming up of paddy crop in Barna command. There is no other crop which can consume the irrigation available in Barna command during Kharif. All the other crops in the region do without irrigation during Kharif. The basic reason is that average rainfall in the command is about 1132 mm per annum.

The black soil of the area is heavy clayey and very deep. Water holding capacity of the soil is maximum that any of the soil can retain. As such normally no irrigation is required during Kharif season unless there is failure of rains during September month, i.e., at the time of maturity of Kharif crops. Hence protection irrigation is the only possibility for Kharif irrigation and that is also not every year.

The late harvesting of Soybean in 1st and 2nd fortnight of October delays the sowing of wheat crops in Rabi season. The late sowing of wheat crops is done by some farmers of the command in the December and results in low productivity. To overcome this problem, it is suggested by Agriculture Department to sow soybean before the onset of monsoon by taking presowing irrigation (Palewa), i.e., during 1st week of June. This will help in increasing the productivity of soybean and also helps in early and timely sowing of Rabi crop particularly wheat. The irrigation for pre-monsoon sowing of soybean has released on experimental basis, but farmers have not given proper response to it.

The Director agriculture M.P. Bhopal has also expressed his doubt about the success of soybean crop sown before the onset of monsoon. The soybean seeds are very delicate. Even while storage of the bags, if stacked one over the other, the seeds coat is damaged and germination is adversely affected. The germ plasm of soybean crop is also extremely soft and delicate. With pre-monsoon irrigation if soybean seed is sown, it may germinate but the scorching heat and high temperature around 45°C in Raisen District may kill at least damage the sprouted seeding and the plant population would be lost. In spite of that, Director agriculture, Bhopal has given advise to Research Wing of his department for sowing of pre-monsoon soybean on demonstration plot of 5 to 10 acres on different research stations.

3.8.2 Cropping Pattern of Rabi Season

The development of Rabi irrigation in the Barna command is satisfactory. The irrigation intensity of Rabi in the year of 1998-99 was 64% against the total intensity of project of 57%.

There is an acute shortage of water during peak demand in December and January month. Almost every year, while the canal runs with its full capacity and sometimes even more than design capacity. The reason is that the cultivators of head reaches take water for their 90% area while the tail enders get only for 30 to 40% area. The intensity can further increase and the farmers of the area desire for 100% irrigation intensity during Rabi. The canal structure is although designed for only 15% extra discharge. The detailed survey is needed for increase of canal capacity and it will require heavy fund for its construction. The water scarcity problem of Rabi irrigation can also be not solved even after increasing the canal capacity about 15% as 100% intensity can not be possible even after increase of capacity. Increasing the irrigation intensity will also increase the water logging problem of the project.

3.8.3 Summer Cropping Pattern

There is no provision of summer irrigation in the command of Barna project. There is sufficient water in the reservoir for about 25 to 30% summer irrigation in the command. The adoption of summer irrigation on such a large area will solve the problem of security of cattles by mutual cooperation among the farmers. Hence there is a great need of summer crop development in the command of the project.

3.8.4 Cropping Pattern Suggested by Different Committee

The designed cropping pattern of project could not be achieved till 1980. The main problem was the adoption of paddy. Hence to suggest a realistic cropping pattern, a state level committee in M.P. reviewed the cropping pattern in the year of 1986 and recommended the pattern given below :

S. No.	Name of Cops	Cropping Intensity (%)	Irrigation Intensity Q₀
KHARIF :			
1	Soybean	27	1.8
2	Jawar/Arhar/Soybean	5	13.4
3	Arhar	10	-
4	Jawar	5	-
5	Paddy	5	5.5
6	Groundnut	2	-
7	Vegetable	1	-
8	Fodder	2	-
9	Others	-	-
	Total Kharif	57	22.5
RABI :			
1	Wheat (Hvy)	15	15
2	Wheat (Local)	30	30
3	Gram	25	15
4	Linseed	2	-
5	Pea	2	-
6	Lentils	10	-
7	Others	2	-
	Total Rabi	86	60
	ANNUAL TOTAL	143	82.5

Farmers of the area did not follow the recommended cropping patern because of the utilisation of irrigation water during the Kharif could not be achieved as major area went under soybean and designed capacity of LBC and RBC has not been checked so as to accommodate the higher intensity of Rabi irrigation.

3.9 RESERVOIR WATER AUDIT STUDY FOR LAST 10 YEARS

The reservoir water balance study of Barna reservoir for the last ten years given in Table 3.9, shows that there is sufficient water in the reservoir after Rabi irrigation on 31st March as balance. The live storage capacity of reservoir at FRL 348.55 m is 455.80 M Cu.m. In the year 1997-98 and 1998-99, the reservoir live water balance on 31st March was 235 and 264 M Cum. respectively. The Rabi irrigation intensity during these years was 58% and 64% respectively.

The catchment of Barna reservoir receives good rain almost every year. After the monsoon is over the reservoir level in the month of October is at full reservoir level after the spill over, i.e., 348.55 m with live capacity 455.80 M Cum. The average consumption during 1997-98 and 1998-99 for Rabi irrigation was 290 M Cum. with average 61% intensity while the designed consumption during Rabi irrigation was 165 M Cum with 57% intensity. The average reservoir balance during 1997-98 and 1998-99 on 31st March was 250 M Cum.

The reservoir balance water on 31st March which is about 250 M Cum for normal year may be utilised for summer crops and this will increase the annual irrigation of command.

3.10 PATTERN OF WATER USE IN LAST 10 YEARS

The year wise seasonal consumption of water for irrigation from year 1989-90 to 1998-99 is shown in Table 3.10. There is no summer irrigation. The Kharif irrigation does not show any specific trend of development. The maximum 2% Kharif irrigation intensity has developed so far against designed 52%.

The delta of water at main canal head in Kharif irrigation for the year 1994-95 was 388 mm which is less than the project design delta of 567 mm of LBC and RBC command. At present the main crop sown in Kharif is soybean.

Table 3.9 : Water Audit Study for last 10 Years

S. No.	Year	Opening balance of reservoir month April (TMC)	Consume during summer Apr-May (TMC)	Balance live capacity on 1st June (TMC)	Water receipt during Jun-Sept. (TMC)	Water consumption during Jun-Sept. (TMC)	Kharif Irrigation (Ha.)	Balance as on 1st Oct. (TMC)	Water consumed during Rabi (TMC)	Rabi irrigation (Ha.)	Closing balance as on 31st March (TMC)
1	1989-90	0.14	-	0.14	0.30	0.0002	45	0.44	0.26	15790	0.180
2	1990-91	0.180	-	0.18	0.362	0.0032	830	0.539	0.314	22670	0.225
3	1991-92	0.225	-	0.225	0.314	0.0002	50	0.539	0.318	27450	0.221
4	1992-93	0.221	-	0.221	0.319	0.0015	360	0.539	0.317	24500	0.222
5	1993-94	0.222	-	0.222	0.317	-	-	0.539	0.317	24530	0.222
6	1994-95	0.222	-	0.222	0.317	0.0007	180	0.539	0.317	24540	0.222
7	1995-96	0.222	-	0.222	0.246	-	-	0.468	0.276	21930	0.192
8	1996-97	0.192	-	0.192	0.235	-	-	0.427	0.217	27600	0.210
9	1997-98	0.210	-	0.210	0.329	-	-	0.539	0.304	31860	0.235
10	1998-99	0.235	-	0.235	0.304	-	-	0.539	0.275	34480	0.264

TMC : Thousand Million Cubic Meter

Table 3.10 : Irrigation Water Use Pattern of Barna Project Last 10 Years

S. No.	Year	Seasonal Consumption of Water							
		Kharif				Rabi			
		Jun/Sept. Vol. (TMC)	Jun/Sept. Irr. Area (Ha.)	Irrgn. Intensity %	Delta (mm)	Oct/Mar Vol. (TMC)	Oct/Mar Irr. Area (Ha.)	Irrgn. Intensity %	Delta (mm)
1	1989-90	0.0002	45	-	444	0.26	15790	29	1645
2	1990-91	0.0032	830	2	385	0.314	22670	41	1385
3	1991-92	0.0002	50	1	400	0.318	27450	50	1158
4	1992-93	0.0015	360	1	416	0.317	24500	45	1293
5	1993-94	-	-	-	-	0.317	24530	45	1292
6	1994-95	0.0007	180	-	388	0.317	24540	45	1292
7	1995-96	-	-	-	-	0.276	21930	40	1258
8	1996-97	-	-	-	-	0.217	27600	50	786
9	1997-98	-	-	-	-	0.304	31860	58	954
10	1998-99	-	-	-	-	0.275	34480	64	797

TMC : Thousand Million Cubic Meter
Irr : Irrigated
Irrgn : Irrigation
Vol. : Volume

Consumption of Water as per Project Report

S. No.	Crops	Irrgn. Area (Ha.)	Irrgn. Intensity, %			Water Demand (TMC)	Delta at Field		Delta at Canal Head I/C 50% Losses	
			LBC	RBC	Total		LBC (mm)	RBC (mm)	LBC (mm)	RBC (mm)
1	Kharif	26900	42	52	52	0.102	378	378	567	567
2	Rabi	33620	83	52	57	0.165	489	489	733	733
	TOTAL	60510	125	104	112	0.267				

The Rabi irrigation intensity during 1989-90 to 1998-99 has grown from 29% to 64%. The cropping pattern of Rabi as per actual and in design has not changed much. The delta of water at main canal head in above years for Rabi irrigation shows decreasing trend with the increase of irrigation intensity. The maximum delta during the year 1989-90 for Rabi irrigation was 1645 mm with 29% irrigation intensity. The delta observed for Rabi irrigation in 1998-99 was 797 mm with 64% irrigation intensity against the design delta of 733 mm and 57% Rabi intensity.

3.10.1 The Project Efficiency

The overall project efficiency during the above year particularly for Rabi irrigation can also worked out by water use pattern to know the performance of the project in above years.

- The delta of water at field (NIR) for Rabi irrigation as per project design = 489 mm
- Delta at main canal head as per project design including 50% canal losses of w/c, minors distributary and main canal (GIR) = 733 mm

The designed project efficiency for Rabi irrigation

= NIR/GIR x 100 = 489/733 x 100 = 66.61 %

The actual observed project efficiency during the year 1998-99 may be calculated as

NIR/GIR x 100 = 489/797 x 100 = 63%

The development of Kharif irrigation in the command is almost nil. In Kharif only protective irrigation is taken some times during failure of rains for one or two watering to crops, therefore project efficiency for Kharif is not calculated.

The following assumptions made for future calculation of crop water requirement

(i)	Field application losses	=	20%
	Field application efficiency	=	80%
(ii)	w/c field channel losses	=	10%
	w/c efficiency	=	90%
(iii)	Canal losses in distributary Minor and sub-minor	=	8%
	Conveyance efficiency of distributary Minor and sub-minor	=	92%
(iv)	Main canal losses	=	5%
	Conveyance efficiency of main canal	=	95%

The overall project efficiency proposed for design

= 0.80 x 0.90 x 0.92 x 0.95

= 62.928

say 63%

3.11 OPERATION AND MAINTENANCE IN BARNA COMMAND

The maintenance is a continuous process for preserving the irrigation works in the same condition as contemplated in the original design so as to perform the intended function. In this connection all the canal network system up to outlet is looked after by division of Barna project at Bari District Raisen. The Chief Engineer operation and maintenance headquartered at Bhopal is the head of Barna project.

The maintenance of canal system in Barna command is not satisfactory. The whole canal networks system in general is unlined having black cotton expansive soil. The day to day and routine maintenance of system is carried out by department permanent labours, seasonal repairs particularly before monsoon and after monsoon is carried out by department's labours, casual labour and also through contract basis.

There is no silt deposition by running of canal as the storage reservoir itself traps the silt load of it's catchment area. But during monsoon, in deep cutting reaches heavy deposition of slipped earth is seen in canal bed. Removal of the slipped earth is necessary for running of canal for Rabi irrigation. The only available period for this is 1st September to 15th October as July, August are the heavy rainfall months, and canal normally opens from 16th October for Rabi irrigation.

Distributary, minors and sub-minors in filling reaches at some place have not sufficient free board and canal banks are not as per design. The main cause of this problem is erosion of soil during monsoon and continuous movement of cattles, human being and vehicles on canal banks, using it as service road. Bank raising and strengthening is necessary at these points.

Structures of canal networks system also needed periodic maintenance. Downstream of fall has been damaged due to high velocity, improper banks protection and improper energy dissipation arrangement.

Railing of VRB, DRB, signboards, chainage and kilometer stone and other structure in some places are damaged by mischievous local people.

Canal gates of minor which are steel plate and spindle rod type, have been damaged badly by farmers and about 70% minors gate are not functioning. The following are the main points to improve the operation and maintenance system of the project.

- Preparation of well planned yearly maintenance plan on the basis of annual inspection register and instruction given by the higher officers with available annual repair funds. Accordingly to yearly maintenance plan timely preparation of estimate and their sanction should be carried out. Most of the work should be done on contract basis by timely calling the tenders and fixing the agency.
- Revision of maintenance norms as per actual required maintenance expenditure in every three years is necessary or it should be based on current labour and material rates.

- Major earth work can be completed in shorter duration and in less cost by use of machines. The necessary major earth work of canal can be completed by machine hired from land development corporation, etc.
- Repairs of minor steel gates, repair of pitching or extension of protection arrangement on downstream of fall. Strengthening of bank of important reaches and other similar special work should be taken under special repairs.
- Outlet with permanent structures or APM system can be changed in modernisation programme or under Ayacut funds.
- It is seen that RCC Railing of DRB and VRB can be easily broken by mischievous persons. The damaged railing can be repaired by cement plastered brick work.
- The cooperation of local people and local administration is desirable to prevent the damage of canal and its structure, minor gates, etc. by mischievous persons.
- Regular visit of higher officers to the field site and their instruction will encourage the subordinate staff towards proper maintenance.
- The command area should be properly connected with wireless or walkie-talkie system so that the tail end positions of water distribution and breach if any can be controlled timely. Each sub-division should be connected with telephone so communication with higher office and public can be maintained for day to day events.
- One diesel jeep among the two sub-division is necessary for operation and maintenance of canal networks. As the present old jeep are not reliable and expensive too.
- Opening the canal for Kharif irrigation in the month of Jun/July should be carefully watched. The discharge in various canals should be increased very slowly to prevent the canal for breaches as there are number of cracks in black cotton in the summer season.

- The well planned operation plan for canal opening/closing in different season with all precautions should be approved by higher officers. A wide publicity through ratio, T.V. and circulating pamphlet of the operation plan among Panch and Sarpanch of concern Panchayat and Warabandi, Osrabandi in command is also necessary, so that cultivators can plan their farming activities in time and there is no chaos among farmers.
- Proper monitoring of operation plan of canal networks and its necessary revision is must during the season or in next season.

3.12 WATER LOGGING IN BARNA COMMAND

After effect of irrigation on agriculture is noticed everywhere in India. The problem of water logging, salinity, alkalinity is very common due to poor water management practices.

An area is said to be water logged when the water table rises to an extent where soil pores in the root zone of the crops becomes saturated resulting in restriction of normal circulation of air decline in the level of oxygen and increase in the level of carbon dioxide. The water table which is considered harmful depends upon the type of soil, crops, quality of water and fringe areas of water table which affect the upper layer of soil due to capillary action/evaporation.

The norms of Central Ground Water Boards in delineating the water logging is as below

(i)	Water logged areas	:	Water table within 2 m of land surface
(ii)	Potential areas for water logging	:	Water table between 2-3 mts below land surface
(iii)	Safe areas	:	Water table below 3 meters of land surface

In Barna command irrigation started in the year of 1975-76 and the problem of water logging was noticed from 1983 onwards in the area of Khiriya station. There were about 8 villages where water logging has been found and the depth of water table in the different years has been given in Annexure No. 2.

In some of the villages there is also a falling trend of water table. The falling trend in water table in these town is only because of private hand pumps, jet pumps, use of dug wells, some villages come in tail ends of distributary of command get hardly any irrigation due to tube well irrigation the water table has decreasing trend.

3.13 IRRIGATION PANCHAYAT , KOLABA SAMITTEE

3.13.1 Irrigation Panchayat

The farmers involvement in day to day work of irrigation water management, proper water distribution, maintenance of w/c and field channels, conflict resolution, irrigation revenue recovery and for implementation of Warabandi is very essential. To achieve all these, a provision of irrigation Panchayat has been made in M.P. irrigation act, 1931 (No. 3 of 1931) and in M.P. irrigation rules 1974, in the irrigated command area.

One irrigation Panchayat is to be formed for each village or for 1000 acre irrigated area. Each irrigation Panchayat having one Sarpanch and two or three Panch as decided by Executive Engineer of that command. They are elected for three years by prescribed election procedure. A man who had not deposited the irrigation revenue for more than three years cannot have a voting right of irrigation Panchayat and he cannot hold any official post. Irrigation Panchayat had given power to collect the revenue of their area and deposit the same in Government treasury or in irrigation sub-division of their area. An incentive of 3% will be given to irrigation Panchayat for deposition irrigation revenue of Rs. 1000/- and 2% for more than Rs. 1000/-. The amount will be distributed in proportion of irrigation revenue collected by Panch. Irrigation Panchayat can impose a fine for Rs. 50/- for canal offense.

The concept of irrigation Panchayat is very good but in the Barna command, their contribution to achieve the purpose was not satisfactory. There are about 70% farmers who had not paid the irrigation dues for more than three years. So they cannot vote for irrigation Panchayat and cannot hold any post of Panch and Sarpanch. Due to all these problems all the irrigation Panchayat in Barna command are inactive at present.

3.13.2 Kolaba Samittee

Canal outlet in local farmer language is known as Kolaba which may be of RCC hume pipe, APM block or any other type. The outlet capacity depend on the water supplied by it to the water course. In general the ouotlet capacity is 28 to 30 litre/sec. The outlet capacity also depend on the irrigated command covered by it.

The Kolaba Samittees are formed by farmers mutual understanding. Each outlet has its own Kolaba Samittee which will be handled by one farmer and three or four thokdar of thok to assist him. Sub-Engineers of water resources department have to take the initiation for meeting of farmers of each Kolaba to form a Kolaba Samittee. The President of Kolaba Samittee and their thokdar will be selected by mutual understanding of farmers. The selected President, thokdar and members will finally be approved by the Executive Engineers of that command. The term of Kolaba Samittee will be for two years. Future selection will be under the guidance of irrigation cooperative society of particular area.

The member of Kolaba Samittee should not be defaulter of irrigation revenue. One member will be for only one Kolaba whether he is having land in more than one Kolaba. Each Kolaba Samittee will look the following work :

- Maintenance of water course and field channel of their Chak.
- Implementation of Warabandi in their Chak.
- Conflict resolution if any.
- To co-operate with water resources department and irrigation cooperative society.
- To help the water resources department for the irrigation revenue recovery. The formation of Kolaba Samittee in Barna command is in progress.

3.14 IRRIGATION REVENUE RECOVERY IN MADHYA PRADESH AND IN BARNA COMMAND

Irrigation revenue recovery position of Madhya Pradesh is not satisfactory. There are arrears of Rs. 148 crores pending up to 31st March 1999 as shown in Table 3.14(a). The yearly demand of irrigation revenue recovery is about 51 crores. In the year of 1999-2000, the recovery was 71% because an order was issued by the Government to make an recovery as good as 100% otherwise since action will be taken against the sub-divisional officer. Hence SDO has recovered to some extent from the farmers but for achieving the target they have deposited the remaining dues from their own pocket. The recovery from the old demand was only 16%. The overall recovery during the year 1999-2000 was 30% of current and old demand. This position is achieved when Government of M.P. has exempted the penalty interest on old demand as per the order issued by Ministry of Water Resources, Madhya Pradesh Vide No. 23/2/93/Medium/31/Bhopal dated 31st Sept. 1994. This exemption was up to 30th June 1995. The irrigation revenue recovery of Barna command was also not satisfactory. In year 1999-2000 only 19% was recovered from current demand and only 5% was recovered from old demand. Overall 7% is recovered from the total demand of current and old.

The revenue recovery of Barna project in the year 1999-2000 is shown in Table 3.14(b).

Table 3.14(a) : Irrigation Revenue Recovery Position in Madhya Pradesh

(All Figures in Lakh Rupees)

S. No.	Chief Engrs. of W.R.D. of M.P	Demand on 1-4-1999 from old balance	Current demand of year 1999-2000	Total demand of year 1999-2000	Recovery from old balance 1-4-1999 to 31-3-2000	Recovery from current balance 1-4-1999 to 31-3-2000	Total recovery from 1-4-1999 to 31-3-2000	Net balance recovery on 31-3-2000	% Recovery		
									of old demand	of current demand	of total demand
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	All CE's of W.R.D. of M.P.	14792	5109	19901	2399	3621	6020	13881	16	71	30

Table 3.14(b) : Irrigation Revenue Recovery Position in Barna Command

(All Figures in Lakh Rupees)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	C.E. operation & mainte-nance BPL	341	36	377	18	7	25	342	5	19	7

3.15 IRRIGATION WATER TAX, IRRIGATION CESS & W/C / F.C. TAX IN M.P.

3.15.1 Irrigation Water tax

The present irrigation water rates in Madhya Pradesh has been enforced from date 1-10-84 vide M.P. Irrigation Department order no. 29/1/B/83/M.M. 31, Bhopal dated 5.11.84. The rates have been increased in the year 1992 vide order no. CR9/92/Medium/31/Bhopal dated 30th Sept., 1992. But due to some political causes, they were cancelled on 30th April 1993. Irrigation rates in Madhya Pradesh can be revised under the rule no. 37 of M.P. Irrigation Rule 1974 read with sub-section (2) of section 37 of M.P. Irrigation Act 1931 (No. 3 of 1931).

The present rates are on the area basis and crop wise. The rates for some important crops is maintained in Annexure 3.

The current water rates for industrial use from irrigation tanks and canal network has been enforced from 1st April 1991.

The water rates for industrial purpose is Rs. 0.63 per cumic meter.

The short term agreement is carried out with farmer in each season. The Allan is made by executive Engineer of the Irrigation Division in prescribed period for each season. On the application of farmers the agreement is made for different crops and area with normal demand rate. After lapse of agreement period, 10% extra rate have been charged up to one month for further agreement. Defaulter of irrigation water charges have no right to make the agreement. There is a rule for penal rates of 1.75 times for irrigation without agreement in case of general farmer and 1.25 times in case of SC/ST, small and marginal farmers.

Penalty at the rate of 10% is imposed for not depositing the irrigation charged within one year from the last date of deposition and 13% penalty is imposed for non-payment of irrigation charges more than one year of schedule date of deposition.

3.15.2 Irrigation Cess

- The irrigation cess at the rate of Rs. 25.00 per ha. is imposed for irrigated command area of canal network of tank and dam.

- In case of land given on lease for tank bed cultivation and in command of lift irrigation scheme of tubewell the irrigation cess is at the rate of Rs. 12.50 per ha.
- In case of area declared under water logging/saline or alkaline land, there will be no irrigation cess, till the reclamation does not take place.

3.15.3 Water Course/Field Channel Tax

The water course or field channel tax which are constructed by Government will be charged @ Rs. 10/- per ha. as per section 75C of the M.P. Irrigation Act 1931.

3.16 DEMOGRAPHIC FEATURES OF BARNA COMMAND

Barna project is a major irrigation project constructed in the Narmada valley in Raisen District of Madhya Pradesh. Two Tehsil, i.e., Bareli and Budni are benefitted by the project. Bareli Tehsil is benefitted by left bank canal system while Budni Tehsil is benefited by right bank canal system. The demographic features of Barna command is given below.

3.16.1 Demographic Features of Barna Command

1.	Gross command area	:	72000 ha
2.	Culturable command area	:	55000 ha
3.	Irrigable command area	:	60500 ha
4.	Total population	:	1,13,000
5.	Rural population	:	96500
6.	No. of cultivators	:	14,830
7.	No. of land holding	:	28,375
8.	Av. size of land holding	:	2 ha
9.	Av. land per cultivator	:	3.60 ha
10.	Population density	:	98 person/sq. km.
11.	No. of villages	:	198

3.17 SOCIO-ECONOMIC AND CULTURAL STATUS OF FARMERS

The socio-economic status and general living standard of farmers of Barna command has improved after coming of Barna project. The single Rabi crop in general was taken by cultivators before the project and their yield was also less as compared to present. The economic position of farmers has risen by adoption of double crops in a year with higher yield.

3.17.1 Size of Holding

The details of size of holding is given below :

The irrigable command area	:	60500 ha.
Total no. of land holding	:	28,375
Av. size of holding	:	2 ha

Size of holding in ha	Nos.	Percentage
0.0-0.5	1956	11.7
0.5-1.0	1082	6.5
1.0-2.0	2388	14.2
2.0-5.0	5637	33.6
5.0-10.0	4091	24.4
10.0-20.0	345	8.0
20.0-30.0	200	1.2
Above 30.0	70	0.4

3.17.2 Ownership Status

Farms are operated by land owners himself and in some cases are jointly operated with labour on Batai System. Subletting of the land to other cultivators is also observed. .

3.17.3 Crop Yield

Yield of crops is in tonnes/ha is given in the Table 3.17.3 below and it will reveal that the yields per ha of crops have gone up considerably high as compared to pre-irrigated period.

