CROPPING PATTERN ANALYSIS IN COMMAND OF SAMRAT ASHOK SAGAR PROJECT IN MADHYA PRADESH

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the dissertation titled "**CROPPING PATTERN ANALYSIS IN COMMAND OF SAMRAT ASHOK SAGAR PROJECT IN MADHYA PRADESH**" which is being submitted in partial fulfilment of the requirements for the award of **Master of Technology** in **Irrigation Water Management** at Water Resources Development Training Centre (WRDTC), Indian Institute of Technology, Roorkee, is an authentic record of my own work carried out during the period of 16th July to 18th January 2002, under the supervision and guidance of **Dr. S. K. Tripathi**, Professor, WRDTC, Indian Institute of Technology, Roorkee.

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

Place : IIT Roorkee **(P. K. SHRIVASTAVA)**

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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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SYNOPSIS

India occupies two percent of the world's area but carry about sixteen percent of its population. The livelihood of almost seventy percent of population depend directly on agriculture or agro-industry. At the time of independence, although a lot of scientific information in the field of agriculture was available throughout the world but the same has not reached to the fields of farmers. In India, irrigation is a costliest input in cultivation of crops. It is made available to the farmers almost free of cost. A nominal revenue is charged from the farmers towards meeting the expenses of operation and maintenance of the canal system. The State Governments are liberal and bear the remaining cost as subsidy to promote agricultural production from irrigated areas. It is good that the country is constantly recording an ever increasing trend in food grain production.

Madhya Pradesh State has a large network of irrigation, but yields of most of the major food grain crops are recording significantly low than India's average production. The cropping intensity is also low and this reflects the fact that in unirrigated areas only one crop can normally be grown, since there is considerable variation in climate, soils and topography throughout the State.

The Samrat Ashok Sagar Project is one of the major project constructed across river Halali, a tributary of river Betwa in Vidisha District, Madhya Pradesh. The project has been designed for gross irrigated area of 37636 ha with cropping intensity of 135%. On the contrary, the use of Kharif irrigation is almost nil against the proposed irrigation intensity of 45%. Only protective irrigation of Kharif is given by farmers in the event of failure of monsoon. The under utilisation of reservoir storage is mainly due to non achievement of annual irrigation in the command.

Keeping in view the above aspect, Samrat Ashok Sagar (Halali) Project is selected for the study, which is situated near Vidisha district in Madhya Pradesh.

It has a major canal network to cater to the needs of water requirement in the command.

The objective of this study is to analyse the cropping pattern that exists and suggest an alternative cropping pattern to improve productivity in the Command.

An attempt is made to maximise the water use by adopting a cropping pattern selected from six alternatives. A cropping pattern with combinations of 24 numbers of feasible crops was found to yield about 29.0 crores annually and best fitted the crop plan of the command area in the greater interest to improve the socio-economic status of the farmers, with respect to self-sufficiency in food requirements. The crops like paddy is adopted. At the same time the cash crops like cotton, sugarcane, oil seeds and vegetables, etc. are also adopted. Hence a cropping pattern capable of providing food, cloth and money (shelter) for the farmer and improving their economic status by exporting the excess production is recommended.

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ABBREVIATIONS

CCA	Culturable Command Area
CI	Cropping Intensity
cumec	cubic meter per second
CWR	Crop Water Requirement
D-1	Distributory 1
D-2	Distributory 2
D-3	Distributory 3
FRL	Full Reservoir Level
GCA	Gross Command Area
HYV	High Yielding Varieties
LBC	Left Bank Canal
LSL	Lowest Sill Level
Mha	Million hectare
M.P.	Madhya Pradesh
MWL	Maximum Water Level
NWMP	National Water Management Project
RBC	Right Bank Canal
SAS	Samrat Ashok Sagar
TBL	Top Bank Level
WRD	Water Resources Department

Chapter 1
INTRODUCTION

1.1 GENERAL

Land and water are the most precious gifts of nature to mankind. The prosperity and history of any nation depends to a great extent on these resources and their management. Water serves as a positive input for many inputs like essential biological functions as a basic element of social and economic infrastructure, and as a natural amenity contributing to social welfare.

India is an agrarian country, about seventy percent of India's population depends for its livelihood on agriculture. India has a geographical area of 328 M. ha out of which the present gross cropped area is about 186.4 M. ha giving a cropping intensity of 130%. The current total production of food grain in the country is about 200 m tonnes which includes about 70 m tonnes of wheat and 80 m tonnes of rice. Gross per capita grain availability is 200 kg per year or about 0.55 kg per day. Out of the cropped area, about 70 percent is under cereals and gives an average productivity of about 1.7 t per ha.

Madhya Pradesh is situated in the heart of the country and is one of the largest State of Indian Union having the geographical area of 30.80 m ha (308 thousand sq. km). The state is bordered by the State of Maharashtra, Gujarat, Rajasthan, Uttar Pradesh and Chhattisgarh. The state is predominantly agriculture oriented and 80% of its population is dependent on agriculture. State is having irrigable area of 5.667 m ha with total agricultural production (1998-99) of 15.25 m tonnes. The State is frequently subjected to vagries of the draught and famine. Water is critical input for agriculture production and its optimum utilisation is of paramount importance for the State of Madhya Pradesh.

Water is made available to the plants by nature by rains, dew and soil moisture, etc. Irrigation enhance crop yield to large extent. Crop production is greatly influenced by farm management practices also in addition to climate and other environmental factors. Agriculture development depends upon various factors like irrigation, latest technology, credit facility, social and psychological factors. Irrigation is one of the important aspects for the development of agriculture. The irrigation requirement has changed due to the use of high yielding varieties of seeds, fertilisers and pesticides applications in the fields.

It is also seen that :

- Irrigation facilitates farmers to adopt HYV and more crops in a year.
- Irrigation protects against famine.
- Fertilizers and pesticides can be used for better yields.
- Salinity and alkalinity problem of the soil can be solved.
- Cash crops like sugarcane, cotton, etc., can be cultivated.
- Irrigation projects provides water supply to domestic and industrial area.
- Plantation can be done along the canal banks side to maintain the hydrological balance.
- Hydropower can be generated from irrigation project.
- Irrigation help in increasing the farm income of farmers.

The society is economically benefitted from the introduction of irrigation. Irrigation in India is considered as social welfare scheme for betterment of farmers and rural society.

1.2 SAMRAT ASHOK SAGAR PROJECT

Samrat Ashok Sagar Project previously named as Halali Dam, is a major irrigation project constructed across Halali river which is a tributary of Betwa river. The Halali river is a non-perennial river and during the summer months, its flow practically comes down to a negligible amount. The river gets ample supply during the monsoon months, i.e., from July to September. It was, therefore, necessary to construct storage reservoir to impound the water during the monsoon months for withdrawal throughout the year according to the irrigation requirements. The actual execution of the dam however started from the year 1973 and completed in 1976. The construction of canal system was started simultaneously along the headwork and was first commissioned in the year 1978 for irrigation. The gross storage capacity of the reservoir is 542.74 M cum and live storage capacity as 226.95 M cum and dead storage is 25.90 M cum. Samrat Ashok Sagar Project is having a culturable command area of 27924 ha and has a designed irrigation potential of 37636 ha (Rabi 25091 ha and Kharif 12545 ha).

1.3 OBJECTIVE OF THE STUDY

The objective of this study entitled **"CROPPING PATTERN ANALYSIS IN COMMAND OF SAMRAT ASHOK SAGAR PROJECT IN MADHYA PRADESH"** is to analyse the cropping pattern that exist and suggest an alternative cropping pattern to improve productivity in the Samrat Ashok Sagar Project Command.

Chapter 2
DESCRIPTION OF THE PROJECT

2.1 HISTORICAL BACKGROUND

The State of Madhya Pradesh lies between latitude 18° North to 26°-30' North and longitude 74° East to 84.5° East with the tropic of Cancer running parallel to the Narmada river. The State can be divided into four regions namely the Northern region, Malwa plateau, the Narmada Valley and the Satpura ranges. The Malwa plateau covers most part of Malwa the wide table land with a mean elevation of 487.68 meters above sea level and has an area of about 89,614 sq. km. It includes all the area lying between the great Vindhyan barrier and upto the South of Gwalior. The main river systems in the State of Madhya Pradesh are (1) the Chambal, (2) Betwa (3) Sone and (4) Narmada.

The Halali Project (Samrat Ashok Sagar Project) is across the river Halali tributary of the river Betwa. The project is intended to provide irrigation facilities in the plains of Vidisha and Raisen districts. The area to be commanded by this project is at the southern end of the Malwa plateau.

River Betwa

The Betwa river of which the mention is made as "Vetravati" in the "Meghdoot" written by Kalidas, has its source in Bhopal State at an altitude of about 472.44 meters above MSL after flowing for about 145 kms in Bhopal State, it forms the boundary between old Madhya Pradesh and Madhya Bharat for a length of about 48 kms.

Halali River

The Halali river is a tributary of the river Betwa. It originates around Bhopal at an altitude of about 487.68 meters above MSL and joins Betwa river near Vidisha after flowing for a length of about 38 km North East. Where it enters a gorge fairly narrow with high hills on both sides. The gorge is about 8 kms in length. This dam site is located about 16 kms from Salamatpur Railway Station to the North of Bhopal, on the Bombay-Delhi main line of Central Railway.

The Halali river is a non perennial river and during summer months its flow practically comes down to a negligible amount. The river gets ample supplies only during the monsoon months, i.e., from July to September. It is therefore, necessary to construct storage reservoir to impound the water during the monsoon months for withdrawal throughout the year, according to the (seasonal and monthly) irrigation requirements.

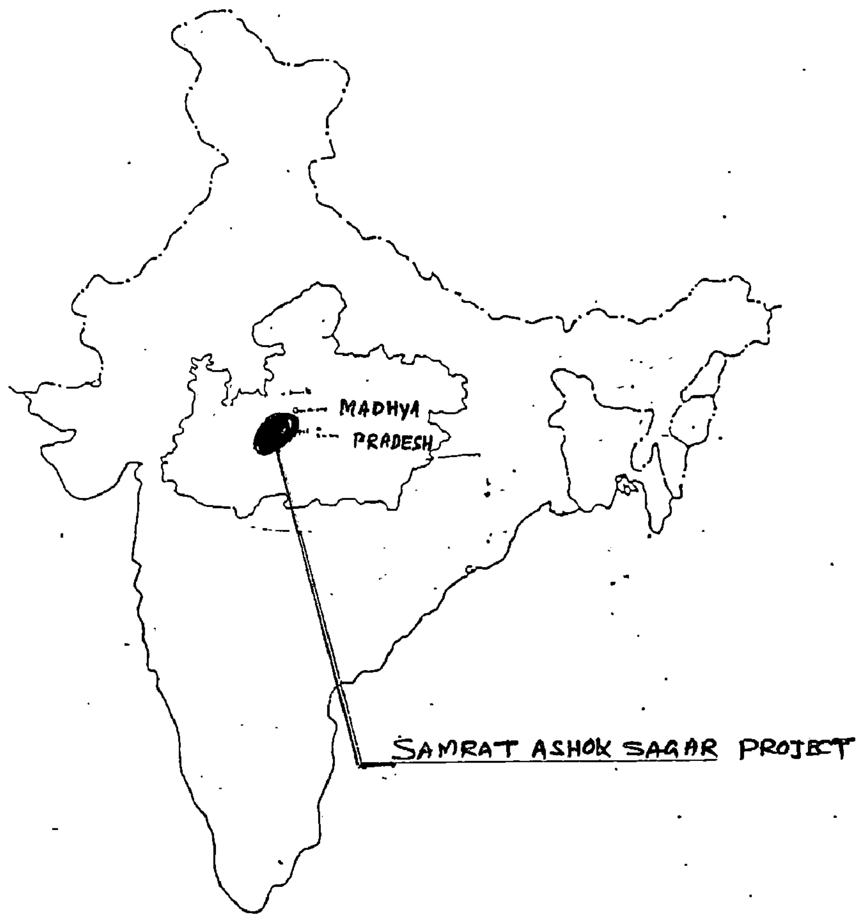
Floods

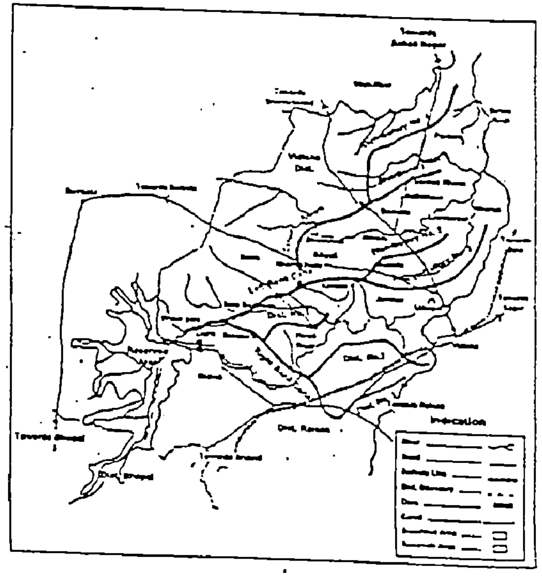
Earlier it was thought that there would be no floods at all in this area, as the river Betwa and its tributaries flow with a steep bed slope and the river has high banks. But during the year 1965, there were abnormal floods which damages more than a crore rupees worth of properties and claimed several invaluable human lives. Further low lying areas of important towns of Vidisha and Kurwai were also submerged in floods causing great damages to life and property. This naturally led to a re-thinking on the project.

2.2 SAMRAT ASHOK SAGAR PROJECT

This is a major irrigation project of Vidisha and Raisen district of Madhya Pradesh. The project is constructed as irrigation cum flood protection scheme across Halali river which is a tributary of Betwa river. The dam site of the project is 40 km North East of Bhopal and 16 km from Salamatpur Railway Station near village Khoa. It is connected by road from Bhopal, Vidisha and Raisen. Most of the command lies in Vidisha district. General location and index map is given in Fig. 2.1.

The administrative approval to the project was accorded way back in 1963 for 404.27 lakh. The actual execution of the head work started in the year 1973. The project was completed in the year 1976 by the Government of Madhya Pradesh Irrigation Department.





S.A.S. Index Map

Fig. 2.1(a) : Location Map of Samrat Ashok Sagar Project (M.P.)

SAMRAT ASHOK SAGAR PROJECT

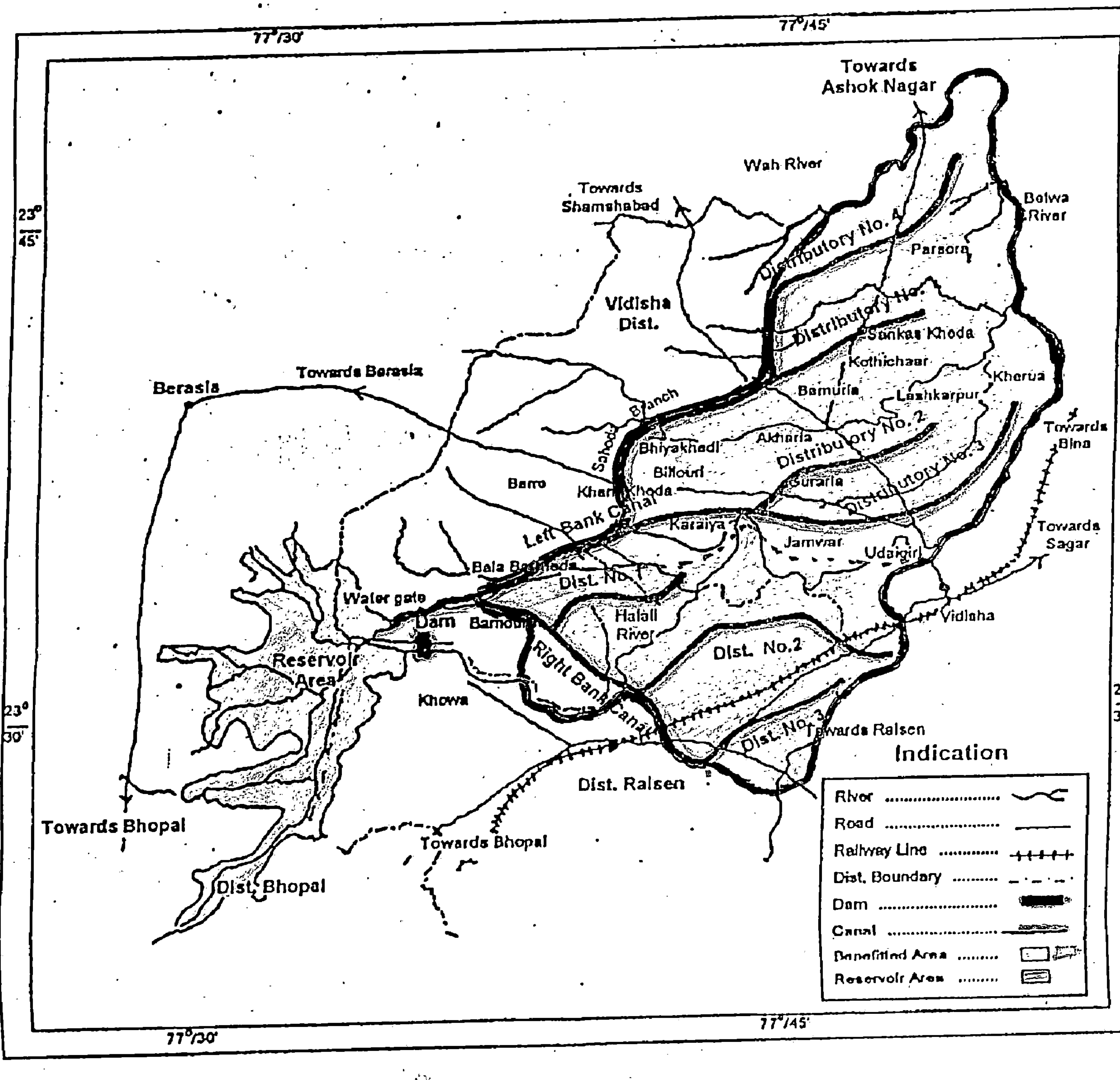


Fig.2.1(b): General Location and Index Map

The project comprises of 945 m long and 29.57 m high earthen dam across river Halali. The main canal is taking off from saddle dam located on left bank. The main canal is 3.24 km long and left bank canal and right bank canal are taking off from main canal at 3.24 km. The left bank canal irrigates 18900 ha and right bank canal irrigates 6192 ha area of Vidisha and Raisen district. Proposed irrigation from the project is 25091 ha of Rabi and 12546 ha of Kharif. The total gross command area is 37419 ha, out of which culturable command area is 27924 ha. Net area served is 25091 ha against this gross irrigated area is 37636 ha. The intensity of irrigation is thus 135%. The annual irrigation schedule in Vidisha district is 31,536 ha of 101 villages and 6070 ha of 33 villages in Raisen district.

In order to improve water deliveries in the existing irrigation scheme, the Govt of India launched the National Water Management Project with assistance of World Bank. Accordingly Govt of M.P. joined the project in February 1999 and accorded Administrative Approval for 19 scheme vide memo no. NWMP/4/C.P./31/89/69 dated 21.1.91 for Rs. 587 million in which Administrative Approval cost of Halali Project was estimated to Rs. 83.77 million.

2.3 SALIENT FEATURES OF SAMRAT ASHOK SAGAR PROJECT

2.3.1 Location of Dam

1.1	State	:	Madhya Pradesh
1.2	District	:	Vidisha & Raisen
1.3	Latitude	:	23°30' N
1.4	Longitude	:	77°33' E
1.5	River	:	Halali river
1.6	Dam site	:	Khoa village 16 km from Salamatpur railway station

2.3.2 Hydrology

2.1	Catchment area	:	699 sq. km.
2.2	Maximum rainfall	:	1680 mm
2.3	Minimum rainfall	:	536 mm
2.4	Average rainfall	:	1108 mm

2.3.3 Design Flood

3.1	Standard project flood	:	4688 cumecs
3.2	Maximum project flood	:	5665 cumecs

2.3.4 Reservoir Data

4.1	TBL	:	RL 466.32 m
4.2	MWL (Flood Control)	:	RL 464.19 m
4.3	FRL (Irrigation)	:	RL 458.4 m
4.4	FRL (Flood Control)	:	RL 459.61 m
4.5	LSL	:	RL 448.95 m
4.6	Crest of flush bar (Additional spillway)	:	RL 462.66 m
4.7	Crest of ungated spillway	:	RL 459.61 m
4.8	Water spread at FRL (irrigation)	:	5259 ha
4.9	Gross storage at MWL	:	67827 ha. m.
4.10	Gross storage at FRL	:	25285 ha. m.
4.11	Live storage at irrigation FRL	:	22695 ha. m.
4.12	Dead storage	:	2590 ha. m.

2.3.5 Dam

5.1	Type	:	Earthen dam
5.2	Top width	:	4.57 m
5.3	Maximum height	:	29.57 m
5.4	Length of dam	:	945.0 m

2.3.6 Spillway

6.1	Length	:	41.15 m
6.2	Crest level	:	RL 459.61 m
6.3	Discharging capacity at MWL	:	642 cumecs

2.3.7 Byewash

7.1	Length	:	60.96 m
7.2	Crest level	:	RL 462.66 m
7.3	Discharging capacity	:	169.92 cumecs

2.3.8 Sluice

8.1	Spill level	:	RL 447.23 m
8.2	No. and size of gate	:	2 Nos. (2.13 x 2.43 m)
8.3	Discharging capacity	:	80.99 cumecs

2.3.9 Irrigation

9.1	Gross Command Area	:	37419 ha.
9.2	Culturable Command Area	:	27924 ha.
9.3	Net Area Served	:	25091 ha
	Annual Irrigation		
9.4	Kharif	:	12545 ha
9.5	Rabi	:	25091 ha
9.6	Total	:	37636 ha
9.7	Intensity of Irrigation :	135%	

2.3.10 Canal

10.1	Length of main canal	:	3.24 km
10.2	Head discharge	:	22.64 cumecs
10.3	Length of LBC	:	17.61 kms
10.4	Head discharge	:	13.73 cumecs
10.5	Length of RBC	:	23.43 kms.
10.6	Head discharge	:	5.24 cumecs
10.7	Length of distributaries		
	10.7.1 Left Bank Canal		
	1. Sahoda Branch Canal	:	12.48 km
	Head discharge	:	8.63 cumecs
	2. D-1/SBC	:	9.72 km
	Head discharge	:	2.94 cumecs
	3. D-2/LBC	:	9.0 km
	Head discharge	:	2.88 cumecs
	4. D-3/LBC	:	16.50 km
	Head discharge	:	4.24 cumecs
	5. D-4/SBC	:	19.44 km
	Head discharge	:	4.35 cumecs

10.7.2 Right Bank Canal

	1. D-1/RBC	:	6.75 km
	Head discharge	:	0.853 cumecs
	2. D-2/RBC	:	4.41 km
	Head discharge	:	1.398 cumecs
	3. D-3/RBC	:	10.86 km
	Head discharge	:	1.367 cumecs
10.8	Length of Distributaries, Minors & Subminors of LBC	:	309.79 kms
10.9	Length of Distributaries, Minors & Subminors of RBC	:	109.48 kms
10.10	Length of high level canal	:	3.22 km
10.11	Discharge of high level canal	:	0.42 cumecs

2.3.11 Financial

11.1	Cost of project (March 1993)	:	Rs. 2471.10 lakhs
11.2	Cost/ha (On annual irrigation)	:	Rs. 6566/-
11.3	Cost/ha (On CCA)	:	Rs. 8850/-
11.4	Benefit Cost Ratio	:	2.68

2.3.12 Completion of Project

12.1	Commencement	:	1973-74
12.2	Completion of Work		
	Main Dam	:	1976-77
	Main Canal	:	1977-78
	Distribution Network	:	1995-96

2.4 SALIENT FEATURES (AS PER NWMP)

2.4.1 Reservoir Data

F.R.L. irrigation	:	459.61 M
Crest of additional spillway	:	458.40 M
Water spread at F.R.L. (Irrigation)	:	6059 ha
Gross storage at F.R.L.	:	33303 ha-m
Live storage	:	30713 ha-m
Dead storage	:	2590 ha-m

2.4.2 Additional Spillway

Crest level	:	458.40 M
Discharging capacity at M.W.L.	:	966 Cumecs

2.4.3 Irrigation

Net area served	:	26000 ha
Annual irrigation :		
(a) Kharif	:	13000 ha
(b) Rabi	:	26000 ha
Total	:	39000 ha
Intensity of irrigation	:	140%

2.4.4 Canal

Main Canal

Head discharge	:	25.58 Cumecs
L.B.C. discharge	:	19.17 Cumecs
R.B.C. discharge	:	6.41 Cumecs

Note : Remaining salient features are same as given in Section 2.3.