Table 3.17.3 : Yield of crops in tonnes per hectare

S. No.	Name of crops	Potential yield (T/ha)	Preproject yield (74-75) (T/ha)	Yield under different years (T/ha)			
				80-81	85-86	90-91	96-97
1	Soybean	2.00	0.38	0.65	0.80	0.90	1.00
2	Wheat Hyv	3.50	0.46	0.80	1.6	1.85	2.30
3	Gram	1.50	0.42	0.60	0.90	1.10	1.25

3.17.4 Farm Animal and Farm Power

1. In general farmer used the old traditional bullocks animal for land cultivation in the command area.
2. Nearly 1500 to 2000 four wheel tractors are used by medium and large farmers and 5 to 10 harvesters are also available in the command area.
3. Fodder is not an irrigated crop in the command, main source of fodder is gram, soybean and wheat.

3.17.5 Literacy

The literacy rate of command area is about 36% of rural population. Primary school are available to almost every village of command area. Sufficient number of middle school and higher secondary schools are also in the command area. While college level education is available at Raisen, Sehore, Bareli and Budni.

3.17.6 Language

Madhya Pradesh is Hindi speaking state of India. Hindi is official language of Madhya Pradesh, while local regional language similar to Hindi are also in the existence in rural and urban areas. Bundelkhandi touch in their local language is spoken in the various Tehsil of Raisen District.

3.17.7 Culture

Raisen District having culture of Bundelkhand. Some part of Raisen District having tribal culture also. Women of command area generally takes the responsibility to manage the house and their domestic animal. Women in rural and urban areas wear cotton sarees, parda system is also in existence in rural areas. Women of small, medium and large holding generally not participate in farming activities while women of marginal farmers take part in all farming activities.

Dowry system and caste system is also in existence in the rural areas. Case of child marriage is also not seen in the command area. Men of rural areas generally wear cotton traditional clothes but nowadays they are also using terricot clothes. All the male of farmers' families take full interest in their farming activities, while medium and large farmers mainly depend on labour and machining. Food habits of command area are similar to North India. Roti, Dal, Vegetable etc. are necessary for their meals. People of the command are very religious. They worship Hindu God and Goddess. There is one big temple of Hanuman and has lot of "Aastha" from people, so Government has kept Tuesday holiday for it instead of Sunday in the offices of command area. They also pray to river Narmada and take holy bath on different religious occasions.

3.18 INFRASTRUCTURE FACILITIES IN BARNA COMMAND

Efforts were made by CADA or the staff of the Agriculture department to extend agriculture developments to the farmers, train the officers and men for the job, train the farmers, arrange timely inputs, provide facilities for credit, marketing, ware housing and processing of produce to make agriculture more remunerative to the farmers.

3.18.1 Training of Officers and Farmers

Training of officers and farmers is an essential input for better farming and adoption of improved technology. It has been reported that as many as 35 agriculture department officers serving in Barna command area and 10000 farmers have so far been trained in various training camps. Besides these camps, WALMI Bhopal is also organising training of officers and farmers.

The staff of the Dy. Director (Agriculture), Senior Agriculture Development Officers, subject matter specialists, rural agriculture extension officers have been giving training to the farmer and the T & V system is being increasingly adopted in the command area. It has naturally raised the productivity of different crops in the command area including those of rainfed Kharif crops.

3.18.2 Agriculture Extension, Training of Farmers Field Demonstrations Adaptive Trials Etc.

The agriculture department staff and Asstt. Director Agriculture of Raisen District have been providing agriculture extension services for the introduction of the revised cropping pattern, use of HYV seeds, fertilizers and pesticides and two way communications system under the T & V system. They claim to have conducted field trials and held demonstration to convince the farmers of the advantages of the adopting full packages of practices advised by them. Due to these efforts, the yields per ha. of various crops in Barna command especially of soybean and wheat have registered considerable improvement. There were, however, indications of lack of sincerity in the implementation of the T & V programme in some of the areas even though it was carried out under the normal and plan activities of the agriculture department. No funding of such activities is done out of central assistance for the CAD programme. Needless, also to say that if the extension wing of CADA works sincerely there is vast potential of pushing up yields and agriculture production in the area through adoption of newer and simpler technologies (e.g. sowing the most suitable variety at the most appropriate time ensuring optimum plant population in the field, applying fertilizers, weedicides and pesticides in appropriate quantities at the right moment, applying irrigation timely and only in required measures.

The role of extension staff in this regard ought not to be under-estimated. The data show that there is a strong case for the development of summer crop in Barna command as the ample quantity of water is available at the beginning of the month of March and after the lining of main canal, the distributaries can be run by rotation during the summer months to provide irrigation to such crop.

3.18.3 Inputs

Improvements in agriculture yields has come about not only from the irrigation but also from the use of fertilizers, pesticides, improved varieties of seeds propagated by CADA officials who also tried to ensure their timely and adequate availability to the extent possible. This is reflected in the figures given in the table below.

Table 3.18.3 : Consumption of Fertilizers, Pesticides and Improved Seeds in Barna Command (Tonne)

Year	Fertilizers			Pesticides	Improved Seeds (Per 1000- ha)
	N	P	K		
1983	950	1178	25	12.0	24.5
1984	1100	1205	35	13.7	25.9
1985	1068	1155	41	15.3	38.3
1986	1200	1300	38	17.5	35.9
1987	1137	1230	40	16.7	45.3
1988	1260	1395	55	18.5	48.4
1990	1178	1437	50	19.4	53.2
1992	1250	1535	70	18.3	60.2
1994	1325	1625	80	12.5	58.7
1996	1350	1665	85	25.4	60.0
1998	1375	1690	91	26.2	60.8

3.18.4 Credit

Short term credit to farmers in the form of seeds, fertilizers and pesticides, etc., is made available from 27 distribution centres of the cooperative sector as many as 15 private agencies are also operating in the command area for sale of fertilizers and pesticides against cash. The input demands are examined by the Agriculture Department at the District level. The inputs are supplied to the farmers through cooperative societies or in the open market by private license holders.

Apart from such inputs lending/sale, various banks also provide long and medium term input for land development, purchase of equipments, etc. Amongst the banks performing such services in the Barna command area are :

- United Commercial Banks
- State Banks of India
- Central Banks
- Central Cooperative Banks
- Kshetriya Gramin Banks and
- Land Development Banks

3.18.5 Farm Equipments

Earlier the farmers in the Barna command area were using the age old agricultural equipments, viz., wooden plough and "bakkhar" mostly drawn by bullocks but now quite of them are using modern equipment like tractors, harvesters combines, thrashers, winnowers, sprayers and dusters, etc. Their prosperity is reflected in their way of living, food habits, clothing and illumination and feasting on ceremonial occasions like birth, marriage, etc. The increase in the number of farm equipment and machinery is shown below :

Farm Equipment and Machinery	Year		
	1980	1990	1999
Tractors	40	1500	2000
Ploughs	-	64	150
Seed drills	42	1520	2050
Plant Protection Equipments	110	2050	3500

3.18.6 Agriculture Wages

The wages of agriculture labour have also risen from Rs. 5/- per day to Rs. 40/- per day in almost a decade. In semi urban areas, it is even Rs. 50/- per day during sowing and harvesting seasons. Local labour not being easily available now, labourers are brought for sowing and harvesting from distant Districts like Betul, Jhabua and have to be paid at least 2 months in advance for ensuring their availability.

3.18.7 Feeder and Link Roads in Barna Command

For enabling the farmers to carry their produce to the nearby mandis round the year a network of roads has been constructed in the command area by P.W.D. under CADA's umbrella. The total length of the roads in the command thus constructed so far is 25 km. Even though 69 km length of roads is yet to be completed and still many more link roads would be required in the command. There has been considerable improvement in the communication networks. This has helped the farmers in the disposal of their produce.

3.18.8 Availability of Markets

The farmers of Barna command area generally take their produce to Piparia, Mandi-deep, Diwanganj, Obeidulla ganj, Salamat pur, Raisen and Bhopal by trucks and tractor trollies for sale through the traders. There are three Krishi Upaj Mandis in the command area namely at Bari, Bareli and Shahganj; considerable improvement is reported to have been effected in the facilities available in the three mandis. Besides weekly markets are also held at Bari, Bareli, Bakhatara, Amaravad-Kalan and Dobi providing marketing avenues to the farmers. Farmers have, by and large, been able to get fairly good competitive biddings in these mandis even though traders are often known to gang up against them for, and often succeed in, getting the prices lowered. However, small farmers with poor withholding capacity, are generally forced to sell their produce to the local traders or the village bania at quite low prices as a condition precedent to giving them loans for farming and other purposes including social obligations.

3.18.9 Godowning and Ware-housing Facility

There are two godowns of cooperative marketing federation and two godowns of ware-housing cooperation. Total storage capacity of these godowns is about 4000 MT which appears to be adequate for the time being. However, small and marginal farmers are still not able to take full advantage of marketing and ware-housing facilities.

3.18.10 Agro-Processing/Agro-Industries

There are no Agro processing industries in Barna command area yet except a Dalia producing plant now being set up by the M.P. State Agro-industries Cooperation on Bari-Bakhtara Road. At present, very little or no summer or perennial crops are grown in the area. By adopting groundwater use as a supplement resource, they can grow summer moong or green fodder for cattle. If such practices are adopted agro-based industries, dairy farming, Gur or Khandsari manufacture etc. can be developed in the command area with considerable economic advantage.

During field surveys one of the reasons given by the cultivators for not adopting sugarcane cultivation was non-existence of any sugar factory around. The cartage of sugarcane to Sehore sugarcane factory nearest to Barna command, would be very costly and un-economic.

3.18.11 Farm Incomes

The farmers of the command area have been getting higher profits from irrigated farming and their economic status has also risen gradually. The results could perhaps have been much better but for the poor educational background of the farmers and large scale "Batai" system of cultivation because of which the tenant farmer has no incentive to invest in land development etc. Prior to CAD programme, the living standards were reflected in the size of holdings mainly, the bigger farmers having a higher standard of living and spending conspicuously while the marginal and small farmers were forced by poor productivity and poor incomes to a pitiable and poor standard of living. From 1975-76, the year from which canal irrigation commenced in the Barna command, almost all categories of farmers started taking interest in irrigated farming and a few in double cropping wherever possible and growing some Hyv of crops which gradually resulted in increased intensity of cropping and in almost doubling the income of most of the farmers.

Chapter 4

DESCRIPTION OF D-1 DISTRIBUTARY OF RBC SYSTEM

4.1 INTRODUCTION

Barna project is a major irrigation project situated in Bari block of Bareli Tehsil in Raisen District. The common canal takes off from right saddle of the main dam from which right and left bank main canals take off.

The distributary (D-1) of right bank canal is about 5.34 km long having a discharge of 3.155 cumecs. It takes off at RD 2970 from right bank canal. The bed slope of the canal is 1:2500, 1:2100 and 1:3000 with friction factor 0.05 as there is soil available in bed and free board adopted is 0.60 m.

There are 6 nos. of structures on the D-1 distributary, out of which 3 nos. are VRBs, 2 Nos. are fall and 1 No. VRB cum head regulator..

4.2 SALIENT FEATURES OF (D-1) DISTRIBUTARY

1.	Location	:	OF takes at RD 2970 in RBC
2.	Design discharge	:	3.155 cumecs (111.40 cusecs)
3.	Velocity	:	0.65 m/sec
4.	Side slope	:	1.5 : 1
5.	Ground level	:	334.05 m
6.	Bed level	:	333.35 m
7.	Full supply level	:	334.45 m
8.	Free board	:	0.60 m
9.	bed width	:	3.10 m
10.	Top width of		
	Right bank	:	4.90 m
	Left bank	:	1.75 m
11.	Design irrigated command area	:	8052 ha

12.	Length of distributary	:	5.34 km
13.	Nos. of minor	:	3
14.	Total length of minor	:	16.65 km
15.	Length of canal service road	:	2.62 km
16.	No. of villages benefitted	:	33
17.	Duty of distributary head	:	0.41/Lit/sec/ha
18.	Total nos. of structures on distributary	:	6
	(a) Village road bridge	:	3 (CH21, CH74.5, CH141
	(b) Head regulator cum VRB	:	1 (CH0)
	(c) Falls	:	2 (CH120, CH151)

4.2.A Design Cropping Pattern and Irrigation Intensity

The designed cropping pattern and irrigation intensity is as per the right bank canal system is shown in Table 3.8 enclosed.

4.3 DESIGN CROP WATER REQUIREMENT

The crop water requirement of the design cropping pattern was assessed as per Director of Agriculture, M.P. Bhopal at the time of formulation of project is given in Table 3.3.3.

4.4 DEVELOPMENT OF IRRIGATION

The development of Kharif irrigation in the command of D-1 distributary is almost nil against the 52% designed irrigation intensity. Cropping pattern in Kharif has changed almost totally due to adoption of soybean as main crops during Kharif. Only protective irrigation is taken by farmers in the event of failure of monsoon during Kharif.

The development of Rabi irrigation in the command is shown in Table 4.4.

Table 4.4 : Development of Rabi Irrigation in D-1 Distributary

S. No.	Year	Wheat		Gram		Others		Total	
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
1	1995-96	3570	42	1100	13	70	3	4740	58
2	1996-97	4410	52	1360	16	90	3	5860	72
3	1997-98	4260	51	1520	18	-	-	5780	69

There is no provision for summer irrigation in project design of Barna command. The development of summer crops by private source of irrigation is also almost nil.

4.5 VILLAGE WISE IRRIGATION IN (D-1) DISTRIBUTARY

The village wise culturable command area and irrigation by (D-1) distributary of RBC system of Barna command can be seen in Table 4.5 for the Rabi irrigation in the year 1995-96, 1996-97 and 1997-98. From the table, it can be clear that the irrigation intensity during Rabi in all the year of tail portion is quite less as compared to middle and head reaches.

4.6 GENERAL MAINTENANCE STATUS OF (D-1) DISTRIBUTARY

The general maintenance status of (D-1) distributary is not satisfactory. A lot is desired in the maintenance of distributary. The present norms of funds (Rs. 50/- per ha/year) for maintenance of canal is grossly inadequate, and thus improperly and ineffectively used. It needs to be revised at least to Rs. 200/- per ha/year and it also needs to be ensured that funds provided for maintenance are used judiciously.

For want of adequate maintenance, the unlined section of distributary have eroded and deformed. The erosion of side slopes has resulted in the silting of canal bed. This has reduced the discharging capacity of various minors of the D-1 distributary and there is encroachment on free board if designed discharge is passed in the channels.

Table 4.5 : Villagewise Irrigation by (D-1) Distributary of RBC System

S. No.	Name of Village	CCA (Ha)	Rabi irrigation in years					
			1995-96		1996-97		1997-98	
			ha	%	ha	%	ha	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(A) Head Reach								
1	Bari Khurd	233	144	62	157	67	153	66
2	Babai	555	364	66	356	64	377	68
3	Rani Purakhurd	227	158	70	160	70	154	68
4	Bamhori Bajeerganj	24	16	67	19	79	24	100
5	Surwara	107	62	61	81	80	82	81
6	Jahanpur	97	59	61	75	77	67	69
7	Ootiyan	267	162	61	224	84	138	52
8	Chaupan Madhaya	113	85	75	93	82	81	72
9	Kanwar	206	150	73	171	83	194	94
10	Mankapur	1115	702	63	750	67	795	71
11	Waman wada	45	45	100	45	100	38	84
	TOTAL	2983	1947	67	2031	69	2103	71
(B) Middle Reach								
12	Bans Pipliya	324	153	47	169	52	172	54
13	Semri ghat	81	41	51	380	48	43	53
14	Dimada	530	217	41	260	49	323	61
15	Kat Kashri	77	38	49	40	52	45	58
16	Patni	227	122	54	137	60	83	37

Contd..

Villagewise Irrigation by (D-1) Distributary of RBC System (Contd...)

(1)	(2)	(3)	Rabi irrigation in years					
			1995-96		1996-97		1997-98	
			(4)	(5)	(6)	(7)	(8)	(9)
17	Bhisthi	128	55	43	62	48	74	58
18	Kothari	287	152	53	148	52	146	51
19	Mophalwara	713	385	53	397	55	422	59
20	Ghurela	261	122	46	129	49	134	51
21	Khurpatni	83	34	41	42	50	53	63
22	Samnapur Kochi	328	192	58	189	56	200	58
	TOTAL	3039	1511	47	1611	52	1695	54
(c) Tail Reach								
23	Bagroda	113	32	28	34	30	29	26
24	Berkhedi	174	39	22	44	25	54	31
25	Dandiya	196	51	26	57	29	59	30
26	Chandpura Khurd	154	43	28	46	30	45	29
27	Dubtalai	332	70	21	86	26	97	29
28	Jamunia	182	33	18	46	25	51	28
29	Gehalpur	97	23	24	25	26	29	30
30	Pal Kashri	530	133	25	143	27	170	32
31	Jaitpura	324	91	28	94	29	107	33
32	Pipaliya Khaki	81	24	29	24	30	26	32
33	Bamhori Modi	150	42	28	42	28	47	31
	TOTAL	2333	581	27	641	28	714	32

All the structures of distributary and minors required minors repairs. The down stream of all the falls are damaged badly due to insufficient protective arrangement for energy dissipation. Pitching or lining at the downstream of each fall upto a length of about 15 m will be helpful to protect the bank from excessive erosion.

Outlet of the distributary and minors having no permanent structures. RCC hume pipes of different diameter as per their command are just burried in bank for the supply of water to water course. Tempering of outlet, lowering the level of outlet, providing extra outlet are very common in the command of the distributary. Almost all the steel gates provided in the minors of the distributary are out of order. They are generally damaged by the farmers. There are few reaches of the channels where there is excessive seepage. Fortunately, now lining is being done.

The maintenance norms of Barna command has not been revised for the last more than 15 years. At present yearly maintenance grant is not able to meet all the necessary maintenance works of the command.

4.7 CONVEYANCE FACILITIES

The command of the sub-division of (D-1) distributary of RBC system of Barna command spreads over an area of about 8000 ha. Presently proper conveyance facilities are not available. Vehicles with officers have become old now. Provision to replace 4 nos. jeeps for this purpose has been made.

Presently the service roads along the (D-1) from CH0 to 175 (5.32 km) have been provided but the condition of the above service road is very poor and cannot be made use of during rains and soon after rains. It is not possible to repair the service road from annual maintenance funds. It is proposed to upgrade the service roads by providing 0.30 m thick moorum on the roads of distributary which will improve the bearing capacity of road sub-grade as the soil used in canal banks is clayey. Thus a proper conveyance facility is desirable for ensuring equitable distribution of water and solve other management problem of the command.

4.8 PROCEDURE FOR OPERATION AND MANAGEMENT

For seasonal irrigation programme, the District Water Utilisation Committee headed by the Collector of concerned District hold the metting at District head quarter. Concerned MLA and the Executive Engineer W.R. Department are the members of the committee. Looking to the water available, the committee decides the area to be irrigated and schedules of running of canals. Cultivators also hold meeting with Ex. Engr and agriculture officers to advice the cultivators about the particular crops recommended for the season. In these meetings, names of villages that can be given water and number of waterings are also discussed and in consultation with the cultivators through irrigation Panchayat, the detailed programme for opening and closing of different canals is finalised.

After the announcement of the irrigation programme, short term agreement with each land holder is drawn by the authorised staff of the department and water required is supplied to the cultivators as per program fixed. But due to inadequate canal capacities supply of water as per declared programme fails. There is no operation plan. Once the canal is open it is closed only when the cultivators refuse to take water. All the distributaries and minors are operated simultaneously. Discharge is regulated by keeping in view the demand reported by field staff and cultivators. Minors in head reach get adequate water while in the tail minors the discharge is either inadequate or no water reaches to the tail minors at all. The cultivators in head reach take more water than those in the tail. There is no equitable distribution. At the time of peak demand, tail reaches of minor or distributaries are rotated and even discharge more than the designed is passed encroaching up on the free board. Due to absence of night irrigation more discharge is demanded during the day and correspondingly wasted at night.

4.9 LIFT IRRIGATION IN COMMAND OF D-1 DISTRIBUTARY

The head and the middle reach farmers of the distributary take irrigation to their field by lifting the canal water. The practice of irrigating in the out command has increased due to free electricity up to 5 HP motor/pumps. The tail end of command is getting reduced quantity of water year by year. Regarding lift irrigation schemes in the command, there is two LIS proposed in the LBC command for an area of 1550 ha, out of which no one is under working. No LIS has been proposed in the command of RBC system of Barna project.

4.10 USE OF GROUND WATER IN THE COMMAND OF D-1 DISTRIBUTARY

There are few tubewells for irrigation in the middle and tail reaches. Ground water is abstracted for irrigation purposes during the dry season from dug wells and tube wells and most of the times by the farmers of tail reaches as they are not getting required quantity of water. Diesel or electricity driven centrifugal pumping sets of 3 HP to 5 HP are used for lifting water from the dug wells. 5 HP to 7 HP submersible pumps are used to extract water from tubewells.

4.11 IRRIGATION REVENUE RECOVERY

The irrigation revenue recovery position in the command of (D-1) distributary is about 22%. About 42 lakhs irrigation recovery is outstanding in the sub-division. Most of the head and middle reaches farmers are influential and are not cooperating to the department for paying their legal irrigation dues. However, poor and tail enders have been seen to deposit their irrigation dues as far as possible. The political leaders of the command are not cooperating for improving of the irrigation revenue recovery.

4.12 DISCHARGE MEASUREMENT DEVICES/STRUCTURES

There are no measuring devices anywhere in the canal system. Discharge in individual distributaries and minors are calculated by gate opening and differential head method. It is contemplated to construct standing wave flumes in all the distributaries and riplogal flumes in minors and sub-minors.

4.13 SOCIO-ECONOMIC DEVELOPMENT

The living standards of the command has improved after the coming up of the Barna project. They had adopted the two cropping pattern of Kharif and Rabi in a year. Their crop's yields have also increased in comparison to pre-project period. Most of them are adopting the mechanised cultivation using tractors, harvestors, thrasher etc. Use of Hvy seeds and fertiliser are also very common in the command. Although the farmer participation in equitable distribution by farming irrigation cooperative society, Kolaba Sammittee is needed in the command area. Head and middle cultivators are not cooperating to department and also to tail enders. The feeling of responsibility regarding payment of irrigation revenue, implementation of Warabandi, adoption of suitable irrigation methods, proper training for cultivation is desirable in the command.

Chapter 5

SCOPE OF THE STUDY AND METHODOLOGY

5.1 SCOPE OF THE STUDY

The present study covers the existing status of the Barna project in Madhya Pradesh, the efficiency of the project, an evaluation of the role and impact of the Command Area Development Authority in achieving the objectives for which it was set up especially in promoting optimum utilisation of the irrigation potential created by the project and in promoting command area development activities. The identification of Irrigation Management problems is essential in the effective functioning of a project and the manner in which these problems could be over come if existing therein any. It also attempts to pinpoint the causes of the various water management problems which can be avoided discretely while formulating such projects in future, not only in Madhya Pradesh but elsewhere also in the country.

5.2 METHODOLOGY

The methodology adopted for the study of various management problems has been enumerated in the coming paragraphs. To start with, data regarding the project, and pre-project conditions was collected from the secondary sources, i.e., from the different departments of the state government and from other published and unpublished sources. Since no bench mark surveys had been conducted in the command area in the pre project period, no data pertaining to there could be available neither they could be collected from the field at this stage.

The socio economic status of farmers of Barna command has improved after the coming up of barna irrigation project. The single Rabi crop in general was taken by cultivators before the inception of the project with low yield, as comapred to the present. The economic position of the farmers has improved by adoption of double crops of Kharif and Rabi with higher yield. In spite of the above development the project is facing the following water management problems :

- Under utilisation of reservoir storage
- Inequitable distribution of water in canal system head to tail
- Water logging
- Poor recovery of irrigation revenue.

The detailed study regarding project design, reservoir balance position, irrigation development in different seasons, present cropping pattern, operation and maintenance status of command, water logging, revenue recovery, etc. has been presented in Chapter 3. The inequitable distribution of canal water from head to tail has been discussed in Chapter 4.

Methodology for the above management problem in brief is described in the following paragraphs.

5.2.1 Under Utilisation of Reservoir Storage

Under utilisation of reservoir storage is mainly due to non achievement of designed annual irrigation in the command. It has been found out by making the study of the water balance in the reservoir. For this purpose a chart has been prepared yearwise for finding out the balance of the water available in the reservoir on 31st March after the Rabi irrigation by considering the balance of the reservoir in the month of April to June, water receipt during June to Sept., water consumption during June to Sept., water required for Kharif and Rabi irrigation.

The above study for the period of 1989-90 to 1998-99 can be seen in Table 3.9. From the study of the observations of the table, it has been concluded that there is sufficient water in the reservoir after the Rabi irrigation on 31st March as balance. The live storage capacity of reservoir at FRL 348.55 m is 0.455 TMC and in the year of 1997-98 & 1998-99 the reservoir live water balance on 31st March was 0.235 and 0.264 TMC respectively. The catchment of Barna reservoir receives good rain almost every year. After the monsoon is over the reservoir level in the month of October is at full reservoir level after spillover, i.e., 348.55 m with live capacity 0.455 TMC. The average consumption during 1997-98 and 1998-99 for Rabi irrigation was 0.290 TMC with average 61% intensity while the designed consumption during Rabi irrigation was 0.165 TMC with 57% intensity. The average balance during 1997-98 and 1998-99 on 31st March was 0.250 TMC. The reservoir balance water on 31st March which is about 0.250 TMC for normal year may be utilised for summer crops and this will increase the annual irrigation of the command.

The full utilisation of reservoir storage in the Barna command could not be achieved due to the following reasons :

(i) Low crop water requirement in Kharif

(ii) Change of Kharif cropping pattern.

(iii) Non development of summer irrigation.

5.2.2 Inequitable Distribution of Water

In equitable distribution of water from head to tail is very common in the Barna project command. For estimating the above facts the (D-1) distributary of right bank canal system of Barna project has been selected for the study. The (D-1) distributary has been divided into three groups, viz., head reach, middle reach and tail reach as shown in Table 4.5. It is observed while seeing the table that the distribution of irrigation in head, middle and tail reaches are not equitable. The irrigation intensities of head reach, middle reach and tail reach is worked out and it is found that it is higher in head reach than to middle and tail reach and higher in middle reach than to tail reach, which shows that there is no equitable distribution of water from head to tail. Irrigation in head reach is recorded 70%, 53% in middle reach while in tail reach it is recorded only 37%.

The causes of inequitable distribution may be following ones :

(i) Poor role of irrigation Panchayat in solving the conflicts for farmers and distributions of irrigation beyond the outlets.

(ii) Allowing the lift irrigation from the canal.

(iii) Non-implementation of Warabandi and Osrabandi.

(iv) Inadequate numbers of discharge measurement devices/structures in canal system.

(v) Canal outlet having no permanent structures, tempering of outlets, increasing the designed diameter of the pipe.

(vi) Insufficient maintenance grant.

(vii) Lack of telecommunication system and conveyance facilities.

(viii) Wasteful use of irrigation by head reaches and avoiding irrigation during night by cultivators.

5.2.3 Water Logging

After effect of irrigation on agriculture is noticed everywhere in India. The problem of water logging is very common due to poor water management practices.

An area is said to be water logged when the water table rises to the extent where soil pores in the root zone of the crops becomes saturated resulting in restriction of normal circulation of air and decline in the level of oxygen and increase in the level of carbon dioxide.

In the command where the problem of water logging occurred have been examined by making auger holes and depth of water from the ground surface level was been measured and the area which is water logged has been marked with the help of following norms, followed by Central Groundwater Board :

(i) Water logged areas : Water table within 2 m of land surface

(ii) Potential areas of water logging : Water table between 2-3 mts.

(iii) Safe areas : Water table below 3 mts.

In Barna command irrigation started in the year of 1975-76 and the problem of water logging was noticed from 1985 onwards in some parts of the command. There were about 8 villages where water logging has been found. Area affected by water logging in these villages separately and depth of water table in these areas have been enclosed as Annexure 4. A study of water tables of 8 villages for pre-monsoon and post-monsoon in different years have been carried out from the data of the Annexure 2. This shows that there is a rising trend of water table in both the season since 1985. The post monsoon water table in each year is naturally higher than pre-monsoon water table as the average rainfall in the command is about 1132 mm per year. It can be seen from the table that for the year of 1995 and 2000 the depth of water table is almost coming to a constant value.

From the study of the table, it is observed that the 4 villages which are having more areas affected by the water logging are situated in the head reaches of the command whereas the other 4 villages near to the tail ends of the commands have less area under water logging. It is concluded that due to over irrigation in the head reaches above situation has arised.

Causes of water logging :

- The borrow pits both side of canal in filling reaches are constant source of recharging the ground water during the rains and irrigation period.
- Less use of ground water by tube wells/dug wells, particularly by head reaches farmers and in general in whole command.
- Non implementation of Warabandi, avoiding night irrigation in general, excess irrigation by head reaches farmers.
- Poor drainage system and its maintenance as the natural drains are infested with weeds and silt, etc.
- Non-adoption of various methods of irrigation like border, Chak basin and furrow as per the topography and types of crops.

- The canal network system including water course and field channel are unlined in Barna command.

5.2.4 Poor Recovery of Irrigation Revenue

In the M.P. Irrigation Department, the irrigation revenue is decided and collected by the Irrigation Department itself. The record of irrigation revenue is kept or prepared by the Chief Engineer basin wise and finally the same is being sent to the Engineer-in-Chief of the Department.

The status of irrigation revenue in Madhya Pradesh in general and Barna command in particular has already been discussed in Chapter 3. From the study of the Table No. 3.14(b) it looks that position of irrigation revenue recovery is not satisfactory in Barna command. In 1999-2000 only 19% is recovered by current demand and only 5% is recovered from old demand. Overall 7% is recovered from the total demand of current and old arrears. There is about 3.52 crores in the balance to be recovered on 31.3.2000 in Barna command.

The causes of low irrigation revenue recovery in Madhya Pradesh and specially in Barna command project are the following :

- Irrigation revenue in Madhya Pradesh is collected by the Water Resources Department. In spite of several attempts and personal contacts to farmers, it's position is not improving. Government has given additional power of Tehsildar's to Asstt. Engineers for collecting the revenue, but implementation of these powers is almost nil due to non-cooperation of politicians and influential farmers.
- Government has wave-off the penalty on irrigation dues so many times. There is general thinking of farmers that one day their irrigation dues will also be waved-off by Government.
- Penalty on irrigation dues is of fixed nature. There is no incremental or compound interest based penalty on old dues.
- There is no training for how to use and implement the various powers of additional Tehsildar on field. There is also no training for implementation of

M.P. Irrigation Act 1931 and M.P. Irrigation Rules 1974. Sub-Engineer, Amins and even officer do not know about the various section and sub-section of the act.

- Government has not shown any inclination to discourage the defaulter by other indirect means. There is no such rule to disallow the defaulter from taking the irrigation water or distributary/minor having more than 50% defaulter will remain closed for irrigation as in the case of State Electricity Board.
- there is no such ban for taking loan from Bank contesting local body election or restriction for purchase of land for defaulter of irrigation dues.
- Farmers having large holding and influential farmers not cooperative with the Department. Almost all of them are big defaulters. Small and poor farmers normally come forward to pay the irrigation dues in time. But medium farmer followed the large farmers attitude. There is no fear and feeling of responsibility to pay the irrigation dues among the large farmers.
- Department has not studied or followed the procedure adopted by the other state like Uttar Pradesh, Haryana and Punjab where dues fixed by Irrigation Department are collected by the revenue Department, so the Irrigation revenue recovery is very high and sometimes it touches to 100% also.

Chapter 6

CROP WATER REQUIREMENT FOR PROPOSED CROPPING PATTERN

6.1 GENERAL

The crop water requirement has not been calculated in the project design as per modern practice. The cropping pattern of Kharif has transformed totally by adoption of soybean as major crops. The development of Kharif irrigation in Barna command is also almost nil, as there is sufficient rains to meet the Kharif crops requirement. Only protective irrigation is taken by farmers during Kharif in the time of failure of rains. The reservoir has also huge live storage balance in the end of Rabi irrigation. Thus summer irrigation is the only possibility to utilise the reservoir storage and increase the irrigation in Barna command. To assess the correct cropping intensity of summer, Kharif and Rabi, the following key point has been considered for proposed cropping pattern.

1. The canal capacity of LBC and RBC system is considered as per project design and there is no need to increase the canal capacity of any system. Only necessary maintenance of design section is desirable.
2. Adopting the Kharif cropping intensity same as per project design considering the soybean as single crop of kharif, i.e., taking 52% soybean in RBC system and 42% in LBC system.
3. The duty of water at outlet head of RBC is higher than duty of LBC head. The present Rabi cropping pattern adopted by farmers is based on wheat and gram as main crops. The proposed intensity for LBC and RBC system for Rabi is 85% and 70% as shown in Table 6.3(a) and 6.3(b), respectively.
4. The project efficiency is considered only 63% of 66.6% of project design. The efficiency/losses at various level is shown in Chapter No. 3.

5. The summer moong (Green gram) has been considered as single summer crop having 60 days crop period. The summer moong is sown in 2nd fortnight of March. The cropping intensity of summer moong comes out to be 44% and 32% respectively for LBC and RBC systems by considering all the above factors.

6. The crop water requirement has been calculated considering evapotranspiration E_{TO} by modified Penman method. The month wise climatological data for the Barna command (Hoshangabad) has been collected from Indian Meteorological Department, Nagpur (Maharashtra) for a period of 1984 to 1999 as shown in Annexure 5. Monthly and daily E_{TO} for the above data has been worked out and is indicated in Table 6.1(b), whereas the abstract of E_{TO} computation is at Table 6.1(a). The same is being used for the calculation of crop water requirement for the proposed cropping pattern in the Barna command. Value of crop factor for different crops at different growing period, first planting fortnight has also been taken as per the FAO24 and M.P. Irrigation Department design series tech. circular no. 25 (issued vide memo no. 205/BODHI/R&C/TC/11/88 dated 20/6/90.

7. Water requirement for land preparation, i.e., presowing (Palewa) requirement is taken 75 mm for Kharif and 60 mm for Rabi and summer crops in the fortnight prior to sowing.

8. Soil moisture may be available if all the water from rainfall or previous irrigation is not used by plants and not fully lost in deep percolation. For the purpose of estimating the crop water requirement and irrigation requirement it is customary to assume the soil moisture contribution, also referred as soil moisture adjustment equal to the consumptive use E_{TO} during the last one or two fortnights before harvest depends upon the type of crop. Soil moisture contribution is thus deductible from the CWR, while estimating the irrigation water requirement.

9. Period of canal maintenance is also available for adopting the proposed cropping pattern. The May to June 2nd fortnight and October are the total closure period of canal system necessary maintenance work can be executed during these periods.

10. he proposed cropping pattern has been checked with reservoir simulation study on preparing the reservoir working table as shown in Table 6.4(a) to 6.4(f) for the period 1975-76 to 90-91. The dependability of crop success for Rabi, Kharif and summer in LBC system is 87%, 87% and 80%, respectively, while for RBC system for Rabi, Kharif and summer is 80% each which is quite satisfactory for adopting of the proposed cropping pattern.

6.2 PROPOSED CROPPING PATTERN AND IRRIGATION INTENSITY OF BARNA COMMAND

The proposed cropping pattern of the Barna command is given in Table 6.2(a).

Table 6.2(a) : Proposed Cropping Pattern

Kharif crop intensity %			Rabi crop intensity %			Summer crop intensity %		
Name of crop	LBC	RBC	Name of crop	LBC	RBC	Name of crop	LBC	RBC
Soybean	42	52	Wheat HYV	70	60	Green gram	44	32
			Gram	15	10			
Total	42	52	Total	85	70	Total	44	32

The proposed irrigation intensity for the above cropping pattern is given below in Table 6.2(b).

Table 6.2(b) : Proposed Irrigation Intensity

System	Irrigation intensity %			
	Rabi	Kharif	Summer	Annual
LBC	85	42	44	171
RBC	70	52	32	154
Total Project	75.42	48.39	36.33	160.14

By adoption of the above cropping pattern, the design annual irrigation intensity of project will increase from 112% to 160.14%. Although Kharif irrigation has less possibility for development but full importance has been given to Kharif irrigation. While calculating the CWR, the intensity of Kharif is also kept same as at the time of project design. Summer irrigation will definitely improve the annual irrigation of Barna project and full utilisation of storage will be achieved. By adoption of three crops in a year the socio-economic status of the farmers of area will be improved.

6.3 CROP WATER REQUIREMENT FOR PROPOSED CROPPING PATTERN

The crop water requirement of proposed cropping pattern is calculated on the basis of M.P. Irrigation Department TC No. 25. In which E_{TO} has been assessed by modified Penman method. The detailed calculation for CWR of soybean, wheat, gram and green gram has been shown in Table 6.3(i) to 6.3(vii). The abstract of CWR for different months has been given in Table 6.3(a) and 6.3(b) respectively for LBC and RBC system.

6.4 RESERVOIR SIMULATION STUDY

To check the proposed cropping pattern, crop water requirement and evaporation losses has been simulated for the period 1975-76 to 1990-91. The monthly inflow data of the above period were collected on physical observation basis and they are more reliable for study. The project design is also based on these data. The overflow has been considered as excess of inflow during the monsoon, crossing the reservoir FRL 348.55 m at capacity 0.539 TMC. The dead storage at 338.1 m with capacity 0.083 TMC has been considered for checking the empty position of reservoir. The simulation study of the reservoir is shown in working table for the period of 1975-76 to 1990-91 in Table 6.4(a) to 6.4(f).

The position of short fall during the above period (15 years, i.e., 1975-76 to 1990-91) for proposed cropping pattern is summarised in statement in Table 6.4(g). The dependability of Rabi, Kharif and summer crops for LBC comes out to be 87%, 87% and 80%, respectively, while for RBC it comes out to be 80% each of the crops. These results are quite satisfactory for adoption of proposed cropping pattern.

TABLE NO. 6.1(a)

ABSTRACT

COMPUTED YEARLY REFERENCE CROP EVAPOTRANSPIRATION (Eto)

BY MODIFIED PANMAN METHOD

(All figures are in mm)

S.NO.	YEAR	JAN	FEB	MAR	APRL	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1	1984	113.77	129.64	201.19	225.6	270.94	228.3	97.65	94.86	72.90	136.71	105.9	97.34	1774.8
2	1985	114.70	129.92	189.41	236.1	275.28	228.0	125.55	90.83	102.60	156.55	117.3	101.06	1867.3
3	1986	115.63	134.96	204.69	215.4	252.34	199.2	118.42	91.14	140.10	139.50	108.0	107.88	1827.26
4	1987	115.94	136.36	201.81	230.4	287.06	213.3	113.46	91.14	112.80	151.28	114.9	109.43	1877.88
5	1988	115.32	142.39	216.38	219.0	261.33	228.3	131.44	132.99	154.50	167.40	117.9	101.06	1988.01
6	1989	111.29	141.12	190.34	213.0	286.13	214.8	149.11	106.02	166.20	168.02	109.8	108.19	1964.02
7	1990	125.55	159.88	177.63	222.6	283.34	222.3	119.04	101.37	126.00	165.23	126.9	80.29	1910.13
8	1991	108.50	130.20	209.56	208.5	272.80	210.3	107.88	104.47	148.20	150.04	111.6	110.36	1872.41
9	1992	119.60	136.30	190.96	231.6	264.12	210.6	99.82	99.51	117.60	161.82	101.1	102.30	1835.33
10	1993	117.80	124.32	199.64	220.2	288.92	156.6	130.51	87.73	68.10	162.13	126.6	113.77	1796.32
11	1994	104.40	141.68	194.99	225.6	276.83	144.9	95.79	89.59	131.70	137.33	116.4	106.64	1765.85
12	1995	111.91	133.28	194.99	213.6	278.69	177.0	140.74	91.45	153.60	140.12	114.9	106.95	1857.23
13	1996	117.80	136.59	201.81	233.4	307.21	192.0	106.33	90.83	93.30	149.73	123.0	94.86	1846.86
14	1997	119.04	143.64	198.09	244.5	279.00	227.7	115.94	104.47	158.70	135.16	118.2	99.51	1943.95
15	1998	109.12	126.56	194.06	237.6	290.16	211,8	108.50	96.72	113.10	135.78	118.8	103.85	1846.05
16	1999	114.08	127.68	188.17	237.3	289.23	182.1	129.27	101.99	135.60	167.40	105.0	106.33	1884.15
	AVERAGE.	114.65	135.90	197.10	225.90	278.96	202.95	118.09	98.44	124.68	151.51	114.76	103.11	1866.10
	DAILY Eto (mm/day)	3.69	4.85	6.35	7.53	8.99	6.76	3.80	3.17	4.15	4.88	3.82	3.32	5.11

TABLE NO. 6.1(b)

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1984

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.700	26.600	35.100	38.600	40.400	37.100	29.900	29.500	27.800	29.300	27.500	23.900
2	Min. air temperature in o C.	10.900	10.500	17.500	21.500	25.100	24.900	22.900	22.900	21.900	18.200	14.700	9.300
3	Mean air temperature in o C.	18.300	18.550	26.300	30.000	32.750	31.000	26.400	26.200	24.850	23.750	21.100	16.600
4	Saturation vapour pressure (ea) in mbar	21.000	21.300	34.230	42.400	49.620	44.900	34.440	34.020	31.410	29.370	25.050	18.920
5	Max.relative humidity (RH Max.%)	61.000	43.000	23.000	22.000	34.000	63.000	87.000	88.000	93.000	70.000	60.000	53.000
6	Min.relative humidity (RH Min.%)	38.000	25.000	12.000	13.000	24.000	42.000	77.000	78.000	83.000	55.000	46.000	37.000
7	Mean.relative humidity (RH Mean.%)	29.500	34.000	17.500	17.500	29.000	52.500	82.000	83.000	88.000	62.500	53.000	45.000
8	Actual vapour pressure (ed) = ea*RHMean/100	10.390	7.240	5.990	7.420	14.380	23.570	28.240	28.230	27.640	18.350	13.270	8.510
9	Vapour pressure dedicit (ea-ed) in mbar	10.610	14.060	28.240	34.980	35.240	21.330	6.200	5.790	3.770	11.020	11.780	10.410
10	Weighing factor (W)	0.670	0.670	0.750	0.786	0.811	0.796	0.760	0.758	0.744	0.733	0.707	0.652
11	(1-W)	0.330	0.330	0.250	0.214	0.189	0.204	0.240	0.242	0.256	0.267	0.293	0.348
12	Cloud cover in oktas	2.900	1.600	0.900	1.500	2.700	4.200	7.800	7.600	7.800	3.100	2.200	2.300
13	Ratio n/N	0.660	0.790	0.860	0.800	0.680	0.530	0.300	0.060	0.030	0.640	0.730	0.720
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.090	7.830	9.570	10.050	9.630	8.485	4.356	4.424	3.858	7.323	6.733	6.106
16	Rns = 0.75 Rs	4.560	5.870	7.170	7.530	7.220	6.360	3.267	3.318	2.893	5.492	5.049	4.579
17	Function of temperature f(T).	14.260	14.310	15.960	16.700	17.380	16.950	15.980	15.940	15.610	15.350	14.820	13.920
18	Function of vapour pressure f(ed).	0.198	0.223	0.232	0.222	0.176	0.122	0.108	0.108	0.111	0.148	0.183	0.214
19	Function of sunshine duration f(n/N)	0.698	0.811	0.878	0.820	0.710	0.580	0.130	0.158	0.130	0.680	0.760	0.750
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	1.970	2.588	3.250	3.040	2.170	1.199	0.224	0.272	0.225	1.544	2.061	2.234
21	Net radiation Rn = Rns-Rnl in mm/day	2.590	3.282	3.920	4.490	5.050	5.161	3.043	3.046	2.668	3.948	2.988	2.345
22	Average wind speed in km/day	105.600	105.600	117.600	129.600	165.600	184.800	158.400	139.200	108.000	69.600	69.600	88.800
23	Average wind speed in m/sec	1.220	1.220	1.360	1.500	1.910	2.130	1.830	1.610	1.250	0.800	0.800	1.020
24	Wind function f(u) =0.27(1+u/100)	0.550	0.550	0.580	0.629	0.717	0.768	0.697	0.645	0.561	0.450	0.450	0.500
25	Adjustment factor 'c'	1.004	0.976	0.924	0.922	0.986	1.022	0.942	0.945	0.963	1.046	0.965	0.941
26	W*Rn mm/day	1.735	2.198	2.940	3.529	4.095	4.108	2.312	2.308	1.984	2.893	2.112	1.528
27	(1-W)*f(u)*(ea-ed)	1.921	2.551	4.094	4.633	4.775	3.341	1.037	0.903	0.541	1.324	1.553	1.811
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.670	4.630	6.490	7.520	8.740	7.610	3.150	3.060	2.430	4.410	3.530	3.140
29	**Monthly Eto (mm/month)**	**113.770**	**129.640**	**201.190**	**225.600**	**270.940**	**228.300**	**97.650**	**94.860**	**72.900**	**136.710**	**105.900**	**97.340**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR -1985

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.500	27.700	32.500	37.600	40.700	37.800	31.200	27.300	29.500	30.400	27.300	25.400
2	Min. air temperature in o C.	8.200	12.400	16.100	20.900	24.800	26.100	23.400	22.600	21.800	16.000	14.200	11.700
3	Mean air temperature in o C.	16.350	20.050	24.300	29.250	32.750	31.950	27.300	24.950	25.650	23.200	20.750	18.550
4	Saturation vapour pressure (ea) in mbar	18.620	23.470	30.370	40.675	49.620	47.460	36.330	31.600	32.930	28.440	24.520	21.300
5	Max.relative humidity (RH Max.%)	55.000	62.000	41.000	38.000	38.000	57.000	82.000	88.000	86.000	45.000	44.000	65.000
6	Min.relative humidity (RH Min.%)	32.000	32.000	21.000	22.000	20.000	32.000	72.000	78.000	73.000	42.000	33.000	44.000
7	Mean.relative humidity (RH Mean.%)	43.500	47.000	31.000	30.000	29.000	44.500	77.000	83.000	79.500	38.500	38.500	54.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.090	11.030	9.410	12.200	14.380	21.110	27.970	26.220	26.170	10.940	9.440	11.600
9	Vapour pressure dedicit (ea-ed) in mbar	10.530	12.440	20.960	28.473	35.240	26.350	8.360	5.380	6.760	17.500	15.080	9.700
10	Weighing factor (W)	0.649	0.696	0.739	0.782	0.811	0.805	0.769	0.745	0.752	0.728	0.703	0.670
11	(1-W)	0.351	0.304	0.261	0.218	0.189	0.195	0.231	0.255	0.248	0.272	0.297	0.330
12	Cloud cover in oktas	0.800	1.600	2.600	1.300	2.500	4.400	6.800	7.770	6.600	1.400	2.400	3.600
13	Ratio n/N	0.870	0.790	0.690	0.820	0.700	0.510	0.180	0.040	0.210	0.810	0.710	0.590
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	7.199	7.830	8.377	10.203	9.798	8.320	5.588	4.266	5.169	8.415	6.623	5.455
16	Rns = 0.75 Rs	5.399	5.872	6.282	7.652	7.348	6.240	4.191	3.199	3.876	6.311	4.967	4.091
17	Function of temperature f(T).	13.870	14.600	15.475	16.550	17.387	17.187	16.160	15.637	15.812	15.240	14.750	14.310
18	Function of vapour pressure f(ed).	0.219	0.194	0.205	0.189	0.176	0.134	0.110	0.118	0.119	0.195	0.205	0.192
19	Function of sunshine duration f(n/N)	0.886	0.811	0.722	0.840	0.730	0.560	0.264	0.140	0.290	0.830	0.740	0.632
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.691	2.297	2.290	2.627	2.233	1.289	0.469	0.258	0.545	2.466	2.237	1.736
21	Net radiation Rn = Rns-Rnl in mm/day	2.708	3.575	3.992	5.025	5.115	4.951	3.722	2.941	3.331	3.845	2.730	2.355
22	Average wind speed in km/day	112.800	96.000	122.400	134.400	170.400	189.600	153.600	144.000	120.000	74.400	79.300	96.000
23	Average wind speed in m/sec	1.300	1.110	1.410	1.550	1.970	2.190	1.770	1.660	1.380	0.860	0.910	1.110
24	Wind function f(u) =0.27(1+u/100)	0.574	0.529	0.600	0.632	0.730	0.781	0.684	0.658	0.594	8.470	0.483	0.529
25	Adjustment factor 'c'	0.956	1.036	0.982	1.003	0.986	0.951	0.969	0.949	0.979	1.003	0.958	0.998
26	W*Rn mm/day	1.757	2.488	2.950	3.929	4.148	3.985	2.862	2.191	2.504	2.799	1.919	1.577
27	(1-W)*f(u)*(ea-ed)	2.121	2.000	3.282	3.922	4.862	4.012	1.320	0.902	0.995	2.237	2.163	1.693
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.700	4.640	6.110	7.870	8.880	7.600	4.050	2.930	3.420	5.050	3.910	3.260
29	**Monthly Eto (mm/month)**	**114.700**	**129.920**	**189.410**	**236.100**	**275.280**	**228.000**	**125.550**	**90.830**	**102.600**	**156.550**	**117.300**	**101.060**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1986