2.5 ENGINEERING ASPECTS

2.5.1 System Design

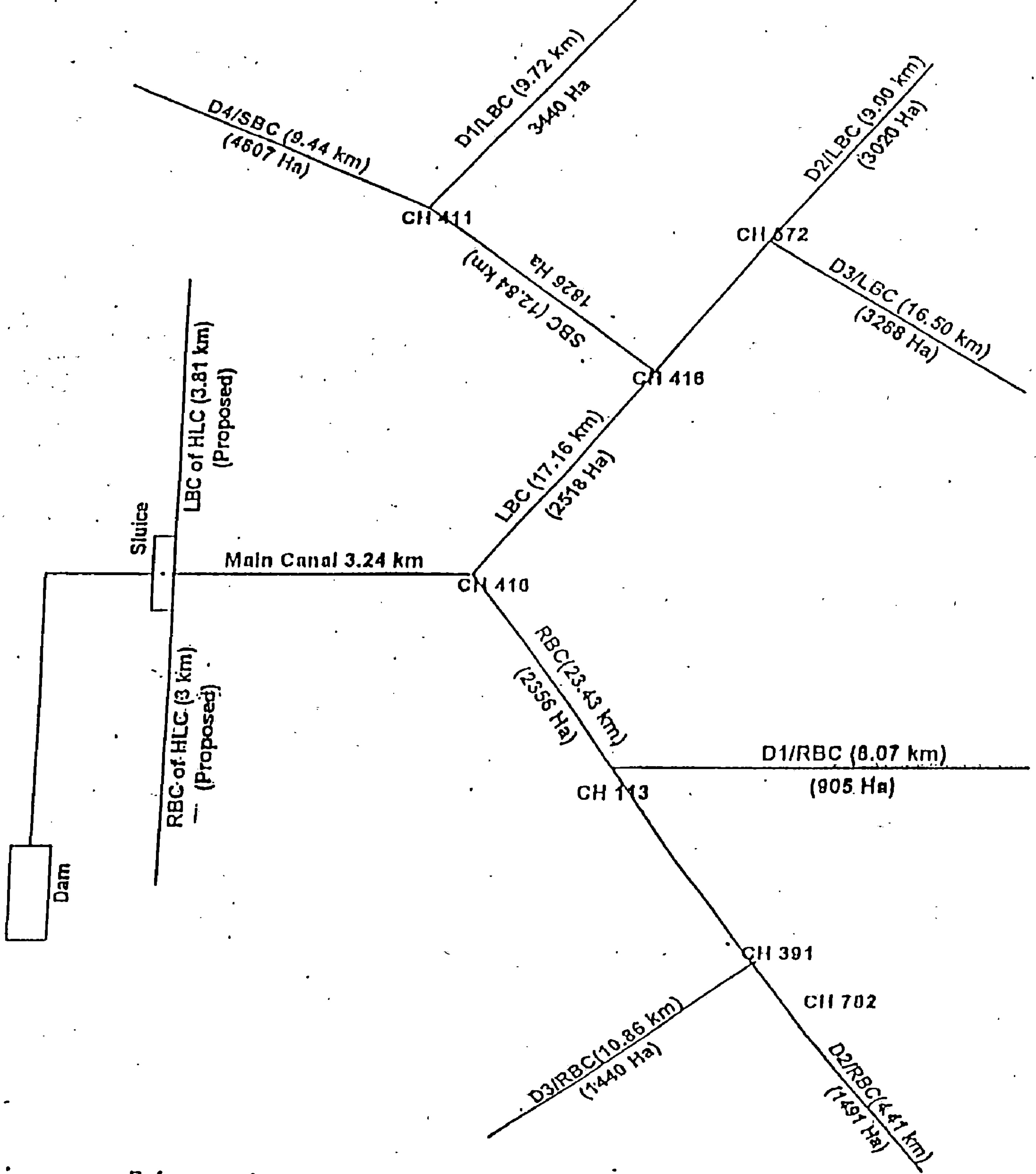
The command of Samrat Ashok Sagar Project is fairly flat. The distributaries takes off from main canal and minors take off from the distributaries. The distributaries and minors in general have been aligned on the ridges to cover the maximum command under irrigation. Schematic diagram showing the layout of main canals and distribution system is given in Fig. 2.2.

2.5.2 Description of Canals

Various canals are described in brief as under

Main Canal

The main canal takes off from the sluice located on the left bank of Halali river. The length of main canal is 3.24 kms. It is in deep cutting in the initial 1050 m and then enters into the plains at R.D. 3240 m from where it bifurcates into the left bank canal and right bank canal.



References :
LBC : Left Bank Canal
RBC : Right Bank Canal
HLC : High Level Canal
CH : Chainage
D : Distributory
SBC : Sahoda-Branch Canal

Fig 2.2 : Schematic Diagram of Samrat Ashok Sagar Project

The main canal goes in deep cutting of the order of 15 meters in the initial reach, which gradually reduces to 4 meters at the tail portion. Because of poor shear properties of soil there are heavy slips.

Left Bank Canal

The left bank canal is 17.16 km long. LBC is aligned as contour canal from R.D. 0 meter to 13560 m and thereafter follows the ridge between Halali river and Sahodara nala. It is in filling where it crosses valley, hence to control excessive seepage pre-cast concrete slab lining has been done in between R.D. 7500 m to 17160 m under NWMP works. In filling reaches the banks have settled in patches. Canal is in heavy cutting from R.D. 1890 m to 2310 m. Heavy slips takes place thus the bed of canal gets raised due to heavy deposits, which are removed every year.

Sahodara Branch Canal

Sahodara branch canal (SBC) takes off from LBC of RD 12430 m. The name of canal is on the Sahodara nala. Its length if 12.33 km. At end, it bifurcates into the distributary no. 1 and distributary no. 4.

Right Bank Canal

The right bank canal in the initial reaches irrigates the area between Pawwa nala and left bank of Halali river. This canal is 23.43 kms long and crosses Halali river by an aqueduct at RD 10350 m to 10700 m. Masonry conduit canal has been constructed in length of one km between RD 12200 m to 13200 m, where the canal passes along the hill toe, just downstream of aqueduct on Halali river. It is in general aligned as a contour canal.

Distributaries, Minors and Subminors

From LBC system one branch canal (SBC) and two distributaries take off namely D2, D3 and from SBC, it bifurcates into distributaries D1 and D4. There are 80 numbers of minors and 41 numbers of subminors in this system. The total length of the distribution system (Minors and Subminors) is 309 kms.

Under RBC system the command area is served by three distributaries namely D1, D2 & D3. There are 26 numbers of minors and 18 numbers of subminors in this system. The total length of the distribution system is 110 km.

The important distributaries taking off from RBC are as follows :

(i) Distributary No. 1 : It takes off at RD 3390 m to irrigate 905 ha. The head discharge is 1.03 cumecs and length is 8.07 km.

(ii) Distributary No. 2 : It takes off from RD 2,3430 m and is 4.41 km long. The head discharge is 1.92 cumecs to irrigate 1491 ha.

(iii) Distributary No. 3 : It takes off from RD 11730 m to provide irrigation in 1440 ha. The head discharge is 1.67 cumecs and the length is 10.8 km.

Chapter 3

SOIL, CLIMATE AND SOCIOLOGICAL CONDITION

3.1 GENERAL

In general the soil is blackish in colour, particularly that at the surface. The texture of the soil is heavy. The development of numerous cracks during the summer extending from surface downwards points to the soil to be analogous to that classed as "black cotton" and to belong to the montmorillonite group. There are patches of land here and there in the area with distinctly grey colour throughout the entire sample depth. The soil in the area is formed as the result of weathering of basaltic trap rock. The soil is deep except for a small patch towards the south near the river Halali and Betwa and in the north near the village Noagai, where it is comparatively less deep.

The presence of lime Kankar nodules mixed with gravel material, i.e., coarser fraction retained on 2 mm dia is noticeable in the surface soil at some sites as high as 30% of that coarser soil fraction is present all along the soil depth. Soil with salt content above 0.2 percent is known to affect the crop yield adversely, but from the soil test results, it is seen that a very major portion of the area has soil low soluble salt content.

3.2 pH OF THE SOIL

pH of the soil, which is a measure of its acidity or alkalinity, is an important consideration in classifying land for agricultural use. The pH of the soil ranges from 7.9 to 9.5. The soil over the major part of the area has pH ranging from 8.0 to 9.0 but about 50% of the area has pH above 8.5. The trend of variation of the soil pH along the profile is irregular in about 93% of the area while in the remaining area, the pH tends to increase along the depth of soil sampled.

3.3 TEXTURE

The top soil over about half the area can be designated as clay loam or clayey. The maximum and the minimum contents of clay percent in soils are 48.3 near the village Gulabganj and 7.8 near the loop formation of the river Betwa respectively. The coarser fraction of soil, i.e., gravel, kankar, etc. is present both in the surface soil and in the sub-soil, the maximum content of this fraction is 22.1 percent in the former and 30.3 percent in the latter.

3.4 CALCIUM CARBONATE CONTENT

The calcium carbonate content in soil, if moderate is known to cause a better physical conditions of a soil, it tends to reduce the size of the soil clods, a desirable effect in the clayey soils but undesirable in sandy soils. In heavy soils calcium carbonate increases the mellowness of its tilth making it easier to work. About 75 percent of the area of the land possess calcium carbonate content ranging from 1.0 to 5.0 percent : about 10 percent of the area has a content of calcium carbonate above 5 percent. The maximum percentage of calcium carbonate is of the order of 6.27 percent only.

3.5 SUB SOIL WATER TABLE

The depth of sub soil water table is tabulated as under :

Description	Average depth of water table	
	October-November	May-June
Left command	5.20 m	8.65 m
Right command	3.00 m	9.40 m

For an assessment of the surface and sub surface drainage aspects, more particularly in the portion where the water table approaches nearer the surface, it is recommended that observations of the water table in the areas are taken at regular intervals to indicate its fluctuation during the various parts of the year. Lastly the soils in the entire area is mostly blackish or brown in colour, clayey in texture and is fairly deep having a large water reserve and free from salts. The drainage of the area is very good.

3.6 CLIMATE

The climate of the project area is not severe, with well defined seasons and is suitable for cultivation throughout the year. This area receives rainfall entirely from the south-west monsoon which breaks in by about the second week of June and lasts till end of September and the climate remains dry during rest of the year. Over 90% of the total rainfall takes place during June to September and is uniformly distributed. The minimum temperature is in the months of December to February with an average temperature ranging from 9°C to 30°C. It begins to rise by middle of February and attains the maximum during May which is the hottest month during the year. The temperature ranges from 12°C to 44°C. The maximum average humidity of 87% (morning) and 77% (evening) is observed in the month of August. Humidity is very low in dry weather season and is maximum in monsoon season. It is as low as 12 and 15 in driest month of April and May.

Wind

Wind speed and direction can vary considerably with time and distance. Wind is usually at minimum around sunrise and at a maximum in the noon. Where air pressure differences occur, daily variation in wind direction is frequent. Wind speed varies with the height above ground. For agricultural use of data, it should be measured at 2.0 m above the ground and expressed in km/day.

In regard to agricultural needs, the suitability of different crops to the various areas in large measure is controlled by climate interacting with soil. Thus it is important to delineate homogeneous soil climatic zones, not only to interpret cropping pattern as they exist, but also to locate inappropriate land use if any, and to project new cropping patterns in consideration of ecological factors.

3.7 CLASSIFICATION ACCORDING TO RAINFALL CRITERIA RELATED TO MOISTURE REQUIREMENT OF VARIOUS CROPS

In 1976, National Agricultural Commission carried out the climatic delineations of India by examining the monthly rainfall distribution at all provincial rain gauge stations of India. Since the time span of most of the crops is 90 days or more, the following limits were set by them

(1) Rainfall < 30 cm/month for at least three consecutive month would be suitable for crops like paddy whose water need is high.

(2) Rainfall between 20-30 cm/month for 3 consecutive months would be suitable for crops whose water needs is high but less than that of paddy.

(3) Rainfall between 10-20 cm/month for at least three consecutive months is considered suitable for crops requiring less water.

(4) Rainfall between 5-10 cm/month for atleast 3 consecutive months is just sufficient for crops that have low water requirements, e.g., beans.

(5) Rainfall < 5 cm/month is not of much significance for crop production.

Climate if also classified as

Monsoon (Kharif)	:	June – September
Post Monsoon (Rabi)	:	October – February
Pre Monsoon (Zaid)	:	March – May

Climatic data such as rainfall, temperature, wind velocity, sun shine & humidity are very much essential for the calculation of crop water requirement.

3.8 SOCIO-ECONOMIC STATUS

Socio-economic status and food habits of the people have their impact on crop diversification and selection. The land tenancy is an important factor influencing farm developments and intensification of crop cultivation. The interests of land owner, owner cum tenant and tenant holders vary as far as the crop inputs are concerned. Nearly 56% of the farm families, covering 19% of land in the command area are of size less than 1 ha, while only about 5% of farm families covering 35% of the total land are larger than 4 ha. This reveals that there is great scope for increasing the cropping intensity as well as for growing of labour intensive crops which will provide greater opportunity of work to the members of family of the small and marginal farmers.

3.9 SIZE OF HOLDING

Size of holding in general is small and marginal. Medium and large holdings are limited.

Average size of holding

S. No.	Average size of holding in ha		Total no. of land holding	Percentage
1	0 –1 ha	Marginal	7019	56.00%
2	1 – 2 ha	Small	2781	22.00%
3	2 – 4 ha	Medium	2300	18.50%
4	4 – 40 ha	Large	370	3.00%
5	Above 40 ha		65	0.50%

Farms are operated by land owner and in some cases jointly operated. Subletting of land to the other cultivators is also prevalent. Socio-economic status and general living standard of farmers of S.A.S. command has improved after construction of Samrat Ashok Sagar Project. The single Rabi crop, in general was taken by cultivators before the project and their yield was also low as compared to the present. The economic condition of farmers has improved by adoption of double crops in a year with higher yield.

Now most of the cultivators are adopting the mechanical cultivation using tractors, thresher, harvestor, etc. The use of hybrid seeds and fertilizers are very common in the command.

Chapter 4

CROP PATTERN ANALYSIS

4.1 GENERAL

In the modern agriculture, cultivation of crop has become truly a science. The intensity of land use has changed. The objective behind raising a crop has totally changed. However, under a given situation, the activity is to be undertaken. Therefore deciding the line of action of a given activity is called "Principle". These could be decided keeping in view the following points.

(i) Crop(s) selected should be well adapted to the soil and climatic condition of the site.

(ii) System adopted should be compatible to the practice in the area.

(iii) Residual effect of crops should have minimum interference with ecology, environment and productivity.

(iv) Cultivation practice should be comprehensive in nature.

(v) Resources of the farmers and the area should be appropriately utilised in the cultivation of crops.

4.2 CULTIVATION PRACTICE

This involve the following steps :

1. Selection of cropping season
2. Selection of site and soil
3. Preparation of seed bed.
4. Raising of nursary
5. Sowing of transplanting
6. Fertilizer application
7. Irrigation
8. Plant protection

9. Interculture operation

10. Weeding

11. Harvesting and threshing

4.3 CROPPING SYSTEM

Crops are grown in a sequence of one, two or more years. Sequencing of crop on a given piece of land in a given period of time is known as crop rotation. These are based on certain principles. Keeping in view the fertility and productivity of the land, convenience of the farmer, removal of the inherent problems of the crops and land. Within these rotation adopt a permanent feature and attain the status of almost a regular occurrence it is termed as cropping system. In the modern agriculture desirable varieties are developed, fertility improvement materials are produced, fast agricultural operation equipments are there, irrigation is almost assured. These conditions have totally changed the face of the modern agriculture.

4.4 CROPPING PATTERN

Cropping pattern has been analysed considering different aspects such as availability of water, suitability of soil, climatic conditions, cultivation practice and marketability of that area. The detailed study is done under following sequential order :

(i) Crop plan designed for Samrat Ashok Sagar Project

(ii) Crop plan as per National Water Management Project

(iii) Suggested crop plan

(i) Crop Plan Designed

Cropping pattern adopted at the time of formulation of project as per given in Table 4.1 has been analysed in view of change of climatic data. The climatic data for the Samrat Ashok Sagar Project for last 10 years (i.e., year 1991 to year 2000) collected and crop water requirement for the crops adopted has been calculated. It was found that the water requirement is slightly higher side. But the crops after construction of the project did not develop as per designed cropping pattern. The cultivators grow soybean crop in Kharif followed by wheat and gram in Rabi.

Table 4.1 : Crop Plan Designed for Samrat Ashok Sagar Project

Crop	Area in ha		Total	Assumed water requirement at outlet (mm)
	Left	Right		
Kharif				
1. Paddy	3777	1240	5017	660
2. Maize & Jwar	945	310	1255	203
3. Pulses	945	310	1255	100
4. Fodder	945	310	1255	100
5. Groundnut	945	310	1255	100
6. Soybean	1888	620	2508	-
Total	9445	3100	12545	-
Rabi				
7. Wheat (hyv)	9450	3096	12546	508
8. Wheat (local)	9450	3095	12545	305
Total	18900	6191	25091	-
Grand Total	28345	9291	37636	-

Source : Summary Report of Sub Project on SIFT Component, July 1999

There is no other crop which can consume the water available in Halali command during Kharif. All the crops in the region grow without irrigation in Kharif. A statement showing the yearwise area irrigated is enclosed at Table No. 4.2. Crop water requirement calculation for the crop plan designed is shown at Table No. 4.3.

The catchment area as well as the area commanded by the project is a part of Malwa Plateau with mean elevation of about 426.7M above mean sea level. The plateau is covered with fertile black soil (Kali Mitti) and clayey soil. All these soils are significantly retentive of moisture to grow all crops like rice, jwar, pulses, wheat, sugarcane and garden crops with irrigation. The area at present is predominantly a Rabi crop (wheat) zone.

Table No. 4.2

SAMRAT ASHOK SAGAR PROJECT

STATEMENT SHOWING THE YEARWISE AREA IRRIGATED

S. No.	Year	Area Irrigated in Ha		
		Kharif	Rabi	Total
1	1977-78	-	2322	2322
2	1979-80	623	5248	5871
3	1980-81	29	5875	5904
4	1981-82	37	6039	6076
5	1982-83	49	7410	7459
6	1983-84	-	9410	9410
7	1984-85	169	12567	12736
8	1985-86	-	15450	15450
9	1986-87	134	15602	15736
10	1987-88	11	14290	14301
11	1988-89	271	19839	20110
12	1989-90	24	20787	20811
13	1990-91	-	22000	22000
14	1991-92	250	22000	22250
15	1992-93	-	23236	23236
16	1993-94	-	23378	23378
17	1994-95	-	23969	23969
18	1995-96	-	23728	23728
19	1996-97	-	24000	24000
20	1997-98	-	23205	23205
21	1998-99	-	23002	23002

Source : Summary Report of Sub Project on SIFT Component, July 1999

Crops and Cropping Pattern :

Crops grown in the command area for different season in irrigated and rainfed areas are as below :

Season	Irrigated	Rainfed
Kharif	-	Soybean, maize, pulses
Rabi	Wheat (Hyv), Wheat (local), Gram	Wheat (local), gram, pea, lentil

Farmers adopted furrows and flood method of irrigation for major crops like wheat, gram and soybean.

Kharif Cropping Pattern

The major emphasis was given to paddy crop of kharif while designing the project. There was a provision of 18% paddy in the project design. On development of irrigation from Samrat Ashok Sagar Project, it is experienced that during kharif the farmers have not come forward 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 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 machinery to prepare the heavy black soil fields for 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 row. Even the tractor drawn implements can not work easily in these soils. Again after harvest of paddy, soil gets so hard that the bullock can not break the soil tilth for Rabi cultivation. There is acute shortage of labour at the time of sowing, weeding and harvest of crops. This may be the major reason for not coming up of paddy crop in Samrat Ashok Sagar command.

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 protective irrigation is the only possibility for Kharif irrigation and that also is 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 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.

Cropping Pattern of Rabi Season

The development of Rabi irrigation in the Samrat Ashok Sagar Project command is satisfactory. The cropping intensity of Rabi is 90% against the total intensity of project of 135%. There is peak demand of water in December and January months. 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 tailenders get only for 30 to 40% area, because of tendency of farmers of head reaches to take more water. Wheat hybrid, wheat local and gram are the major Rabi crops which cover almost 80-90% area.

Summer Cropping Pattern

There is no provision of summer irrigation in the project command, but sufficient water is available in the reservoir. The adoptation of summer irrigation will solve the problem of security of cattles by mutual cooperation among the farmers.

(ii) Crop Plan as per NWMP

In order to improve irrigation efficiencies the Govt of India launched the National Water Management Project with assistance of World Bank. In view of above, cropping pattern is proposed based on past and present cultivation practices. Crops proposed in Kharif season is soybean while in Rabi season, wheat and grams with 140% cropping intensity.

Crop water requirement is worked out and shown in Table No. 4.4.

(iii) Suggested Crop Plan

Proposal No. 1

The crops in Kharif and Rabi season have been analysed under this proposal. Selected crops for analysis are soybean, rice, sugarcane, wheat(Hyv), wheat (local) and gram with 140% cropping intensity. Requirement of water for all the crops is calculated monthwise. It is essential to keep in mind that the water requirements for crop should not exceed the limit.

In proposal 1, total crop water requirement is worked out to 20168.39 ha.m. which is within the availability limit of water in reservoir, i.e., 22695 ha.m. Maximum crop water requirement is worked out to 3330.28 ha.m. and 802.82 ha.m, both in the month of January at the head of left bank canal and right bank canal respectively. Crop water requirement calculation is shown as per Table No. 4.5, 4.5(a) and 4.5(b).

Proposal 2

Proposal 2 is analysed with modified cropping pattern. In this, crops sown are rice, soybean, groundnut, fodder, pulses and cotton in kharif season while wheat (hyv), wheat (local), gram and berseem in Rabi season. Overall crop water requirement for the above cropping pattern is worked out to 20549.80 ha.m. This pattern is better than previous one because of more number of crops. Monthwise crop water requirement calculation is shown as per Table No. 4.6, 4.6(a) and 4.6(b).

Proposal 3

Proposal 3 is planned in such a way which fulfils food habits, cattle need, cultivation practices and marketability need of that area. 9 numbers of Kharif crops and 13 numbers of Rabi crops are sown in LBC and RBC command with 140% cropping intensity. 55 percent cropping intensity is maintained in Kharif crops while 85 percent in Rabi crops pulses are proposed to utilise the water in summer season and Kharif season. CWR calculation is shown as per Table No. 4.7, 4.7(a) and 4.7(b).

Proposal 4

Finally one more proposal is being analysed. In this, two more commercial crops are added to reach final conclusion. Two crops added are cotton and sugarcane. Other crops are same as proposal 3. Total number of crops grown in this proposal are 24 (i.e., 11 nos in Kharif and 13 nos. in Rabi) both the crops (cotton and sugarcane) are of high yielding nature.

At present these two crops are not grown in the command area. Sugarcane is not grown because it needs water in almost every month. While supply of water is not reliable, no industry is setup in nearby areas. So farmers do not come forward for producing sugarcane. Cotton is not grown due to labour problem. Farmer is not habitual to take more crops in Kharif season.

Maximum water requirement for the cropping pattern is worked out to 4304.83 ha.m. in the month of January. While overall requirement for all the month worked out to 20990.00 ha.m. Detailed calculation is shown as per Table No. 4.8, 4.8(a) and 4.8(b). Graphical representation is also shown as per Fig. 4.1 to 4.7.

Above proposal is well balanced in self sufficiency. Farmers traditional crop keeps on priority. Some crops are introduced as new crops such as paddy, pulses, mustard, berseem and vegetable, etc. Paddy is suggested in head reach of canal because it needs more water during its growth (nursery as well as planting) possibility of getting water with reliability is more in head reach areas.

Sorghum and berseem fulfils the cattle need and vegetable is required for daily need as well it gives good return. Soybean in Kharif seasons and wheat and grams in Rabi seasons are the traditional crops of that area. As per the suitability of soil, and favourable climates, these two crops cotton and sugarcane may be introduced in small percentage of areas. Protective irrigation can be made available to sugarcane crop.

This cropping pattern is most appropriate giving maximum benefits as well serves the purpose of self sufficiency in food habits, cattle need, marketability, etc.

4.5 COST OF CULTIVATION

Cost of cultivation for each crop is analysed and shown in Table 4.9. This cost includes seed rates per hectare, fertilizers used, labour involved (from sowing to harvest), tractor and electricity used, irrigation, etc.

For Example :

Soybean crop is having cost of cultivation, Rs. 4975 per ha

Yield of crop = 12 quintel per ha

Rate = Rs. 900/- per quintel

Total value of yield = 900 x 12 = 10,800/-

Benefit = Total sale value – Cost of cultivation

= 10,800 - 4975

= Rs. 5825 per hectare

Similarly benefit per hectare for all the crops is calculated and these values are used in linear programming (LINDO) in Chapter 6 to maximize the benefits.