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.500	30.300	33.300	37.400	40.300	37.300	31.300	28.700	30.400	31.900	29.900	25.900
2	Min. air temperature in o C.	9.100	13.500	16.500	20.600	24.900	25.100	23.500	22.800	21.000	18.400	16.600	10.900
3	Mean air temperature in o C.	16.800	21.900	24.900	29.000	32.600	31.200	27.400	25.750	25.700	25.150	23.250	18.400
4	Saturation vapour pressure (ea) in mbar	19.160	26.250	31.510	40.100	49.220	45.440	36.540	33.120	33.030	31.985	28.520	21.160
5	Max.relative humidity (RH Max.%)	51.000	51.000	33.000	34.000	30.000	64.000	83.000	91.000	78.000	60.000	60.000	55.000
6	Min.relative humidity (RH Min.%)	32.000	27.000	16.000	21.000	17.000	42.000	67.000	81.000	61.000	39.000	45.000	34.000
7	Mean.relative humidity (RH Mean.%)	41.500	39.000	24.500	27.500	23.500	53.000	75.000	86.000	69.500	49.500	52.500	44.500
8	Actual vapour pressure (ed) = ea*RHMean/100	7.950	10.230	7.710	11.020	11.560	24.080	27.400	28.480	22.950	15.832	14.973	9.416
9	Vapour pressure dedicit (ea-ed) in mbar	11.210	16.010	23.791	29.080	37.660	21.360	9.140	4.640	10.080	16.153	13.547	11.744
10	Weighing factor (W)	0.654	0.715	0.745	0.781	0.810	0.798	0.770	0.753	0.753	0.747	0.728	0.672
11	(1-W)	0.346	0.285	0.255	0.219	0.190	0.202	0.230	0.247	0.247	0.253	0.272	0.328
12	Cloud cover in oktas	2.100	1.600	1.500	3.200	2.300	5.700	7.400	7.500	4.800	3.200	2.800	2.900
13	Ratio n/N	0.740	0.790	0.800	0.630	0.720	0.340	0.090	0.070	0.470	0.630	0.670	0.660
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.510	7.830	9.152	8.734	9.961	6.919	4.849	4.503	7.062	7.259	6.404	5.805
16	Rns = 0.75 Rs	4.880	5.870	6.864	6.550	7.470	5.189	3.636	3.377	5.296	5.444	4.803	4.353
17	Function of temperature f(T).	13.960	14.980	15.620	16.500	17.350	16.730	16.180	15.837	15.825	15.687	15.250	14.280
18	Function of vapour pressure f(ed).	0.220	0.198	0.221	0.194	0.192	0.120	0.113	0.107	0.125	0.161	0.170	0.205
19	Function of sunshine duration f(n/N)	0.770	0.811	0.820	0.670	0.750	0.410	0.182	0.166	0.526	0.670	0.706	0.698
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.364	2.405	2.830	2.144	2.498	0.823	0.332	0.281	1.040	1.692	1.830	2.043
21	Net radiation Rn = Rns-Rnl in mm/day	2.516	3.465	4.034	4.406	4.972	4.366	3.304	3.096	4.256	3.752	2.973	2.310
22	Average wind speed in km/day	124.800	100.800	120.000	124.800	160.800	180.000	163.200	148.800	105.600	64.800	60.000	100.800
23	Average wind speed in m/sec	1.440	1.160	1.380	1.440	1.860	2.080	1.880	1.720	1.220	0.750	0.690	1.160
24	Wind function f(u) =0.27(1+u/100)	0.606	0.540	0.594	0.600	0.700	0.756	0.710	0.670	0.550	0.440	0.430	0.540
25	Adjustment factor 'c'	0.934	0.977	1.000	0.989	0.902	0.985	0.948	0.951	1.023	0.980	0.961	0.960
26	W*Rn mm/day	1.645	2.477	3.000	3.441	4.027	3.484	2.544	2.332	3.204	2.802	2.164	1.552
27	(1-W)*f(u)*(ea-ed)	2.350	2.463	3.603	3.821	5.008	3.261	1.492	0.767	1.369	1.798	1.584	2.080
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.730	4.820	6.603	7.180	8.140	6.640	3.820	2.940	4.670	4.500	3.600	3.480
29	**Monthly Eto (mm/month)**	**115.630**	**134.960**	**204.690**	**215.400**	**252.340**	**199.200**	**118.420**	**91.140**	**140.100**	**139.500**	**108.000**	**107.880**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1987

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.300	29.100	35.700	37.700	40.700	37.400	30.200	27.000	30.400	32.400	27.200	26.300
2	Min. air temperature in o C.	8.800	12.100	18.600	23.300	23.700	24.400	22.100	21.800	21.400	18.300	12.000	10.200
3	Mean air temperature in o C.	17.050	20.600	27.150	30.500	32.200	30.900	26.150	24.400	25.900	25.350	19.600	18.250
4	Saturation vapour pressure (ea) in mbar	19.460	24.300	36.000	43.650	48.140	44.650	33.910	30.560	33.410	32.360	22.840	20.950
5	Max.relative humidity (RH Max.%)	50.000	39.000	27.000	27.000	34.000	56.000	86.000	88.000	82.000	51.000	39.000	46.000
6	Min.relative humidity (RH Min.%)	28.000	21.000	15.000	16.000	15.000	39.000	70.000	80.000	69.000	35.000	28.000	30.000
7	Mean.relative humidity (RH Mean.%)	39.000	30.000	21.000	21.500	24.500	47.500	78.000	84.000	75.500	43.000	33.500	38.000
8	Actual vapour pressure (ed) = ea*RHMean/100	7.589	7.290	7.560	9.380	11.790	21.200	26.440	25.670	25.220	13.910	7.650	7.960
9	Vapour pressure dedicit (ea-ed) in mbar	11.871	17.010	28.440	34.270	36.350	23.450	7.470	4.890	8.190	18.450	15.190	12.990
10	Weighing factor (W)	0.656	0.702	0.767	0.791	0.807	0.795	0.757	0.740	0.755	0.749	0.690	0.669
11	(1-W)	0.344	0.298	0.233	0.209	0.193	0.205	0.243	0.260	0.245	0.251	0.310	0.331
12	Cloud cover in oktas	1.400	1.800	1.000	1.300	1.500	4.800	7.300	7.500	6.300	2.400	2.000	0.500
13	Ratio n/N	0.810	0.770	0.850	0.820	0.800	0.470	0.100	0.070	0.250	0.710	0.750	0.900
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.884	7.708	9.504	10.203	10.614	7.990	4.972	4.503	5.460	7.773	6.842	7.000
16	Rns = 0.75 Rs	5.163	5.781	7.128	7.652	7.960	5.990	3.729	3.377	4.095	5.829	5.131	5.250
17	Function of temperature f(T).	14.010	14.720	16.130	16.825	17.250	16.925	15.930	15.500	15.875	15.737	14.520	14.250
18	Function of vapour pressure f(ed).	0.222	0.223	0.222	0.206	0.191	0.134	0.117	0.120	0.120	0.180	0.221	0.220
19	Function of sunshine duration f(n/N)	0.830	0.796	0.870	0.840	0.820	0.526	0.190	0.166	0.330	0.740	0.780	0.910
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.581	2.612	3.115	2.911	2.701	1.192	0.354	0.308	0.628	2.096	2.502	2.852
21	Net radiation Rn = Rns-Rnl in mm/day	2.582	3.169	4.013	4.741	5.259	4.798	3.375	3.069	3.467	3.733	2.629	2.398
22	Average wind speed in km/day	105.600	105.600	124.800	139.200	168.000	187.200	168.000	129.600	124.800	72.000	69.600	76.800
23	Average wind speed in m/sec	1.220	1.220	1.440	1.610	1.940	2.160	1.940	1.500	1.440	0.830	0.800	0.880
24	Wind function f(u) =0.27(1+u/100)	0.550	0.550	0.606	0.645	0.723	0.775	0.723	0.619	0.606	0.464	0.457	0.477
25	Adjustment factor 'c'	0.952	0.972	0.918	0.918	0.995	0.944	0.948	0.962	0.982	0.989	0.967	0.968
26	W*Rn mm/day	1.693	2.224	3.077	3.750	4.240	3.814	2.554	2.271	2.617	2.796	1.814	1.604
27	(1-W)*f(u)*(ea-ed)	2.245	2.787	4.015	4.619	5.072	3.725	1.312	0.786	1.215	2.148	2.151	2.050
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.740	4.870	6.510	7.680	9.260	7.110	3.660	2.940	3.760	4.880	3.830	3.530
29	**Monthly Eto (mm/month)**	**115.940**	**136.360**	**201.810**	**230.400**	**287.060**	**213.300**	**113.460**	**91.140**	**112.800**	**151.280**	**114.900**	**109.430**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1988

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	26.500	28.800	32.900	37.400	39.800	38.200	32.000	31.400	31.100	33.700	29.900	25.200
2	Min. air temperature in o C.	11.800	11.800	16.400	21.400	24.800	25.800	23.100	22.500	21.000	18.600	14.700	11.100
3	Mean air temperature in o C.	19.150	20.300	24.650	29.400	32.300	32.000	27.550	26.950	26.050	26.150	22.300	18.150
4	Saturation vapour pressure (ea) in mbar	22.210	23.850	31.030	41.020	48.410	47.600	36.850	33.590	33.700	33.910	26.910	20.810
5	Max.relative humidity (RH Max.%)	52.000	39.000	26.000	35.000	27.000	59.000	83.000	83.000	76.000	50.000	52.000	62.000
6	Min.relative humidity (RH Min.%)	33.000	23.000	15.000	26.000	18.000	36.000	58.000	64.000	55.000	32.000	39.000	47.000
7	Mean.relative humidity (RH Mean.%)	42.500	31.000	20.500	30.500	22.500	47.500	70.500	73.500	65.500	41.000	45.500	54.500
8	Actual vapour pressure (ed) = ea*RHMean/100	9.439	7.390	6.360	12.510	10.890	22.610	25.970	24.680	22.070	13.900	12.240	11.340
9	Vapour pressure dedicit (ea-ed) in mbar	12.771	16.460	24.670	28.510	37.520	24.990	10.880	8.910	11.630	20.010	14.670	9.470
10	Weighing factor (W)	0.683	0.699	0.742	0.783	0.808	0.806	0.771	0.765	0.756	0.757	0.719	0.668
11	(1-W)	0.317	0.301	0.258	0.217	0.192	0.194	0.229	0.235	0.244	0.243	0.281	0.332
12	Cloud cover in oktas	3.700	0.900	1.700	2.700	1.800	4.100	7.000	6.100	4.100	0.600	1.400	2.500
13	Ratio n/N	0.580	0.860	0.780	0.680	0.770	0.540	0.150	0.280	0.540	0.890	0.810	0.700
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	5.675	8.255	9.011	9.121	10.369	8.564	5.339	6.162	7.571	8.923	7.165	6.000
16	Rns = 0.75 Rs	4.256	6.191	6.758	6.840	7.770	6.423	4.000	4.621	5.678	6.692	5.373	4.500
17	Function of temperature f(T).	14.430	14.660	15.562	16.580	17.275	17.200	16.240	16.090	15.900	15.930	15.060	14.230
18	Function of vapour pressure f(ed).	0.205	0.223	0.120	0.187	0.195	0.126	0.120	0.120	0.130	0.180	0.188	0.193
19	Function of sunshine duration f(n/N)	0.624	0.878	0.804	0.710	0.796	0.590	0.240	0.354	0.590	0.902	0.830	0.730
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	1.845	2.870	1.501	2.201	2.681	1.278	0.466	0.683	1.219	2.586	2.349	2.000
21	Net radiation Rn = Rns-Rnl in mm/day	2.411	3.321	5.257	4.639	5.089	5.145	3.534	3.938	4.459	4.106	3.024	2.500
22	Average wind speed in km/day	120.000	98.400	115.200	120.000	172.800	192.000	148.800	134.400	112.800	67.200	67.200	81.600
23	Average wind speed in m/sec	1.380	1.130	1.330	1.380	2.000	2.220	1.720	1.550	1.300	0.770	0.770	0.940
24	Wind function f(u) =0.27(1+u/100)	0.594	0.530	0.580	0.594	0.730	0.788	0.671	0.632	0.574	0.451	0.451	0.490
25	Adjustment factor 'c'	0.919	0.989	0.920	1.000	0.900	0.956	0.966	0.990	1.031	1.019	0.976	1.016
26	W*Rn mm/day	1.646	2.321	3.900	3.632	4.110	4.146	2.724	3.012	3.371	3.108	2.174	1.670
27	(1-W)*f(u)*(ea-ed)	2.404	2.650	3.691	3.674	5.258	3.820	1.671	1.323	1.628	2.192	1.859	1.540
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.720	4.910	6.980	7.300	8.430	7.610	4.240	4.290	5.150	5.400	3.930	3.260
29	**Monthly Eto (mm/month)**	**115.320**	**142.390**	**216.380**	**219.000**	**261.330**	**228.300**	**131.440**	**132.990**	**154.500**	**167.400**	**117.900**	**101.060**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1989

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.700	30.800	33.100	38.400	40.200	37.200	33.500	28.900	31.400	34.800	29.100	25.900
2	Min. air temperature in o C.	10.600	14.000	15.900	21.300	25.200	25.500	24.200	22.400	20.600	18.800	16.200	10.300
3	Mean air temperature in o C.	18.150	22.400	24.500	29.850	32.700	31.350	28.850	25.650	26.000	26.800	22.650	18.100
4	Saturation vapour pressure (ea) in mbar	20.810	27.080	30.750	42.050	49.490	45.840	39.750	32.930	33.600	35.280	27.500	20.740
5	Max.relative humidity (RH Max.%)	59.000	47.000	29.000	25.000	37.000	59.000	76.000	86.000	68.000	38.000	56.000	49.000
6	Min.relative humidity (RH Min.%)	39.000	25.000	18.000	17.000	17.000	43.000	59.000	74.000	53.000	24.000	42.000	31.000
7	Mean.relative humidity (RH Mean.%)	49.000	36.000	23.500	21.000	27.000	51.000	67.500	80.000	60.500	31.000	49.000	40.000
8	Actual vapour pressure (ed) = ea*RHMean/100	10.190	9.740	7.220	8.830	13.360	23.370	26.830	26.340	20.320	10.930	13.470	8.290
9	Vapour pressure dedicit (ea-ed) in mbar	10.620	17.340	23.530	33.220	36.130	22.470	12.920	6.590	13.280	24.350	14.030	12.444
10	Weighing factor (W)	0.668	0.720	0.741	0.794	0.810	0.789	0.780	0.752	0.756	0.764	0.722	0.667
11	(1-W)	0.332	0.280	0.259	0.206	0.190	0.211	0.220	0.248	0.244	0.236	0.278	0.333
12	Cloud cover in oktas	1.900	1.300	1.000	2.000	1.300	4.500	6.600	7.100	3.300	1.500	2.900	1.800
13	Ratio n/N	0.760	0.820	0.850	0.750	0.820	0.500	0.210	0.130	0.620	0.800	0.660	0.770
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.621	8.012	9.504	9.662	10.777	8.235	5.832	4.977	8.153	8.346	6.345	6.356
16	Rns = 0.75 Rs	4.965	6.000	7.128	7.246	8.082	6.176	4.374	3.732	6.114	6.259	4.758	4.767
17	Function of temperature f(T).	14.230	15.080	15.525	16.670	17.375	17.037	16.470	15.812	15.900	16.060	15.130	14.230
18	Function of vapour pressure f(ed).	0.199	0.202	0.223	0.211	0.183	0.123	0.115	0.118	0.138	0.195	0.182	0.217
19	Function of sunshine duration f(n/N)	0.788	0.840	0.870	0.780	0.840	0.550	0.290	0.220	0.660	0.820	0.698	0.796
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.231	2.558	3.012	2.743	2.670	1.152	0.549	0.410	1.448	2.567	1.922	2.457
21	Net radiation Rn = Rns-Rnl in mm/day	2.734	3.442	4.116	4.503	5.412	5.024	3.825	3.322	4.666	3.692	2.836	2.310
22	Average wind speed in km/day	108.000	103.200	120.000	124.800	165.600	177.600	158.400	139.200	105.600	69.600	72.000	93.600
23	Average wind speed in m/sec	1.250	1.190	1.380	1.440	1.910	2.050	1.830	1.610	1.220	0.800	0.830	1.080
24	Wind function f(u) =0.27(1+u/100)	0.561	0.548	0.594	0.606	0.710	0.749	0.697	0.645	0.550	0.450	0.460	0.520
25	Adjustment factor 'c'	0.944	0.981	0.922	0.920	0.998	0.954	0.970	0.964	1.045	1.004	0.954	0.945
26	W*Rn mm/day	1.826	2.478	3.049	3.575	4.383	3.963	2.983	2.498	3.527	2.820	2.047	1.540
27	(1-W)*f(u)*(ea-ed)	1.977	2.660	3.619	4.147	4.873	3.551	1.981	1.054	1.782	2.585	1.794	2.154
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.590	5.040	6.140	7.100	9.230	7.160	4.810	3.420	5.540	5.420	3.660	3.490
29	**Monthly Eto (mm/month)**	**111.290**	**141.120**	**190.340**	**213.000**	**286.130**	**214.800**	**149.110**	**106.020**	**166.200**	**168.020**	**109.800**	**108.190**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD
FOR THE YEAR - 1990

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.100	31.600	32.400	37.400	41.100	37.300	31.200	28.200	29.400	33.000	30.400	25.300
2	Min. air temperature in o C.	8.000	13.300	16.800	20.600	24.600	25.200	23.500	22.100	21.000	17.800	14.900	14.900
3	Mean air temperature in o C.	16.550	22.450	24.600	29.000	32.850	31.250	27.350	25.150	25.200	25.400	22.650	20.100
4	Saturation vapour pressure (ea) in mbar	18.860	27.160	30.940	40.100	49.890	45.570	36.430	31.980	32.080	32.460	27.500	23.550
5	Max.relative humidity (RH Max.%)	42.000	32.000	47.000	27.000	27.000	61.000	83.000	90.000	80.000	45.000	43.000	83.000
6	Min.relative humidity (RH Min.%)	23.000	16.000	28.000	12.000	12.000	43.000	67.000	80.000	65.000	28.000	27.000	62.000
7	Mean.relative humidity (RH Mean.%)	32.500	24.000	37.500	19.500	19.500	52.000	75.000	75.000	72.500	36.500	35.000	72.500
8	Actual vapour pressure (ed) = ea*RHMean/100	6.120	6.510	11.600	7.810	9.720	23.690	27.320	23.980	23.250	11.840	9.620	17.070
9	Vapour pressure dedicit (ea-ed) in mbar	12.740	20.650	19.340	32.290	40.170	21.880	9.110	8.000	8.830	20.620	17.880	6.480
10	Weighing factor (W)	0.651	0.720	0.742	0.781	0.811	0.798	0.769	0.747	0.748	0.750	0.722	0.697
11	(1-W)	0.349	0.280	0.258	0.219	0.189	0.202	0.231	0.253	0.252	0.250	0.278	0.303
12	Cloud cover in oktas	0.600	0.500	3.300	1.200	0.300	4.600	7.400	7.800	5.500	1.500	1.600	5.200
13	Ratio n/N	0.890	0.900	0.620	0.830	0.920	0.490	0.090	0.030	0.370	0.800	0.790	0.420
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.476	16.438	15.800	14.562	12.848	10.948	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	7.304	8.498	7.884	10.280	11.594	8.155	4.849	4.187	6.334	8.351	7.061	4.604
16	Rns = 0.75 Rs	5.478	6.373	5.913	7.710	8.695	6.116	3.636	3.140	4.750	6.263	5.295	3.453
17	Function of temperature f(T).	13.910	15.090	15.550	16.500	17.410	17.012	16.170	15.687	15.700	15.750	15.130	14.620
18	Function of vapour pressure f(ed).	0.229	0.227	0.192	0.220	0.202	0.121	0.113	0.120	0.123	0.190	0.203	0.154
19	Function of sunshine duration f(n/N)	0.902	0.910	0.660	0.850	0.930	0.540	0.182	0.130	0.436	0.820	0.811	0.480
20.	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.873	3.117	1.970	3.085	3.270	1.111	0.332	0.244	0.841	2.453	2.490	1.080
21	Net radiation Rn = Rns-Rnl in mm/day	2.605	3.256	3.943	4.625	5.425	5.005	3.304	2.896	3.909	3.810	2.805	2.373
22	Average wind speed in km/day	112.800	124.800	122.400	134.400	170.400	180.000	170.400	134.400	112.800	79.200	74.400	84.000
23	Average wind speed in m/sec	1.300	1.440	1.410	1.550	1.970	2.080	1.970	1.550	1.300	0.910	0.860	0.970
24	Wind function f(u) =0.27(1+u/100)	0.570	0.600	0.600	0.630	0.730	0.750	0.730	0.630	0.570	0.480	0.470	0.496
25	Adjustment factor 'c'	0.959	0.984	0.969	0.921	0.921	1.015	0.944	0.953	1.005	1.000	0.970	0.991
26	W*Rn mm/day	1.695	2.344	2.925	3.612	4.390	3.993	2.540	2.163	2.920	2.857	2.025	1.653
27	(1-W)*f(u)*(ea-ed)	2.534	3.469	2.993	4.455	5.542	3.314	1.536	1.275	1.268	2.474	2.336	0.962
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	4.050	5.710	5.730	7.420	9.140	7.410	3.840	3.270	4.200	5.330	4.230	2.590
29	**Monthly Eto (mm/month)**	**125.550**	**159.880**	**177.630**	**222.600**	**283.340**	**222.300**	**119.040**	**101.370**	**126.000**	**165.230**	**126.900**	**80.290**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1991

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	23.700	26.700	32.000	37.200	40.100	32.000	31.100	28.000	33.100	31.700	27.200	26.400
2	Min. air temperature in o C.	10.700	11.000	18.800	21.000	24.100	25.700	22.900	21.700	22.100	16.700	12.800	10.500
3	Mean air temperature in o C.	17.200	18.850	25.400	29.100	32.100	28.850	27.000	24.850	27.600	24.200	20.000	18.450
4	Saturation vapour pressure (ea) in mbar	19.640	21.790	32.460	40.330	47.870	39.750	35.700	31.410	36.960	30.180	23.400	21.230
5	Max.relative humidity (RH Max.%)	69.000	45.000	36.000	25.000	24.000	54.000	85.000	85.000	72.000	54.000	42.000	45.000
6	Min.relative humidity (RH Min.%)	39.000	26.000	12.000	15.000	10.000	31.000	73.000	74.000	54.000	27.000	30.000	30.000
7	Mean.relative humidity (RH Mean.%)	54.000	35.500	24.000	20.000	17.000	42.500	79.000	79.500	63.000	40.500	36.000	37.500
8	Actual vapour pressure (ed) = ea*RHMean/100	10.600	7.730	7.790	8.060	8.130	16.890	28.200	24.970	23.280	12.220	8.420	7.960
9	Vapour pressure dedicit (ea-ed) in mbar	9.040	14.060	24.670	32.270	39.740	22.860	7.500	6.440	13.680	17.960	14.990	13.270
10	Weighing factor (W)	0.658	0.678	0.750	0.781	0.806	0.780	0.766	0.744	0.772	0.738	0.696	0.672
11	(1-W)	0.342	0.322	0.250	0.219	0.194	0.220	0.234	0.256	0.228	0.262	0.304	0.328
12	Cloud cover in oktas	2.400	2.100	1.100	2.700	0.700	5.000	7.600	7.200	5.100	1.700	2.200	1.200
13	Ratio n/N	0.710	0.740	0.840	0.680	0.880	0.450	0.060	0.120	0.430	0.780	0.730	0.830
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.358	7.526	9.433	9.121	11.267	7.823	4.600	4.898	6.770	8.217	6.733	6.656
16	Rns = 0.75 Rs	4.768	5.644	7.074	6.841	8.450	5.867	3.450	3.673	5.077	6.162	5.049	4.992
17	Function of temperature f(T).	14.040	14.370	15.750	16.520	17.225	16.470	16.100	15.610	16.220	15.450	14.600	14.290
18	Function of vapour pressure f(ed).	0.197	0.221	0.221	0.220	0.218	0.155	0.109	0.120	0.123	0.188	0.215	0.220
19	Function of sunshine duration f(n/N)	0.740	0.770	0.860	0.710	0.894	0.510	0.158	0.210	0.490	0.804	0.760	0.850
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.046	2.445	2.993	2.580	3.357	1.301	0.277	0.393	0.977	2.335	2.385	2.672
21	Net radiation Rn = Rns-Rnl in mm/day	2.722	3.199	4.081	4.261	5.093	4.566	3.173	3.280	4.100	3.827	2.664	2.320
22	Average wind speed in km/day	100.800	120.000	122.400	129.600	163.200	189.600	172.800	144.000	100.800	60.000	64.800	88.800
23	Average wind speed in m/sec	1.160	1.380	1.410	1.500	1.880	2.190	2.000	1.660	1.160	0.690	0.750	1.020
24	Wind function f(u) =0.27(1+u/100)	0.540	0.590	0.600	0.610	0.710	0.780	0.730	0.650	0.540	0.430	0.440	0.500
25	Adjustment factor 'c'	1.012	0.962	1.000	0.911	0.919	0.938	0.938	0.961	1.020	1.000	0.967	0.954
26	W*Rn mm/day	1.791	2.168	3.060	3.327	4.104	3.561	2.430	2.440	3.165	2.824	1.854	1.559
27	(1-W)*f(u)*(ea-ed)	1.669	2.671	3.700	4.310	5.473	3.922	1.281	1.071	1.684	2.023	2.003	2.176
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.500	4.650	6.760	6.950	8.800	7.010	3.480	3.370	4.940	4.840	3.720	3.560
29	**Monthly Eto (mm/month)**	**108.500**	**130.200**	**209.560**	**208.500**	**272.800**	**210.300**	**107.880**	**104.470**	**148.200**	**150.040**	**111.600**	**110.360**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1992

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	26.600	30.300	36.300	39.300	40.900	39.100	31.100	28.100	30.100	33.400	29.300	25.200
2	Min. air temperature in o C.	9.900	12.800	18.400	21.600	25.300	25.600	22.300	21.400	20.900	17.600	16.400	10.500
3	Mean air temperature in o C.	18.250	21.550	27.350	30.450	33.100	32.350	26.700	24.750	25.500	25.500	22.850	17.850
4	Saturation vapour pressure (ea) in mbar	20.950	25.720	36.430	43.520	50.590	48.540	35.070	31.220	32.650	22.650	27.840	20.420
5	Max.relative humidity (RH Max.%)	51.000	44.000	28.000	20.000	26.000	56.000	87.000	88.000	84.000	49.000	58.000	53.000
6	Min.relative humidity (RH Min.%)	29.000	27.000	18.000	10.000	11.000	34.000	75.000	79.000	70.000	28.000	43.000	34.000
7	Mean.relative humidity (RH Mean.%)	40.000	35.500	23.000	15.000	18.500	45.000	81.000	83.500	77.000	38.500	50.500	43.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.380	9.130	8.370	6.520	9.350	21.840	28.400	26.070	25.140	12.570	14.060	8.880
9	Vapour pressure dedicit (ea-ed) in mbar	12.570	16.590	28.060	37.000	41.240	26.700	6.670	5.150	7.510	20.080	13.780	11.540
10	Weighing factor (W)	0.669	0.711	0.769	0.790	0.813	0.808	0.763	0.743	0.751	0.751	0.724	0.664
11	(1-W)	0.331	0.289	0.231	0.210	0.187	0.192	0.237	0.257	0.249	0.249	0.276	0.336
12	Cloud cover in oktas	2.200	2.400	2.300	1.100	2.400	5.300	7.700	7.100	5.800	1.000	4.100	2.400
13	Ratio n/N	0.730	0.710	0.720	0.840	0.710	0.400	0.040	0.130	0.330	0.850	0.540	0.710
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.460	7.340	8.580	10.350	9.870	7.410	4.430	4.970	6.040	8.667	5.688	6.056
16	Rns = 0.75 Rs	4.845	5.505	6.435	7.762	7.402	5.557	3.322	3.727	4.530	6.500	4.266	4.542
17	Function of temperature f(T).	14.250	14.910	16.170	16.810	17.470	17.287	16.040	15.587	15.775	15.775	15.170	14.170
18	Function of vapour pressure f(ed).	0.216	0.208	0.216	0.227	0.206	0.130	0.108	0.120	0.120	0.187	0.180	0.211
19	Function of sunshine duration f(n/N)	0.760	0.740	0.750	0.860	0.740	0.460	0.140	0.220	0.400	0.870	0.590	0.740
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.339	2.294	2.611	3.281	2.663	1.033	0.242	0.411	0.757	2.566	1.611	2.212
21	Net radiation Rn = Rns-Rnl in mm/day	2.506	3.211	3.816	4.481	4.739	4.524	3.080	3.316	3.773	3.934	2.655	2.330
22	Average wind speed jn km/day	120.000	100.800	129.600	132.000	175.200	184.800	146.400	153.600	120.000	64.800	60.000	91.200
23	Average wind speed in m/sec	1.380	1.160	1.500	1.520	2.020	2.130	1.690	1.770	1.380	0.750	0.690	1.050
24	Wind function f(u) =0.27(1+u/100)	0.590	0.540	0.610	0.620	0.740	0.760	0.660	0.680	0.590	0.440	0.430	0.510
25	Adjustment factor 'c'	0.935	0.966	0.895	0.924	0.892	0.930	0.951	0.957	0.996	1.014	0.948	0.939
26	W*Rn mm/day	1.676	2.283	2.934	3.539	3.852	3.655	2.350	2.463	2.833	2.954	1.922	1.547
27	(1-W)*f(u)*(ea-ed)	2.454	2.589	3.953	4.817	5.706	3.896	1.043	0.900	1.103	2.199	1.635	1.977
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.860	4.700	6.160	7.720	8.520	2.020	3.220	3.210	3.920	5.220	3.370	3.300
29	**Monthly Eto (mm/month)**	**119.660**	**136.300**	**190.960**	**231.600**	**264.120**	**210.600**	**99.820**	**99.510**	**117.600**	**161.820**	**101.100**	**102.300**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1993

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.200	27.500	32.600	38.900	41.600	34.600	33.100	28.800	29.700	32.300	28.600	26.600
2	Min. air temperature in o C.	11.200	12.200	16.500	22.600	26.400	24.400	22.900	22.900	21.900	18.200	11.900	9.800
3	Mean air temperature in o C.	18.200	19.850	24.550	30.750	34.000	29.500	28.000	25.850	25.800	25.250	20.250	18.200
4	Saturation vapour pressure (ea) in mbar	20.880	23.190	34.840	44.270	53.200	41.250	37.800	33.310	33.220	32.170	23.770	20.880
5	Max.relative humidity (RH Max.%)	70.000	58.000	40.000	19.000	33.000	75.000	82.000	90.000	86.000	54.000	39.000	46.000
6	Min.relative humidity (RH Min.%)	39.000	27.000	21.000	11.000	19.000	52.000	67.000	82.000	73.000	36.000	25.000	26.000
7	Mean.relative humidity (RH Mean.%)	54.500	42.500	30.500	15.000	26.000	63.500	74.500	86.000	79.500	45.000	32.000	36.000
8	Actual vapour pressure (ed) = ea*RHMean/100	11.370	9.850	9.400	6.640	13.830	26.190	28.160	28.650	26.400	14.470	7.600	7.510
9	Vapour pressure dedicit (ea-ed) in mbar	9.510	13.340	21.440	37.630	39.370	15.060	9.640	4.660	6.820	17.700	16.170	13.370
10	Weighing factor (W)	0.669	0.693	0.742	0.793	0.820	0.783	0.776	0.754	0.754	0.748	0.698	0.669
11	(1-W)	0.331	0.307	0.258	0.207	0.180	0.217	0.224	0.246	0.246	0.252	0.302	0.331
12	Cloud cover in oktas	1.700	2.500	1.700	3.000	1.800	6.600	6.700	7.700	7.000	0.900	0.400	0.200
13	Ratio n/N	0.780	0.700	0.780	0.650	0.770	0.210	0.190	0.040	0.150	0.860	0.910	0.930
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.720	7.280	9.010	8.880	10.360	5.840	5.660	4.260	4.730	8.730	7.710	7.150
16	Rns = 0.75 Rs	5.040	5.460	6.750	6.660	7.770	4.380	4.240	3.190	3.540	6.540	5.780	5.360
17	Function of temperature f(T).	14.240	14.570	15.530	16.880	17.700	16.600	16.300	15.860	15.850	15.710	14.650	14.240
18	Function of vapour pressure f(ed).	0.193	0.201	0.206	0.226	0.180	0.119	0.109	0.106	0.118	0.175	0.222	0.222
19	Function of sunshine duration f(n/N)	0.804	0.730	0.804	0.690	0.796	0.290	0.272	0.140	0.240	0.878	0.920	0.940
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.209	2.137	2.572	2.632	2.536	0.572	0.483	0.235	0.448	2.413	2.992	2.971
21	Net radiation Rn = Rns-Rnl in mm/day	2.831	3.323	4.178	4.028	5.234	3.808	3.757	2.955	3.092	4.127	2.788	2.389
22	Average wind speed in km/day	124.800	112.800	129.600	139.200	168.000	182.400	144.000	148.800	124.800	74.700	79.200	86.400
23	Average wind speed in m/sec	1.440	1.300	1.500	1.610	1.940	2.110	1.660	1.720	1.440	0.860	0.910	1.000
24	Wind function f(u) =0.27(1+u/100)	0.600	0.570	0.610	0.640	0.720	0.760	0.650	0.670	0.600	0.470	0.480	0.500
25	Adjustment factor 'c'	1.007	0.959	0.995	0.898	0.993	0.957	0.975	0.945	0.969	1.011	0.984	0.967
26	W*Rn mm/day	1.893	2.302	3.100	3.194	4.291	2.981	2.915	2.228	2.331	3.086	1.946	1.590
27	(1-W)*f(u)*(ea-ed)	1.888	2.334	3.374	4.985	5.102	2.483	1.403	0.768	1.006	2.096	2.344	2.212
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.800	4.440	6.440	7.340	9.320	5.220	4.210	2.830	2.270	5.230	4.220	3.670
29	**Monthly Eto (mm/month)**	**117.800**	**124.320**	**199.640**	**220.200**	**288.900**	**156.600**	**130.510**	**87.730**	**68.100**	**162.130**	**126.600**	**113.770**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1994

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.600	28.500	33.200	38.800	39.300	32.700	27.700	29.000	30.200	29.800	28.400	25.000
2	Min. air temperature in o C.	9.800	11.800	16.600	22.500	24.900	23.600	22.300	22.400	20.800	18.600	12.800	8.100
3	Mean air temperature in o C.	17.200	20.150	24.900	30.650	32.100	28.150	25.000	25.700	25.500	24.200	20.600	16.550
4	Saturation vapour pressure (ea) in mbar	19.640	23.620	31.510	44.020	37.870	38.140	31.700	33.030	32.650	30.180	24.300	18.860
5	Max.relative humidity (RH Max.%)	57.000	35.000	23.000	30.000	42.000	81.000	88.000	87.000	79.000	71.000	48.000	51.000
6	Min.relative humidity (RH Min.%)	30.000	19.000	11.000	16.000	22.000	59.000	78.000	80.000	66.000	49.000	30.000	29.000
7	Mean.relative humidity (RH Mean.%)	43.500	27.000	17.000	23.000	32.000	70.000	83.000	83.500	72.500	60.000	39.000	40.000
8	Actual vapour pressure (ed) = ea*RHMean/100	8.540	6.370	5.350	10.120	15.310	26.700	26.310	27.580	23.670	18.100	9.470	7.540
9	Vapour pressure dedicit (ea-ed) in mbar	11.100	17.250	26.160	33.900	32.560	11.440	5.390	5.450	8.980	12.080	14.830	11.320
10	Weighing factor (W)	0.658	0.697	0.745	0.792	0.806	0.776	0.746	0.753	0.751	0.738	0.702	0.651
11	(1-W)	0.342	0.303	0.255	0.208	0.194	0.224	0.254	0.247	0.249	0.262	0.298	0.349
12	Cloud cover in oktas	2.500	1.200	1.200	0.900	1.600	6.400	7.700	7.700	5.100	3.500	1.500	0.900
13	Ratio n/N	0.700	0.830	0.830	0.860	0.790	0.240	0.040	0.040	0.430	0.600	0.800	0.860
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.310	8.070	9.360	10.510	10.530	6.093	4.430	4.260	6.770	7.060	7.110	6.800
16	Rns = 0.75 Rs	4.720	6.050	7.020	7.880	7.890	4.560	3.320	3.190	5.070	5.290	5.330	5.100
17	Function of temperature f(T).	14.040	14.630	15.620	16.860	17.225	16.330	15.650	15.825	15.770	15.450	14.720	13.910
18	Function of vapour pressure f(ed).	0.214	0.228	0.230	0.199	0.166	0.116	0.118	0.112	0.121	0.149	0.205	0.222
19	Function of sunshine duration f(n/N)	0.730	0.850	0.850	0.878	0.811	0.320	0.140	0.140	0.490	0.640	0.820	0.878
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.193	2.835	3.053	2.945	2.318	0.606	0.258	0.248	0.935	1.473	2.474	2.711
21	Net radiation Rn = Rns-Rnl in mm/day	2.527	3.215	3.967	4.935	5.572	3.954	3.062	2.942	4.135	3.817	2.856	2.389
22	Average wind speed in km/day	103.200	108.000	117.600	120.000	165.600	187.200	158.400	124.800	103.200	72.000	69.600	96.000
23	Average wind speed in m/sec	1.190	1.250	1.360	1.380	1.910	2.160	1.830	1.440	1.190	0.830	0.800	1.110
24	Wind function f(u) =0.27(1+u/100)	0.540	0.560	0.580	0.590	0.710	0.770	0.690	0.600	0.540	0.460	0.450	0.520
25	Adjustment factor 'c'	0.939	0.981	0.922	0.933	0.995	0.960	0.943	0.960	1.019	1.039	0.974	0.954
26	W*Rn mm/day	1.661	2.240	2.955	3.908	4.491	3.068	2.284	2.215	3.105	2.816	2.004	1.555
27	(1-W)*f(u)*(ea-ed)	2.049	2.926	3.869	4.160	4.484	1.973	0.944	0.800	1.207	1.455	1.988	2.054
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.480	5.060	6.290	7.520	8.930	4.830	3.090	2.890	4.390	4.430	3.880	3.440
29	**Monthly Eto (mm/month)**	**104.400**	**141.680**	**194.990**	**225.600**	**276.830**	**144.900**	**95.790**	**89.590**	**131.700**	**137.330**	**116.400**	**106.640**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1995

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	26.000	26.600	34.800	37.200	40.900	38.900	32.000	28.400	30.500	32.200	29.100	26.600
2	Min. air temperature in o C.	9.200	9.900	17.800	20.700	24.800	25.900	23.300	22.200	19.500	17.500	13.800	11.600
3	Mean air temperature in o C.	17.600	18.250	26.300	28.950	32.850	32.400	27.650	25.300	25.000	24.850	21.450	19.100
4	Saturation vapour pressure (ea) in mbar	20.120	20.950	34.230	39.980	49.890	48.680	37.060	32.270	31.700	31.410	25.570	22.140
5	Max.relative humidity (RH Max.%)	53.000	44.000	29.000	28.000	33.000	77.000	81.000	88.000	72.000	53.000	59.000	59.000
6	Min.relative humidity (RH Min.%)	25.000	21.000	17.000	20.000	17.000	27.000	66.000	79.000	54.000	37.000	41.000	36.000
7	Mean.relative humidity (RH Mean.%)	39.000	32.500	23.000	24.000	25.000	52.000	73.500	83.500	63.000	45.000	50.000	47.500
8	Actual vapour pressure (ed) = ea*RHMean/100	7.840	6.800	7.870	9.590	12.470	25.310	27.230	26.940	19.970	14.130	12.780	10.510
9	Vapour pressure dedicit (ea-ed) in mbar	12.280	14.150	26.360	30.390	37.420	23.370	9.830	5.330	11.730	17.280	12.790	11.630
10	Weighing factor (W)	0.662	0.669	0.750	0.780	0.811	0.808	0.772	0.749	0.746	0.744	0.710	0.682
11	(1-W)	0.338	0.331	0.250	0.220	0.189	0.192	0.228	0.251	0.254	0.256	0.290	0.318
12	Cloud cover in oktas	2.300	1.700	1.700	1.600	2.700	7.000	6.300	7.600	3.800	3.300	0.900	1.800
13	Ratio n/N	0.720	0.780	0.780	0.790	0.680	0.150	0.250	0.060	0.570	0.620	0.860	0.770
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.410	7.760	9.010	9.970	9.630	5.350	6.160	4.420	7.780	7.190	7.430	6.350
16	Rns = 0.75 Rs	4.800	5.820	6.750	7.470	7.220	4.010	4.620	3.310	5.830	5.390	5.570	4.760
17	Function of temperature f(T).	14.120	14.250	15.960	16.490	17.410	17.300	16.230	15.720	15.650	15.610	14.890	14.420
18	Function of vapour pressure f(ed).	0.220	0.226	0.220	0.204	0.187	0.120	0.113	0.115	0.140	0.178	0.186	0.197
19	Function of sunshine duration f(n/N)	0.750	0.804	0.804	0.811	0.710	0.240	0.330	0.158	0.616	0.660	0.878	0.796
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.329	2.589	2.823	2.728	2.311	0.498	0.600	0.285	1.349	1.833	2.431	2.261
21	Net radiation Rn = Rns-Rnl in mm/day	2.471	3.231	3.927	4.742	4.909	3.512	4.020	3.025	4.481	3.557	3.139	2.499
22	Average wind speed in km/day	98.400	120.000	124.800	124.800	170.400	184.800	158.400	129.600	98.400	67.200	67.200	98.400
23	Average wind speed in m/sec	1.130	1.380	1.440	1.440	1.970	2.130	1.830	1.500	1.130	0.770	0.770	1.130
24	Wind function f(u) =0.27(1+u/100)	0.530	0.590	0.600	0.600	0.730	0.760	0.690	0.610	0.530	0.450	0.450	0.530
25	Adjustment factor 'c'	0.944	0.968	0.913	0.924	0.984	0.946	0.977	0.960	1.041	0.977	0.983	0.943
26	W*Rn mm/day	1.635	2.161	2.945	3.698	3.981	2.837	3.103	2.265	3.342	2.646	2.228	1.704
27	(1-W)*f(u)*(ea-ed)	2.199	2.763	3.954	4.010	5.162	3.410	1.546	0.816	1.579	1.990	1.669	1.960
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.610	4.760	6.290	7.120	8.990	5.900	4.540	2.950	5.120	4.520	3.830	3.450
29	**Monthly Eto (mm/month)**	**111.910**	**133.280**	**194.990**	**213.600**	**278.680**	**177.000**	**140.740**	**91.450**	**153.600**	**140.120**	**114.900**	**106.950**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1996

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.900	29.100	33.700	40.500	42.100	36.500	28.200	28.700	28.200	31.000	28.400	23.700
2	Min. air temperature in o C.	9.900	13.400	16.600	23.000	26.800	25.500	22.500	22.600	21.800	17.900	12.600	11.100
3	Mean air temperature in o C.	17.900	21.250	25.150	31.750	34.450	31.000	25.350	25.650	25.000	24.450	20.500	17.400
4	Saturation vapour pressure (ea) in mbar	20.480	25.270	31.980	46.920	54.550	44.900	32.360	32.930	31.700	30.650	24.150	19.880
5	Max.relative humidity (RH Max.%)	50.000	47.000	25.000	22.000	31.000	61.000	81.000	90.000	88.000	61.000	45.000	65.000
6	Min.relative humidity (RH Min.%)	29.000	23.000	14.000	14.000	13.000	42.000	71.000	80.000	78.000	40.000	27.000	46.000
7	Mean.relative humidity (RH Mean.%)	39.500	35.000	19.500	18.000	22.000	51.500	76.000	85.000	83.000	50.500	36.000	55.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.080	8.840	6.230	8.440	12.000	23.120	24.590	27.990	26.310	15.480	8.690	11.030
9	Vapour pressure dedicit (ea-ed) in mbar	12.400	16.430	25.750	38.480	42.550	21.780	7.770	4.940	5.390	15.170	15.460	8.850
10	Weighing factor (W)	0.665	0.708	0.747	0.803	0.823	0.796	0.749	0.752	0.746	0.740	0.701	0.660
11	(1-W)	0.335	0.292	0.253	0.197	0.177	0.204	0.251	0.248	0.254	0.260	0.299	0.340
12	Cloud cover in oktas	1.300	2.400	0.400	1.200	0.900	6.300	7.800	7.600	6.800	2.700	0.400	3.100
13	Ratio n/N	0.820	0.710	0.910	0.830	0.860	0.250	0.030	0.060	0.180	0.680	0.910	0.640
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.930	7.340	9.920	10.280	11.100	6.170	4.350	4.420	4.950	7.570	7.710	5.700
16	Rns = 0.75 Rs	5.190	5.500	7.440	7.710	8.320	4.620	3.260	3.310	3.710	5.670	5.780	4.270
17	Function of temperature f(T).	14.180	14.850	15.680	17.130	17.790	16.950	15.730	15.810	15.650	15.510	14.700	14.080
18	Function of vapour pressure f(ed).	0.220	0.211	0.228	8.215	0.190	0.124	0.120	0.110	0.118	0.165	0.213	0.195
19	Function of sunshine duration f(n/N)	0.840	0.740	0.920	0.850	0.870	0.330	0.130	0.150	0.260	0.710	0.920	0.680
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.620	2.310	3.280	3.130	2.940	0.690	0.240	0.260	0.480	1.810	2.880	1.860
21	Net radiation Rn = Rns-Rnl in mm/day	2.570	3.190	4.160	4.580	5.380	3.930	3.020	3.050	3.230	3.860	2.900	2.410
22	Average wind speed in km/day	105.600	105.600	127.200	134.400	172.800	196.800	168.000	139.200	105.600	69.600	72.000	79.200
23	Average wind speed in m/sec	1.220	1.220	1.470	1.550	2.000	2.270	1.940	1.610	1.220	0.800	0.830	0.910
24	Wind function f(u) =0,27(1+u/100)	0.550	0.550	0.610	0.630	0.730	0.800	0.720	0.640	0.550	0.450	0.460	0.480
25	Adjustment factor 'c'	0.953	0.963	0.922	0.921	1.000	0.958	0.936	0.954	0.984	1.049	0.987	1.012
26	W*Rn mm/day	1.709	2.258	3.100	3.677	4.420	3.128	2.261	2.293	2.409	2.834	2.032	1.590
27	(1-W)*f(u)*(ea-ed)	2.284	2.638	3.970	4.775	5.490	3.554	1.404	0.784	0.752	1.774	2.126	1.440
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.800	4.710	6.510	7.780	9.910	6.400	3.430	2.930	3.110	4.830	4.100	3.060
29	**Monthly Eto (mm/month)**	**117.800**	**136.590**	**201.810**	**233.400**	**307.210**	**192.000**	**106.330**	**90.830**	**93.300**	**149.730**	**123.000**	**94.860**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1997

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.000	27.400	35.500	38.800	40.000	37.400	30.500	28.600	33.200	31.200	28.200	25.100
2	Min. air temperature in o C.	9.000	11.300	18.500	22.900	25.100	25.600	23.100	22.200	22.000	19.400	11.800	9.700
3	Mean air temperature in o C.	17.000	19.350	27.000	30.850	32.550	31.500	26.800	25.400	27.600	25.300	20.000	17.400
4	Saturation vapour pressure (ea) in mbar	19.400	22.490	35.700	44.520	49.080	46.250	35.280	32.460	36.960	32.270	23.400	19.880
5	Max.relative humidity (RH Max.%)	47.000	38.000	30.000	21.000	33.000	61.000	84.000	88.000	69.000	67.000	46.000	57.000
6	Min.relative humidity (RH Min.%)	26.000	20.000	15.000	13.000	20.000	30.000	71.000	75.000	51.000	54.000	33.000	38.000
7	Mean.relative humidity (RH Mean.%)	36.500	29.000	22.500	17.000	26.500	45.500	77.500	81.500	60.000	60.500	39.500	47.500
8	Actual vapour pressure (ed) = ea*RHMean/100	7.080	6.520	8.030	7.560	13.000	21.040	27.340	26.450	22.170	19.520	9.240	9.440
9	Vapour pressure dedicit (ea-ed) in mbar	12.320	15.970	27.670	36.960	36.080	25.210	7.940	6.010	14.790	12.750	14.160	10.440
10	Weighing factor (W)	0.656	0.686	0.766	0.794	0.809	0.801	0.764	0.750	0.772	0.749	0.696	0.660
11	(1-W)	0.344	0.314	0.234	0.206	0.191	0.199	0.236	0.250	0.228	0.251	0.304	0.340
12	Cloud cover in oktas	0.500	0.800	0.900	1.600	1.900	4.700	7.100	7.000	4.500	3.800	0.300	1.600
13	Ratio n/N	0.900	0.870	0.860	0.790	0.760	0.480	0.130	0.150	0.500	0.570	0.920	0.790
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	7.350	8.310	9.570	9.970	10.280	8.070	5.170	5.130	7.280	6.860	7.760	6.450
16	Rns = 0.75 Rs	5.510	6.230	7.170	7.470	7.710	6.050	3.870	3.850	5.460	5.140	5.820	4.830
17	Function of temperature f(T).	14.000	14.470	16.100	16.910	17.330	17.070	16.060	15.750	16.220	15.720	14.600	14.080
18	Function of vapour pressure f(ed).	0.224	0.227	0.220	0.222	0.185	0.135	0.113	0.117	0.129	0.142	0.207	0.205
19	Function of sunshine duration f(n/N)	0.910	0.880	0.870	0.810	0.780	0.530	0.220	0.240	0.550	0.610	0.930	0.810
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.860	2.890	3.080	3.040	2.500	1.220	0.390	0.440	1.150	1.360	2.810	2.330
21	Net radiation Rn = Rns-Rnl in mm/day	2.650	3.340	4.090	4.430	5.210	4.830	3.480	3.410	4.310	3.780	3.010	2.500
22	Average wind speed in km/day	100.800	124.800	120.000	129.600	163.200	172.800	148.800	141.600	100.800	60.000	64.800	81.600
23	Average wind speed in m/sec	1.160	1.440	1.380	1.500	1.880	2.000	1.720	1.630	1.160	0.690	0.750	0.940
24	Wind function f(u) =0,27(1+u/100)	0.540	0.600	0.590	0.610	0.710	0.730	0.670	0.650	0.540	0.430	0.440	0.490
25	Adjustment factor 'c'	0.960	0.970	0.920	0.920	0.990	1.010	0.960	0.960	1.030	1.040	0.990	0.950
26	W*Rn mm/day	1.730	2.290	3.130	3.510	4.210	3.860	2.650	2.550	3.320	2.830	2.090	1.650
27	(1-W)*f(u)*(ea-ed)	2.280	3.000	3.820	4.640	4.890	3.660	1.250	0.970	1.820	1.370	1.890	1.730
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.840	5.130	6.390	8.150	9.000	7.590	3.740	3.370	5.290	4.360	3.940	3.210
29	Monthly Eto (mm/month)	119.040	143.640	198.090	244.500	279.000	227.700	115.940	104.470	158.700	135.160	118.200	99.510