Table No. 4.3

WATER DEMAND (Ha-m) TABLE AT PROJECT HEAD

ABSTRACT OF CROP WATER REQUIREMENT FOR THE CROPPING PATTERN (ORIGINAL PLAN WITH 135% CI)

Crops/ Intensity/ Area Months	Paddy 18% 5017 ha	Maize & Jawar 4.5% 1255 ha	Pulses 4.5% 1255 ha	Fodder 4.5% 1255 ha	Groundnut 4.5% 1255 ha	Soybean 5% 2508 ha	Total Kharif 45% 12545 ha	Wheat (Hyv) 45% 12546 ha	Wheat (Local) 45% 12545 ha	Total 90% 25091 ha	Grand Total 135% 37636 ha
January	0.00	0.00	0.00	2193.54	0.00	0.00	0.00	2463.78	2251.58	4715.36	4715.36
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2440.60	1620.95	4061.55	4061.55
March	0.00	0.00	39.85	0.00	0.00	0.00	39.85	2057.54	0.00	2057.54	2097.39
April	0.00	0.00	349.62	0.00	0.00	0.00	349.62	0.00	0.00	0.00	349.62
May	0.00	0.00	155.62	0.00	0.00	0.00	155.62	0.00	0.00	0.00	155.62
June	308.06	156.88	0.00	156.88	156.88	313.50	1092.20	0.00	0.00	0.00	1092.20
July	1545.35	0.00	0.00	0.00	0.00	0.00	1545.35	0.00	0.00	0.00	1545.35
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	842.83	0.00	0.00	0.00	0.00	0.00	842.83	0.00	0.00	0.00	842.83
October	451.28	0.00	0.00	21.97	39.07	0.00	512.32	0.00	1254.50	1254.50	1766.82
November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1935.97	1716.78	3652.75	3652.75
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1275.42	1940.46	3215.88	3215.88
Total	**3147.52**	**156.88**	**545.09**	**178.85**	**195.95**	**313.50**	**4537.79**	**10173.31**	**8784.27**	**18957.58**	**23495.37**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head Discharge of LBC = 13.73 cumec

Head Discharge of RBC = 5.24 cumec

Total discharge = 18.97 cumec

Peak discharge required in the month of January = $Q = 4715.36 \times 10^4 / 31 \times 24 \times 60 \times 60)$ = 17.61 cumec < 18.97 cumec

Table No. 4.4

WATER DEMAND (Ha-m) TABLE AT PROJECT HEAD

ABSTRACT OF CROP WATER REQUIREMENT FOR THE CROPPING PATTERN (NWMP RECOMMENDATION WITH 140% CI)

Crops/ Intensity/ Area Months	Soybean 47% 13000 ha	Wheat (Hyv) 36% 10000 ha	Wheat (Local) 36% 10000 ha	Gram 21% 6000 ha	Total Rabi 93% 26000 ha	Grand Total 140% 39000 ha
January	0.00	1963.80	1794.80	1089.58	4848.18	4848.18
February	0.00	1945.32	1292.11	655.96	3893.39	3893.39
March	0.00	1640.00	0.00	0.00	1640.00	1640.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00
June	1624.99	0.00	0.00	0.00	0.00	1624.99
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
October	0.00	0.00	1000.00	600.00	1600.00	1600.00
November	0.00	1543.10	1368.50	570.77	3482.37	3482.37
December	0.00	1016.60	1546.80	859.21	3422.61	3422.61
Total	**1624.99**	**8108.81**	**7002.21**	**3775.53**	**18886.55**	**20511.54**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head Discharge of LBC = 13.73 cumec

Head Discharge of RBC = 5.24 cumec

Total discharge = 18.97 cumec

Peak discharge required in the month of January = Q = 4848.18 x 10^4 / 31 x 24 x 60 x 60)
= 18.10 cumec < 18.97 cumec

Table No. 4.5

PROPOSAL – 1

WATER DEMAND TABLE AT PROJECT HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED AT 140% CROPPING INTENSITY

UNIT : Ha-m

Crops/ Intensity/ Area Months	Soybean 55% 15358 ha	Rice 5% 1396 ha	Total Kharif 60% 16754 ha	Wheat 40% 11170 ha	Wheat Local 25% 7000 ha	Gram 10% 2792 ha	Total Rabi 75% 20962 ha	Sugarcane 5% 1396 ha	Grand Total Kharif + Rabi 140% 39112 ha
January	0.00	0.00	0.00	2193.54	1256.36	507.01	3956.91	176.18	4133.09
February	0.00	0.00	0.00	2172.86	904.47	305.22	3382.55	152.77	3535.27
March	0.00	0.00	0.00	1834.21	0.00	0.00	1834.21	193.97	2028.18
April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	175.90	175.90
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	199.63	199.63
June	1919.75	85.72	2005.47	0.00	0.00	0.00	0.00	56.65	2062.12
July	0.00	430.00	430.00	0.00	0.00	0.00	0.00	0.00	430.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	234.52	234.52	0.00	0.00	0.00	0.00	49.77	284.29
October	0.00	125.57	125.57	0.00	700.00	0.00	700.00	261.05	1086.62
November	0.00	0.00	0.00	1723.64	957.95	544.78	3226.37	228.78	3455.15
December	0.00	0.00	0.00	1135.52	1082.76	399.79	2618.07	160.07	2778.14
Total	**1919.75**	**875.81**	**2795.56**	**9059.80**	**4901.50**	**1756.80**	**15718.10**	**1654.72**	**20168.39**

CCA of LBC = 20927 ha Head discharge of LBC = 13.73 cumec

CCA of RBC = 6997 ha Head discharge of RBC = 5.24 cumec

CCA = 27924 ha

Table No. 4.5(a)

PROPOSAL – 1

WATER DEMAND TABLE AT LEFT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Soybean 10858 ha	Rice 896 ha	Total Kharif 19754 ha	Wheat 7979 ha	Wheat Local 7000 ha	Gram 2792 ha	Total Rabi 3330.28 ha	Sugarcane	Grand Total Kharif + Rabi
January	0.00	0.00	0.00	1566.91	1256.36	507.01	3330.28	0.00	**3330.28**
February	0.00	0.00	0.00	1552.15	904.47	305.22	2761.84	0.00	2761.84
March	0.00	0.00	0.00	1308.56	0.00	0.00	1308.56	0.00	1308.56
April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	1357.25	55.02	1412.27	0.00	0.00	0.00	0.00	0.00	1412.27
July	0.00	275.99	275.99	0.00	0.00	0.00	0.00	0.00	275.99
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	150.52	150.52	0.00	0.00	0.00	0.00	0.00	150.52
October	0.00	80.60	80.60	0.00	700.00	0.00	700.00	0.00	780.60
November	0.00	0.00	0.00	1231.24	957.95	544.78	2733.97	0.00	2733.97
December	0.00	0.00	0.00	811.14	1082.76	399.79	2293.69	0.00	2293.69
Total	**1357.25**	**562.13**	**1919.38**	**6471.65**	**4901.50**	**1756.80**	**13129.95**	**0.00**	**15049.33**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \frac{3330.28 \times 10^4}{31 \times 24 \times 60 \times 60} = 12.43\ m^3/sec < 13.73\ m^3/sec$ in the month of January

Table No. 4.5(b)

PROPOSAL – 1

WATER DEMAND TABLE AT RIGHT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Soybean 4500 ha	Rice 500 ha	Total Kharif	Wheat 3191 ha	Wheat Local	Gram	Total Rabi	Sugarcane 1396 ha	Grand Total Kharif + Rabi
January	0.00	0.00	0.00	626.64	0.00	0.00	626.64	176.18	**802.82**
February	0.00	0.00	0.00	620.73	0.00	0.00	620.73	152.72	773.45
March	0.00	0.00	0.00	523.99	0.00	0.00	523.99	193.92	717.96
April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	175.90	175.90
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	199.63	199.63
June	562.50	30.70	593.20	0.00	0.00	0.00	0.00	56.65	649.85
July	0.00	154.01	154.01	0.00	0.00	0.00	0.00	0.00	154.01
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	84.00	84.00	0.00	0.00	0.00	0.00	49.77	133.77
October	0.00	44.97	44.97	0.00	0.00	0.00	492.40	261.05	306.02
November	0.00	0.00	0.00	492.40	0.00	0.00	324.39	228.78	721.18
December	0.00	0.00	0.00	324.39	0.00	0.00	2588.15	161.07	485.46
Total	**562.50**	**313.68**	**876.18**	**2588.15**	**0.00**	**0.00**	**13129.95**	**1654.72**	**5119.05**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \frac{802.82 \times 10^4}{31 \times 24 \times 60 \times 60} = 2.99\ m^3/sec < 5.24\ m^3/sec$ in the month of January

Table No. 4.6

PROPOSAL – 2

WATER DEMAND TABLE AT PROJECT HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED AT 140% CROPPING INTENSITY

UNIT : Ha-m

Crops/ Intensity/ Area Months	Rice 5% 1396 ha	Green Gram 9% 2500 ha	Soybean 30% 8377 ha	Groundnut 9% 2500 ha	Sorghum 4% 1117 ha	Cotton 3% 838 ha	Total Kharif 60% 16728 ha	Wheat 30% 8377 ha	Wheat Local 25% 6981 ha	Gram 20% 5585 ha	Berseem 5% 1396 ha	Total Rabi 80% 22339 ha	Grand Total Kharif + Rabi 140% 39067 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1645.07	1252.95	1014.24	287.78	4200.04	4200.04
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1629.59	902.02	610.61	360.96	3503.18	3503.18
March	0.00	79.39	0.00	0.00	0.00	0.00	79.39	1373.83	0.00	0.00	408.44	1782.27	1861.66
April	0.00	696.45	0.00	0.00	0.00	0.00	696.45	0.00	0.00	0.00	0.00	0.00	696.45
May	0.00	309.99	0.00	0.00	0.00	0.00	309.99	0.00	0.00	0.00	0.00	0.00	309.99
June	85.72	0.00	1047.13	312.50	139.63	69.75	1584.98	0.00	0.00	0.00	0.00	0.00	1584.98
July	430.00	0.00	0.00	0.00	0.00	0.00	430.00	0.00	0.00	0.00	0.00	0.00	430.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	234.52	0.00	0.00	0.00	0.00	0.00	234.52	0.00	0.00	0.00	0.00	0.00	234.52
October	125.57	0.00	0.00	77.83	19.55	139.82	362.77	0.00	698.10	0.00	32.10	730.20	1092.97
November	0.00	0.00	0.00	0.00	0.00	130.73	130.73	1292.65	955.35	1089.80	218.50	3556.30	3687.03
December	0.00	0.00	0.00	0.00	0.00	29.33	29.33	851.60	1079.82	799.77	188.46	2919.65	2948.98
Total	**875.81**	**1085.83**	**1047.13**	**390.33**	**159.18**	**299.88**	**3858.16**	**6792.74**	**4888.24**	**3514.42**	**1496.24**	**16691.64**	**20549.80**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Table No. 4.6(a)

PROPOSAL – 2

WATER DEMAND TABLE AT LEFT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Rice 1000 ha	Green Gram 1800 ha	Soybean 6200 ha	Groundnut 1800 ha	Sorghum 800 ha	Cotton 600 ha	Total Kharif 12200 ha	Wheat 6200 ha	Wheat Local 5200 ha	Gram 4185 ha	Berseem 5% 1000 ha	Total Rabi 16585 ha	Grand Total Kharif + Rabi 28785 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1217.55	933.30	760.00	206.15	3117.00	**3117.00**
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1206.10	671.90	457.55	258.57	2594.12	2594.12
March	0.00	57.16	0.00	0.00	0.00	57.16	57.16	1016.80	0.00	0.00	292.58	1309.38	1366.54
April	0.00	501.44	0.00	0.00	0.00	501.44	501.44	0.00	0.00	0.00	0.00	0.00	501.44
May	0.00	223.19	0.00	0.00	0.00	223.19	223.19	0.00	0.00	0.00	0.00	0.00	223.19
June	61.40	0.00	775.00	225.00	0.00	114.40	114.40	0.00	0.00	0.00	0.00	0.00	1161.40
July	308.02	0.00	0.00	0.00	0.00	308.02	308.02	0.00	0.00	0.00	0.00	0.00	308.02
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	167.99	0.00	0.00	0.00	0.00	167.99	167.99	0.00	0.00	0.00	0.00	0.00	167.99
October	89.95	0.00	0.00	56.04	100.11	260.10	260.10	0.00	520.00	0.00	22.99	542.99	803.09
November	0.00	0.00	0.00	0.00	93.60	93.60	93.60	956.72	711.62	816.62	156.52	2641.48	2735.08
December	0.00	0.00	0.00	0.00	21.00	21.00	21.00	630.29	804.34	599.29	135.00	2168.92	2189.92
Total	**627.36**	**781.79**	**775.00**	**281.04**	**114.00**	**214.71**	**2793.90**	**5027.46**	**3641.16**	**2633.46**	**1071.81**	**12373.89**	**15167.79**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \frac{3117.00 \times 10^4}{31 \times 24 \times 60 \times 60} = 11.64\ m^3/sec < 13.73\ m^3/sec$

in the month of January

Table No. 4.6(b)

PROPOSAL – 2

WATER DEMAND TABLE AT RIGHT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Rice 396 ha	Green Gram 700 ha	Soybean 2177 ha	Groundnut 700 ha	Sorghum 317 ha	Cotton 238 ha	Total Kharif 4528 ha	Wheat 2177 ha	Wheat Local 1781 ha	Gram 1400 ha	Berseem 396 ha	Total Rabi 5754 ha	Grand Total Kharif + Rabi 10282 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	427.52	319.65	254.24	81.63	1083.04	**1083.04**
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	423.49	230.12	153.06	102.39	909.06	909.06
March	0.00	22.23	0.00	0.00	0.00	0.00	22.23	357.03	0.00	0.00	115.86	452.89	495.12
April	0.00	195.01	0.00	0.00	0.00	0.00	195.01	0.00	0.00	0.00	0.00	0.00	195.01
May	0.00	86.80	0.00	0.00	0.00	0.00	86.80	0.00	0.00	0.00	0.00	0.00	86.80
June	24.32	0.00	272.13	87.50	39.63	0.00	423.58	0.00	0.00	0.00	0.00	0.00	423.58
July	121.98	0.00	0.00	0.00	0.00	0.00	121.98	0.00	0.00	0.00	0.00	0.00	121.98
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	66.53	0.00	0.00	0.00	0.00	0.00	66.53	0.00	0.00	0.00	0.00	0.00	66.53
October	35.62	0.00	0.00	21.79	5.55	39.71	102.67	0.00	178.10	0.00	9.11	187.21	289.88
November	0.00	0.00	0.00	0.00	0.00	37.13	37.13	335.93	243.73	273.18	61.98	914.82	951.95
December	0.00	0.00	0.00	0.00	0.00	8.33	8.33	221.31	275.48	200.48	53.46	750.73	759.06
Total	**248.45**	**304.04**	**272.13**	**109.29**	**45.18**	**85.17**	**1064.26**	**1765.28**	**1247.08**	**880.96**	**424.43**	**4317.75**	**5382.01**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \frac{1083.04 \times 10^4}{31 \times 24 \times 60 \times 60} = 4.04\ m^3/sec < 5.24\ m^3/sec$

in the month of January

Table No. 4.7

PROPOSAL – 3

WATER DEMAND TABLE AT PROJECT HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED AT 140% CROPPING INTENSITY

UNIT : Ha-m

Crops/ Intensity/ Area — Months	Rice 5% 1396 ha	Maize 10% 2792 ha	Red Gram 4% 1116 ha	Black Gram 3% 838 ha	Green Gram 3% 838 ha	Soybean 20% 5585 ha	Groundnut 5% 1396 ha	Sorghum 3% 838 ha	Vegetable 2% 6558 ha	Total Kharif 55% 15357 ha	Wheat (Hybrid) 40% 11170 ha	Wheat (Local) 25% 6981 ha	Gram 5% 1396 ha	Pea 2% 558 ha	Lentil 2% 558 ha	Mustard 3% 838 ha	Linseed 2.5% 698 ha	Berseem 2.5% 698 ha	Potato 1% 280 ha	Tomato 1% 280 ha	Cauliflower 1% 280 ha	Total Rabi 85% 23737 ha	Grand Total Kharif + Rabi 140% 39094 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2193.56	1252.95	253.51	0.00	72.94	157.79	130.95	143.89	47.06	52.18	0.00	4304.83	4304.83
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2172.92	902.02	156.62	0.00	116.12	46.09	38.44	180.48	21.38	13.40	0.00	3647.47	3647.47
March	0.00	0.00	0.00	0.00	26.61	0.00	0.00	0.00	0.00	26.61	1831.88	0.00	0.00	0.00	44.16	0.00	0.00	204.22	0.00	0.00	0.00	2080.26	2106.87
April	0.00	0.00	0.00	106.36	233.45	0.00	0.00	0.00	0.00	339.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	339.81
May	0.00	0.00	0.00	279.50	103.91	0.00	0.00	0.00	0.00	383.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	383.41
June	85.72	349.00	0.00	10.86	0.00	698.12	174.50	104.75	69.75	1492.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1492.70
July	430.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	430.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	430.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	234.52	0.00	21.20	0.00	0.00	0.00	0.00	0.00	0.00	255.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	255.72
October	125.57	0.00	186.36	0.00	0.00	0.00	43.46	14.67	0.00	370.06	0.00	698.10	139.60	86.71	0.00	83.80	69.55	16.05	30.41	0.00	43.25	1167.47	1537.53
November	0.00	0.00	180.78	0.00	0.00	0.00	0.00	0.00	0.00	180.78	1723.64	955.35	132.80	101.81	0.00	95.50	79.27	109.25	40.94	55.36	46.35	3340.27	3520.55
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1135.54	1079.82	199.91	47.59	75.97	139.66	115.89	94.23	46.49	36.04	0.00	2971.14	2971.14
Total	875.81	349.00	388.34	396.72	363.97	698.12	217.96	119.42	69.75	3479.00	9057.52	4888.24	882.44	236.11	309.19	522.84	434.10	748.12	186.28	156.98	89.60	17511.00	20990.00

CCA of LBC = 20927 ha   Head discharge of LBC = 13.73 cumec

CCA of RBC = 6997 ha   Head discharge of RBC = 5.24 cumec

CCA = 27924 ha

Table No. 4.7(a)

PROPOSAL – 3

WATER DEMAND TABLE AT LEFT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Rice 1000 ha	Maize 2000 ha	Red Gram 800 ha	Black Gram 600 ha	Green Gram 600 ha	Soybean 4185 ha	Groundnut 1000 ha	Sorghum 600 ha	Vegetable 400 ha	Total Kharif 11185 ha	Wheat (Hybrid) 8370 ha	Wheat (Local) 5400 ha	Gram 1000 ha	Pea 400 ha	Lentil 400 ha	Mustard 600 ha	Linseed 500 ha	Berseem 500 ha	Potato 200 ha	Tomato 200 ha	Cauliflower 200 ha	Total Rabi 17770 ha	Grand Total Kharif + Rabi 28955 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1643.70	969.19	181.60	0.00	52.29	112.98	93.80	103.07	33.61	37.27	0.00	3227.51	3227.51
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1628.23	697.74	112.19	0.00	83.24	33.00	27.54	129.28	15.27	9.57	0.00	2736.06	2736.06
March	0.00	0.00	0.00	0.00	19.05	0.00	0.00	0.00	0.00	19.05	1372.68	0.00	0.00	0.00	31.66	0.00	0.00	146.29	0.00	0.00	0.00	1550.63	1569.68
April	0.00	0.00	0.00	76.15	167.15	0.00	0.00	0.00	0.00	243.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	243.30
May	0.00	0.00	0.00	200.12	74.40	0.00	0.00	0.00	0.00	274.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	274.52
June	61.40	250.00	0.00	7.78	0.00	523.12	125.00	75.00	50.00	1092.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1092.30
July	308.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	308.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	308.02
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	167.99	0.00	15.20	0.00	0.00	0.00	0.00	0.00	0.00	183.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	183.19
October	89.95	0.00	133.59	0.00	0.00	0.00	31.13	10.50	0.00	265.17	0.00	540.00	100.00	62.16	0.00	60.00	49.82	11.50	21.72	0.00	30.89	876.09	1141.26
November	0.00	0.00	129.59	0.00	0.00	0.00	0.00	0.00	0.00	129.59	1291.57	738.99	95.13	72.98	0.00	68.38	56.78	78.26	29.24	39.54	33.11	2503.98	2633.57
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	850.89	835.27	143.20	34.11	54.46	100.00	83.02	67.50	33.21	25.74	0.00	2227.40	2227.40
Total	627.36	250.00	278.38	284.05	260.60	523.12	156.13	85.50	50.00	2515.14	6787.07	3781.19	632.12	169.25	221.64	374.35	310.96	535.90	133.06	112.12	64.00	13121.67	15636.81

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \dfrac{3227.51 \times 10^4}{31 \times 24 \times 60 \times 60} = 12.05\ m^3/sec < 13.73\ m^3/sec$

in the month of January

Table No. 4.7(b)

PROPOSAL – 3

WATER DEMAND TABLE AT RIGHT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area / Months	Rice 396 ha	Maize 792 ha	Red Gram 316 ha	Black Gram 238 ha	Green Gram 238 ha	Soybean 1400 ha	Groundnut 396 ha	Sorghum 238 ha	Vegetable 158 ha	Total Kharif 4172 ha	Wheat (Hybrid) 2800 ha	Wheat (Local) 1581 ha	Gram 396 ha	Pea 158 ha	Lentil 158 ha	Mustard 238 ha	Linseed 198 ha	Berseem 198 ha	Potato 80 ha	Tomato 80 ha	Cauliflower 80 ha	Total Rabi 5967 ha	Grand Total Kharif + Rabi 10139 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	549.86	283.76	71.91	0.00	20.65	44.81	37.15	40.82	13.45	14.91	0.00	1077.32	1077.32
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	544.69	204.28	44.43	0.00	32.88	13.09	10.90	51.20	6.11	3.83	0.00	911.41	911.41
March	0.00	0.00	0.00	0.00	7.56	0.00	0.00	0.00	0.00	7.56	459.20	0.00	0.00	0.00	12.50	0.00	0.00	57.93	0.00	0.00	0.00	529.63	537.19
April	0.00	0.00	0.00	30.21	66.30	0.00	0.00	0.00	0.00	96.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	96.51
May	0.00	0.00	0.00	79.38	29.51	0.00	0.00	0.00	0.00	108.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108.89
June	24.32	99.00	0.00	3.08	0.00	175.00	49.50	29.75	19.75	400.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	400.40
July	121.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	121.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	121.98
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	66.53	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	72.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	72.53
October	35.62	0.00	52.77	0.00	0.00	0.00	12.33	4.17	0.00	104.89	0.00	158.10	39.60	24.55	0.00	23.80	19.73	4.55	8.69	0.00	12.36	291.38	396.27
November	0.00	0.00	51.19	0.00	0.00	0.00	0.00	0.00	0.00	51.19	432.07	216.36	37.67	28.83	0.00	27.12	22.49	30.99	11.70	15.82	13.24	836.29	887.48
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	284.65	244.55	56.71	13.48	21.51	39.66	32.87	26.73	13.28	10.30	0.00	743.74	743.74
Total	**248.45**	**99.00**	**109.96**	**112.67**	**103.37**	**175.00**	**61.83**	**33.92**	**19.75**	**963.95**	**2270.47**	**1107.05**	**250.32**	**66.86**	**87.54**	**148.49**	**123.14**	**212.22**	**53.22**	**44.85**	**25.60**	**4389.77**	**5353.72**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \frac{1077.32 \times 10^4}{31 \times 24 \times 60 \times 60} = 4.02\ m^3/sec < 5.24\ m^3/sec$

in the month of January

Table No. 4.8

PROPOSAL – 4

WATER DEMAND TABLE AT PROJECT HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED AT 140% CROPPING INTENSITY

UNIT : Ha-m

Crops/ Intensity/ Area — Months	Soybean 21.5% 6000 ha	Groundnut 3.6% 1000 ha	Maize 1.8% 500 ha	Red Gram 1.8% 500 ha	Black Gram 1.8% 500 ha	Green Gram 5.4% 1500 ha	Rice 5.4% 1500 ha	Sorghum 3.5% 1000 ha	Vegetable 1.8% 500 ha	Cotton 3.6% 1000 ha	Sugarcane 3.6% 1000 ha	Total Kharif 54% 15000 ha	Wheat (Hyv) 26.8% 7500 ha	Wheat (local) 26.8% 7500 ha	Gram 7.2% 2000 ha	Barley 3.6% 1000 ha	Pea 3.6% 1000 ha	Lentil 1.8% 500 ha	Mustard 3.6% 1000 ha	Linseed 1.8% 500 ha	Safeflower 1.8% 5008 ha	Berseem 1.8% 500 ha	Potato 3.6% 1000 ha	Tomato 1.8% 500 ha	Cauliflower 1.8% 500 ha	Total Rabi 86% 24000 ha	Grand Total Kharif + Rabi 140% 39000 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.20	126.20	1472.85	1346.1	363.19	181.59	0.00	65.36	188.29	93.80	93.80	103.07	168.06	93.51	0.00	4169.62	4295.82
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.43	109.43	1458.99	969.08	218.64	109.33	0.00	104.05	55.00	27.54	27.54	129.28	76.36	24.01	0.00	3199.82	3309.25
March	0.00	0.00	0.00	0.00	0.00	47.63	0.00	0.00	0.00	0.00	138.95	186.58	1230.00	0.00	0.00	0.00	0.00	39.57	0.00	0.00	0.00	146.29	0.00	0.00	0.00	1415.86	1602.44
April	0.00	0.00	0.00	0.00	63.46	417.87	0.00	0.00	0.00	0.00	126.00	607.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	607.33
May	0.00	0.00	0.00	0.00	166.77	186.00	0.00	0.00	0.00	0.00	143.00	495.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	495.77
June	750.00	125.00	62.50	0.00	6.48	0.00	92.11	125.00	62.50	0.00	40.58	1264.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1264.17
July	0.00	0.00	0.00	0.00	0.00	0.00	462.03	0.00	0.00	0.00	0.00	462.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	462.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	9.50	0.00	0.00	251.99	0.00	0.00	0.00	35.65	297.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	297.04
October	0.00	31.13	0.00	83.49	0.00	0.00	134.92	17.47	0.00	166.85	187.00	620.86	0.00	750.00	0.00	0.00	155.39	0.00	100.00	49.82	49.82	11.50	108.60	0.00	77.23	1302.36	1923.22
November	0.00	0.00	0.00	80.99	0.00	0.00	0.00	0.00	0.00	156.01	163.88	400.88	1157.32	1026.38	390.26	195.13	182.46	0.00	113.96	56.79	56.79	78.26	146.22	99.21	82.77	3585.55	3986.43
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.00	114.66	149.66	762.45	1160.10	286.40	143.19	85.29	68.07	166.66	83.02	83.02	67.50	166.04	64.59	0.00	3136.33	3285.99
Total	750.00	156.13	62.50	173.98	236.71	651.50	941.05	142.47	62.50	357.86	1185.35	4720.00	5081.61	5251.66	1258.49	629.24	423.14	277.05	623.91	310.97	310.97	535.90	665.28	281.32	160.0	16809.50	21529.59

CCA of LBC = 20927 ha — Head discharge of LBC = 13.73 cumec

CCA of RBC = 6997 ha — Head discharge of RBC = 5.24 cumec

CCA = 27924 ha

Table No. 4.8(a)

PROPOSAL – 4

WATER DEMAND TABLE AT LEFT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Soybean 4500 ha	Groundnut 750 ha	Maize 370 ha	Red Gram 370 ha	Black Gram 370 ha	Green Gram 1125 ha	Rice 1125 ha	Sorghum 750 ha	Vegetable 370 ha	Cotton 750 ha	Sugarcane 750 ha	Total Kharif 11230 ha	Wheat (Hyv) 5620 ha	Wheat (local) 5620 ha	Gram 1500 ha	Barley 750 ha	Pea 750 ha	Lentil 370 ha	Mustard 750 ha	Linseed 370 ha	Safeflower 370 ha	Berseem 370 ha	Potato 750 ha	Tomato 370 ha	Cauliflower 370 ha	Total Rabi 17960 ha	Grand Total Kharif + Rabi 29190 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	94.65	94.65	1103.65	1008.67	272.39	136.19	0.00	48.36	141.21	69.41	69.41	76.27	126.04	69.19	0.00	3120.80	3215.45
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.07	82.07	1093.27	726.16	163.98	81.99	0.00	76.99	41.25	20.38	20.38	95.66	57.27	17.76	0.00	2395.09	2477.17
March	0.00	0.00	0.00	0.00	0.00	35.72	0.00	0.00	0.00	0.00	104.21	139.93	921.68	0.00	0.00	0.00	0.00	29.28	0.00	0.00	0.00	108.25	0.00	0.00	0.00	1059.21	1199.14
April	0.00	0.00	0.00	0.00	46.96	313.40	0.00	0.00	0.00	0.00	94.50	454.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	454.86
May	0.00	0.00	0.00	0.00	123.41	139.50	0.00	0.00	0.00	0.00	107.25	370.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	370.16
June	562.50	93.75	46.25	0.00	4.79	0.00	69.08	93.75	46.25	0.00	30.43	946.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	946.80
July	0.00	0.00	0.00	0.00	0.00	0.00	346.52	0.00	0.00	0.00	0.00	346.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	346.52
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	7.03	0.00	0.00	188.99	0.00	0.00	0.00	26.73	222.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	222.75
October	0.00	23.35	0.00	61.78	0.00	0.00	101.19	13.10	0.00	125.15	140.25	464.80	0.00	562.00	0.00	0.00	116.54	0.00	75.00	36.86	36.86	8.51	81.45	0.00	57.15	974.40	1439.20
November	0.00	0.00	0.00	59.93	0.00	0.00	0.00	0.00	0.00	117.00	122.91	299.84	867.21	769.10	292.69	146.34	136.84	0.00	85.47	42.02	42.02	57.91	109.66	73.41	61.25	2683.95	2983.79
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.25	86.00	112.24	571.30	869.30	214.80	107.39	63.96	50.37	125.00	61.43	61.43	49.95	124.53	47.79	0.00	2347.35	2459.59
Total	**562.50**	**117.10**	**46.25**	**128.74**	**175.16**	**488.62**	**705.78**	**106.85**	**46.25**	**268.40**	**889.00**	**3534.65**	**4557.15**	**3935.26**	**943.88**	**471.95**	**317.34**	**205.00**	**467.93**	**230.10**	**230.10**	**396.55**	**498.95**	**208.15**	**118.40**	**12580.76**	**16115.50**

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \dfrac{3215.45 \times 10^4}{31 \times 24 \times 60 \times 60} = 12.005\ m^3/sec < 13.73\ m^3/sec$

in the month of January

Table No. 4.8(b)

PROPOSAL – 4

WATER DEMAND TABLE AT RIGHT BANK CANAL HEAD

ABSTRACT OF THE CROP WATER REQUIREMENT FOR THE CROPPING PATTERN PROPOSED

UNIT : Ha-m

Crops/ Area Months	Soybean 1500 ha	Groundnut 250 ha	Maize 130 ha	Red Gram 130 ha	Black Gram 130 ha	Green Gram 375 ha	Rice 375 ha	Sorghum 250 ha	Vegetable 130 ha	Cotton 250 ha	Sugarcane 250 ha	Total Kharif 3770 ha
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.55	31.55
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.35	27.35
March	0.00	0.00	0.00	0.00	0.00	11.90	0.00	0.00	0.00	0.00	34.73	46.63
April	0.00	0.00	0.00	0.00	16.50	104.46	0.00	0.00	0.00	0.00	31.50	152.46
May	0.00	0.00	0.00	0.00	43.36	46.50	0.00	0.00	0.00	0.00	35.75	125.61
June	187.50	31.25	16.25	0.00	1.68	0.00	23.02	31.25	16.25	0.00	10.14	317.34
July	0.00	0.00	0.00	0.00	0.00	0.00	115.50	0.00	0.00	0.00	0.00	115.50
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	2.47	0.00	0.00	62.99	0.00	0.00	0.00	8.91	74.39
October	0.00	7.78	0.00	21.70	0.00	0.00	33.73	4.36	0.00	41.71	46.75	156.06
November	0.00	0.00	0.00	21.05	0.00	0.00	0.00	0.00	0.00	39.00	40.97	101.04
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.75	28.66	37.41
Total	187.50	39.03	16.25	45.22	61.54	162.86	235.24	35.61	16.25	89.46	296.31	1185.35

Months	Wheat (Hyv) 1880 ha	Wheat (local) 1880 ha	Gram 500 ha	Barley 250 ha	Pea 250 ha	Lentil 130 ha	Mustard 250 ha	Linseed 130 ha	Safeflower 130 ha	Berseem 130 ha	Potato 250 ha	Tomato 130 ha	Cauliflower 130 ha	Total Rabi 6040 ha	Grand Total Kharif + Rabi 9810 ha
January	369.19	337.42	90.79	45.39	0.00	16.99	47.07	24.38	24.38	26.79	42.01	24.31	0.00	1048.82	1080.37
February	365.72	242.91	54.66	27.33	0.00	27.05	13.75	7.16	7.16	33.61	19.09	6.24	0.00	804.73	832.08
March	308.32	0.00	0.00	0.00	0.00	10.28	0.00	0.00	0.00	38.03	0.00	0.00	0.00	356.65	403.28
April	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	152.46
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125.61
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	317.34
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	115.50
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	74.39
October	0.00	188.00	0.00	0.00	38.84	0.00	25.00	12.95	12.95	2.99	27.15	0.00	20.08	327.96	484.02
November	290.10	257.28	97.56	48.78	45.61	0.00	28.49	14.76	14.76	20.34	36.55	25.79	21.52	901.60	1002.64
December	191.12	290.79	71.60	35.79	21.32	17.69	41.66	21.58	21.58	17.55	41.51	16.79	0.00	788.98	826.39
Total	1524.45	1316.40	314.61	157.29	105.77	72.05	155.97	80.87	80.87	139.35	166.31	73.15	41.60	4228.74	5414.09

CCA of LBC = 20927 ha

CCA of RBC = 6997 ha

CCA = 27924 ha

Head discharge of LBC = 13.73 cumec

Head discharge of RBC = 5.24 cumec

Peak discharge required = $Q = \frac{1080.37 \times 10^4}{31 \times 24 \times 60 \times 60} = 4.034\ m^3/sec < 5.24\ m^3/sec$

in the month of January

Table No. 4.9

COST OF CULTIVATION OF CROPS

S. No.	Name of Crop	Seed			Manure			Pesticides (Rs/ha)	Land prep. and labour cost (Rs/ha)	Other expdt Irri/Elec./ Harvest (Rs/ha)	Total cost of cultivation (Rs/ha)	Yield (q/ha)	Rate per q	Gross return (Rs/ha)	Net benefit (Rs/ha)
		Kg/ha	Rate/Kg	Value (Rs)	Name	Qty Kg/ha	Value (Rs)								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Kharif														
1	Soybean	100	14.75	1475	DAP MOP	100 35	1000	500	800	1200	4975	12	900	10800	**5825**
2	Groundnut	100	25.00	2500	DAP	100	900	250	800	1200	5650	12	1000	12000	**6350**
3	Maize	40	9.00	360	NPK Urea	100 50	1010	250	1000	1100	3720	15	500	7500	**3780**
4	Red Gram	30	31.00	930	DAP	200	1800	400	840	1000	4970	10	1100	11000	**6030**
5	Black Gram	20	31.00	620	DAP	100	900	250	800	800	3370	7	1200	8400	**5030**
6	Green Gram	20	31.00	620	DAP	100	900	250	800	800	3370	7	1200	8400	**5030**
7	Paddy	30	10.00	300	DAP MOP Urea	120 90 175	2272	250	1200	1800	5822	24	500	12000	**6178**
8	Sorghum	30	15	450	NPK Urea	100 50	1010	250	1000	1100	3810	20	400	8000	**4190**
9	Vegetable	5	40	200	NPK DAP S. phos phate	150 50 50	1695	400	1800	2000	6095	70	150	10500	**4405**
10	Cotton	30	12	360	NPK DAP	100 50	1230	250	1200	1000	4040	2.5	6000	15000	**10960**
11	Sugarcane	6000	1.0	6000	NPK Urea	250 250	3100	250	2200	3000	14550	600	65	39000	**24450**
	Rabi														
12	Wheat (Hyv)	100	10.00	1000	NPK Urea	150 175	1975	250	1400	2200	6825	22	600	13200	**6375**
13	Wheat (Local)	100	13.25	1325	NPK Urea	75 50	815	190	1000	1500	4830	12	750	9000	**4170**
14	Gram	80	25	2000	DAP	100	900	550	800	1000	5250	10	1500	15000	**9750**
15	Barley	100	10.00	1000	NPK Urea	75 50	815	400	905	1000	4120	18	450	8100	**3980**
16	Pea	100	29.00	2900	DAP	100	900	250	800	1000	5850	10	1200	12000	**6150**
17	Lentil	40	23.00	920	DAP	100	900	350	1100	1400	4670	7	1400	9800	**5130**
18	Mustard	20	26.00	520	NPK	100	780	150	800	1000	3250	8	1400	11200	**7950**
19	Linseed	20	26.00	520	NPK	100	780	150	800	1000	3250	8	1400	11200	**7950**
20	Safeflower	25	26.00	650	NPK	50	390	150	800	1000	2990	8	1400	11200	**8210**
21	Berseem	20	125	2500	Urea	200	920	0.00	800	1000	5220	360	50	18000	**12780**
22	Potato	1500	10.00	15000	NPK	150	1170	150	800	1000	18120	350	100	35000	**16880**
23	Tomato	0.50	500	250	DAP NPK S. phos phate	200 50 100	2490	400	1500	1800	6440	150	100	15000	**8560**
24	Cauliflower	0.5	600	300	-do-	-do-	2490	250	1000	1200	5240	100	200	20000	**14760**

As per Project Report (Existing)

Unit =ha-m

Month	Water Needed (ha-m)	Water Available (ha-m)
May	155.62	1000
June	1092.62	1500
July	1545.35	500
Aug	0.00	0
Sept	842.83	500
Oct	1766.82	1500
Nov	3652.75	3822
Dec	3215.88	3000
Jan	4715.36	4303
Feb	4061.55	4303
Mar	2097.39	1800
Apr	349.62	467
TOTAL	23495.79	22695

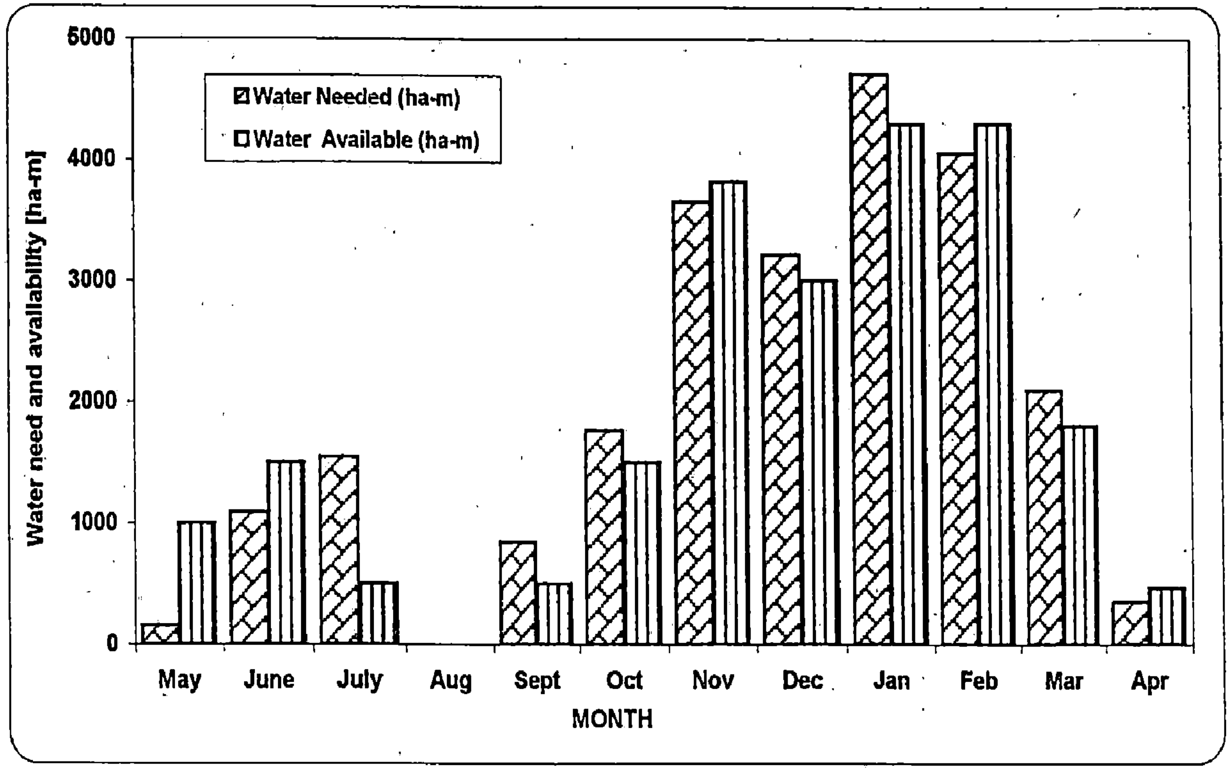


Fig. 4.1: Showing the statement of water balance for the existing cropping pattern taking average weather condition prevailing from 1991-2000 at Samrat Ashok Sagar Project (M.P.)

As per NWMP

Unit =ha-m

Month	Water Needed (ha-m)	Water Available (ha-m)
May	0.00	1000.00
Jun	1624.99	1500.00
July	80.00	500.00
Aug	0.00	0.00
Sept	180.00	500.00
Oct	1600.00	1500.00
Nov	3482.37	3822.00
Dec	3422.61	3000.00
Jan	4848.18	4303.00
Feb	3893.39	4303.00
Mar	1640.00	1800.00
Apr	0.00	467.00
TOTAL	20771.54	22695.00

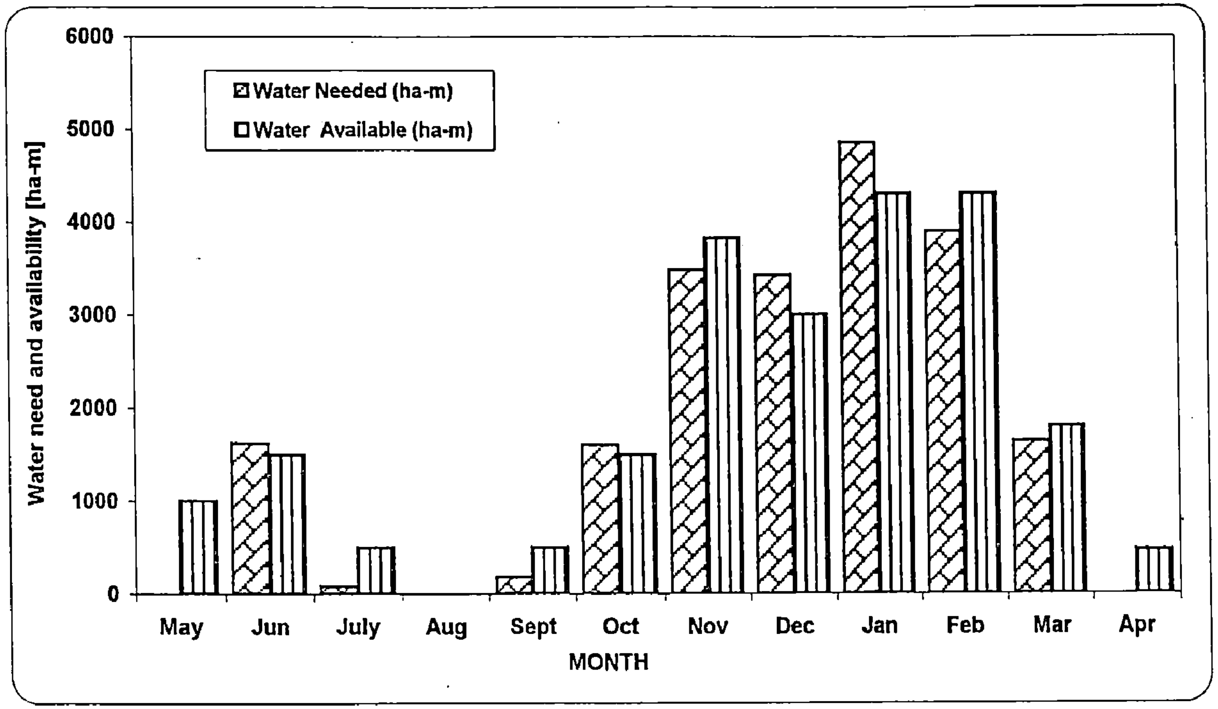


Fig. 4.2: Showing the statement of water balance for the NWMP proposed cropping pattern taking average weather condition prevailing from 1991-2000 at Samrat Ashok Sagar Project (M.P.)

proposal - 1

Unit =ha-m

Month	Water Needed (ha-m)	Water Available (ha-m)
May	199.63	1000.00
June	2062.12	1500.00
July	430.00	500.00
Aug	0.00	0.00
Sept	284.29	500.00
Oct	1086.62	1500.00
Nov	3455.15	3822.00
Dec	2778.14	3000.00
Jan	4133.09	4303.00
Feb	3535.27	4303.00
Mar	2028.18	1800.00
Apr	175.90	467.00
TOTAL	20168.39	22695.00

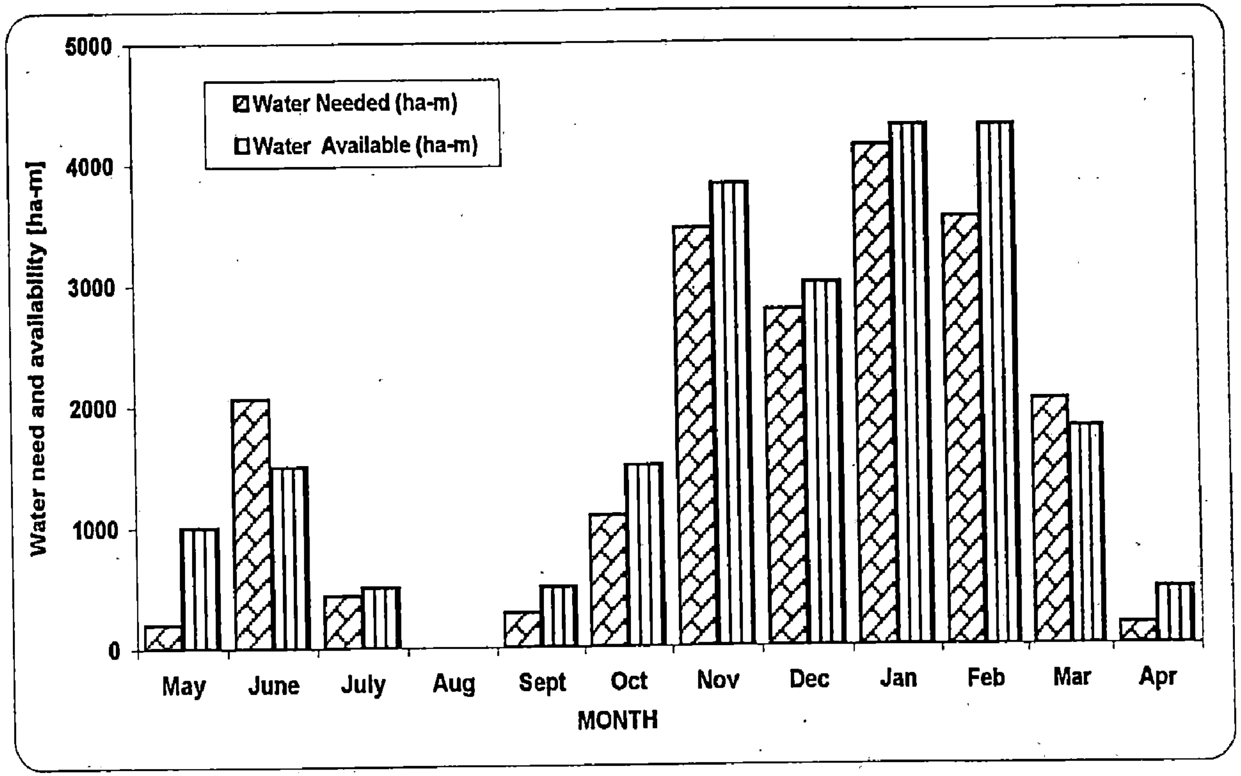


Fig. 4.3: Showing the statement of water balance for the cropping pattern Proposal no.1 taking average weather condition prevailing from 1991-2000 at Samrat Ashok Sagar Project (M.P.)

proposal - 2

Unit =ha-m

Month	Water Needed (ha-m)	Water Available (ha-m)
May	309.99	1000.00
June	1584.98	1500.00
July	430.00	500.00
Aug	0.00	0.00
Sept	234.52	500.00
Oct	1092.97	1500.00
Nov	3687.03	3822.00
Dec	2948.98	3000.00
Jan	4200.04	4303.00
Feb	3503.18	4303.00
Mar	1861.66	1800.00
Apr	696.45	467.00
TOTAL	20549.80	22695.00

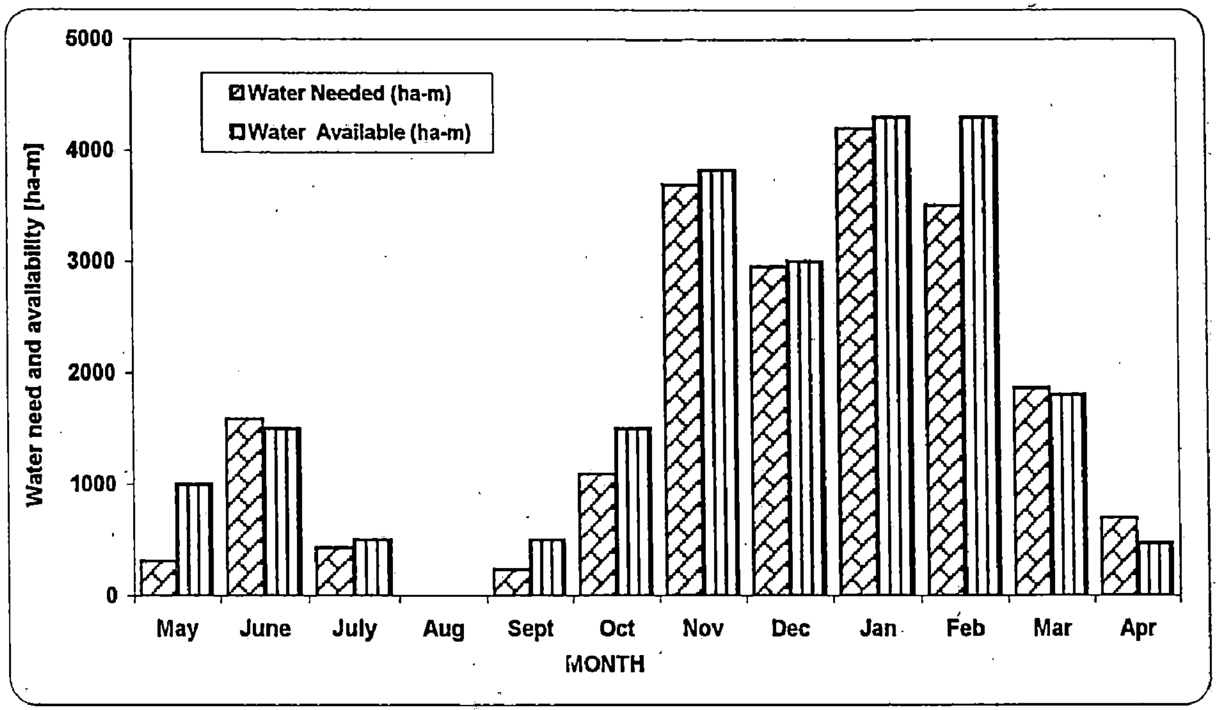


Fig. 4.4: Showing the statement of water balance for the cropping pattern Proposal no. 2 taking average weather condition prevailing from 1991-2000 at Samrat Ashok Sagar Project (M.P.)