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1998

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	24.000	27.500	32.700	39.300	40.700	35.600	29.800	29.300	29.700	31.100	27.800	26.100
2	Min. air temperature in o C.	8.400	11.700	15.700	22.000	26.000	25.400	22.600	22.800	22.000	19.600	11.600	9.400
3	Mean air temperature in o C.	16.200	19.600	24.200	30.650	33.350	30.500	26.200	26.050	25.850	25.350	19.700	17.750
4	Saturation vapour pressure (ea) in mbar	18.440	22.840	30.180	44.020	51.310	43.650	34.020	33.700	33.310	32.360	22.980	20.300
5	Max.relative humidity (RH Max.%)	62.000	51.000	33.000	18.000	31.000	64.000	87.000	88.000	83.000	75.000	49.000	53.000
6	Min.relative humidity (RH Min.%)	32.000	29.000	15.000	12.000	15.000	47.000	76.000	79.000	72.000	57.000	32.000	38.000
7	Mean.relative humidity (RH Mean.%)	47.000	40.000	24.000	15.000	23.000	55.500	81.500	83.500	77.500	66.000	40.500	45.500
8	Actual vapour pressure (ed) = ea*RHMean/100	8.660	9.130	7.240	6.600	11.800	24.220	27.720	28.130	25.810	21.350	9.300	9.230
9	Vapour pressure dedicit (ea-ed) in mbar	9.780	13.710	22.940	37.420	39.510	19.430	6.300	5.570	7.500	11.010	13.680	11.070
10	Weighing factor (W)	0.648	0.690	0.738	0.792	0.815	0.791	0.758	0.756	0.754	0.749	0.691	0.663
11	(1-W)	0.352	0.310	0.262	0.208	0.185	0.209	0.242	0.244	0.246	0.251	0.309	0.337
12	Cloud cover in oktas	2.000	2.000	2.200	0.700	1.700	4.700	7.100	7.400	5.900	3.600	0.600	1.000
13	Ratio n/N	0.750	0.750	0.730	0.880	0.780	0.480	0.130	0.090	0.310	0.590	0.890	0.850
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.560	7.580	8.650	10.660	10.450	8.070	5.170	4.660	5.890	6.990	7.600	6.750
16	Rns = 0.75 Rs	4.920	5.680	6.480	7.990	7.830	6.050	3.870	3.490	4.410	5.240	5.700	5.060
17	Function of temperature f(T).	13.840	14.520	15.450	16.860	17.530	16.820	15.940	15.900	15.860	5.730	14.540	14.150
18	Function of vapour pressure f(ed).	0.213	0.208	0.223	0.227	0.191	0.120	0.111	0.109	0.120	0.133	0.207	0.207
19	Function of sunshine duration f(n/N)	0.780	0.780	0.760	0.890	0.800	0.530	0.220	0.180	0.380	0.630	0.900	0.870
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.290	2.350	2.610	3.400	2.670	1.060	0.380	0.310	0.720	1.310	2.700	2.540
21	Net radiation Rn = Rns-Rnl in mm/day	2.630	3.330	3.870	4.590	5.160	4.990	3.490	3.180	3.690	3.930	3.000	2.520
22	Average wind speed in km/day	96.000	112.800	115.200	139.200	168.000	187.200	158.400	136.800	103.200	79.200	74.400	81.600
23	Average wind speed in m/sec	1.110	1.300	1.330	1.610	1.940	2.160	1.830	1.580	1.190	0.910	0.860	0.940
24	Wind function f(u) =0.27(1+u/100)	0.520	0.570	0.580	0.640	0.720	0.770	0.690	0.630	0.540	0.480	0.470	0.490
25	Adjustment factor 'c'	1.010	0.960	0.990	0.920	0.990	1.000	0.950	0.960	1.000	1.030	0.980	0.960
26	W*Rn mm/day	1.700	2.290	2.850	3.630	4.200	3.940	2.640	2.400	2.780	2.940	2.070	1.670
27	(1-W)*f(u)*(ea-ed)	1.790	2.420	3.480	4.980	5.260	3.120	1.050	0.850	0.990	1.320	1.980	1.820
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.520	4.520	6.260	7.920	9.360	7.060	3.500	3.120	3.770	4.380	3.960	3.350
29	**Monthly Eto (mm/month)**	**109.120**	**126.560**	**194.060**	**237.600**	**290.160**	**211.800**	**108.500**	**96.720**	**113.100**	**135.780**	**118.800**	**103.850**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET0) BY MODIFIED PANMAN METHOD FOR THE YEAR - 1999

S. No	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in o C.	25.900	29.000	33.700	38.000	40.500	35.000	31.700	29.300	30.600	33.800	28.600	26.000
2	Min. air temperature in o C.	11.100	12.400	17.100	21.300	25.700	24.300	23.300	22.500	21.100	18.800	12.200	9.500
3	Mean air temperature in o C.	18.500	20.700	25.400	29.650	33.100	29.650	27.500	25.900	25.850	26.300	20.400	17.750
4	Saturation vapour pressure (ea) in mbar	21.300	24.450	32.460	41.590	50.590	41.590	36.750	33.410	33.310	34.230	24.000	20.300
5	Max.relative humidity (RH Max.%)	63.000	60.000	51.000	35.000	43.000	70.000	85.000	88.000	83.000	45.000	61.000	65.000
6	Min.relative humidity (RH Min.%)	39.000	34.000	43.000	20.000	24.000	54.000	70.000	77.000	64.000	29.000	48.000	45.000
7	Mean.relative humidity (RH Mean.%)	51.000	47.000	47.000	27.500	33.500	62.000	77.500	82.500	73.500	37.000	54.500	55.000
8	Actual vapour pressure (ed) = ea*RHMean/100	10.860	11.490	15.250	11.430	16.940	25.780	28.480	27.560	24.480	12.660	13.080	11.160
9	Vapour pressure dedicit (ea-ed) in mbar	10.440	12.960	17.210	30.160	33.650	15.810	8.270	5.850	8.830	21.570	10.920	9.140
10	Weighing factor (W)	0.673	0.703	0.750	0.784	0.813	0.784	0.771	0.755	0.754	0.750	0.700	0.663
11	(1-W)	0.327	0.297	0.250	0.216	0.187	0.216	0.229	0.245	0.246	0.250	0.300	0.337
12	Cloud cover in oktas	2.400	1.300	1.400	0.900	0.800	5.500	6.500	7.100	4.700	1.000	3.200	1.000
13	Ratio n/N	0.710	0.820	0.810	0.860	0.870	0.370	0.220	0.130	0.480	0.850	0.630	0.850
14	Extra terresterial radiations in mm/day	10.510	12.140	14.080	15.460	16.330	16.470	16.430	15.800	14.560	12.840	10.940	10.010
15	Short wave radiation Rs = (0.25+0.5*n/N)*Ra	6.350	8.010	9.220	10.510	11.180	7.160	5.910	4.970	7.130	8.660	6.180	6.750
16	Rns = 0.75 Rs	4.760	6.000	6.910	7.880	8.380	5.370	4.430	3.730	5.340	6.490	4.630	5.060
17	Function of temperature f(T).	14.300	14.740	15.750	16.630	17.470	16.630	16.200	15.870	15.860	15.960	14.680	14.150
18	Function of vapour pressure f(ed).	0.195	0.192	0.167	0.192	0.155	0.120	0.107	0.112	0.120	0.186	0.185	0.194
19	Function of sunshine duration f(n/N)	0.740	0.840	0.830	0.870	0.880	0.430	0.300	0.220	0.530	0.870	0.670	0.870
20	Net longwave radiation Rnl = f(T)*f(ed)*f(n/N)	2.060	2.370	2.180	2.770	2.380	0.850	0.520	0.390	1.000	2.580	1.810	2.380
21	Net radiation Rn = Rns-Rnl in mm/day	2.700	3.630	4.730	5.110	6.000	4.520	3.910	3.340	4.340	3.910	2.820	2.660
22	Average wind speed in km/day	103.200	105.600	120.000	120.000	165.600	192.000	165.600	139.200	96.000	69.600	69.600	96.000
23	Average wind speed in m/sec	1.190	1.220	1.380	1.380	1.910	2.220	1.910	1.610	1.110	0.800	0.800	1.110
24	Wind function f(u) =0.27(1+u/100)	0.540	0.550	0.590	0.590	0.710	0.780	0.710	0.640	0.520	0.450	0.450	0.520
25	Adjustment factor 'c'	1.010	0.980	1.000	1.010	1.000	0.980	0.960	0.960	1.030	1.010	1.020	1.020
26	W*Rn mm/day	1.810	2.550	3.540	4.000	4.870	3.540	3.010	2.520	3.270	2.930	1.970	1.770
27	(1-W)*f(u)*(ea-ed)	1.840	2.110	2.530	3.840	4.460	2.660	1.340	0.910	1.120	2.420	1.470	1.600
28	Eto = c*{W*Rn+(1-W)*f(u)*(ea-ed) in mm/day	3.680	4.560	6.070	7.910	9.330	6.070	4.170	3.290	4.520	5.400	3.500	3.430
29	**Monthly Eto (mm/month)**	**114.080**	**127.680**	**188.170**	**237.300**	**289.230**	**182.100**	**129.270**	**101.990**	**135.600**	**167.400**	**105.000**	**106.330**

Table 6.3(i) : ESTIMATION OF CROP WATER REQUIREMENT

FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Soybean (1 Kh)
SOWING TIME: 16th-30th June
DURATION : 105 days; Growth stages (days) : 20/30/30/25

(All figures in mm)

S. No.	Particulars	June 16th to 30th (15 days)	July		August		September	
			1 to 5	6 to 31	1 to 4	5 to 31	1 to 3	4 to 28
1	E_{TO} (mm)	101.4	19.0	114.29	12.68	85.76	12.45	112.23
2	Crop coefficient (K_c)	0.4	0.4	0.8	0.8	1.15	1.15	0.8
3	Consumptive use E_{TC} (mm)	40.56	7.6	91.43	10.14	98.62	14.31	89.78
4	Plant use (pre-sowing) mm	75	-	-	-	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	-	-	-	-
6	Gross consumptive use (mm)	115.56	99.03		108.76		50.23	
7	Rainfall	92.9	376.88		388.59		220.41	
8	Effective rainfall	40.56	99.03		108.76		50.23	
9	Net irrigation requirement	75	-		-		-	
10	Gross requirement at main canal head with 63% project efficiency	119.05						
11	Total depth of water required at main canal head (i) for 19830 ha with 20% (LBC) intensity (ii) for 35050 ha with 22% (RBC) intensity	 0.0047 0.0092						

Table 6.3(ii) : ESTIMATION OF CROP WATER REQUIREMENT FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Soybean (2 Kh)
SOWING TIME: 1 – 15 July
DURATION : 105 days, Growth stages (days) : 20/30/30/25

(All figures in mm)

S. No.	Particulars	July		August		September		October
		1-20	21-30	1-19	20-31	1-18	19-30	1-13
1	E_{TO} (mm)	76	42.09	60.23	38.21	74.7	49.98	63.44
2	Crop coefficient (K_c)	0.4	0.8	0.8	1.15	1.15	0.8	0.8
3	Consumptive use E_{TC} (mm)	30.4	33.67	48.18	43.94	85.90	39.98	50.75
4	Plant use (pre-sowing) mm	75	-	-	-	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	-	-	(-)6.66)	(-) 50.75
6	Gross consumptive use (mm)	139.07		92.12		119.22		-
7	Rainfall	376.88		388.59		220.41		21.23
8	Effective rainfall	64.07		92.12		119.22		-
9	Net irrigation requirement	75		-		-		-
10	Gross requirement at main canal head with 63% project efficiency	119.05						
11	Total depth of water required at main canal head (iii) for 19830 ha with 22% (LBC) intensity (iv) for 35050 ha with 30% (RBC) intensity	 0.0051 0.0125						

Table 6.3(iii) : ESTIMATION OF CROP WATER REQUIREMENT

FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Wheat Hyv
SOWING TIME: 15 to 30 November
DURATION : 135 days, Growth stages (days) : 15/30/55/35

(All figures in mm)

S. No.	Particulars	Nov.	December		January	February		March
		15-30	1-30	31	1-31	1-23	24-28	1-30
1	E_{TO} (mm)	57.3	99.6	3.51	114.65	111.55	24.35	190.5
2	Crop coefficient (K_c)	0.30	0.70	1.05	1.05	1.05	0.65	0.65
3	Consumptive use E_{TC} (mm)	17.19	69.72	3.68	120.38	117.12	15.82	123.82
4	Plant use (pre-sowing) mm	60	-	-	-	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	-	-	-	(-)123.82
6	Gross consumptive use (mm)	77.19	73.4		120.38	132.94		-
7	Rainfall	11.41	14.45		10.88	5.20		5.36
8	Effective rainfall	-	10.02		-	-		-
9	Net irrigation requirement	77.19	63.38		120.38	132.94		-
10	Gross requirement at main canal head with 63% project efficiency	122.52	100.60		191.07	211.01		-
11	Total depth of water required at main canal head							
	(v) for 19830 ha with 20% (LBC) intensity	0.0048	0.0039		0.0075	0.0083		-
	(vi) for 35050 ha with 10% (RBC) intensity	0.0043	0.0036		0.0067	0.0074		-

Table 6.3(iv) : ESTIMATION OF CROP WATER REQUIREMENT

FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Wheat Hyv
SOWING TIME: 1 to 15 November
DURATION : 135 days, Growth stages (days) : 15/30/55/35

(All figures in mm)

S. No.	Particulars	Nov.		December		January	February		March
		1-15	**16-30**	**1-15**	**16-31**	**1-31**	**1-8**	**9-28**	**1-15**
1	E_{TO} (mm)	57.3	57.46	49.8	53.31	114.65	38.8	97.1	95.25
2	Crop coefficient (K_c)	0.30	0.70	0.70	1.05	1.05	1.05	0.65	0.65
3	Consumptive use E_{TC} (mm)	17.19	40.22	34.86	55.97	120.38	40.74	63.11	61.91
4	Plant use (pre-sowing) mm	60	-	-	-	-	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	-	-	-	(-)47.33	(-)61.91
6	Gross consumptive use (mm)	117.41		90.83		120.38	56.52		-
7	Rainfall	11.41		14.45		10.88	5.20		-
8	Effective rainfall	-		10.28		-	-		-
9	Net irrigation requirement	117.41		80.55		120.38	56.52		-
10	Gross requirement at main canal head with 63% project efficiency	186.36		127.86		191.10	89.71		-
11	Total depth of water required at main canal head								
	(vii) for 19830 ha with 20% (LBC) intensity	0.0073		0.0050		0.0075	0.0035		-
	(viii) for 35050 ha with 20% (RBC) intensity	0.0130		0.0089		0.0133	0.0062		-

Table 6.3(v) : ESTIMATION OF CROP WATER REQUIREMENT FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Wheat Hyv
SOWING TIME: 1 to 15 December
DURATION : 120 days, Growth stages (days) : 15/25/50/30

(All figures in mm)

S. No.	Particulars	December		January		February	March
		1-15	16-31	1-9	10-31	1-28	1-30
1	E_{TO} (mm)	49.8	53.31	33.28	81.37	135.9	184.35
2	Crop coefficient (K_c)	0.30	0.70	0.70	1.05	1.05	0.65
3	Consumptive use E_{TC} (mm)	14.94	37.32	23.30	85.44	142.70	119.83
4	Plant use (pre-sowing) mm	60	-	-	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	-	-	(-)119.83
6	Gross consumptive use (mm)	112.26		108.74		142.70	-
7	Rainfall	14.45		10.88		5.20	5.36
8	Effective rainfall	10.02		-		-	-
9	Net irrigation requirement	102.24		108.74		142.70	-
10	Gross requirement at main canal head with 63% project efficiency	162.28		172.60		226.50	-
11	Total depth of water required at main canal head						
	(ix) for 19830 ha with 30% (LBC) intensity	0.0096		0.0102		0.0134	-
	(x) for 35050 ha with 30% (RBC) intensity	0.0170		0.0181		0.0238	-

Table 6.3(vi) : ESTIMATION OF CROP WATER REQUIREMENT FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Gram
SOWING TIME: 1 – 15 November
DURATION : 120 days, Growth stages (days) : 20/25/45/30

(All figures in mm)

S. No.	Particulars	November		December		January		February
		1-20	21-30	1-14	15-31	1-29	30-31	1-28
1	E_{TO} (mm)	76.4	38.36	49.8	53.31	107.01	7.64	135.90
2	Crop coefficient (K_c)	0.26	0.94	0.94	1.00	1.00	0.55	0.55
3	Consumptive use E_{TC} (mm)	19.86	36.05	46.81	53.31	107.01	4.20	74.74
4	Plant use (pre-sowing) mm	60	-	-	-	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	-	(-)36.9	(-)4.20	(-)74.74
6	Gross consumptive use (mm)	115.91		100.12		70.11		-
7	Rainfall	11.41		14.45		10.88		5.20
8	Effective rainfall	-		10.40		-		-
9	Net irrigation requirement	115.91		89.72		70.11		-
10	Gross requirement at main canal head with 63% project efficiency	183.98		142.41		111.28		-
11	Total depth of water required at main canal head							
	(xi) for 19830 ha with 15% (LBC) intensity	0.0054		0.0042		0.0033		-
	(xii) for 35050 ha with 10% (RBC) intensity	0.0064		0.0049		0.0039		-

Table 6.3(vii) : ESTIMATION OF CROP WATER REQUIREMENT FOR BARNA COMMAND

DISTRICT : HOSHANGABAD (M.P.)
CROP : Green Gram (Moong)
SOWING TIME: 15-30 March
DURATION : 60 days, Growth stages (days) : 15/15/15/15

(All figures in mm)

S. No.	Particulars	March	April		May
		16-31	1-15	16-30	1-15
1	E_{TO} (mm)	95.25	112.95	112.95	139.48
2	Crop coefficient (K_c)	0.26	0.84	1.15	0.81
3	Consumptive use E_{TC} (mm)	24.76	94.88	129.90	112.98
4	Plant use (pre-sowing) mm	60	-	-	-
5	Soil moisture adjustment (mm)	-	-	-	(-)112.98
6	Gross consumptive use (mm)	84.76	94.88	129.90	-
7	Rainfall	5.36	4.95		-
8	Effective rainfall	-	-		-
9	Net irrigation requirement	84.76	224.80		-
10	Gross requirement at main canal head with 63% project efficiency	133.34	356.82		-
11	Total depth of water required at main canal head (xiii) for 19830 ha with 44% (LBC) intensity (xiv) for 35050 ha with 32% (RBC) intensity	 0.012 0.015	 0.031 0.040		 - -

Table 6.3(a) : Abstract of Water Requirement in Different Month at Main Canal Head of LBC Command

S. No	Name of Crop	% Crop/ Area(ha)	Gross Irrigation Requirement of LBC Command												Total Qty. of water in TMC
			Kharif Irrign.					Rabi Irrign				Summer Irrign			
			Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
1	A. Kharif														
	Soybean 1 KH	20/3966	0.0047												
	Soybean 2 KH	22/4363		0.0051											
	Total Kharif	42/8329													
2	B. Rabi														
	Wheat Hyv	20/3966						0.0048	0.0039	0.0075	0.0083				
	Wheat Hyv	20/3966						0.0073	0.0050	0.0075	0.0035				
	Wheat Hyv	30/5949							0.0096	0.0102	0.0134				
	Gram	15/2974						0.0054	0.0042	0.0033					
	Total Rabi	85/16855													
3	C. Summer														
	Green gram (Moong)	44/8725										0.012	0.031		
	Total summer	44/8725													
4	Total requirement for LBC command in TMC		0.0047	0.0051			-	0.0175	0.0227	0.0285	0.0252	0.012	0.031		
5	Desired capacity at main canal head in cumecs										10.64				
6	Designed capacity of LBC at main canal head cumecs										12.20				

Table 6.3(b) : Abstract of Water Requirement in Different Month at Main Canal Head of RBC Command

S. No	Name of Crop	% Crop/ Area(ha)	Gross Irrigation Requirement of RBC Command												Total Qty. of water in TMC
			Kharif Irrign.					Rabi Irrign				Summer Irrign			
			Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
1	A. Kharif														
	Soybean 1 KH	22/7711	0.0092												
	Soybean 2 KH	30/10515		0.0125											
	Total Kharif	52/18226													
2	B. Rabi														
	Wheat Hyv	10/3505						0.0043	0.0036	0.0067	0.0074				
	Wheat Hyv	20/7010						0.0130	0.0089	0.0133	0.0062				
	Wheat Hyv	30/10515							0.0170	0.0181	0.0238				
	Gram	10/3505						0.0064	0.0049	0.0039					
	Total Rabi	70/24535													
3	C. Summer														
	Green gram (Moong)	32/11216										0.015	0.040		
	Total summer	32/11216													
4	Total requirement for RBC command in TMC		0.0092	0.0125				0.024	0.0350	0.041	0.0374	0.015	0.040		
5	Desired capacity at main canal head in cumecs									15.30					
6	Designed capacity of RBC at main canal head cumecs									15.66					

Table 6.4(a) : RESERVOIR WORKING TABLE FOR PROPOSED CROPPING PATTERN

Year	Month	Gross capacity at the beginning of month (TMC)	Inflow from the catchment (TMC)	Total (TMC)	Utilisation				Over flow (TMC)	% of failure over the require ment of crops LBC RBC
					LBC TMC	RBC (TMC)	Evapor ation (TMC)	Total (TMC)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6+7 +8)	(10)	(11)
75-76	Oct	0.539	0.049	0.588	-	-	0.009	0.009	0.04	
	Nov	0.539	-	0.539	0.0175	0.024	0.007	0.0485		
	Dec	0.485	-	0.485	0.0227	0.0350	0.002	0.0597		
76-77	Jan	0.425	-	0.425	0.0285	0.041	0.002	0.0715		
	Feb	0.353	-	0.353	0.0252	0.0374	0.005	0.0676		
	Mar	0.285	-	0.285	0.012	0.015	0.008	0.035		
	Apr	0.250	-	0.250	0.0310	0.040	0.012	0.083		
	May	0.167	-	0.167	-	-	0.013	0.013		
	Jun	0.154	-	0.154	0.0047	0.0092	0.007	0.020		
	Jul	0.134	0.029	0.163	0.0051	0.0125	0.002	0.019		
	Aug	0.144	0.386	0.530	-	-	0.004	0.004		
	Sep	0.526	0.051	0.577	-	-	0.006	0.006	0.032	
	Oct	0.539	-	0.539	-	-	0.009	0.009		
	Nov	0.530	-	0.530	0.0175	0.024	0.007	0.0485		
	Dec	0.481	-	0.481	0.0227	0.0350	0.002	0.0597		
77-78	Jan	0.421	-	0.421	0.0285	0.041	0.002	0.0715		
	Feb	0.350	-	0.350	0.0252	0.0374	0.005	0.0676		
	Mar	0.282	-	0.282	0.012	0.015	0.008	0.035		
	Apr	0.247	-	0.247	0.0310	0.040	0.012	0.083		
	May	0.164	-	0.164	-	-	0.013	0.013		
	Jun	0.151	0.007	0.158	0.0047	0.0092	0.007	0.020		
	Jul	0.138	0.236	0.374	0.0051	0.0125	0.002	0.019		
	Aug	0.355	0.359	0.714	-	-	0.004	0.004	0.171	
	Sep	0.539	0.221	0.760	-	-	0.006	0.006	0.215	
	Oct	0.539	-	0.539	-	-	0.009	0.009		
	Nov	0.530	-	0.530	0.0175	0.024	0.007	0.0485		
	Dec	0.481	-	0.481	0.0227	0.035	0.002	0.0597		

Table 6.4(b) : RESERVOIR WORKING TABLE FOR PROPOSED CROPPING PATTERN

Year	Month	Gross capacity at the beginning of month (TMC)	Inflow from the catchment (TMC)	Total (TMC).	Utilisation				Over flow (TMC)	% of failure over the require ment of crops LBC RBC
					LBC TMC	RBC (TMC)	Evapor ation (TMC)	Total (TMC)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6+7 +8)	(10)	(11)
78-79	Jan	0.422	-	0.422	0.0285	0.041	0.002	0.715		
	Feb	0.351	-	0.351	0.0252	0.0374	0.005	0.0676		
	Mar	0.283	-	0.283	0.012	0.015	0.008	0.035		
	Apr	0.248	-	0.248	0.0312	0.040	0.012	0.083		
	May	0.165	-	0.165	-	-	0.013	0.013		
	Jun	0.152	0.004	0.156	0.0047	0.0092	0.007	0.020		
	Jul	0.136	0.317	0.453	0.0051	0.0125	0.002	0.019		
	Aug	0.434	0.360	0.794	-	-	0.004	0.004	0.251	
	Sep	0.539	0.003	0.542	-	-	0.006	0.006		
	Oct	0.536	-	0.536	-	-	0.009	0.009		
	Nov	0.527	-	0.527	0.0175	0.024	0.007	0.0485		
	Dec	0.479	-	0.479	0.0227	0.035	0.002	0.0597		
79-80	Jan	0.419	-	0.419	0.0285	0.041	0.002	0.0715		
	Feb	0.348	-	0.348	0.0252	0.0374	0.005	0.0676		
	Mar	0.280	-	0.280	0.012	0.015	0.008	0.035		
	Apr	0.245	-	0.245	0.0310	0.040	0.012	0.083		
	May	0.162	-	0.162	-	-	0.013	0.013		
	Jun	0.149	0.0006	0.150	0.0047	0.0092	0.007	0.020		
	Jul	0.130	0.031	0.161	0.0051	0.0125	0.002	0.019		
	Aug	0.142	0.034	0.176	-	-	0.004	0.004		
	Sep	0.172	0.062	0.234	-	-	0.006	0.006		
	Oct	0.228	-	0.228	-	-	0.009	0.009		
	Nov	0.219	-	0.219	0.0175	0.024	0.007	0.0485		
	Dec	0.170	-	0.170	0.0227	0.035	0.002	0.0597		
80-81	Jan	0.104	-	0.104	0.0285	0.041	0.002	0.0715		100 100
	Feb	0.102	-	0.102	0.0252	0.0374	0.005	0.0676		100 100
	Mar	0.097	-	0.097	0.012	0.015	0.008	0.035		100 100
	Apr	0.089	-	0.089	0.0310	0.040	0.012	0.083		100 100
	May	0.083	-	0.083	-	-	0.013	0.013		
	Jun	0.070	0.025	0.095	0.0047	0.0092	0.007	0.020		- 100
	Jul	0.0833	0.179	0.263	0.0051	0.0125	0.002	0.019		
	Aug	0.243	0.181	0.424	-	-	0.004	0.004		
	Sep	0.420	0.117	0.537	-	-	0.006	0.006		
	Oct	0.531	-	0.531	-	-	0.009	0.009		
	Nov	0.522	-	0.522	0.0175	0.024	0.007	0.0485		
	Dec	0.474	-	0.474	0.0227	0.035	0.002	0.0597		