proposal - 3

Unit =ha-m

Month	Water Needed (ha-m)	Water Available (ha-m)
May	383.41	1000
June	1492.70	1500
July	430.00	500
Aug	0.00	0
Sept	255.72	500
Oct	1537.53	1500
Nov	3520.55	3822
Dec	2971.14	3000
Jan	4304.83	4303
Feb	3647.47	4303
Mar	2106.87	1800
April	339.81	467
TOTAL	20990.03	22695

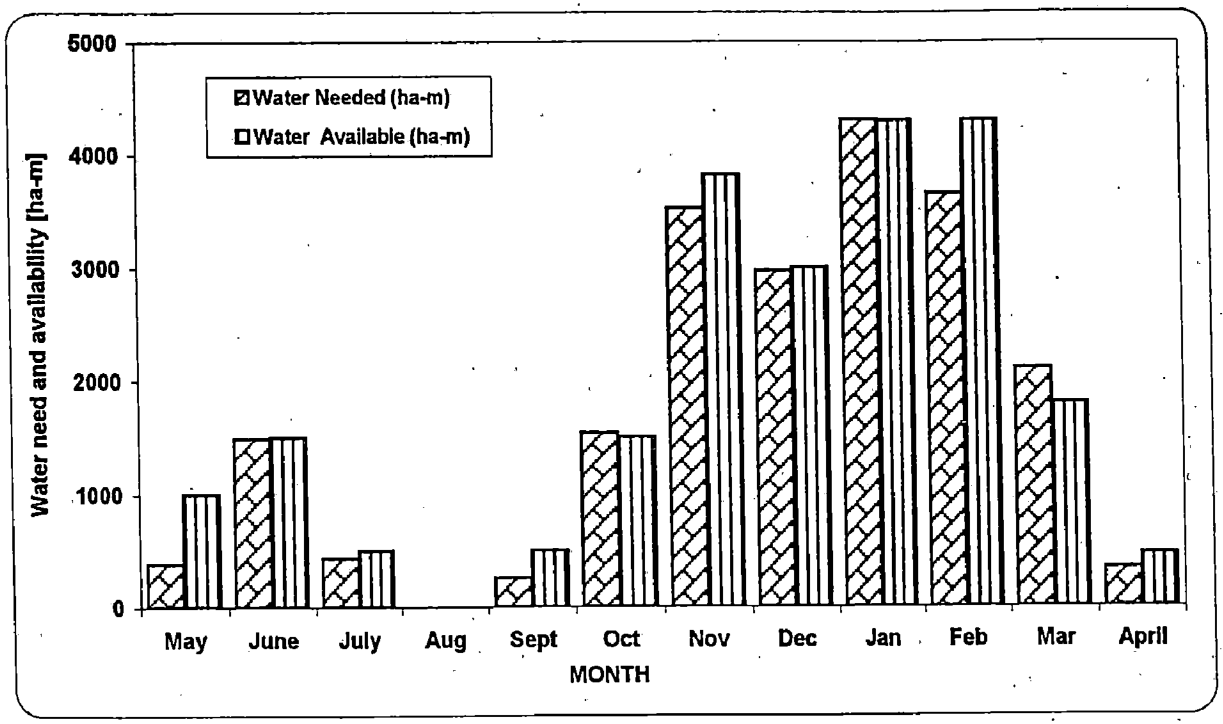


Fig. 4.5: Showing the statement of water balance for the cropping pattern Proposal no. 3 taking average weather condition prevailing from 1991-2000 at Samrat Ashok Sagar Project (M.P.)

prop -4

Unit =ha-m

Month	Water Needed (ha-m)	Water Available (ha-m)
May	495.77	1000.00
June	1264.17	1500.00
July	462.03	500.00
Aug	0.00	0.00
Sept	297.14	500.00
Oct	1923.22	1500.00
Nov	3986.43	3822.00
Dec	3285.99	3000.00
Jan	4295.82	4303.00
Feb	3309.25	4303.00
Mar	1602.44	1800.00
April	607.33	467.00
TOTAL	21529.59	22695.00

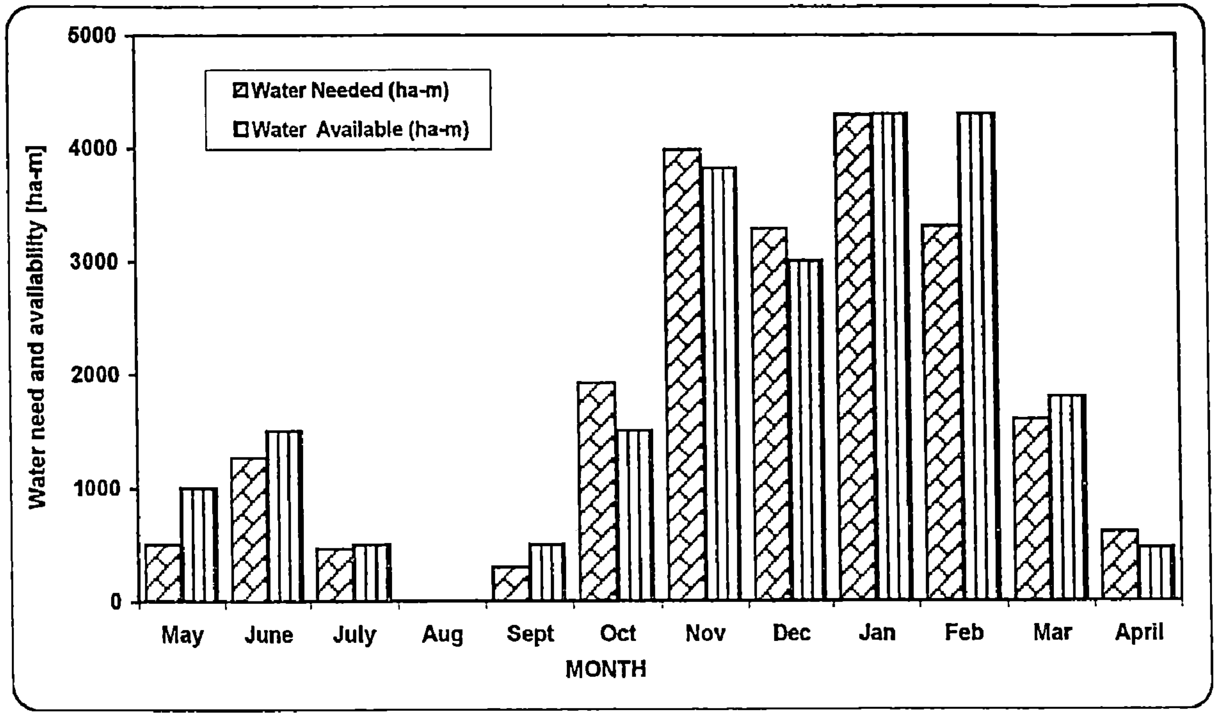


Fig. 4.6: Showing the statement of water balance for the cropping pattern proposal no 4 taking average weather condition prevailing from 1991-2000 at Samrat Ashok Sagar Project (M.P.)

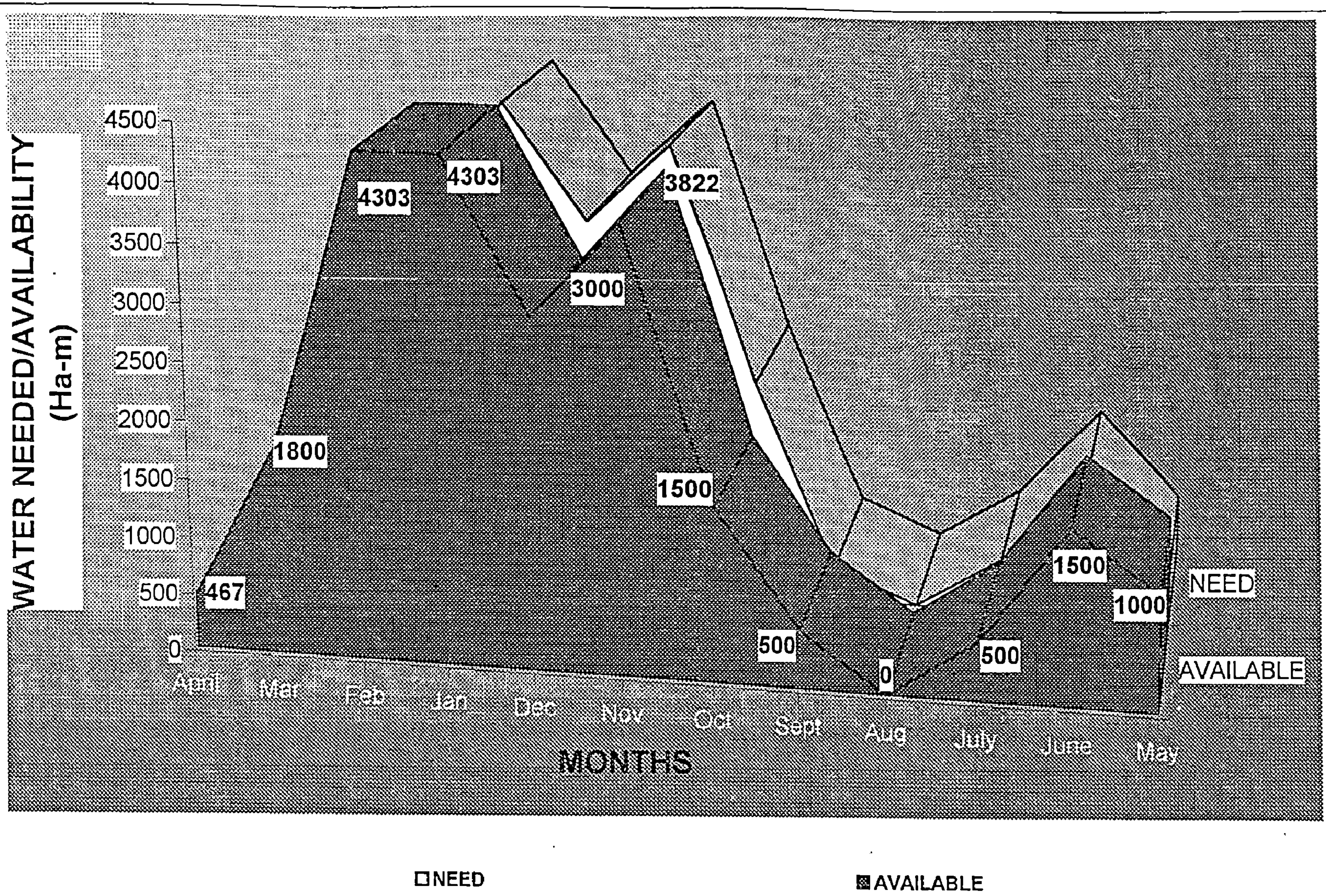


Fig. 4.7 : 3-D VIEW - WATER BALANCE FOR THE RECOMMENDED CROPPING PATTERN (PROPOSAL-4)

Chapter 5

CROP WATER REQUIREMENT

The availability of water in the right quantity and at right time is essential for healthy plant growth and yield. The crop water requirement is one of the basic needs for planning of any irrigation project.

5.1 DEFINITION OF C.W.R.

Crop water requirements are defined as "the depth of water needed to meet the water loss through evapotranspiration (ET_{crop}) of a disease free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment." OR it can be defined in another way that amount of water required at the root zone of a plant (crop) right from the germination (sowing) of the seed upto the time of harvest for healthy growth and optimum yield is termed as the crop water requirement.

The crop water need mainly depends on climate, soil type and growth storage. Major components of a climate effecting crop water need are sun shine, temperature, humidity and wind speed.

5.2 METHODOLOGY

The methodology adopted to achieve the aforesaid goal consists of the following steps :

(i) Collection of climatological data.

(ii) Computation of reference crop evapotranspiration (ET_o) by modified Penman method.

(iii) Selection of crop coefficient for the various crops suggested under cropping system.

(iv) Computation of consumptive use.

(v) Effective rainfall

(vi) Computation of net irrigation requirement

(vii) Computation of gross irrigation requirement

(viii) Monthly estimated crop water requirement and total water requirement for the entire command.

(i) Collection of Climatic Data

The climatological data of Bhopal/Hoshangabad station, which are the nearest I. M.d. station to the Samrat Ashok Sagar Project Command area were collected. These data are processed to compute the crop water requirement. Monthwise climatic data are shown at Annexure 1 and 2.

(ii) ET_o (Reference Evapotranspiration)

The effect of climate on crop water requirement is given by the reference evapotranspiration (ET_o) which is defined as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height actively growing, completely shading the ground and not short of water."

ET_o is expressed in mm per day. Primarily the choice of method must be based on the type of climatic data available and on the accuracy required in determining water needs.

The Modified Penman method would offer the best results with minimum possible error of plus or minus 10 percent in summer, and upto 20 percent under low evaporative conditions (FAO 24, 1992).

The relationship recommended in the above method is given by

$$ET_o = C\,[\underbrace{W.R_n}_{\text{Radiation term}} + \underbrace{(1 - W).f(u).(ea - ed)}_{\text{Aerodynamic term}}]$$

where, ET_o = Reference crop evapotranspiration in mm/day

W = Temperature-related weighing factor.

Rn = Net radiation in equivalent evaporation in mm/day

or Rn = 0.75Rs – Rnl

Rs = Incoming short wave radiation

[(0.25 + 0.50 n/N) Ra]

n = Actual sunshine hour/day

N = Maximum possible sunshine duration, hour/day

Ra = Extra terrestrial radiation in mm/day.

Rnl = Net long wave radiation in mm/day

or Rnl = f(n/N).f(T).f(ed)

where, f(n/N) = Function of the ratio of the sunshine durations

f(T) = Function of temperature

f(ed) = Function of actual vapour pressure

f(U) = Wind related function

= [0.27 (1 + U/100)]

U in km/day.

(ea – ed) = Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar.

c = Adjustment factor to compensate for the effect of day and night weather conditions.

(Source : FAO 24, 1992)

Thus, monthly ET_o is calculated from the year 1991 to year 2000. An abstract of 10 years ET_o and yearly ET_o are shown in Table 5.1(a) and 5.1(b).

(iii) Crop Coefficient

The relation between the reference gross crop and the crop actually grown is given by the crop coefficient. ET_{crop} can be found by

$$ET_{crop} = K_c . ET_o$$

Crop coefficient varies with the growth stages. FAO (33) has designated the growth stages in the following terms :

(1) Initial stage

This is the period from sowing transplanting to the ground cover of about 10%.

(2) Crop development stage

Starts in the end of initial stage and lasts until the ground cover is 60-70%.

(3) Mid season stage

Starts in the end of crop development and lasts with the grain formation.

(4) Late season stage

This starts from grain formatin to the date of harvest.

The values of K_c for different crops adopted in the cropping pattern are taken from FAO Paper No. 33 on the "Yield Response to Water" Published by Food and Agriculture Organisation of the United Nations (Table 18).

(iv) Consumptive Use

Water is mainly needed to meet the demand of evapotranspiration and the metabolic activities of the plant. Both of these together is known as consumptive use. Since the water requirement in the metabolic activities of the plant is very low (below 1%) hence it is negligible.

ET_c or $ET_{crop} = ET_o \times K_c$

(v) Effective Rainfall

The effective rainfall is the total rainfall minus runoff, minus evaporation and minus deep percolation. Only the water retained in the root zone can be used by the plants and represents what is called the effective part of the rain water.

The equation developed to compute the effective precipitation is given below.

$Pe = 0.8\,P - 25$ if $P > 75$ mm/month

$Pe = 0.6\,P - 10$ if $P < 75$ mm/month

where, Pe = Effective precipitation in mm

P = Precipitation in mm.

The above formula is mostly applicable to rice crop only. For other crops, USDA (1969) chart is used for calculation of effective rainfall.

(vi) Net Irrigation Requirement (NIR)

Irrigation water need is calculated using the following formula :

$NIR = ET_{crop} + SAT + PERC + WL - Pe - GWC$

where, NIR = Net Irrigation Requirement

ET_{crop} = Evapotranspiration of crop

SAT = Saturation requirement of crop field

PERC = Percolation requirement of crop field.

WL = Water Layer

Pe = Effective rainfall

GEC = Ground Water Contribution

(vii) Gross Irrigation Requirement (GIR)

GIR = NIR + Efficiency

where, GIR = Gross Irrigation Requirements

Efficiency = Field Application Efficiency/Overall System Efficiency

In the calculation, application efficiency is considered as 75% while conveyance efficiency is 80%. Crop water requirement calculation for each crop is shown in Table No. 5.2(i) to 5.2(xxiv).

(viii) Monthly Water Requirement and Total Water Requirement for Entire Command

On the basis of Gross Irrigation Requirement in metre depth for each crop, the monthly crop water requirement is calculated in hectare meter by multiplying the sown area of individual crop in proposed cropping pattern and also calculated the total water requirement for entire command in hectare meter. It is shown in tabular form in different proposals. An abstract of all the crop plans showing crop water requirement and availability (monthwise) is given in Table 5.3.

Table No. 5.1(a)

ABSTRACT

COMPUTED YEARLY REFERENCE CROP EVAPOTRANSPIRATION (E_{TO}) BY MODIFIED PANMAN METHOD

Unit in mm

S. No.	Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	1991	99.830	137.870	193.940	211.220	277.900	219.930	108.970	107.040	142.730	154.050	116.150	109.460
2	1992	119.460	111.750	119.460	115.600	119.460	115.600	119.460	119.460	115.600	119.460	115.600	119.460
3	1993	110.050	125.190	181.470	240.420	269.520	166.400	133.670	96.880	95.760	162.320	128.310	111.510
4	1994	114.180	103.130	114.180	110.500	114.180	110.500	114.180	114.180	110.500	114.180	110.500	114.180
5	1995	107.880	136.700	185.530	213.720	253.150	170.910	145.920	94.400	163.350	146.500	113.160	108.000
6	1996	117.830	110.230	117.830	114.030	117.830	114.030	117.830	117.830	114.030	117.830	114.030	117.830
7	1997	117.700	130.200	193.130	215.820	250.660	209.610	118.390	108.220	144.810	127.040	127.830	97.770
8	1998	105.000	127.650	177.600	234.510	271.440	202.020	114.080	90.770	117.480	141.270	123.330	101.400
9	1999	120.340	108.690	120.340	116.460	120.340	116.460	120.340	120.340	116.460	120.340	116.460	120.340
10	2000	112.380	105.130	112.380	108.750	112.380	108.750	112.380	112.380	108.750	112.380	108.750	112.380
	AVERAGE	**112.465**	**119.654**	**151.586**	**168.103**	**190.686**	**153.421**	**120.522**	**108.15**	**122.947**	**131.537**	**117.412**	**111.233**
	E_{TO}/day mm/day	**3.620**	**4.260**	**4.890**	**5.600**	**6.150**	**5.110**	**3.880**	**3.120**	**4.090**	**4.240**	**3.910**	**3.220**

Table No. 5.1(b)