Table 6.4(c) : RESERVOIR WORKING TABLE FOR PROPOSED CROPPING PATTERN

Year (1)	Month (2)	Gross capacity at the beginning of month (TMC) (3)	Inflow from the catchment (TMC) (4)	Total (TMC) (5)	Utilisation				Over flow (TMC) (10)	% of failure over the requirement of crops LBC RBC (11)
					LBC (TMC) (6)	RBC (TMC) (7)	Evaporation (TMC) (8)	Total (TMC) (9) = (6+7+8)		
81-82	Jan	0.415	-	0.415	0.0285	0.041	0.002	0.0715		
	Feb	0.344	-	0.344	0.0252	0.0374	0.005	0.0676		
	Mar	0.277	-	0.277	0.012	0.015	0.008	0.035		
	Apr	0.242	-	0.242	0.0310	0.040	0.012	0.083		
	May	0.159	-	0.159	-	-	0.013	0.013		
	Jun	0.146	0.026	0.172	0.0047	0.0092	0.007	0.020		
	Jul	0.152	0.029	0.181	0.0051	0.0125	0.002	0.019		
	Aug	0.162	0.164	0.326	-	-	0.004	0.004		
	Sep	0.322	0.015	0.337	-	-	0.006	0.006		
	Oct	0.331	-	0.331	-	-	0.009	0.009		
	Nov	0.322	-	0.322	0.0175	0.024	0.007	0.0485		
	Dec	0.274	-	0.274	0.0227	0.035	0.002	0.0597		
82-83	Jan	0.214	-	0.214	0.0285	0.041	0.002	0.0715		
	Feb	0.143	-	0.143	0.0252	0.0374	0.005	0.0676		- 20
	Mar	0.083	-	0.083	0.012	0.015	0.008	0.035		100 100
	Apr	0.075	-	0.075	0.0310	0.040	0.012	0.083		100 100
	May	0.063	-	0.063	-	-	0.013	0.013		
	Jun	0.050	-	0.050	0.0047	0.0092	0.007	0.020		100 100
	Jul	0.043	0.026	0.069	0.0051	0.0125	0.002	0.019		100 100
	Aug	0.067	0.357	0.424	-	-	0.004	0.004		
	Sep	0.420	0.115	0.535	-	-	0.006	0.006		
	Oct	0.529	-	0.529	-	-	0.009	0.009		
	Nov	0.520	-	0.520	0.0175	0.024	0.007	0.0485		
	Dec	0.472	-	0.472	0.0227	0.035	0.002	0.0597		
83-84	Jan	0.412	-	0.412	0.0285	0.041	0.002	0.0715		
	Feb	0.341	-	0.341	0.0252	0.0374	0.005	0.0676		
	Mar	0.273	-	0.273	0.012	0.015	0.008	0.035		
	Apr	0.238	-	0.238	0.0310	0.040	0.012	0.083		
	May	0.155	-	0.155	-	-	0.013	0.013		
	Jun	0.142	-	0.142	0.0047	0.0092	0.007	0.020		
	Jul	0.122	0.019	0.141	0.0051	0.0125	0.002	0.019		
	Aug	0.122	0.376	0.498	-	-	0.004	0.004		
	Sep	0.494	0.228	0.722	-	-	0.006	0.006	0.177	
	Oct	0.539	0.002	0.541	-	-	0.009	0.009		
	Nov	0.532	-	0.532	0.0175	0.024	0.007	0.0485		
	Dec	0.484	-	0.484	0.0227	0.035	0.002	0.0597		

Table 6.4(d) : RESERVOIR WORKING TABLE FOR PROPOSED CROPPING PATTERN

Year	Month	Gross capacity at the beginning of month (TMC)	Inflow from the catchment (TMC)	Total (TMC)	Utilisation				Over flow (TMC)	% of failure over the requirement of crops LBC RBC
					LBC TMC	RBC (TMC)	Evaporation (TMC)	Total (TMC)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6+7+8)	(10)	(11)
84-85	Jan	0.424	-	0.424	0.0285	0.041	0.002	0.0715		
	Feb	0.353	-	0.353	0.0252	0.0374	0.005	0.0676		
	Mar	0.286	-	0.286	0.012	0.015	0.008	0.035		
	Apr	0.251	-	0.251	0.0310	0.040	0.012	0.083		
	May	0.168	-	0.168	-	-	0.013	0.013		
	Jun	0.155	-	0.155	0.0047	0.0092	0.007	0.020		
	Jul	0.135	0.058	0.193	0.0051	0.0125	0.002	0.019		
	Aug	0.174	0.574	0.748	-	-	0.004	0.004	0.205	
	Sep	0.539	0.022	0.561	-	-	0.006	0.006	0.016	
	Oct	0.539	-	0.539	-	-	0.009	0.009		
	Nov	0.530	-	0.530	0.0175	0.024	0.007	0.0485		
	Dec	0.482	-	0.482	0.0227	0.035	0.002	0.0597		
85-86	Jan	0.423	-	0.423	0.0285	0.041	0.002	0.0715		
	Feb	0.352	-	0.352	0.0252	0.0374	0.005	0.0676		
	Mar	0.284	-	0.284	0.012	0.015	0.008	0.035		
	Apr	0.249	-	0.249	0.0310	0.040	0.012	0.083		
	May	0.166	-	0.166	-	-	0.013	0.013		
	Jun	0.153	-	0.153	0.0047	0.0092	0.007	0.020		
	Jul	0.133	0.073	0.206	0.0051	0.0125	0.002	0.019		
	Aug	0.187	0.356	0.543	-	-	0.004	0.004		
	Sep	0.539	0.235	0.774	-	-	0.006	0.006	0.229	
	Oct	0.539	0.146	0.685	-	-	0.009	0.009	0.137	
	Nov	0.539	-	0.539	0.0175	0.024	0.007	0.0485		
	Dec	0.491	-	0.491	0.0227	0.035	0.002	0.0597		
86-87	Jan	0.431	-	0.431	0.0285	0.041	0.002	0.0715		
	Feb	0.360	-	0.360	0.0252	0.0374	0.005	0.0676		
	Mar	0.293	-	0.293	0.012	0.015	0.008	0.035		
	Apr	0.258	-	0.258	0.0310	0.04	0.012	0.083		
	May	0.175	-	0.175	-	-	0.013	0.013		
	Jun	0.162	-	0.162	0.0047	0.0092	0.007	0.020		
	Jul	0.142	0.702	0.844	0.0051	0.0125	0.002	0.019	0.286	
	Aug	0.539	0.176	0.715	-	-	0.004	0.004	0.172	
	Sep	0.539	0.053	0.592	-	-	0.006	0.006	0.047	
	Oct	0.539	-	0.539	-	-	0.009	0.009		
	Nov	0.530	-	0.530	0.0175	0.024	0.007	0.0485		
	Dec	0.481	-	0.481	0.0227	0.035	0.002	0.0597		

Table 6.4(e) : RESERVOIR WORKING TABLE FOR PROPOSED CROPPING PATTERN

Year	Month	Gross capacity at the beginning of month (TMC)	Inflow from the catchment (TMC)	Total (TMC)	Utilisation				Over flow (TMC)	% of failure over the requirement of crops LBC RBC
					LBC TMC	RBC (TMC)	Evaporation (TMC)	Total (TMC)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6+7+8)	(10)	(11)
87-88	Jan	0.421	-	0.421	0.0285	0.041	0.002	0.0715		
	Feb	0.349	-	0.349	0.0252	0.0374	0.005	0.0676		
	Mar	0.281	-	0.281	0.012	0.015	0.008	0.035		
	Apr	0.246	-	0.246	0.0310	0.040	0.012	0.083		
	May	0.163	-	0.163	-	-	0.013	0.013		
	Jun	0.150	-	0.150	0.0047	0.0092	0.007	0.020		
	Jul	0.130	0.003	0.133	0.0051	0.0125	0.002	0.019		
	Aug	0.114	0.188	0.302	-	-	0.004	0.004		
	Sep	0.298	0.198	0.497	-	-	0.006	0.006		
	Oct	0.491	-	0.491	-	-	0.009	0.009		
	Nov	0.482	-	0.482	0.0175	0.024	0.007	0.0485		
	Dec	0.433	-	0.433	0.0277	0.035	0.002	0.0597		
88-89	Jan	0.373	-	0.373	0.0285	0.041	0.002	0.0715		
	Feb	0.301	-	0.301	0.0252	0.0374	0.005	0.0676		
	Mar	0.234	-	0.234	0.012	0.015	0.008	0.035		
	Apr	0.199	-	0.199	0.0310	0.040	0.012	0.083		
	May	0.116	-	0.116	-	-	0.013	0.013		
	Jun	0.103	0.0035	0.106	0.0047	0.0092	0.007	0.020		
	Jul	0.086	0.032	0.118	0.0051	0.0125	0.002	0.019		
	Aug	0.099	0.155	0.254	-	-	0.004	0.004		
	Sep	0.250	0.012	0.262	-	-	0.006	0.006		
	Oct	0.256	0.002	0.258	-	-	0.009	0.009		
	Nov	0.249	-	0.249	0.0175	0.024	0.007	0.0485		
	Dec	0.201	-	0.201	0.0227	0.035	0.002	0.0597		
89-90	Jan	0.142	-	0.142	0.0285	0.041	0.002	0.0715		- 30
	Feb	0.0832	-	0.0832	0.0252	0.0374	0.005	0.0676		100 100
	Mar	0.078	-	0.078	0.012	0.015	0.008	0.035		100 100
	Apr	0.070	-	0.070	0.0310	0.040	0.012	0.083		100 100
	May	0.058	-	0.058	-	-	0.013	0.013		
	Jun	0.045	0.005	0.05	0.0047	0.0092	0.007	0.020		100 100
	Jul	0.043	0.031	0.074	0.0051	0.0125	0.002	0.019		100 100
	Aug	0.072	0.239	0.311	-	-	0.004	0.004		
	Sep	0.307	0.227	0.534	-	-	0.006	0.006		
	Oct	0.528	-	0.528	-	-	0.009	0.009		
	Nov	0.519	-	0.519	0.0175	0.024	0.007	0.0485		
	Dec	0.471	-	0.471	0.0227	0.035	0.002	0.0597		

Table 6.4(f) : RESERVOIR WORKING TABLE FOR PROPOSED CROPPING PATTERN

Year	Month	Gross capacity at the beginning of month (TMC)	Inflow from the catchment (TMC)	Total (TMC)	Utilisation				Over flow (TMC)	% of failure over the require ment of crops LBC RBC
					LBC TMC	RBC (TMC)	Evapor ation (TMC)	Total (TMC)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6+7 +8)	(10)	(11)
90-91	Jan	0.411	-	0.411	0.0285	0.041	0.002	0.0715		
	Feb	0.340	-	0.340	0.0252	0.0374	0.005	0.0676		
	Mar	0.272	-	0.272	0.012	0.015	0.008	0.035		
	Apr	0.237	-	0.237	0.0310	0.040	0.012	0.083		
	May	0.154	-	0.154	-	-	0.013	0.013		
	Jun	0.141	-	0.141	0.0047	0.0092	0.007	0.020		
	Jul	0.121	0.081	0.202	0.0051	0.0125	0.002	0.019		
	Aug	0.183	0.202	0.385	-	-	0.004	0.004		
	Sep	0.381	0.311	0.692	-	-	0.006	0.006	0.147	
	Oct	0.539	0.050	0.589	-	-	0.009	0.009	0.041	

Table 6.4 (g) : Statement of Shortfall of Irrigation for Proposed Cropping pattern

SUMMARY OF WORKING TABLE

S. No.	Year	Month	% of Short fall		Remarks	
			LBC	RBC	LBC	RBC
1	80-81	Jan	100%	100%	Rabi 100%	Rabi 100%
		Feb	100%	100%	Rabi 100%	Rabi 100%
		Mar	100%	100%	Summer 100%	Summer 100%
		Apr	100%	100%	Summer 100%	Summer 100%
		Jun	-	100%	-	Kharif 100%
2	82-83	Feb	-	20%	-	Rabi 20%
		Mar	100%	100%	Summer 100%	Summer 100%
		Apr	100%	100%	Summer 100%	Summer 100%
		Jun	100%	100%	Kharif 100%	Kharif 100%
		Jul	100%	100%	Kharif 100%	Kharif 100%
3	89-90	Jan	-	30%	-	Rabi 30%
		Feb	100%	100%	Rabi 100%	Rabi 100%
		Mar	100%	100%	Summer 100%	Summer 100%
		Apr	100%	100%	Summer 100%	Summer 100%
		Jun	100%	100%	Kharif 100%	Kharif 100%
		Jul	100%	100%	Kharif 100%	Kharif 100%

The failure in respect of LBC	(i) Rabi	2/15 = 13%	Success	87%
	(ii) Kharif	2/15 = 13%	Success	87%
	(iii) Summer	3/15 = 20%	Success	80%
The failure in respect of RBC	(i) Rabi	3/15 = 20%	Success	80%
	(ii) Kharif	3/15 = 20%	Success	80%
	(iii) Summer	3/15 = 20%	Success	80%

Chapter 7

SUMMARY AND CONCLUSION

7.1 SUMMARY

The Barna project located in the Raisen District of Madhya Pradesh is the first major River Valley Project of the state and taken up in the second five year plan. It is designed for annual irrigation of 60500 ha. by multiple cropping with intensity of irrigation varying from 104% to 125% on right and left bank canal system respectively. The irrigation from the Barna reservoir started in the year 1975-76.

The development of Kharif irrigation in the Barna command is almost nil. The maximum of 2% of Kharif irrigation has been recorded in the year of 1990-91 against the 52% of project performance designed. The summer irrigation was not at all suggested by the agriculture department at the time of formulation of project. Development of Rabi irrigation is satisfactory. The Rabi irrigation intensity during the year 1998-99 was 64% against design of 57%.

The socio economic status and general living standard of farmers of Barna command has improved after the coming up of the Barna project. The single crop in general was taken by cultivators before the inception of the project. The economic position of the farmers has improved by adoption of double crops of Kharif and Rabi with higher yield. In spite of the above development under utilisation of created irrigation potential and water logging problems have been noticed from the beginning of irrigation development. The project was completed about 20 years ago. It is necessary to identify the other problems. For identification of irrigation management problems a complete study of the project from the very beginning is required for all the related field of irrigation under different subheads like irrigation development, water use pattern, different project design parameters, canal study, study of reservoir balance and its use, position of water logging, minor wise/outlet wise irrigation distribution in head, middle and tail of canal system, operation and maintenance status, role of non government organisation, irrigation revenue recovery, socio economic status and infrastructural facilities.

On study of all the above field major irrigation management problems identified are as below :

(i) Under utilisation of reservoir storage

(ii) Inequitable distribution of water in canal system head to tail.

(iii) Water logging

(iv) Poor irrigation revenue recovery.

The summary of the above problems and their remedial measures are given below.

7.1.1 Under Utilisation of Reservoir Storage

Under utilisation of reservoir storage is due to non achievement of annual irrigation and particularly non development of Kharif irrigation. The cropping pattern of Kharif has been replaced by adoption of soybean as major Kharif crops. It requires less water and farmer of the area prefer rainfed cultivation of Kharif crops as there is about 1132 mm average annual rainfall and about 1000 mm rain during Kharif period. The protective irrigation is given to Kharif crops in the time of failure of rains. the development of paddy as Kharif crops is not suitable due to various cultivation problem in Black cotton clay soils of the command.

Sugarcane development will further increase the water logging and inequity problems of command. As the farmers of head reach may adopt it due to easily availability of irrigation and tail enders will get hardly any water for their seasonal crops.

Keeping the present protective irrigation development for soybean as same, the possibility for summer development should be found out. The huge live storage balance in the reservoir after Rabi irrigation can be utilised for summer irrigation of the command. On calculating the requirement of need of crops the figure for summer moong comes out to be about 37%.

The complete crop water requirement of Kharif, Rabi and summer for LBC and RBC system is calculated, keeping the canal capacity same as per project design by present design practice. The reservoir simulation study is also carried out for the year 1975-76 to 1990-91 for finding the dependability and failures of crops in different years. The dependability of irrigation for LBC and RBC comes to 85% and 80% respectively which is quite satisfactory and higher than project design.

The proposed cropping intensity in different season is suggested below :

Kharif crop intensity %			Rabi crop intensity %			Summer crop intensity %		
Name of crop	LBC	RBC	Name of crop	LBC	RBC	Name of crop	LBC	RBC
Soybean	42	52	Wheat HYV	70	60	Green gram	44	32
			Gram	15	10			
Total	42	52	Total	85	70	Total	44	32

The proposed irrigation intensity for the above cropping pattern is given below :

Season	Irrigation intensity %	
	LBC	RBC
Kharif	42	52
Rabi	85	70
Summer	44	32
Total	171%	154%

The Kharif intensity is kept same as per the project design. The Rabi intensity is kept slightly higher side than project design, keeping the canal capacity as same as per the project design. The possible summer intensity for Green Gram comes to 44% and 32% for LBC and RBC system respectively. There is a good possibility of development of summer irrigation in the command. The annual irrigation will increase on adoption of summer irrigation and the live balance of the reservoir will be fruitfully utilised for socio-economic development of farmers of the command.

7.1.2 Inequitable Irrigation Distribution in Canal System Head to Tail

In equitable distribution of irrigation water head to tail is very common in Barna command. For identifying the problem the irrigation intensity at head, middle and tail reaches of (D-1) distributary of RBC system is selected. The villages are divided in head, middle and tail reaches as per their location in the command. The irrigation intensity of head reach is about 70% while in middle and tail reach it comes out to 53% and 37% respectively. The distribution in outlets of minors from head to tail is also not equitable.

The equitable distribution of irrigation water is one of the objective of an ideal irrigation project. The causes of inequitable distribution has been summarised below :

Non implementation of Warabandi/Osrabandi, allowing the lift irrigation from the canal. Absence of permanent structures of outlets, tempering of outlet gates, poor maintenance, insufficient maintenance grant, avoiding night irrigation by head reach cultivators and wasteful use of irrigation by them, poor role of non Govt. organisation for irrigation management beyond the outlets, less use of ground water and lack of communication system are the main causes for the problem.

The remedial measures for the problem has been suggested below.

Permanent canal outlets system, removal of extra outlets, disallowing the lift irrigation in the problematic distributary and minors, repairs of minor gates, restoring the canal systems by necessary maintenance, revision of maintenance norms, implementation of Warabandi, perfect communication system. Charging the head reaches farmers penal irrigation rate for irrigation more than design intensity and fixing the joint responsibility for equitable distribution of tail and head reaches officers are the remedial measures for equitable distribution of irrigation in Barna command.

7.1.3 Water Logging in Barna Command

An area of 555 ha is reported to be water logged in Barna command. This is about 1.0% of design CCA of the project. The water logging in the area is almost constant and it is not increasing at present. But proper care is required for future control and checking the present situation. The cause of water logging in the Barna command is given as below.

Excess irrigation by head reaches farmers of canal system particularly in initial years of irrigation, poor maintenance of drainage system, inequitable distribution of irrigation, little use of ground water in the command area are the causes of water logging in the command.

The remedial measures suggested for water logging are given as below.

Promoting the conjunctive use of ground water and surface water in all the villages of the command, equitable distribution of water, proper maintenance of drainage system by silt clearance, joining the canal borrow pits to near by drains, adoption of summer crops by lifting the groundwater are the remedial measures for water logging.

7.1.4 Poor Irrigation Revenue Recovery

The recovery position of revenue is very poor in Barna command. So far out of 3.77 crore only 24.77 lakh has been collected which is only 6.5%. The causes of poor recovery is summarised below :

(i) Waving off the irrigation penalty of defaulters by the Govt.

(ii) Insufficient training and support to officers for implementation of various powers given under M.P. Irrigation Act 1931.

(iii) No follow up of the procedure adopted by other state having higher recovery rate.

(iv) Not discouraging the defaulters by indirect measures like disallowing them for contesting local body election, purchase and sale of land and disallowing loans to defaulters.

(v) Non-cooperation of political leaders.

(vi) Poor role of NGO's for collection of revenue recovery.

The remedial measures for improving the revenue recovery are given below.

(i) Complete reviewal of recovery procedure is necessary. The procedure of other states having higher rate of recovery like U.P. may be followed where the irrigation revenue is collected by revenue department instead of irrigation department.

(ii) Indirect measures like disallowing defaulters from contesting the local body election, from taking loans and from purchase and sale of any immovable property will also be helpful in improving the revenue recovery position in the command.

(iii) Proper training to officers and staff regarding various rules, regulations and act for taking the strong action against the defaulters is also necessary.

(iv) Co-operation of political leaders and influential farmers and non Govt. organisation is also desirable.

7.2 CONCLUSION

In most of the project of India, the design benefits of the project differ with the actual physical achievements. Even a well designed irrigation project is ought to have some problems in due course of time. The complete evaluation of project is necessary to know the different problems correctly.

In Barna project of Madhya Pradesh, the problem of under utilisation of irrigation and reservoir storage, water logging, in equitable distribution of irrigation and poor irrigation revenue recovery has been identified by detailed study of all the related field.

The cause of different problems are found out by the above study. The remedial measures suggested for all the above problems will be helpful to manage the project in proper way. A periodic reviewal of project, their problems and implementation of remedial measures is necessary for all the important irrigation project of the country.

REFERENCES

Chaudhary, M. S.; Dak, T. M. and Sharma, M. L. (1985)
"Environmental and Socio-Economic Impact of Irrigation Water Management in India", Proceedings of the Seminar on Irrigation Water management held at Roorkee (Jan 12-13, 1985), pp. IV-1.

Chaudhary, T. N. (1988)
"Irrigation Management for Optimising Root Distribution Water Uptake Relationship in Wheat for Grain production", Proceeding held at Karnal, India (Feb. 24-27, 1988), Published by CSSRI, Karnal (1990), pp 99-104.

Dhawan, B. D. (1989)
"Studies in Irrigation and Water Management" published by Commonwealth Publishers, New Delhi, pp. 1-17.

FAO (1981)
"Yield Response to Water", FAO Irrigation and Drainage paper No. 33, Published by Food and Agriculture Organisation of the United Nations, Rome (Italy) 1981.

FAO (1992)
"Guideline for Predicting Crop Water Requirement" FAO Irrigation and Drainage Paper No. 24, Published by Food and Agriculture Organisation of the United Nations, Rome (Italy).

Hargreaves, G. H. (1956)
"Irrigation requirements based on climatic data"; In the proceedings of ASCE Journal of I & D Division.

Jain, A. K. (1996)
"A discussion work entitled 'study on the problem of Irrigation management in Tawa Command with particular reference to Nasirabad distributary", done at WRDTC, University of Roorkee, Roorkee, Dec. 1996.

Michael, A. M. (1986)
"Soil plant-water relationship; In "Irrigation theory and practice", published by Vani educational Books, A Division of Vikas Publishing House Pvt. Ltd., New Delhi.

Mohile, A. D. and Pathak, R. S. (1993)
A Theme Paper for "National Workshop on Farmers participation in Management of Irrigation System", Proceedings of National Workshop on Farmer's Participation held at WRDTC, University of Roorkee, Oct. 1993, pp-7.

Narayan Rao, K. R. (1989)
"Irrigation Management under Major River Valley project", CBIP Publication No. 122, p. 42.

Nigam, P. S. and Gupta, Y. N. (1985)
"Irrigation Water Management", Proceedings of the Seminar on Irrigation Water Management held at Roorkee (Jan 12-13, 1985), pp 27.

Reddy, V. (1989)
"Dynamics of Irrigation Water Management", Published by S. B. Nangia, New Delhi, pp. 46-47.

Singh, Bharat (1985)
"Irrigation Management in India", Proceeding of the Seminar on Irrigation Water management held at Roorkee (Jan 12-13, 1985), pp. I1-I13.

Sinha, C. P. (1985)
"Irrigation Management in India", Proceedings of the Seminar held at Roorkee 9Jan 12-13, 1985), pp. III-171.

Singh, R. P. (1993)
"Important Issues on Farmers Participation in Irrigation Management", National Workshop Proceedings on Farmers Participation at WRDTC, University of Roorkee, Oct. 1993, pp 65-66.