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	23.900	29.600	34.200	37.100	41.300	36.900	31.100	27.000	31.400	33.200	28.400	25.800
2	Min. air temperature in °C.	9.500	14.000	18.200	21.600	26.900	25.700	23.800	22.600	20.900	17.700	14.800	10.800
3	Mean air temperature in °C.	16.700	21.800	26.200	29.350	34.000	31.300	27.450	24.800	26.150	25.450	21.600	18.300
4	Saturation vapour pressure (e_a) in mbar	19.040	26.100	34.020	40.900	53.200	45.710	36.650	31.320	33.920	32.550	25.800	21.020
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	36.000	24.000	20.000	17.000	42.000	79.000	80.000	63.000	41.000	36.000	38.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	10.280	9.400	8.160	8.180	9.040	19.200	28.950	25.050	21.270	13.350	9.290	7.980
9	Vapour pressure dedicit (e_a-e_d) in mbar	8.760	16.700	25.860	32.720	44.160	26.510	7.700	6.270	12.550	19.200	16.510	13.040
10	Weighing factor (W)	0.657	0.718	0.762	0.787	0.820	0.803	0.775	0.748	0.762	0.754	0.716	0.675
11	(1-W)	0.343	0.282	0.238	0.213	0.180	0.197	0.225	0.252	0.238	0.246	0.284	0.325
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	0.750	0.750	0.850	0.700	0.850	0.450	0.060	0.150	0.425	0.800	0.750	0.850
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.480	7.525	9.450	9.261	11.040	7.850	4.610	5.135	6.722	8.280	6.775	6.660
16	R_{ns} = 0.75 R_s	4.860	5.644	7.088	6.946	8.280	5.888	3.458	3.851	5.042	6.210	5.081	4.995
17	Function of temperature f(T).	13.940	14.960	15.940	16.570	17.700	17.025	16.190	15.600	15.930	15.760	14.920	14.260
18	Function of vapour pressure f(e_d).	0.198	0.206	0.218	0.218	0.210	0.144	0.105	0.120	0.133	0.183	0.207	0.220
19	Function of sunshine duration f(n/N)	0.780	0.780	0.870	0.730	0.870	0.510	0.158	0.240	0.485	0.820	0.780	0.870
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.153	2.404	3.023	2.637	3.234	1.250	0.269	0.449	1.028	2.365	2.409	2.729
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.707	3.240	4.064	4.309	5.046	4.637	3.189	3.402	4.014	3.845	2.672	2.266
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)	0.542	0.594	0.600	0.620	0.711	0.782	0.737	0.659	0.542	0.432	0.445	0.510
25	Adjustment factor 'c'	0.945	0.961	0.921	0.913	0.916	0.939	0.938	0.963	1.017	1.006	0.968	0.957
26	W*R_n mm/day	1.779	2.326	3.097	3.391	4.138	3.724	2.471	2.545	3.059	2.899	1.913	1.529
27	(1-W)*f(u)*(e_a-e_d)	1.629	2.797	3.696	4.320	5.649	4.084	1.276	1.041	1.619	2.040	2.086	2.160
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.220**	**4.920**	**6.260**	**7.040**	**8.970**	**7.330**	**3.520**	**3.450**	**4.760**	**4.970**	**3.880**	**3.530**
29	**Monthly ET_o (mm/month)**	**99.830**	**137.870**	**193.940**	**211.220**	**277.900**	**219.930**	**108.970**	**107.040**	**142.730**	**154.050**	**116.150**	**109.460**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	26.400	27.000	34.300	38.200	40.600	39.900	33.200	28.500	30.300	31.100	28.600	26.500
2	Min. air temperature in °C.	10.500	11.100	17.100	21.700	25.300	26.500	24.500	22.900	20.600	18.500	14.400	11.100
3	Mean air temperature in °C.	18.450	19.050	25.700	29.950	32.950	33.200	28.850	25.700	25.450	24.800	21.500	18.800
4	Saturation vapour pressure (e_a) in mbar	21.230	22.070	33.030	42.280	50.170	50.880	39.760	33.030	32.550	31.320	25.650	21.720
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	36.000	23.000	15.000	19.000	45.000	81.000	83.000	77.000	38.000	51.000	43.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	8.492	7.950	7.600	6.340	9.530	22.900	32.200	27.400	25.060	11.900	13.080	9.340
9	Vapour pressure dedicit (e_a-e_d) in mbar	12.738	14.120	25.430	35.940	40.640	27.980	7.560	5.630	7.490	19.420	12.570	12.380
10	Weighing factor (W)	0.676	0.685	0.757	0.790	0.815	0.816	0.784	0.757	0.754	0.748	0.715	0.682
11	(1-W)	0.324	0.315	0.243	0.210	0.185	0.184	0.216	0.243	0.246	0.252	0.285	0.318
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	0.750	0.750	0.750	0.850	0.750	0.400	0.040	0.150	0.350	0.850	0.550	0.750
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.480	7.525	8.750	10.420	10.230	7.440	4.440	5.135	6.180	8.160	5.690	6.172
16	R_{ns} = 0.75 R_s	4.860	5.644	6.563	7.815	7.673	5.580	3.330	3.851	4.635	6.120	4.268	4.629
17	Function of temperature f(T).	14.290	14.400	15.825	16.700	17.440	17.500	16.470	15.825	15.760	17.030	14.900	14.360
18	Function of vapour pressure f(e_d).	0.215	0.220	0.222	0.228	0.205	0.125	0.089	0.113	0.120	0.190	0.185	0.206
19	Function of sunshine duration f(n/N)	0.780	0.780	0.780	0.870	0.780	0.460	0.140	0.240	0.420	0.870	0.600	0.780
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.396	2.471	2.740	3.313	2.789	1.006	0.205	0.429	0.794	2.815	1.654	2.307
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.464	3.173	3.822	4.502	4.884	4.574	3.125	3.422	3.841	3.305	2.614	2.322
22	Average wind speed in 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)	0.594	0.542	0.620	0.626	0.743	0.769	0.665	0.685	0.594	0.445	0.432	0.516
25	Adjustment factor 'c'	0.936	0.969	0.900	0.926	0.900	0.931	0.950	0.958	0.999	1.012	0.949	0.945
26	W*R_n mm/day	1.665	2.173	2.893	3.557	3.980	3.732	2.450	2.591	2.896	2.472	1.869	1.583
27	(1-W)*f(u)*(e_a-e_d)	2.452	2.411	3.831	4.728	5.586	3.959	1.086	0.937	1.094	2.178	1.548	2.032
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.850**	**4.440**	**6.050**	**7.670**	**8.610**	**7.160**	**3.360**	**3.380**	**3.990**	**4.710**	**3.240**	**3.420**
29	**Monthly ET_o (mm/month)**	**119.460**	**111.750**	**119.460**	**115.600**	**119.460**	**115.600**	**119.460**	**119.460**	**115.600**	**119.460**	**115.600**	**119.460**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	26.300	28.000	31.500	38.100	42.000	36.600	31.500	28.800	28.900	32.100	29.100	26.000
2	Min. air temperature in °C.	10.600	12.000	16.300	22.100	27.200	25.900	23.300	22.500	21.700	19.700	13.800	10.100
3	Mean air temperature in °C.	18.450	20.000	23.900	30.100	34.600	31.250	27.400	25.650	25.300	25.900	21.450	18.050
4	Saturation vapour pressure (e_a) in mbar	21.230	23.400	29.630	42.650	55.000	45.580	36.540	32.930	32.270	33.410	25.580	20.670
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.%)	55.000	42.000	30.000	15.000	26.000	64.000	75.000	86.000	80.000	45.000	32.000	36.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	11.677	9.828	8.889	6.398	14.300	29.171	27.405	28.320	25.816	15.035	8.186	7.441
9	Vapour pressure dedicit (e_a-e_d) in mbar	9.554	13.572	20.741	36.253	40.700	16.409	9.135	4.610	6.454	18.376	17.394	13.229
10	Weighing factor (W)	0.674	0.700	0.739	0.791	0.826	0.802	0.774	0.756	0.753	0.759	0.715	0.670
11	(1-W)	0.326	0.300	0.261	0.209	0.174	0.198	0.226	0.244	0.247	0.241	0.285	0.330
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	0.800	0.725	0.800	0.650	0.800	0.250	0.225	0.040	0.150	0.850	0.900	0.900
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.740	7.370	9.100	10.032	10.637	6.198	5.968	4.266	4.723	8.600	7.590	6.912
16	R_{ns} = 0.75 R_s	5.055	5.530	6.825	7.524	7.980	4.650	4.476	3.199	3.540	6.450	5.690	5.184
17	Function of temperature f(T).	14.290	14.600	15.380	16.725	17.820	17.010	16.180	15.810	15.725	15.875	14.890	14.200
18	Function of vapour pressure f(e_d).	0.192	0.202	0.211	0.228	0.177	0.104	0.113	0.118	0.120	0.170	0.218	0.223
19	Function of sunshine duration f(n/N)	0.820	0.755	0.820	0.690	0.820	0.33	0.305	0.14	0.24	0.87	0.91	0.91
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.250	2.227	2.661	2.631	2.586	0.583	0.557	0.261	0.453	2.348	2.954	2.880
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.805	3.303	4.164	4.893	5.394	4.067	3.919	2.938	3.087	4.102	2.736	2.304
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	74.400	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)	0.607	0.574	0.620	0.645	0.723	0.762	0.658	0.671	0.607	0.470	0.483	0.503
25	Adjustment factor 'c'	0.940	0.962	0.910	0.915	0.908	0.967	0.982	0.947	0.969	1.008	0.983	0.962
26	W*R_n mm/day	1.890	2.312	3.077	3.870	4.455	3.261	3.033	2.221	2.324	3.113	1.956	1.543
27	(1-W)*f(u)*(e_a-e_d)	1.889	2.336	3.356	4.888	5.120	2.475	1.359	1.079	0.970	2.082	2.395	2.196
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.550**	**4.470**	**5.850**	**8.010**	**8.700**	**5.550**	**4.310**	**3.130**	**3.190**	**5.240**	**4.280**	**3.600**
29	**Monthly ET_o (mm/month)**	**110.050**	**125.190**	**181.470**	**240.420**	**269.520**	**166.400**	**133.670**	**96.880**	**95.760**	**162.320**	**128.310**	**111.510**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	26.000	26.900	35.200	36.300	41.400	34.500	28.100	30.200	30.200	32.200	28.900	26.200
2	Min. air temperature in °C.	12.600	11.800	17.500	21.000	26.700	25.200	23.000	20.800	20.800	17.600	13.900	9.100
3	Mean air temperature in °C.	19.300	19.350	26.350	28.650	34.050	29.850	25.550	25.500	25.500	24.900	21.400	17.650
4	Saturation vapour pressure (e_a) in mbar	22.420	22.490	34.330	39.290	53.250	42.050	32.750	32.650	32.650	31.510	25.500	20.670
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.%)	44.000	27.000	17.000	23.000	32.000	70.000	83.000	83.000	72.000	60.000	39.000	40.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	9.865	6.072	5.836	9.037	17.040	29.435	27.183	27.100	23.508	18.906	9.945	8.268
9	Vapour pressure dedicit (e_a-e_d) in mbar	12.555	16.418	28.494	30.253	36.210	12.615	5.568	5.551	9.142	12.604	15.555	12.402
10	Weighing factor (W)	0.689	0.690	0.763	0.783	0.820	0.789	0.755	0.755	0.755	0.749	0.714	0.670
11	(1-W)	0.311	0.310	0.237	0.217	0.180	0.211	0.245	0.245	0.245	0.251	0.286	0.330
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	0.725	0.850	0.850	0.850	0.800	0.250	0.040	0.040	0.425	0.625	0.800	0.850
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.355	8.127	9.450	10.419	10.637	6.199	4.446	4.266	6.722	7.166	7.046	6.666
16	R_{ns} = 0.75 R_s	4.766	6.095	7.088	7.814	7.978	4.649	3.334	3.200	5.042	5.375	5.285	4.999
17	Function of temperature f(T).	14.460	14.470	15.970	16.430	17.700	16.670	15.790	15.770	15.770	15.625	14.880	14.200
18	Function of vapour pressure f(e_d).	0.201	0.230	0.230	0.210	0.155	0.103	0.114	0.115	0.122	0.145	0.200	0.217
19	Function of sunshine duration f(n/N)	0.755	0.870	0.870	0.870	0.820	0.330	0.140	0.140	0.485	0.665	0.820	0.870
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.194	2.895	3.196	3.002	2.250	0.567	0.252	0.254	0.933	1.507	2.440	2.681
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.572	3.200	3.892	4.812	5.728	4.082	3.082	2.946	4.109	3.868	2.844	2.318
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)	0.549	0.562	0.588	0.594	0.717	0.775	0.698	0.607	0.549	0.464	0.458	0.529
25	Adjustment factor 'c'	0.941	0.894	0.923	0.932	0.997	0.964	0.944	0.961	1.018	0.976	0.972	0.952
26	W*R_n mm/day	1.772	2.208	2.970	3.768	4.697	3.221	2.327	2.224	3.102	2.897	2.031	1.553
27	(1-W)*f(u)*(e_a-e_d)	2.142	2.858	3.968	3.900	4.674	2.064	0.952	0.825	1.229	1.469	2.037	2.166
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.680**	**4.530**	**6.400**	**7.150**	**9.340**	**5.100**	**3.100**	**2.930**	**4.410**	**4.260**	**3.950**	**3.540**
29	**Monthly ET_o (mm/month)**	**114.180**	**103.130**	**114.180**	**110.500**	**114.180**	**110.500**	**114.180**	**114.180**	**110.500**	**114.180**	**110.500**	**114.180**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	22.900	27.900	31.000	37.300	40.300	40.500	32.100	29.200	31.700	33.500	29.400	26.700
2	Min. air temperature in °C.	9.100	11.800	16.500	20.500	25.700	27.500	23.700	23.200	21.800	19.300	13.600	12.100
3	Mean air temperature in °C.	16.000	19.850	23.750	28.900	33.000	34.000	27.900	26.200	26.750	26.400	21.500	19.400
4	Saturation vapour pressure (e_a) in mbar	18.200	23.190	29.380	39.870	50.300	53.200	37.590	34.020	35.180	34.440	25.650	22.560
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	33.000	23.000	24.000	25.000	52.000	73.000	83.000	63.000	45.000	50.000	47.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	7.098	7.653	6.757	9.569	12.575	27.664	27.441	28.237	22.163	15.498	12.825	10.603
9	Vapour pressure dedicit (e_a-e_d) in mbar	11.102	15.537	22.623	30.301	37.725	25.536	10.149	5.783	13.017	18.942	12.825	11.957
10	Weighing factor (W)	0.650	0.697	0.737	0.784	0.815	0.820	0.779	0.762	0.767	0.764	0.715	0.691
11	(1-W)	0.350	0.303	0.263	0.216	0.185	0.180	0.221	0.238	0.233	0.236	0.285	0.309
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	0.750	0.800	0.800	0.800	0.700	0.150	0.275	0.060	0.600	0.650	0.850	0.800
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.484	7.826	9.100	10.033	9.819	5.372	6.380	4.424	7.994	7.326	7.317	6.419
16	R_{ns} = 0.75 R_s	4.863	5.870	6.825	7.525	7.364	4.029	4.785	3.318	5.996	5.494	5.488	4.814
17	Function of temperature f(T).	13.800	14.570	15.350	16.480	17.450	17.700	16.280	15.940	16.050	15.980	14.900	14.480
18	Function of vapour pressure f(e_d).	0.224	0.222	0.226	0.204	0.187	0.111	0.113	0.109	0.129	0.165	0.186	0.197
19	Function of sunshine duration f(n/N)	0.780	0.820	0.820	0.820	0.730	0.240	0.350	0.158	0.640	0.690	0.870	0.820
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.411	2.652	2.845	2.757	2.382	0.472	0.644	0.275	1.325	1.819	2.411	2.339
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.452	3.217	3.980	4.768	4.982	3.558	4.141	3.043	4.671	3.675	3.077	2.475
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)	0.536	0.594	0.607	0.607	0.730	0.769	0.698	0.620	0.536	0.451	0.451	0.536
25	Adjustment factor 'c'	0.948	0.969	0.914	0.924	0.892	0.883	0.983	0.960	1.046	0.980	0.980	0.945
26	W*R_n mm/day	1.594	2.242	2.934	3.738	4.060	2.917	3.226	2.319	3.582	2.808	2.200	1.710
27	(1-W)*f(u)*(e_a-e_d)	2.081	2.796	3.611	3.973	5.095	3.535	1.565	0.853	1.625	2.018	1.650	1.979
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.480**	**4.880**	**5.980**	**7.130**	**8.170**	**5.700**	**4.710**	**3.050**	**5.450**	**4.730**	**3.770**	**3.490**
29	**Monthly ET_o (mm/month)**	**107.880**	**136.700**	**185.530**	**213.720**	**253.150**	**170.910**	**145.920**	**94.400**	**163.350**	**146.500**	**113.160**	**108.000**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	24.400	28.800	35.000	39.000	41.200	38.900	32.200	28.300	31.000	30.800	29.900	26.300
2	Min. air temperature in °C.	11.900	12.700	18.200	21.300	25.700	26.400	23.900	22.500	22.100	18.500	13.800	9.600
3	Mean air temperature in °C.	18.150	20.750	26.600	30.150	33.450	32.650	28.050	25.400	26.550	24.650	21.850	17.950
4	Saturation vapour pressure (e_a) in mbar	20.810	24.520	34.860	42.770	51.600	49.350	38.950	32.460	34.750	31.030	26.180	23.330
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.%)	40.000	35.000	20.000	18.000	22.000	51.000	76.000	85.000	83.000	51.000	36.000	55.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	8.324	8.582	6.972	7.699	11.352	25.169	29.602	27.591	28.843	15.825	9.425	12.832
9	Vapour pressure dedicit (e_a-e_d) in mbar	12.486	15.938	27.888	35.071	40.248	24.182	9.348	4.869	5.908	15.205	16.755	10.499
10	Weighing factor (W)	0.672	0.707	0.766	0.791	0.817	0.813	0.780	0.754	0.765	0.746	0.718	0.670
11	(1-W)	0.328	0.293	0.234	0.209	0.183	0.187	0.220	0.246	0.235	0.254	0.282	0.330
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	0.825	0.750	0.900	0.850	0.850	0.275	0.030	0.060	0.200	0.700	0.900	0.650
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.873	7.525	9.800	10.419	11.046	6.405	4.363	4.424	5.087	7.644	7.588	5.678
16	R_{ns} = 0.75 R_s	5.155	5.644	7.350	7.814	8.285	4.804	3.272	3.318	3.815	5.733	5.691	4.259
17	Function of temperature f(T).	14.230	14.750	16.020	16.740	17.560	17.360	16.300	15.680	16.010	15.560	14.970	14.200
18	Function of vapour pressure f(e_d).	0.217	0.214	0.225	0.222	0.193	0.120	0.102	0.112	0.105	0.162	0.206	0.186
19	Function of sunshine duration f(n/N)	0.845	0.780	0.910	0.870	0.870	0.350	0.130	0.158	0.280	0.730	0.910	0.690
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.609	2.462	3.280	3.233	2.948	0.729	0.216	0.277	0.471	1.840	2.806	1.822
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.546	3.182	4.070	4.581	5.336	4.075	3.056	3.041	3.345	3.893	2.885	2.436
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	0.880	0.830	0.910
24	Wind function f(u) =0.27(1+u/100)	0.555	0.555	0.613	0.633	0.737	0.801	0.724	0.646	0.555	0.458	0.464	0.484
25	Adjustment factor 'c'	0.954	0.969	0.919	0.924	0.911	0.898	0.939	0.955	0.987	0.983	0.987	0.940
26	W*R_n mm/day	1.711	2.249	3.118	3.623	4.360	3.313	2.384	2.293	2.559	2.904	2.071	1.632
27	(1-W)*f(u)*(e_a-e_d)	2.273	2.592	4.003	4.639	5.425	3.624	1.488	0.774	0.771	1.768	2.194	1.676
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.800**	**4.690**	**6.540**	**7.630**	**8.910**	**6.230**	**3.640**	**2.930**	**3.290**	**4.590**	**4.210**	**3.110**
29	**Monthly ET_o (mm/month)**	**117.830**	**110.230**	**117.830**	**114.030**	**117.830**	**114.030**	**117.830**	**117.830**	**114.030**	**117.830**	**114.030**	**117.830**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	24.000	27.500	33.800	35.800	39.000	35.700	29.600	29.500	30.800	31.200	28.600	21.100
2	Min. air temperature in °C.	9.800	11.600	17.600	20.500	24.400	24.200	23.600	22.700	22.100	18.200	19.200	12.900
3	Mean air temperature in °C.	16.900	19.550	25.700	28.150	31.700	29.950	26.600	26.100	26.450	24.700	23.900	17.000
4	Saturation vapour pressure (e_a) in mbar	19.280	22.790	33.030	38.150	46.790	42.280	34.860	33.810	34.550	31.130	29.630	19.400
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.%)	36.000	29.000	22.000	17.000	27.000	45.000	78.000	81.000	60.000	60.000	40.000	47.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	6.941	6.609	7.267	6.486	12.633	19.026	27.191	27.386	20.730	18.678	11.852	9.118
9	Vapour pressure dedicit (e_a-e_d) in mbar	12.339	16.181	25.763	31.665	34.157	23.254	7.669	6.424	13.820	12.452	17.778	10.282
10	Weighing factor (W)	0.659	0.693	0.757	0.781	0.807	0.790	0.766	0.761	0.765	0.747	0.739	0.660
11	(1-W)	0.341	0.307	0.243	0.219	0.193	0.210	0.234	0.239	0.235	0.253	0.261	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	0.875	0.850	0.850	0.800	0.775	0.475	0.150	0.150	0.500	0.600	0.900	0.800
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	7.133	8.127	9.450	10.033	10.433	8.058	5.351	5.135	7.268	7.007	7.588	6.419
16	R_{ns} = 0.75 R_s.	5.350	6.095	7.088	7.525	7.825	6.044	4.013	3.851	5.451	5.255	5.691	4.814
17	Function of temperature f(T).	13.980	14.510	15.825	16.330	17.125	16.700	16.020	15.920	15.990	15.580	15.380	14.000
18	Function of vapour pressure f(e_d).	0.224	0.222	0.226	0.204	0.187	0.111	0.113	0.109	0.129	0.165	0.186	0.197
19	Function of sunshine duration f(n/N)	0.890	0.870	0.870	0.820	0.800	0.530	0.240	0.240	0.550	0.640	0.910	0.820
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.787	2.802	3.112	2.732	2.562	0.982	0.434	0.416	1.134	1.645	2.603	2.262
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.563	3.293	3.976	4.793	5.263	5.061	3.579	3.435	4.316	3.610	3.088	2.553
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)	0.542	0.607	0.594	0.620	0.711	0.737	0.672	0.652	0.542	0.432	0.445	0.490
25	Adjustment factor 'c'	0.959	0.885	0.922	0.922	0.906	0.950	0.969	0.969	0.964	0.976	0.988	0.952
26	W*R_n mm/day	1.689	2.282	3.010	3.743	4.247	3.998	2.741	2.614	3.302	2.697	2.282	1.685
27	(1-W)*f(u)*(e_a-e_d)	2.281	3.015	3.719	4.299	4.685	3.597	1.206	1.002	1.761	1.361	2.065	1.714
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.810**	**4.690**	**6.200**	**7.420**	**8.090**	**7.220**	**3.830**	**3.500**	**4.880**	**3.960**	**4.290**	**3.240**
29	**Monthly ET_o (mm/month)**	**117.700**	**130.200**	**193.130**	**215.820**	**250.660**	**209.610**	**118.390**	**108.220**	**144.810**	**127.040**	**127.830**	**97.770**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	23.600	27.600	31.900	38.400	42.100	37.900	30.600	30.200	31.200	32.300	28.900	27.600
2	Min. air temperature in °C.	10.800	12.400	15.900	22.300	26.800	26.400	23.700	23.700	23.200	21.200	15.400	10.000
3	Mean air temperature in °C.	17.200	20.000	23.900	30.350	34.450	32.150	27.150	26.950	27.200	26.750	22.150	18.800
4	Saturation vapour pressure (e_a) in mbar	19.640	23.400	29.630	43.280	54.550	48.000	36.020	35.600	36.120	35.180	26.650	21.720
5	Max.relative humidity (RH Max.%)	62.000	57.000	33.000	18.000	31.000	64.000	87.000	85.000	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	74.000	72.000	57.000	32.000	38.000
7	Mean.relative humidity (RH Mean.%)	47.000	40.000	24.000	15.000	23.000	56.000	82.000	83.000	78.000	66.000	40.000	55.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	9.231	9.360	7.111	6.492	12.547	26.880	29.536	29.548	28.174	23.219	10.660	11.946
9	Vapour pressure dedicit (e_a-e_d) in mbar	10.409	14.040	22.519	36.788	42.004	21.120	6.484	6.052	7.946	11.961	15.990	9.774
10	Weighing factor (W)	0.662	0.700	0.739	0.793	0.825	0.811	0.772	0.769	0.772	0.767	0.721	0.682
11	(1-W)	0.338	0.300	0.261	0.207	0.175	0.189	0.228	0.231	0.228	0.233	0.279	0.318
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	0.750	0.850	0.800	0.475	0.150	0.090	0.325	0.600	0.850	0.850
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	6.484	7.525	8.750	10.419	10.637	8.058	5.351	4.661	5.996	7.007	7.317	6.666
16	R_{ns} = 0.75 R_s	4.863	5.644	6.563	7.814	7.978	6.044	4.013	3.496	4.497	5.255	5.488	4.999
17	Function of temperature f(T).	14.040	14.600	15.380	16.790	17.790	17.240	16.130	16.100	16.140	16.050	15.030	14.360
18	Function of vapour pressure f(e_d).	0.208	0.206	0.224	0.227	0.187	0.115	0.102	0.102	0.109	0.124	0.196	0.190
19	Function of sunshine duration f(n/N)	0.780	0.780	0.780	0.870	0.820	0.530	0.240	0.182	0.395	0.640	0.870	0.870
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.278	2.346	2.687	3.316	2.728	1.051	0.395	0.299	0.695	1.274	2.563	2.374
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.585	3.298	3.875	4.498	5.250	4.993	3.618	3.197	3.802	3.982	2.925	2.626
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	96.000
23	Average wind speed in m/sec	1.110	1.300	1.300	1.610	1.940	2.160	1.830	1.580	1.190	0.910	0.860	1.110
24	Wind function f(u) =0.27(1+u/100)	0.529	0.575	0.581	0.646	0.724	0.775	0.698	0.639	0.549	0.484	0.471	0.529
25	Adjustment factor 'c'	0.948	0.965	0.913	0.922	0.908	0.943	0.963	0.961	0.997	1.036	0.978	0.953
26	W*R_n mm/day	1.712	2.308	2.864	3.567	4.331	4.049	2.793	2.458	2.935	3.054	2.109	1.791
27	(1-W)*f(u)*(e_a-e_d)	1.862	2.420	3.415	4.918	5.319	3.095	1.031	0.894	0.994	1.348	2.101	1.645
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.390**	**4.560**	**5.730**	**7.820**	**8.760**	**6.740**	**3.680**	**3.220**	**3.920**	**4.560**	**4.120**	**3.270**
29	**Monthly ET_o (mm/month)**	**105.000**	**127.650**	**177.600**	**234.510**	**271.440**	**202.020**	**114.080**	**90.770**	**117.480**	**141.270**	**123.330**	**101.400**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) 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 °C.	25.400	27.100	34.500	40.800	41.000	35.300	29.900	28.500	29.000	30.100	29.900	25.400
2	Min. air temperature in °C.	9.300	14.700	16.600	21.900	26.600	24.300	23.400	22.400	21.700	18.500	14.000	9.300
3	Mean air temperature in °C.	17.350	20.900	25.550	31.350	33.800	29.800	26.650	25.450	25.350	24.300	21.950	17.350
4	Saturation vapour pressure (e_a) in mbar	19.820	24.750	32.750	45.850	52.620	41.940	34.960	32.550	32.360	30.370	26.320	19.820
5	Max.relative humidity (RH Max.%)	59.000	73.000	35.000	22.000	41.000	70.000	84.000	86.000	94.000	74.000	50.000	65.000
6	Min.relative humidity (RH Min.%)	37.000	49.000	20.000	11.000	20.000	51.000	71.000	78.000	82.000	62.000	38.000	41.000
7	Mean.relative humidity (RH Mean.%)	48.000	61.000	28.000	17.000	30.000	60.000	78.000	82.000	88.000	68.000	44.000	53.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	9.514	15.098	9.170	7.795	15.786	25.164	27.269	26.691	28.477	20.652	11.581	10.505
9	Vapour pressure dedicit (e_a-e_d) in mbar	10.306	9.653	23.580	38.056	36.834	16.776	7.691	5.859	3.883	9.718	14.739	9.315
10	Weighing factor (W)	0.663	0.709	0.755	0.803	0.819	0.789	0.766	0.755	0.753	0.743	0.720	0.663
11	(1-W)	0.337	0.291	0.245	0.197	0.181	0.211	0.234	0.245	0.247	0.257	0.280	0.337
12	Cloud cover in oktas	0.980	3.100	0.600	0.550	2.350	5.150	7.000	7.000	6.950	3.400	1.500	0.850
13	Ratio n/N	0.850	0.650	0.850	0.860	0.750	0.400	0.150	0.150	0.160	0.650	0.800	0.850
14	Extra terrestrial radiations in mm/day (R_a)	10.375	12.040	14.000	15.435	16.365	16.530	16.465	15.800	14.535	12.740	10.840	9.875
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	7.003	6.923	9.450	10.496	10.228	7.439	5.351	5.135	4.797	7.326	7.046	6.666
16	R_{ns} = 0.75 R_s	5.252	5.192	7.088	7.872	7.671	5.579	4.013	·3.851	3.597	5.494	5.285	4.999
17	Function of temperature f(T).	14.070	14.780	15.780	17.030	17.650	17.060	16.030	15.760	15.730	15.470	15.000	14.070
18	Function of vapour pressure f(e_d).	0.205	0.169	0.208	0.221	0.162	0.120	0.113	0.116	0.107	0.136	0.192	0.197
19	Function of sunshine duration f(n/N)	0.870	0.690	0.870	0.878	0.780	0.460	0.240	0.240	0.248	0.690	0.820	0.870
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.509	1.723	2.856	3.304	2.230	0.942	0.435	0.439	0.417	1.452	2.362	2.411
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.743	3.469	4.232	4.567	5.441	4.637	3.579	3.412	3.180	4.042	2.923	2.588
22	Average wind speed in km/day	148.800	187.200	132.000	144.000	220.800	230.400	232.800	240.000	199.200	141.600	96.000	102.000
23	Average wind speed in m/sec	1.720	2.160	1.520	1.670	2.550	2.670	2.690	2.770	2.300	1.630	1.110	1.180
24	Wind function f(u) =0.27(1+u/100)	0.672	0.775	0.626	0.659	0.866	0.892	0.899	0.918	0.808	0.652	0.529	0.545
25	Adjustment factor 'c'	0.935	0.920	0.820	0.918	0.868	0.900	0.920	0.900	0.927	0.949	0.960	0.940
26	W*R_n mm/day	1.819	2.459	3.195	3.668	4.456	3.659	2.741	2.576	2.395	3.004	2.104	1.716
27	(1-W)*f(u)*(e_a-e_d)	2.333	2.178	3.619	4.939	5.775	3.158	1.617	1.318	0.775	1.629	2.184	1.712
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.880**	**4.270**	**5.590**	**7.900**	**8.880**	**6.140**	**4.010**	**3.510**	**2.940**	**4.400**	**4.120**	**3.220**
29	**Monthly ET_o (mm/month)**	**120.340**	**108.690**	**120.340**	**116.460**	**120.340**	**116.460**	**120.340**	**120.340**	**116.460**	**120.340**	**116.460**	**120.340**