Tyagi, N. K. (1988)
A Paper from the National Symposium on "Management of Irrigation System", Proceeding held at Karnal, India (Feb. 24-27, 1988), Published by Central Soil Salinity Research Institute, Karnal (1990), pp. 5-12.

Other Literature Cited

Report and Financial Statements of Barna Project (1956), Published by Central Water Commission, Govt. of India, New Delhi.

Report on Distributary No. (D-1) of RBC (1980), Published by Executive Engineer, Barna, RBC Division, Water Resources Department, Bari, Distt. Raisen.

"Estimation of Crop Water Requirement and Irrigation Water Requirement", Design Series Technical Circular No. 25 Published by M.P. Irrigation Deptt. Vide No. 205/BODHI/R&C/TC/11/88 dated 20.6.90.

Revised Project Report of Barna (1991), Published by Chief Engineer, Operation and Maintenance, Water resources Department, Bhopal.

Final Report on Evaluation Study of Barna CAD Project (Vol. I and Vol. II, 1995), Published by Redecon (India) Pvt. Ltd., New Delhi.

Performance and Evaluation Report (1995), Published by Chief Engineer, Operation and Maintenance, Water Resources Department, Bhopal.

Summary Report of Project on Sift Component (1999), Published by Chief Engineer, Operation and Maintenance, Water Resources Department, Bhopal.

Progress Report of Irrigation Revenue Recovery No. 3352036/March 2000, Published by Engineer in Chief M.P. Water resources Department, Bhopal.

Annexure 1

Barna Project

Monthly Water Requirement of Crops for Barna Project (As adopted for RBC and LBC)

S. No.	Crops	Total water requirement in inches	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
	KHARIF													
1	Paddy local & HYV	23"	4	4	4	3,4	2,2	-	-	-	-	-	-	-
2	HY Maize/Jowar	6"	-	-	-	3	3	-	-	-	-	-	-	-
3	Pulses	4'	-	-	-	2,2	-	-	-	-	-	-	-	-
4	Ground Nut	4"	-	-	-	4	-	-	-	-	-	-	-	-
5	Vegetable	16"	-	3,3	-	3,3	4	-	-	-	-	-	-	-
6	Soybean	10"	-	-	-	6	4	-	-	-	-	-	-	-
7	Fodder	4"	-	-	-	4	-	-	-	-	-	-	-	-
	RABI													
1	Wheat HYV	22"	-	-	-	-	2	3	5	5	2	3,2	-	-
2	Wheat Local	16"	-	-	-	-	2	3	3	3	3	2	-	-
3	Vegetable	32"	-	-	-	-	3	7	7	2,2	2,2	3	-	-
4	Gram	4"	-	-	-	4	-	-	-	-	-	-	-	-

Annexure 2 : Ground Water Table in Barna Command in Different Years for Water logged Areas

S. No.	Name of Village	Water table depth from G.L. (Pre-monsoon) in m				Water table depth from G.L. (Post-monsoon) in m			
		1985	1990	1995	2000	1985	1990	1995	2000
1	Surwara	3.42	3.18	2.16	1.92	2.89	2.17	1.82	1.67
2	Kanwar	4.19	3.97	2.88	2.01	3.88	3.42	1.88	1.71
3	Amrawad	3.88	3.42	2.69	1.94	3.62	2.99	1.74	1.69
4	Chanpur	4.72	4.59	3.88	2.92	4.22	4.11	1.89	1.77
5	Bhondiya	5.12	4.77	4.02	3.11	4.89	4.22	2.22	2.01
6	Bhaisaya	4.28	3.86	3.42	2.79	3.89	3.16	2.44	2.11
7	Satramau	5.22	4.61	3.88	3.01	4.76	3.99	2.67	2.28
8	Dhansari	3.67	3.31	2.51	1.78	3.16	2.34	1.90	1.64

Annexure 3 : Irrigation Water Rates for Some Important Crops in M.P.

S. No.	Crop	Rate per Ha in Rs.
1	Paddy (Kharif)	247
2	Paddy (Rabi)	494
3	Wheat	247
4	Banana, pan, garden crops, rubber, sugarcane	741
5	Ground nut, jawar, moong, soybean, arhar, udad	124
6	Cotton (Hybrid)	494
7	Vegetables	741
8	Berseem grass (Fodder crop)	371
9	Only Palewa	99

Annexure 4 : Areawise Waterlogged Villages in Barna Command

S. No.	Name of Village	Area affected by water logging (ha)
1	Surwara	105.42
2	Kanwar	103.87
3	Amrawad	102.66
4	Chanpur	12.16
5	Bhondiya	58.19
6	Bhaisaya	57.88
7	Satramau	10.91
8	Dhansari	104.09
	Total Area	555.18

ANNEXURE NO. 5

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **JANUARY** Height above M.S.L. - **302 M.**

Latitude : 77° 46 ' E Latitutude : 22° 46' N

S.No.	Year	Temperature in ° c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	25.7	10.9	61	38	45.2	2.9	4.4	105.6	1.22
2	1985	24.5	8.2	55	32	25.6	0.8	4.7	112.8	1.30
3	1986	24.5	9.1	51	32	15.1	2.1	5.2	124.8	1.44
4	1987	25.3	8.8	50	28	0.0	1.4	4.4	105.6	1.22
5	1988	26.5	11.8	52	33	3.9	3.7	5.0	120.0	1.38
6	1989	25.7	10.6	59	39	24.1	1.9	4.5	108.0	1.25
7	1990	25.1	8.0	42	23	0.0	0.6	4.7	112.8	1.30
8	1991	23.7	10.7	69	39	0.0	2.4	4.2	100.8	1.16
9	1992	26.6	9.9	51	29	5.2	2.2	5.0	120.0	1.38
10	1993	25.2	11.2	70	39	26.5	1.7	5.2	124.8	1.44
11	1994	24.6	9.8	57	30	1.5	2.5	4.3	103.2	1.19
12	1995	26.0	9.2	53	25	0.0	2.3	4.1	98.4	1.13
13	1996	25.9	9.9	50	29	0.0	1.3	4.4	105.6	1.22
14	1997	25.0	9.0	47	26	0.0	0.5	4.2	100.8	1.16
15	1998	24.0	8.4	62	32	13.2	2.0	4.0	96.0	1.11
16	1999	25.9	11.1	63	39	13.9	2.4	4.3	103.2	1.19
	AVEG:	**25.263**	**9.788**	**55.750**	**32.063**	**10.888**	**1.919**	**4.538**	**108.900**	**1.256**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **FEBRUARY** Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E Latitutude : 22^{0} 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	26.6	10.5	43	25	1.8	1.6	4.3	105.6	1.22
2	1985	27.7	12.4	62	32	22.7	1.6	4.0	96.0	1.11
3	1986	30.3	13.5	51	27	14.0	1.6	4.2	100.8	1.16
4	1987	29.1	12.1	39	21	0.0	1.8	4.4	105.6	1.22
5	1988	28.8	11.8	39	23	3.2	0.9	4.1	98.4	1.13
6	1989	30.8	14.0	47	25	0.0	1.3	4.3	103.2	1.19
7	1990	31.6	13.3	32	16	0.0	0.5	5.2	124.8	1.44
8	1991	26.7	11.0	45	26	7.6	2.1	5.0	120.0	1.38
9	1992	30.3	12.8	44	27	0.0	2.4	4.2	100.8	1.16
10	1993	27.5	12.2	58	27	13.5	2.5	4.7	112.8	1.30
11	1994	28.5	11.8	35	19	0.6	1.2	4.5	108.0	1.25
12	1995	26.6	9.9	44	21	1.4	1.7	5.0	120.0	1.38
13	1996	29.1	13.4	47	23	1.7	2.4	4.4	105.6	1.22
14	1997	27.4	11.3	38	20	0.0	0.8	5.2	124.8	1.44
15	1998	27.5	11.7	51	29	3.2	2.0	4.7	112.8	1.3
16	1999	29.0	12.4	60	34	13.6	1.3	4.4	105.6	1.22
	AVEG:	**28.594**	**12.131**	**45.938**	**24.688**	**5.206**	**1.606**	**4.538**	**109.050**	**1.258**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** | Month : **MARCH** | Height above M.S.L. - **302 M.**

Latitude : 77^0 46 ' E | Latitutude : 22^0 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	35.1	17.5	23	12	0.0	0.9	4.9	117.6	1.36
2	1985	32.5	16.1	41	21	7.0	2.6	5.1	122.4	1.41
3	1986	33.3	16.5	33	16	5.1	1.5	5.0	120.0	1.38
4	1987	35.7	18.6	27	15	0.8	1.0	5.2	124.8	1.44
5	1988	32.9	16.4	26	15	0.3	1.7	4.8	115.2	1.33
6	1989	33.1	15.9	29	18	7.0	1.0	5.0	120.0	1.38
7	1990	32.4	16.8	47	28	35.1	3.3	5.1	122.4	1.41
8	1991	32.0	18.8	36	12	13.1	1.1	5.1	122.4	1.41
9	1992	36.3	18.4	28	18	0.0	2.3	5.4	129.6	1.50
10	1993	32.6	16.5	40	21	16.0	1.7	5.4	129.6	1.50
11	1994	33.2	16.6	23	11	0.0	1.2	4.9	117.6	1.36
12	1995	34.8	17.8	29	17	0.0	1.7	5.2	124.8	1.44
13	1996	33.7	16.6	25	14	0.0	0.4	5.3	127.2	1.47
14	1997	35.5	18.5	30	15	0.0	0.9	5.0	120.0	1.38
15	1998	32.7	15.7	33	15	0.0	2.2	4.8	115.2	1.33
16	1999	33.7	17.1	51	43	1.5	1.4	5.0	120.0	1.38
	AVEG:	**33.719**	**17.113**	**32.563**	**18.188**	**5.369**	**1.556**	**5.075**	**121.800**	**1.405**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **APRIL** Height above M.S.L. - **302 M.**

Latitude : $77^0 46'$ E Latitutude : $22^0 46'$ N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	38.6	21.5	22	13	1.4	1.5	5.4	129.6	1.50
2	1985	37.6	20.9	38	22	16.2	1.3	5.6	134.4	1.55
3	1986	37.4	20.6	34	21	2.8	3.2	5.2	124.8	1.44
4	1987	37.7	23.3	27	16	0.0	1.3	5.8	139.2	1.61
5	1988	37.4	21.4	35	26	0.0	2.7	5.0	120.0	1.38
6	1989	38.4	21.3	25	17	0.6	2.0	5.2	124.8	1.44
7	1990	37.4	20.6	27	12	10.5	1.2	5.6	134.4	1.55
8	1991	37.2	21.0	25	15	2.0	2.7	5.4	129.6	1.50
9	1992	39.3	21.6	20	10	0.0	1.1	5.5	132.0	1.52
10	1993	38.9	22.6	19	11	0.0	3.0	5.8	139.2	1.61
11	1994	38.8	22.5	30	16	25.8	0.9	5.0	120.0	1.38
12	1995	37.2	20.7	28	20	3.9	1.6	5.2	124.8	1.44
13	1996	40.5	23.0	22	14	0.0	1.2	5.6	134.4	1.55
14	1997	38.8	22.9	21	13	0.0	1.6	5.4	129.6	1.50
15	1998	39.3	22.0	18	12	0.0	0.7	5.8	139.2	1.61
16	1999	38.0	21.3	35	20	16.1	0.9	5.0	120.0	1.38
	AVEG:	38.281	21.700	26.625	16.125	4.956	1.681	5.406	129.750	1.498

CLIMATOLOGICAL DATA

Station : HOSHANGABAD　　Month : MAY　　Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E　　Latitutude : 22^{0} 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	40.4	25.1	34	24	16.5	2.7	6.9	165.6	1.91
2	1985	40.7	24.8	38	20	14.1	2.5	7.1	170.4	1.97
3	1986	40.3	24.9	30	17	2.9	2.3	6.7	160.8	1.86
4	1987	40.7	23.7	34	15	8.5	1.5	7.0	168.0	1.94
5	1988	39.8	24.8	27	18	1.0	1.8	7.2	172.8	2.00
6	1989	40.2	25.2	37	17	0.0	1.3	6.9	165.6	1.91
7	1990	41.1	24.6	27	12	0.0	0.3	7.1	170.4	1.97
8	1991	40.1	24.1	24	10	0.0	0.7	6.8	163.2	1.88
9	1992	40.9	25.3	26	11	0.0	2.4	7.3	175.2	2.02
10	1993	41.6	26.4	33	19	1.8	1.8	7.0	168.0	1.94
11	1994	39.3	24.9	42	22	14.0	1.6	6.9	165.6	1.91
12	1995	40.9	24.8	33	17	6.4	2.7	7.1	170.4	1.97
13	1996	42.1	26.8	31	13	5.0	0.9	7.2	172.8	2.00
14	1997	40.0	25.1	33	20	4.2	1.9	6.8	163.2	1.88
15	1998	40.7	26.0	31	15	2.8	1.7	7.0	168.0	1.94
16	1999	40.5	25.7	43	24	12.2	0.8	6.9	165.6	1.91
	AVEG:	**40.581**	**25.138**	**32.688**	**17.125**	**5.588**	**1.681**	**6.994**	**167.850**	**1.938**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **JUNE** Height above M.S.L. - **302 M.**

Latitude : 77^{0} 46 ' E Latitutude : 22^{0} 46' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	37.1	24.9	63	42	29.8	4.2	7.7	184.8	2.13
2	1985	37.8	26.1	57	32	13.2	4.4	7.9	189.6	2.19
3	1986	37.3	25.1	64	42	141.7	5.7	7.5	180.0	2.08
4	1987	37.4	24.4	56	39	114.6	4.8	7.8	187.2	2.16
5	1988	38.2	25.8	59	36	45.7	4.1	8.0	192.0	2.22
6	1989	37.2	25.5	59	43	125.0	4.5	7.4	177.6	2.05
7	1990	37.3	25.2	61	43	105.3	4.6	7.5	180.0	2.08
8	1991	32.0	25.7	54	31	67.7	5.0	7.9	189.6	2.19
9	1992	39.1	25.6	56	34	21.7	5.3	7.7	184.8	2.13
10	1993	34.6	24.4	75	52	215.2	6.6	7.6	182.4	2.11
11	1994	32.7	23.6	81	59	195.2	6.4	7.8	187.2	2.16
12	1995	38.9	25.9	77	27	89.6	7.0	7.7	184.8	2.13
13	1996	36.5	25.5	61	42	62.0	6.3	8.2	196.8	2.27
14	1997	37.4	25.6	61	30	45.8	4.7	7.2	172.8	2.00
15	1998	35.6	25.4	64	47	129.9	4.7	7.8	187.2	2.16
16	1999	35.0	24.3	70	54	84.1	5.5	8.0	192.0	2.22
	AVEG:	**36.506**	**25.188**	**63.625**	**40.813**	**92.906**	**5.238**	**7.731**	**185.550**	**2.143**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **JULY** Height above M.S.L. - **302 M.**

Latitude : 77^0 46 ' E Latitutude : 22^0 46 ' N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	29.9	22.9	87	77	367.2	7.8	6.6	158.4	1.83
2	1985	31.2	23.4	82	72	239.9	6.8	6.4	153.6	1.77
3	1986	31.3	23.5	83	67	169.2	7.4	6.8	163.2	1.88
4	1987	30.2	22.1	86	70	511.7	7.3	7.0	168.0	1.94
5	1988	32.0	23.1	83	58	453.2	7.0	6.2	148.8	1.72
6	1989	33.5	24.2	76	59	270.2	6.6	6.6	158.4	1.83
7	1990	31.2	23.5	83	67	191.2	7.4	7.1	170.4	1.97
8	1991	31.1	22.9	85	73	511.8	7.6	7.2	172.8	2.00
9	1992	31.1	22.3	87	75	375.1	7.7	6.1	146.4	1.69
10	1993	33.1	22.9	82	67	453.4	6.7	6.0	144.0	1.66
11	1994	27.7	22.3	88	78	461.2	7.7	6.6	158.4	1.83
12	1995	32.0	23.3	81	66	112.0	6.3	6.6	158.4	1.83
13	1996	28.2	22.5	81	71	776.1	7.8	7.0	168.0	1.94
14	1997	30.5	23.1	84	71	447.6	7.1	6.2	148.8	1.72
15	1998	29.8	22.6	87	76	331.7	7.1	6.6	158.4	1.83
16	1999	31.7	23.3	85	70	358.7	6.5	6.9	165.6	1.91
	AVEG:	30.906	22.994	83.750	69.813	376.888	7.175	6.619	158.850	1.834

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **AUGUST** Height above M.S.L. - **302 M.**

Latitude : 77° 46 ' E Latitutude : 22° 46' N

S.No.	Year	Temperature in ° c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	29.5	22.9	88	78	308.5	7.6	5.8	139.2	1.61
2	1985	27.3	22.6	88	78	217.5	7.7	6.0	144.0	1.66
3	1986	28.7	22.8	91	81	531.3	7.5	6.2	148.8	1.72
4	1987	27.0	21.8	88	80	412.8	7.5	5.4	129.6	1.50
5	1988	31.4	22.5	83	64	132.7	6.1	5.6	134.4	1.55
6	1989	28.9	22.4	86	74	131.2	7.1	5.8	139.2	1.61
7	1990	28.2	22.1	90	80	219.9	7.8	5.6	134.4	1.55
8	1991	28.0	21.7	85	74	326.0	7.2	6.0	144.0	1.66
9	1992	28.1	21.4	88	79	569.9	7.1	6.4	153.6	1.77
10	1993	28.8	22.9	90	82	519.7	7.7	6.2	148.8	1.72
11	1994	29.0	22.4	87	80	210.0	7.7	5.2	124.8	1.44
12	1995	28.4	22.2	88	79	373.7	7.6	5.4	129.6	1.50
13	1996	28.7	22.6	90	80	767.0	7.6	5.8	139.2	1.61
14	1997	28.6	22.2	88	75	722.8	7.0	5.9	141.6	1.63
15	1998	29.3	22.8	88	79	440.5	7.4	5.7	136.8	1.58
16	1999	29.3	22.5	88	77	334.0	7.1	5.8	139.2	1.61
	AVEG:	**28.700**	**22.363**	**87.875**	**77.500**	**388.594**	**7.356**	**5.800**	**139.200**	**1.608**

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **SEPTEMBER** Height above M.S.L. - **302 M.**

Latitude : $77^0 46'$ E Latitutude : $22^0 46'$ N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	27.8	21.9	93	83	767.7	7.8	4.5	108.0	1.25
2	1985	29.5	21.8	86	73	387.7	6.6	5.0	120.0	1.38
3	1986	30.4	21.0	78	61	154.2	4.8	4.4	105.6	1.22
4	1987	30.4	21.4	82	69	142.6	6.3	5.2	124.8	1.44
5	1988	31.1	21.0	76	55	98.5	4.1	4.7	112.8	1.30
6	1989	31.4	20.6	68	53	70.9	3.3	4.4	105.6	1.22
7	1990	29.4	21.0	80	65	189.0	5.5	4.7	112.8	1.3
8	1991	33.1	22.1	72	54	81.3	5.1	4.2	100.8	1.16
9	1992	30.1	20.9	84	70	161.0	5.8	5.0	120.0	1.38
10	1993	29.7	21.9	86	73	317.7	7.0	5.2	124.8	1.44
11	1994	30.2	20.8	79	66	254.5	5.1	4.3	103.2	1.19
12	1995	30.5	19.5	72	54	89.5	3.8	4.1	98.4	1.13
13	1996	28.2	21.8	88	78	213.6	6.8	4.4	105.6	1.22
14	1997	33.2	22.0	69	51	32.6	4.5	4.2	100.8	1.16
15	1998	29.7	22.0	83	72	335.0	5.9	4.3	103.2	1.19
16	1999	30.6	21.1	83	64	230.9	4.7	4.0	96.0	1.11
	AVEG:	**30.331**	**21.300**	**79.938**	**65.063**	**220.419**	**5.444**	**4.538**	**108.900**	**1.256**

CLIMATOLOGICAL DATA

Station : HOSHANGABAD — Month : OCTOBER — Height above M.S.L. - 302 M.

Latitude : 77^0 46 ' E — Latitutude : 22^0 46' N

S.No.	Year	erature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	29.3	18.2	70	55	121.3	3.1	2.9	69.6	0.80
2	1985	30.4	16.0	45	32	0.0	1.4	3.1	74.4	0.86
3	1986	31.9	18.4	60	39	21.7	3.2	2.7	64.8	0.75
4	1987	32.4	18.3	51	35	0.3	2.4	3.0	72.0	0.83
5	1988	33.7	18.6	50	32	0.0	0.6	2.8	67.2	0.77
6	1989	34.8	18.8	38	24	0.0	1.5	2.9	69.6	0.80
7	1990	33.0	17.8	45	28	0.0	1.5	3.3	79.2	0.91
8	1991	31.7	16.7	54	27	7.2	1.7	2.5	60.0	0.69
9	1992	33.4	17.6	49	28	0.0	1.0	2.7	64.8	0.75
10	1993	32.3	18.2	54	36	9.1	0.9	3.1	74.4	0.86
11	1994	29.8	18.6	71	49	34.9	3.5	3.0	72.0	0.83
12	1995	32.2	17.5	53	37	1.9	3.3	2.8	67.2	0.77
13	1996	31.0	17.9	61	40	10.0	2.7	2.9	69.6	0.88
14	1997	31.2	19.4	67	54	84.2	3.8	2.5	60.0	0.69
15	1998	31.1	19.6	75	57	48.7	3.6	3.3	79.2	0.91
16	1999	33.8	18.8	45	29	0.4	1.0	2.9	69.6	0.80
	AVEG:	32.000	18.150	55.500	37.625	21.231	2.200	2.900	69.600	0.806

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **NOVEMBER** Height above M.S.L. - **302 M.**

Latitude : 77° 46 ' E Latitutude : 22° 46 ' N

S.No.	Year	Temperature in ° c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	27.5	14.7	60	46	16.7	2.2	2.9	69.6	0.80
2	1985	27.3	14.2	44	33	2.0	2.4	3.3	79.2	0.91
3	1986	29.9	16.6	60	45	13.9	2.8	2.5	60.0	0.69
4	1987	27.2	12.0	39	28	0.0	2.0	2.9	69.6	0.88
5	1988	29.9	14.7	52	39	0.0	1.4	2.8	67.2	0.77
6	1989	29.1	16.2	56	42	49.0	2.9	3.0	72.0	0.83
7	1990	30.4	14.9	43	27	0.0	1.6	3.1	74.4	0.86
8	1991	27.2	12.8	42	30	0.0	2.2	2.7	64.8	0.75
9	1992	29.3	16.4	58	43	100.5	4.1	2.5	60.0	0.69
10	1993	28.6	11.9	39	25	0.0	0.4	3.3	79.2	0.91
11	1994	28.4	12.8	48	30	0.0	1.5	2.9	69.6	0.80
12	1995	29.1	13.8	59	41	0.5	0.9	2.8	67.2	0.77
13	1996	28.4	12.6	45	27	0.0	0.4	3.0	72.0	0.83
14	1997	28.2	11.8	46	33	0.0	0.3	2.7	64.8	0.75
15	1998	27.8	11.6	49	32	0.0	0.6	3.1	74.4	0.86
16	1999	28.6	12.2	61	48	0.0	3.2	2.9	69.6	0.80
	AVEG:	28.556	13.700	50.063	35.563	11.413	1.806	2.900	69.600	0.806

CLIMATOLOGICAL DATA

Station : **HOSHANGABAD** Month : **DECEMBER** Height above M.S.L. - **302 M.**

Latitude : $77^0 46'$ E Latitutude : $22^0 46'$ N

S.No.	Year	Temperature in ^{0} c.		Humidity %		Rainfall in the month	Cloud Cover in	Wind speed in 24 Hrs		
		Maximum	Minimum	At 8.30 hrs	At 17.30 hrs	(mm)	(oktas)	(Km/hr)	(Km/day)	(m/sec)
1	1984	23.9	9.3	53	37	0.0	2.3	3.7	88.8	1.02
2	1985	25.4	11.7	65	44	14.7	3.6	4.0	96.0	1.11
3	1986	25.9	10.9	55	34	3.9	2.9	4.2	100.8	1.16
4	1987	26.3	10.2	46	30	0.0	0.5	3.2	76.8	0.88
5	1988	25.2	11.1	62	47	34.7	2.5	3.4	81.6	0.94
6	1989	25.9	10.3	49	31	0.0	1.8	3.9	93.6	1.08
7	1990	25.3	14.9	83	62	134.5	5.2	3.5	84.0	0.97
8	1991	26.4	10.5	45	30	0.0	1.2	3.7	88.8	1.02
9	1992	25.2	10.5	53	34	0.0	2.4	3.8	91.2	1.05
10	1993	26.6	9.8	46	26	0.0	0.2	3.6	86.4	1.00
11	1994	25.0	8.1	51	29	0.0	0.9	4.0	96.0	1.11
12	1995	26.6	11.6	59	36	2.1	1.8	4.1	98.4	1.13
13	1996	23.7	11.1	65	46	41.3	3.1	3.3	79.2	0.91
14	1997	25.1	9.7	57	38	0.0	1.6	3.4	81.6	0.94
15	1998	26.1	9.4	53	38	0.0	1.0	3.4	81.6	0.94
16	1999	26.0	9.5	65	45	0.0	1.0	4.0	96.0	1.11
	AVEG:	25.538	10.538	56.688	37.938	14.450	2.000	3.700	88.800	1.023