COMPUTATION OF REFERENCE CROP EVAPOTRANSPIRATION (ET_o) BY MODIFIED PANMAN METHOD FOR THE YEAR - 2000

S. No.	PARTICULARS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	Max. air temperature in °C.	25.800	26.000	32.700	40.200	38.400	35.800	29.300	30.300	31.600	35.200	31.200	21.700
2	Min. air temperature in °C.	9.800	10.500	15.600	22.800	25.100	24.900	23.100	23.000	21.700	18.900	15.400	10.200
3	Mean air temperature in °C.	17.800	18.250	24.150	31.500	31.750	30.350	26.200	26.650	26.650	27.050	23.300	15.950
4	Saturation vapour pressure (e_a) in mbar	20.360	20.950	30.080	46.250	46.920	43.270	34.020	34.960	34.960	35.700	28.610	18.140
5	Max.relative humidity (RH Max.%)	65.000	51.000	32.000	27.000	52.000	69.000	87.000	83.000	74.000	47.000	46.000	49.000
6	Min.relative humidity (RH Min.%)	37.000	33.000	16.000	13.000	36.000	51.000	77.000	70.000	58.000	27.000	32.000	29.000
7	Mean.relative humidity (RH Mean.%)	51.000	42.000	24.000	20.000	44.000	60.000	82.000	77.000	66.000	37.000	39.000	39.000
8	Actual vapour pressure (e_d) = e_a*RHMean/100	10.384	8.799	7.219	9.250	20.645	25.962	27.896	26.919	23.074	13.209	11.158	7.075
9	Vapour pressure dedicit (e_a-e_d) in mbar	9.976	12.151	22.861	37.000	26.275	17.308	6.124	8.041	11.886	22.491	17.452	11.065
10	Weighing factor (W)	0.670	0.673	0.740	0.805	0.808	0.794	0.762	0.766	0.766	0.770	0.732	0.650
11	(1-W)	0.330	0.327	0.260	0.195	0.192	0.206	0.238	0.234	0.234	0.230	0.268	0.350
12	Cloud cover in oktas	0.730	1.380	0.160	0.830	3.400	5.500	7.430	6.000	4.120	1.420	1.250	1.000
13	Ratio n/N	0.850	0.800	0.900	0.850	0.650	0.375	0.090	0.300	0.550	0.800	0.838	0.850
14	Extra terrestrial radiations in mm/day (R_a)	10.400	12.100	14.000	15.450	16.350	16.500	16.450	15.800	14.550	12.800	10.900	9.900
15	Short wave radiation R_s = (0.25+0.5*n/N)*R_a	7.020	7.865	9.800	10.429	9.401	7.219	4.853	6.320	7.639	8.320	7.292	6.683
16	R_{ns} = 0.75 R_s	5.265	5.899	7.350	7.822	7.051	5.414	3.640	4.740	5.729	6.240	5.469	5.012
17	Function of temperature f(T).	14.200	14.250	15.440	17.075	17.140	16.790	15.940	16.030	16.030	16.100	15.260	13.800
18	Function of vapour pressure f(e_d).	0.198	0.212	0.224	0.207	0.136	0.120	0.110	0.115	0.125	0.184	0.194	0.225
19	Function of sunshine duration f(n/N)	0.870	0.820	0.910	0.870	0.690	0.440	0.182	0.370	0.600	0.820	0.870	0.870
20	Net longwave radiation R_{nl} = f(T)*f(e_d)*f(n/N)	2.446	2.477	3.147	3.075	1.608	0.887	0.319	0.682	1.202	2.429	2.576	2.701
21	Net radiation Rn = R_{ns}-R_{nl} in mm/day	2.819	3.422	4.203	4.747	5.443	4.528	3.320	4.058	4.527	3.811	2.893	2.311
22	Average wind speed in km/day	116.800	205.200	168.000	184.800	172.800	240.000	218.400	187.200	165.600	72.000	72.000	69.600
23	Average wind speed in m/sec	1.350	2.370	1.940	2.130	2.000	2.770	2.520	2.160	1.910	0.830	0.830	0.800
24	Wind function f(u) =0.27(1+u/100)	0.585	0.824	0.724	0.769	0.737	0.918	0.860	0.775	0.717	0.464	0.464	0.458
25	Adjustment factor 'c'	0.950	0.933	0.896	0.893	0.980	0.900	0.902	0.970	1.000	1.010	0.980	0.950
26	W*R_n mm/day	1.889	2.303	3.110	3.821	4.398	3.595	2.530	3.108	3.468	2.934	2.118	1.502
27	(1-W)*f(u)*(e_a-e_d)	1.927	3.274	4.301	5.548	3.716	3.273	1.253	1.459	1.995	2.402	2.172	1.773
28	**Eto = c*{W*R_n+(1-W)*f(u)*(e_a-e_d) in mm/day**	**3.630**	**5.200**	**6.640**	**8.370**	**7.950**	**6.180**	**3.410**	**4.430**	**5.460**	**5.390**	**4.200**	**3.110**
29	**Monthly ET_o (mm/month)**	**112.380**	**105.130**	**112.380**	**108.750**	**112.380**	**108.750**	**112.380**	**112.380**	**108.750**	**112.380**	**108.750**	**112.380**

Table 5.2(i)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Soybean
Sowing Time : 16-30 June
Period : 105 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					75.00	100.00	125.00
June 16-30	76.65	0.40	30.66	123.38	30.66	-		
July 1-5	19.4	0.40	7.76	356.30	88.46	0.00	0.00	0.00
July 6-31	100.88	0.80	80.70					
Aug 1-4	12.48	0.80	9.98	325.99	106.85	0.00	0.00	0.00
Aug 5-31	84.24	1.15	96.87					
Sept 1-3	12.27	1.15	14.11	178.76	95.91	0.00	0.00	0.00
Sept 4-28	102.25	0.80	81.80					
Total						**75.00**	**100.00**	**125.00**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(ii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Groundnut
Sowing Time : 16-30 June
Period : 122 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					75.00	100.00	125.00
June 16-30	76.65	0.45	34.49	123.38	34.49			
July 1-10	38.80	0.45	17.46	356.30	78.57	0.00	0.00	0.00
July 11-31	81.48	0.75	61.11					
Aug 1-9	28.08	0.75	21.06	325.99	91.07	0.00	0.00	0.00
Aug 10-31	68.64	1.02	70.01					
Sept 1-18	73.62	1.02	75.09	178.76	114.35	0.00	0.00	0.00
Sept 19-30	49.08	0.80	39.26					
Oct 1-15	63.60	0.80	50.88	47.41	32.20	18.68	24.90	31.13
Total						**93.68**	**124.90**	**156.13**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2(iii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Maize
Sowing Time : 16-30 June
Period : 105 days **(All figures are in mm)**
Soil Type : Clayey

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					75.00	100.00	125.00
June 16-30	76.65	0.40	30.66	123.38	30.66	0.00	0.00	0.00
July 1-5	19.40	0.40	7.76	356.30	80.51	0.00	0.00	0.00
July 6-30	97.00	0.75	72.75					
Aug 1-31	96.72	1.15	88.22	325.99	88.22	0.00	0.00	0.00
Sept 1-4	16.36	1.15	18.81	178.76	100.61	0.00	0.00	0.00
Sept 5-29	102.25	0.80	81.80					
Total						**75.00**	**100.00**	**125.00**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2(iv)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Red gram (Arhar)
Sowing Time : 1-15 July
Period : 153 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
July 1-31	120.52	0.40	48.20	356.30	48.20	0.00	0.00	0.00
Aug 1-31	96.91	0.65	62.99	325.99	62.99	0.00	0.00	0.00
Sept 1-30	122.95	1.03	126.63	178.76	115.00	11.63	15.50	19.40
Oct 1-31	131.53	1.05	138.10	47.41	37.85	100.25	133.66	167.10
Nov. 1-30	117.41	0.83	97.45	2.63		97.45	129.93	162.40
Total						**209.33**	**279.09**	**348.90**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(v)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Black gram (Urad)
Sowing Time : 1-15 April
Period : 81 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
April 1-20	112.00	0.26	29.12	7.71	0.00	29.12	101.55	126.93
April 21-30	56.0	0.84	47.04	-		47.04		
May 1-10	61.50	0.84	51.66	12.61	0.00	51.66	266.90	333.63
May 11-31	129.15	1.15	148.52	-		148.52		
June 1-20	102.20	0.81	82.78	123.38	75.0	7.78	10.37	12.96
Total						**284.12**	**378.82**	**473.52**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(vi)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Green gram (Moong)
Sowing Time : 16-31 March
Period : 60 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
March 16-31	73.35	0.26	19.07	11.31		19.07	25.00	31.78
April 1-15	84.00	0.84	70.56	7.71	0.00	167.16	222.88	278.60
April 16-30	84.00	1.15	96.60					
May 1-15	92.25	0.81	74.72	12.61	0.00	74.72	99.62	124.53
Total						**260.95**	**347.93**	**434.90**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2 (vii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Rice
Sowing Time : 10-30 June
Period : 123 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	S&P (mm)	E_{TC} + S&P	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9	10	11
Nursery	Field Preparation (1/20th area), i.e. 600/20 =							30.00	40.00	50.00
June 10-30	107.31	1.10	118.04	63.00	181.04	86.36	44.08	136.96/20 = 6.84	182.61/20 = 9.13	228.26/20 = 11.41
July 1-10	38.80	1.10	42.68	30.00	72.68/20 = 3.63		-	-	-	-
Transplanting							-	-	-	-
July 5-10	Field preparation & transplanting				285.00		-	-	-	-
July 11-31	81.48	1.15	93.70	63.00	156.70		-	-	-	-
					= 445.33	356.30	260.04	185.29	247.05	308.80
Aug 1-9	28.08	1.15	32.29	27.00	59.29		-	-	-	-
Aug 10-31	68.64	1.20	82.36	66.00	148.36		-	-	-	-
					= 207.65	325.99	235.79	0.00	0.00	0.00
Sept 1-8	32.72	1.20	39.26	24.00	63.26		-	-	-	-
Sept 9-30	89.98	1.00	89.98	66.00	155.98		-	-	-	-
					= 219.24	178.76	118.08	101.16	134.88	168.60
Oct 1-10	42.40	1.00	42.40	30.00	72.40	47.41	18.44	53.96	71.94	89.95
Total								**377.25**	**503.00**	**628.76**

S&P = Seepage & percolation (mm), Clayloam = 3-5 mm/day, sandy loam = 5-7 mm/day
Pe = Effective rainfall (mm), Pe = 0.8P – 25 if P ≥ 75 mm/month, Pe = 0.6P – 10 if P ≤ 75 mm/month
E_{TO} = Evapotranspiration of a reference crop (mm), E_{TC} = Evapotranspiration of crop (mm)

Table 5.2(viii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Sorghum
Sowing Time : 16-30 June
Period : 122 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					75.00	100.00	125.00
June 16-30	76.65	0.30	22.99	123.38	22.99	0.00		
July 1-5	19.40	0.30	5.82	356.30	73.72	0.00	0.00	0.00
July 6-31	97.00	0.70	67.90					
Aug 1-31	96.72	1.00	96.72	325.99	96.72	0.00	0.00	0.00
Sept 1-14	57.26	1.00	57.26	178.76	106.51	0.00	0.00	0.00
Sept 15-30	65.44	0.75	49.25					
Oct 1-15	63.60	0.75	42.70	47.41	32.20	10.50	14.00	17.50
Total						**85.50**	**114.00**	**142.50**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(ix)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Vegetable
Sowing Time : 1-15 June
Period : 102 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					75.00	100.00	125.00
June 1-20	102.20	0.40	40.88	123.38	76.65	0.00	0.00	0.00
June 21-30	51.10	0.70	35.77					
July 1-10	38.80	0.70	27.16	352.30	112.71	0.00	0.00	0.00
July 11-31	81.48	1.05	85.55					
Aug 1-20	62.40	0.80	49.92	325.99	70.51	0.00	0.00	0.00
Aug 21-31	34.32	0.60	20.59					
Sept 1-10	40.90	0.60	24.54	178.76	24.54	0.00	0.00	0.00
Total						**75.00**	**100.00**	**125.00**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2(x)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Cotton
Sowing Time : 15-30 June
Period : 183 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
June 15-30	81.76	0.40	32.70	123.38	32.70	0.00	0.00	0.00
July 1-31	120.52	0.70	84.36	356.30	84.36	0.00	0.00	0.00
August 1-31	96.91	0.70	67.84	325.99	67.84	0.00	0.00	0.00
Sept 1-30	122.95	1.05	86.07	178.76	86.07	0.00	0.00	0.00
Oct 1-31	131.53	1.05	138.11	47.41	38.00	100.11	133.48	166.85
Nov. 1-30	117.41	0.80	93.93	2.63	0.00	93.93	125.24	156.55
Dec 1-15	48.30	0.65	31.40	16.26	10.00	21.40	28.53	35.67
Total						**215.44**	**287.25**	**359.07**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2(xi)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Sugarcane
Sowing Time : 1-15 April
Period : 365 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
April 1-30	168.10	0.45	75.64	7.71	0.00	75.64	100.85	126.06
May 1-31	190.68	0.45	85.80	12.61	0.00	85.80	114.40	143.00
June 1-12	61.36	0.45	27.61	-	-	-	-	-
June 13-30	92.05	0.85	78.24	-	-	-	-	-
			= 105.85	123.38	81.50	24.35	32.46	40.58
July 1-31	120.52	0.85	102.44	356.30	102.44	0.00	0.00	0.00
Aug 1-24	75.02	0.85	63.77	-	-	-	-	-
Aug 25-31	21.88	1.15	25.16	-	-	-	-	-
			= 88.93	325.99	88.93	0.00	0.00	0.00
Sept 1-30	122.95	1.15	141.39	178.76	120.00	21.39	28.52	35.65
Oct 1-31	131.53	1.15	151.25	47.41	39.00	112.25	149.66	187.08
Nov 1-5	19.57	1.15	22.50	-	-	-	-	-
Nov 6-30	97.85	0.78	75.83	-	-	-	-	-
			= 98.33	2.63	-	98.33	131.10	163.88
Dec 1-31	100.00	0.775	77.50	16.26	8.70	58.80	91.73	114.66
Jan 1-17	61.67	0.775	47.79	-	-	-	-	-
Jan 18-31	50.79	0.55	27.93	-	-	-	-	-
			= 75.72	9.1	-	75.72	100.96	126.20
Feb 1-28	119.35	0.55	65.64	8.0	-	65.64	87.52	109.40
March 1-31	151.59	0.55	83.37	11.31	-	83.37	111.16	138.95
Total						**711.29**	**948.36**	**1185.46**

Table 5.2(xii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Wheat (Hyv)
Sowing Time : 15-30 November
Period : 135 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					75.00	100.00	125.00
Nov 15-30	58.65	0.30	17.59	2.63	0.00	17.59	23.45	29.31
Dec 1-31	100.00	0.70	70.00	16.26	9.00	61.00	81.33	101.66
Jan 1-31	112.22	1.05	117.83	9.10	0.00	117.83	157.10	196.38
Feb 1-23	97.98	1.05	102.88	8.00	0.00	116.72	155.62	194.53
Feb 24-28	21.30	0.65	13.84					
Mar 1-31	151.59	0.65	98.53	11.31	0.00	98.53	131.37	164.21
Total						**486.67**	**648.89**	**811.10**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xiii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Wheat (local)
Sowing Time : 17-31 October
Period : 105 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					60.00	80.00	100.00
Oct 17-31	63.60	0.30	19.08	47.41	19.08	0.00	0.00	0.00
Nov 1-30	117.30	0.70	82.11	2.63	0.00	82.11	109.48	136.85
Dec 1-31	99.82	1.05	104.81	16.26	12.00	92.81	123.74	154.68
Jan 1-24	86.88	1.05	91.22	9.10	0.00	107.69	143.58	179.48
Jan 25-31	25.34	0.65	16.47					
Feb 1-28	119.28	0.65	77.53	8.00	0.00	77.53	103.37	129.21
Total						**420.14**	**560.18**	**700.20**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xiv)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Gram
Sowing Time : 1-15 November
Period : 120 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					60.00	80.00	100.00
Nov 1-20	78.20	0.26	20.33	2.63	0.00	57.08	76.10	95.13
Nov 21-30	39.10	0.94	36.75					
Dec 1-15	48.30	0.94	45.40	16.26	11.0	85.92	114.56	143.20
Dec 16-31	51.52	1.00	51.52					
Jan 1-29	104.98	1.00	104.98	9.10	0.00	108.96	145.28	181.60
Jan 30-31	7.24	0.55	3.98					
Feb 1-28	119.28	0.55	65.60	8.00	0.00	65.60	87.46	109.33
Total						**377.56**	**503.40**	**629.25**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xv)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Barley
Sowing Time : 1-15 November
Period : 120 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					60.00	80.00	100.00
Nov 1-20	78.20	0.26	20.33	2.63	0.00	57.08	76.10	95.13
Nov 21-30	39.10	0.94	36.75					
Dec 1-15	48.30	0.94	45.40	16.26	11.00	85.92	114.56	143.20
Dec 16-31	51.52	1.00	51.52					
Jan 1-29	104.98	1.00	104.98	9.10	0.00	108.96	145.28	181.60
Jan 30-31	7.24	0.55	3.98					
Feb 1-28	119.28	0.55	65.60	8.0	0.00	65.60	87.46	109.33
Total						**377.56**	**503.40**	**629.25**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xvi)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Pea
Sowing Time : 1-15 October
Period : 81 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					60.00	80.00	100:00
Oct 1-20	84.80	0.40	33.92	47.41	33.35	33.25	44.33	55.41
Oct 21-31	46.64	0.70	32.65					
Nov 1-10	39.10	0.70	27.37	2.63	0.00	109.48	145.97	182.46
Nov 11-30	78.20	1.05	82.11					
Dec 1-20	64.40	0.95	61.18	16.26	10.00	51.18	68.24	85.30
Total						**253.91**	**338.50**	**423.15**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2(xvii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Lentil
Sowing Time : 1-15 December
Period : 75 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing =					60.00	80.00	100.00
Dec 1-31	100.00	0.30	30.00	16.26	8.0	22.00	29.33	36.66
Jan 1-31	112.46	0.70	78.72	9.1	0.00	78.72	104.96	131.20
Feb 1-28	119.35	1.05	125.31	8.00	0.00	125.31	167.08	208.85
Mar 1-15	73.35	0.65	47.67	11.31	0.00	47.67	63.56	79.45
Total						**333.70**	**444.93**	**556.15**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xviii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Mustard
Sowing Time : 17-31 October
Period : 122 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) =					60.00	80.00	100.00
Oct 17-31	63.60	0.31	19.71	47.41	19.71	0.00	0.00	0.00
Nov 1-25	97.75	0.48	46.92	2.63	0.00	68.42	91.22	114.00
Nov 26-30	19.55	1.10	21.50					
Dec 1-31	100.00	1.10	110.00	16.26	10.00	100.00	133.33	166.66
Jan 1-14	50.68	1.10	55.75	9.10	0.00	112.98	150.64	188.30
Jan 15-31	61.54	0.93	57.23					
Feb 1-15	63.90	0.52	33.20	8.00	0.00	33.20	44.26	55.30
Total						**374.60**	**499.40**	**624.30**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xix)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Linseed
Sowing Time : 17-31 October
Period : 122 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing =					60.00	80	100
Oct 17-31	63.60	0.31	19.71	47.41	19.71	0.00	0.00	0.00
Nov 1-25	97.75	0.48	46.92	2.63	0.00	68.42	91.22	114.00
Nov 26-30	19.55	1.10	21.50					
Dec 1-31	100.00	1.10	110.00	16.26	10.00	100.00	133.33	166.66
Jan 1-14	50.68	1.10	55.75	9.1	0.00	112.98	150.64	188.30
Jan 15-31	61.54	0.93	57.23					
Feb 1-15	63.90	0.52	33.20	8.00	0.00	33.20	44.26	55.30
Total						**374.60**	**499.40**	**624.30**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xx)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Safflower
Sowing Time : 17-31 October
Period : 122 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing =					60.00	80	100
Oct 17-31	63.60	0.31	19.71	47.41	19.71	0.00	0.00	0.00
Nov 1-25	97.75	0.48	46.92	2.63	0.00	68.42	91.22	114.00
Nov 26-30	19.55	1.10	21.50					
Dec 1-31	100.00	1.10	110.00	16.26	10.00	100.00	133.33	166.66
Jan 1-14	50.68	1.10	55.75	9.1	0.00	112.98	150.64	188.30
Jan 15-31	61.54	0.93	57.23					
Feb 1-15	63.90	0.52	33.20	8.00	0.00	33.20	44.26	55.30
Total						**374.60**	**499.40**	**624.30**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xxi)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Berseem
Sowing Time : 1-15 October
Period : 166 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
Oct 1-31	131.53	0.35	46.00	47.41	32.20	13.80	18.40	23.00
Nov 1-30	117.41	0.80	93.92	2.63	0.00	93.92	125.22	156.53
Dec 1-31	100.00	0.90	90.00	16.26	9.00	81.00	108.00	135.00
Jan 1-31	112.46	1.10	123.70	9.10	0.00	123.70	164.93	206.16
Feb 1-28	119.35	1.30	155.15	8.00	0.00	155.15	206.86	258.58
Mar 1-15	151.59	1.10	175.55	11.31	0.00	175.55	234.06	292.58
Total						**643.12**	**857.49**	**1071.86**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xxii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Potato
Sowing Time : 16-31 October
Period : 122 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) = 60 mm					60.00	80.00	100.00
Oct 16-31	67.84	0.45	30.52	47.41	25.00	5.52	7.36	9.20
Nov 1-30	117.41	0.75	88.05	2.63	0.00	88.05	117.40	146.75
Dec 1-31	100.00	1.10	110.00	16.26	10.00	100.00	133.33	166.66
Jan 1-31	112.46	0.90	101.21	9.10	0.00	101.21	134.94	168.68
Feb 1-15	63.90	0.72	46.00	8.00	0.00	46.00	61.33	76.66
Total						**400.78**	**534.35**	**667.95**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.2(xxiii)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Tomato
Sowing Time : 1-15 November
Period : 101 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
	Pre sowing (Palewa) = 60.00 mm					60.00	80.00	100.00
Nov 1-25	97.75	0.45	43.98	2.63	0.00	58.64	78.18	97.73
Nov 26-30	19.55	0.75	14.66					
Dec 1-20	64.40	0.74	48.30	16.26	10.00	77.26	103.01	128.76
Dec 21-31	35.42	1.10	38.96					
Jan 1-15	54.30	1.10	59.73	9.1	0.00	111.85	149.13	186.41
Jan 16-31	57.92	0.90	52.12					
Feb 1-9	38.34	0.75	28.75	8.00	0.00	28.75	38.33	47.91
Total						**336.50**	**448.65**	**560.80**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table 5.2(xxiv)

CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Cauliflower
Sowing Time : 1-15 September
Period : 91 days
Soil Type : Black cotton

(All figures are in mm)

Period	E_{TO} (mm)	K_c	E_{TC} (mm)	Rain (mm)	Pe (mm)	NIR (mm)	FIR (mm) 75% AE	GIR (mm) 80% CE
1	2	3	4	5	6	7	8	9
Sept 1-20	81.80	0.45	36.81	178.38	67.48	0.00	0.00	0.00
Sept 21-30	40.90	0.75	30.67					
Oct 1-10	42.40	0.75	31.80	47.41	36.70	93.04	124.05	155.06
Oct 11-31	89.04	1.10	97.94					
Nov 1-20	78.20	0.90	70.38	2.63	0.00	99.70	132.93	166.16
Nov 21-30	39.10	0.75	29.32					
Total						**192.74**	**256.98**	**321.23**

E_{TO} = Evapotranspiration of a reference crop (mm)
K_c = Crop coefficient for evapotranspiration (= E_{TC}/E_{TO})
E_{TC} = Evapotranspiration of crop (mm)
Pe = Effective rainfall (rain stored in the rootzone) (mm) USDA method
NIR = Net Irrigation Requirement [E_{TC} + Seepage & Percolation) – Pe]
FIR = Field Irrigation Requirement (NIR/AE)
AE = Application efficiency ranging between 50-75%, i.e., water stored in rootzone/water applied to field
GIR = Gross Irrigation Requirement (mm), i.e., FIR/Conveyance efficiency
CE = Conveyance efficiency ranging between 70-80%, i.e., water received at field gate/water released at project head

Table No. 5.3

ABSTRACT OF ALL CROP PLANS

WATER BALANCE (REQUIREMENT AND AVAILABILITY) STATEMENT OF SAMRAT ASHOK SAGAR PROJECT

(Unit : Ha-m)

S. No.	Particulars	Crop Water Requirement/Availability												Total
		May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	
1	**Water requirements** Cropping pattern as per design (original plan)	155.62	1092.62	1545.35	0.00	842.83	1766.82	3652.75	3215.88	4715.36	4061.55	2097.39	349.62	**23495.3**
2	As per NWMP	0.00	1624.99	0.00	0.00	0	1600	3482.37	3422.61	4848.18	3893.39	1640	0	**20511.5**
3	As per Proposal-1	199.63	2062.12	430	0.00	284.29	1086.62	3455.15	2778.14	4133.09	3535.27	2028.18	175.9	**20168.39**
4	As per Proposal-2	309.99	1584.98	430	0.00	234.52	1092.97	3687.03	2948.98	4200.04	3503.18	1861.66	696.45	**20549.8**
5	As per Proposal-3	383.41	1492.7	430	0.00	255.72	1537.53	3520.55	2971.14	4304.83	3647.47	2106.87	339.81	**20990**
6	As per Proposal-4	495.77	1264.17	462.03	0.00	297.14	1923.22	3986.43	3285.99	4295.82	3309.25	1602.44	607.33	**21529.59**
	Water availability	1000	1500	500	0.00	500	1500	3822	3000	4303	4303	1800	467	**22695**

Chapter 6
OPTIMIZATION

6.1 PROGRAMMING APPROACH

Programming approach is essentially an efficient way of determining optimality condition when number of alternatives associated with equal number of constraints of different kinds and magnitude are operating. Such programming models have the distinct advantage of solving optimization problems of complex nature precisely and quickly using digital computer.

6.2 LINEAR PROGRAMMING APPROACH

The linear programming type of optimization problem was first recognised in 1930s by economists for optimal allocation of resources. During World War II, the United States air force sought more effective procedures of allocating resources data and turned it to linear programming. George B. Dantzig, a member of air force group, formulated the general linear programming problem and devised the Simplex method of solution in 1947.

Linear programming is a mathematical method of allocating scarce resources to achieve an objective within the bounds of constraints. Linear programming involves formulation and solution of a certain type of managerial problem by optimizing a linear objective function subject to linear constraints.

The Linear programming models are capable of handling varied and complex water resources management problem as they can accommodate a large number of decision variables along with large number of constraints. The constraints equation in a linear programming problem may be in the form of equalities or inequalities.

Badenhop and Cashdollar (1974) found the most profitable crops combinations that could be grown in Tungbhadra Irrigation Project area in India from the alternative sets of land and water uses. Linear programming was the technique used to choose the most profitable crop combination under 12 situations for each of 4 selected representative farms.

Singh and Sirohi (1977) worked out the optimal pattern of distribution of water, using available ground water as a supplement to canal water, in upper Ganga canal in westers U.P. to maximize the return.

Ranvir Singh (1981) worked out a plan involving land and water resources and their future development for individual river basin and also for the India as a whole. Multilevel and multiperiod analysis were done using programming technique to optimize land, water and fertilizer resources for each of the 20 river basins individually and also for Indian sub-continent.

Seniviratne (1986) used both linear programming and simulation models to arrive at most suitable optimal cropping pattern for Tawa Irrigation Project, M.P., India.

6.3 REQUIREMENTS

Linear programming problems must meet the following requirements :

6.3.1 The Objective Function

The function being optimised is called the objective function. A linear programming problem must have an explicit objective criterion to optimize. The objective function may be one of the either maximization or minimization of the criterion, but never both.

6.3.2 Functional Constraints

The system or resource restrictions normally are referred as constraints. If there are unlimited resources, efficient resource allocation would present no managerial problem. In order to apply linear programming, a decision problem must involve activities that require consumption of limited resources. The amount of limited resources is usually expressed as constraints of the problem.

6.3.3 Decision Variables

Variables are usually inter-related in terms of utilisation of resources, and require simultaneous solutions. Moreover these activities or decision variables should be non negative.

6.4 APPLICATION AREAS

Linear programming has been successfully applied to a wide spectrum of problems across many fields. However, business and industry, agriculture, and military sectors have made the most extensive use of linear programming.

6.5 MODEL

If the problem involves 'n' decision variables and 'm' constraints, the typical linear programming model can be formulated mathematically as follows :

Model

Maximize or minimize $Z = B_1X_1 + B_2X_2 + \ldots\ldots + B_nX_n$

Subjected to,

$$a_{11}X_1 + a_{12}X_2 + \ldots\ldots + a_{1n}X_n \le \text{ or } = \ge b_1$$

$$a_{21}X_1 + a_{22}X_2 + \ldots\ldots + a_{2n}X_n \le \text{ or } = \ge b_2$$

$$\ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots$$

$$\ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots$$

$$a_{m1}X_1 + a_{m2}X_2 + \ldots\ldots + a_{mn}X_n \le \text{ or } = \ge b_m$$

$$X_1, X_2, \ldots\ldots X_n \ge 0$$

Where

B_j = Benefit coefficient

a_{ij} = Technological coefficient

b_j = Given resources (RHS value)

X_j = Decision (or activity) variable

m = Number of system constraints, and

n = Number of decision variabels

6.6 LIMITATIONS

Any specification of values for the decision variables is called a solution and a solution for which all the constraints are satisfied is a feasible solution. Whereas an infeasible solution is the one for which at least one constraint is violated. Linear programming does not give the solution of infeasible problems.

6.7 LINEAR PROGRAMMING MODEL FOR THE STUDY AREA

The model is formulated for the command area of Samrat Ashok Sagar Project, District Vidisha, Madhya Pradesh in order to suggest an optimal cropping pattern for the project command.

6.7.1 Objective Function

Maximization of net benefits

A model cropping pattern keeping in. view the food habits, climate, marketability, cultivation practices is proposed for the command. Net benefit from each crop as per the proposed cropping pattern is calculated and given in Table 4.9 (Chapter 4). The formulated objective function in the optimization run VI is as follows.

$$\begin{aligned} \text{Maximize } Z = {} & 5825\,X_1 + 6350\,X_2 + 3780\,X_3 + 6030\,X_4 + 5030\,X_5 \\ & + 5030\,X_6 + 6178\,X_7 + 4190\,X_8 + 4405\,X_9 + 10960\,X_{10} \\ & + 24450\,X_{11} + 6375\,R_1 + 4170\,R_2 + 9750\,R_3 + 3980\,R_4 \\ & + 6150\,R_5 + 5130\,R_6 + 7950\,R_7 + 7950\,R_8 + 8210\,R_9 \\ & + 12780\,R_{10} + 16880\,R_{11} + 8560\,R_{12} + 14760\,R_{13} \end{aligned}$$

whereas $X_1, X_2, \ldots\ldots, X_{11}$ and

$R_1, R_2, \ldots\ldots, R_{13}$ are assigned to areas (in hectare) under following crops respectively.

Kharif Crops		Rabi Crops	
X_1	Soybean	R_1	Wheat (hyv)
X_2	Groundnut	R_2	Wheat (local)
X_3	Maize	R_3	Gram
X_4	Red Gram	R_4	Barley
X_5	Black Gram	R_5	Pea
X_6	Green Gram	R_6	Lentil
X_7	Paddy (Rice)	R_7	Mustard
X_8	Sorghum	R_8	Linseed
X_9	Vegetable	R_9	Safflower
X_{10}	Cotton	R_{10}	Berseem
X_{11}	Sugarcane	R_{11}	Potato
		R_{12}	Tomato
		R_{13}	Cauliflower

6.7.2 Constraints

(i) Water availability constraints

The monthwise gross irrigation requirement for each crop and as a whole gross irrigation requirements for each crop is taken from crop water requirement tables for different run. The gross irrigation requirement in any month by all the grown crops in that month is considered to be not more than the water available for utilization in that month.

The water constraints are as follows :

$$0.125 X_1 + 0.156 X_2 + 0.125 X_3 + 0.349 X_4 + 0.473 X_5 + 0.435 X_6 + 0.628 X_7 + 0.142 X_8 + 0.125 X_9 + 0.359 X_{10} + 1.185 X_{11} \leq 4800 \quad \text{(Water available in Kharif in ha-m)}$$

Similarly,

$$0.811 R_1 + 0.700 R_2 + 0.629 R_3 + 0.629 R_4 + 0.423 R_5 + 0.556 R_6 + 0.624 R_7 + 0.624 R_8 + 0.624 R_9 + 1.071 R_{10} + 0.667 R_{11} + 0.560 R_{12} + 0.321 R_{13} \leq 17600 \text{ (Water available in Rabi in ha-m)}$$

Monthwise constraints are also calculated for different runs.

(ii) Land availability constraints

In these constraints, the cropping intensity is considered and fixed to a limit of 146% (56% Kharif and 90% Rabi). Also keep in mind that sowing area of Kharif or Rabi crop may not exceed the designed C.C.A. of Left Bank and Right Bank Canal. The constraints equations under this run VI are as follows :

Kharif Area

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} \leq 15750$$

For Rabi Area

$$R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7 + R_8 + R_9 + R_{10} + R_{11} + R_{12} + R_{13} \leq 25200$$

(iii) Minimum Area Constraints

Minimum area for each crops taken in proposed cropping pattern has been fixed as per food habits, cultivation practices and marketability requirements of that area. The constraints equations for cropwise minimum area formulated as :

<u>Kharif Crops</u>

(i) Minimum area for soybean in ha

$X_1 \geq 6000$

(ii) Minimum area for groundnut in ha

$X_2 \geq 1000$

(iii) Minimum area for maize in ha

$X_3 \geq 500$

(iv) Minimum area for red gram in ha

$X_4 \geq 500$

(v) Minimum area for black gram in ha

$X_5 \geq 500$

(vi) Minimum area for green gram in ha

$X_6 \geq 1500$

(vii) Minimum area for paddy (rice) in ha

$X_7 \geq 1500$

(viii) Minimum area for sorghum in ha

$X_8 \geq 1000$

(ix) Minimum area for vegetables in ha

$X_9 \geq 500$

(x) Minimum area for cotton in ha

$X_{10} \geq 1000$

(xi) Minimum area for sugarcane in ha

$X_{11} \geq 1000$

Rabi Crops

(xii) Minimum area for wheat (hyv) in ha

$R_1 \geq 7500$

(xiii) Minimum area for wheat (local) in ha

$R_2 \geq 7500$

(xiv) Minimum area for gram in ha

$R_3 \geq 2000$

(xv) Minimum area for barley in ha

$R_4 \geq 1000$

(xvi) Minimum area for pea in ha

$R_5 \geq 1000$

(xvii) Minimum area for lentil in ha

$R_6 \geq 500$

(xviii) Minimum area for mustard in ha

$R_7 \geq 1000$

(xix) Minimum area for linseed in ha

$R_8 \geq 500$

(xx) Minimum area for safflower in ha

$R_9 \geq 500$

(xxi) Minimum area for berseem in ha

$R_{10} \geq 500$

(xxii) Minimum area for potato in ha

$R_{11} \geq 1000$

(xxiii) Minimum area for tomato in ha

$R_{12} \geq 500$

(xxiv) Minimum area for cauliflower in ha

$R_{13} \geq 500$

Using the above model, various linear programming optimal plans have been prepared considering different combinations of constraints in order to arrive at an optimal one. An abstract of various optimal plans studied under linear programming model are enlisted at Table 6.1. Figures 6.1 to 6.7 illustrate the different optimized cropping patterns for Samrat Ashok Sagar Project.

Table 6.1 : CROP PATTERN UNDER DIFFERENT OPTIMIZATION RUN

Crops	Area						
	Run I	Run II	Run III	Run IV	Run V	Run VI	Run VII
Kharif							
Soybean	13000	6183	6750	2500	6000	6620	12500
Groundnut	0.00	1396	1396	0.00	1000	1000	0.00
Maize	0.00	2792	2792	0.00	500	500	250
Red Gram	0.00	1116	1116	0.00	500	500	250
Black Gram	0.00	238	238	0.00	500	500	0.00
Green Gram	0.00	838	1256	0.00	1500	1500	0.00
Paddy	0.00	1396	1396	0.00	1500	1500	0.00
Sorghum	0.00	838	838	0.00	1000	1000	0.00
Vegetable	0.00	558	558	0.00	500	500	0.00
Cotton	0.00	0.00	0.00	12500	1000	1000	0.00
Sugarcane	0.00	0.00	0.00	0.00	1000	1000	0.00
Rabi							
Wheat (Hyv)	10000	11170	11170	0.00	7500	7500	8750
Wheat (Local)	8000	6981	6981	0.00	7500	7500	6250
Gram	8000	1396	1595	0.00	2000	2000	7500
Barley	0.00	0.00	0.00	0.00	1000	1000	0.00
Pea	0.00	558	558	0.00	1000	1000	500
Lentil	0.00	558	558	0.00	500	500	2000
Mustard	0.00	838	838	0.00	1000	1000	0.00
Linseed	0.00	698	698	0.00	500	500	0.00
Safeflower	0.00	0.00	0.00	0.00	500	500	0.00
Berseem	0.00	672.50	798	0.00	500	500	0.00
Potato	0.00	306.50	280	24000	1000	2165.60	0.00
Tomato	0.00	280	280	0.00	500	500	0.00
Cauliflower	0.00	280	280	0.00	500	534.40	0.00
Gross Area	39000	39093	40376.25	39000	39000	40820	38000
C.C.A.	27924	27924	27924	27924	27924	27924	27924
Cropping Intensity	139.66	140.00	144.59	139.66	139.66	146.18	136.10
Net Benefit (Rs. Crores)	**25.08**	**23.49**	**24.34**	**55.66**	**26.95**	**29.33**	**24.35**

Note :

Run I : NWMP proposal
Run II : Cropping pattern (22 nos crops) without cotton & sugarcane crops, 140% CI
Run III : Cropping pattern (22 nos crops) without cotton & sugarcane crops, 145% CI
Run IV : Cropping pattern (24 nos crops) including cotton & sugarcane crops, without cropwise constant, cash crop oriented
Run V : Utility based cropping pattern with cropwise constant, 140% CI
Run VI : Utility based crop plan with cropwise constant, 146% CI
Run VII : Existing cropping pattern

The results recorded in Table 6.1 computed using LINDO. It shows that run VI is able to give a benefit of Rs. 29.33 crores with the cropping intensity of about 146%. The important feature of this cropping pattern is that almost all the crops of farmers and area need are included in the crop pattern. This also fulfils the need of diversified cropping pattern against the sole cropping pattern being observed in most of the command areas. In upper Ganga, it is sugarcane based.

(Run : 1)
Culturable command area = 27924 ha
Gross area irrigated = 39000 ha
Cropping Intensity = 139.66%
Net Benefit = Rs 25.08 Crores

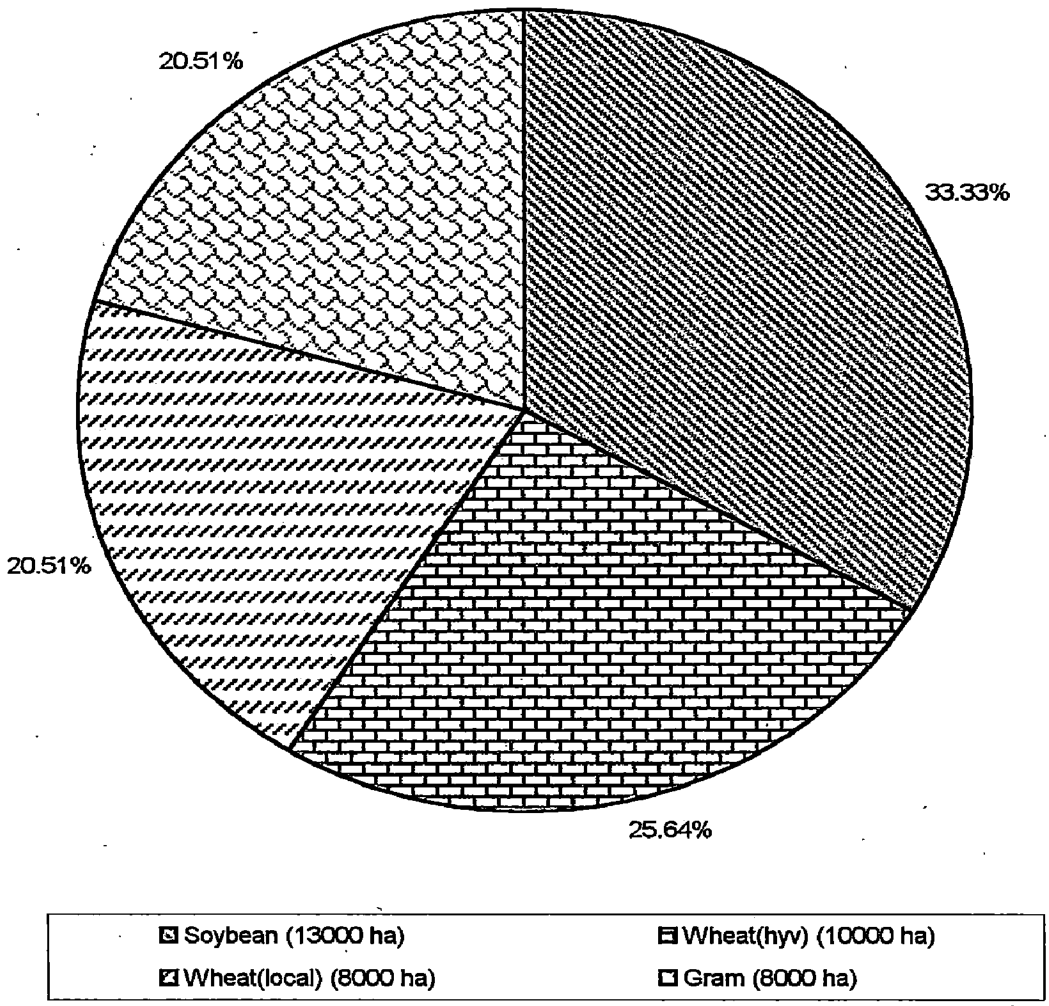


Fig. 6.1 : NWMP proposed optimized cropping pattern for Samrat Ashok Sagar Project (M.P.)

(Run : 2)
Culturable command area = 27924 ha
Gross area irrigated = 39093 ha
Cropping Intensity = 140.00%
Net Benefit = Rs 23.49 Crores

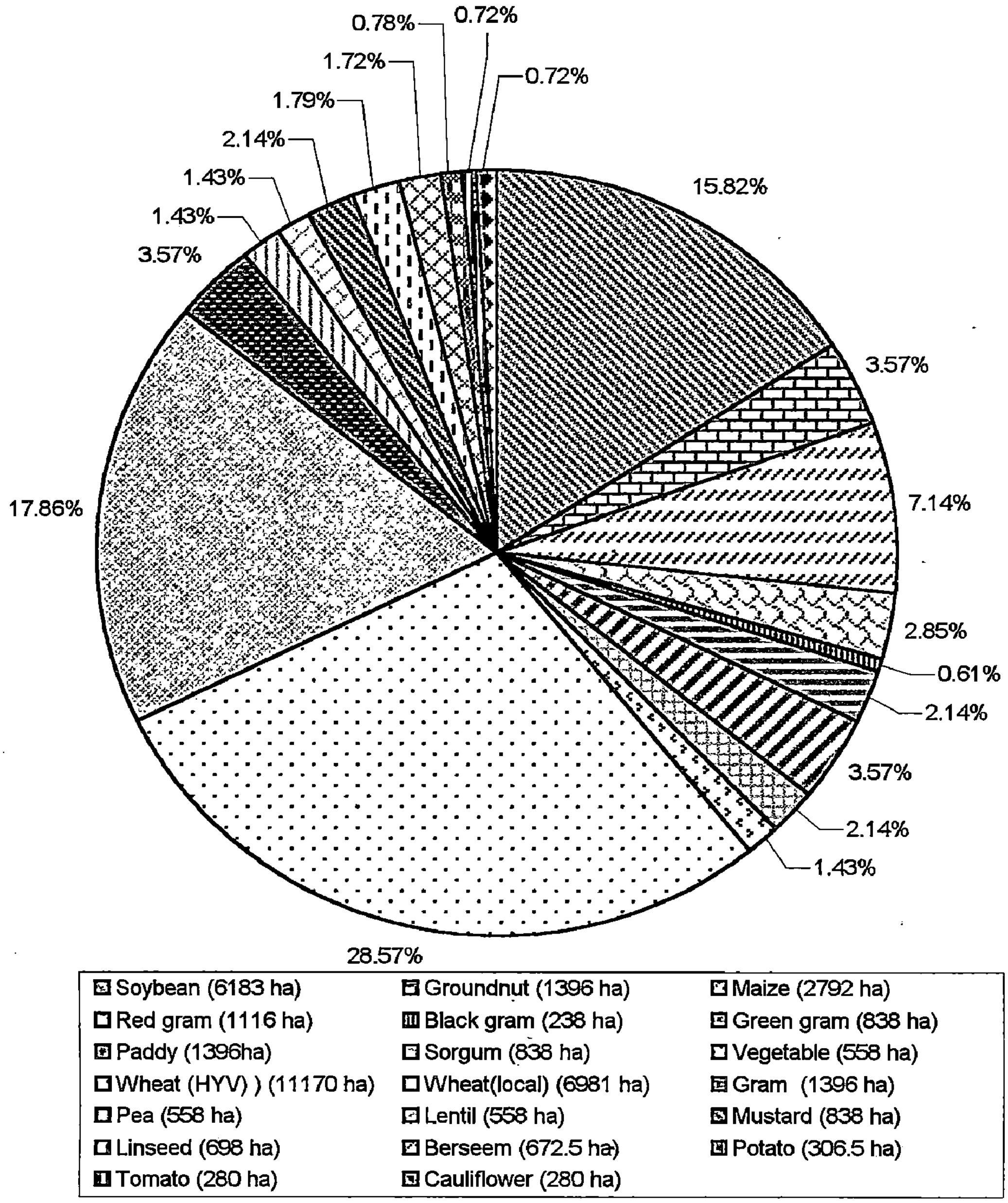


Fig. 6.2 : Proposed optimized cropping pattern for Samrat Ashok Sagar Project (M.P.)

(Run : 3)
Culturable command area = 27924 ha
Gross area irrigated = 40376 ha
Cropping Intensity = 144.59%
Net Benefit = Rs 24.34 Crores

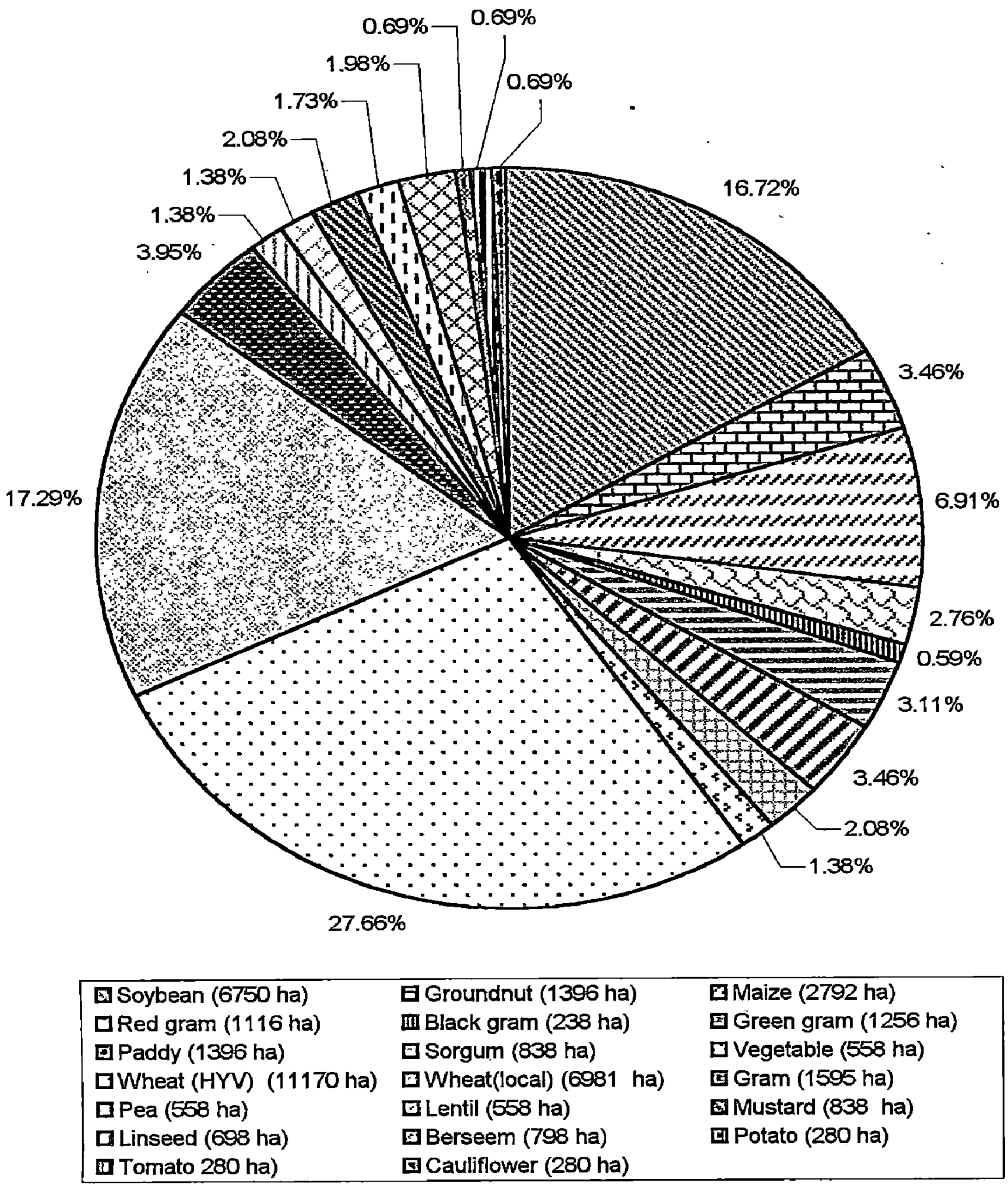


Fig. 6.3 : Proposed optimized cropping pattern for Samrat Ashok Sagar Project (M.P.)

(Run : 4)
Culturable command area = 27924 ha
Gross area irrigated = 39000 ha
Cropping Intensity = 139.66 %
Net Benefit = Rs 55.66 Crores

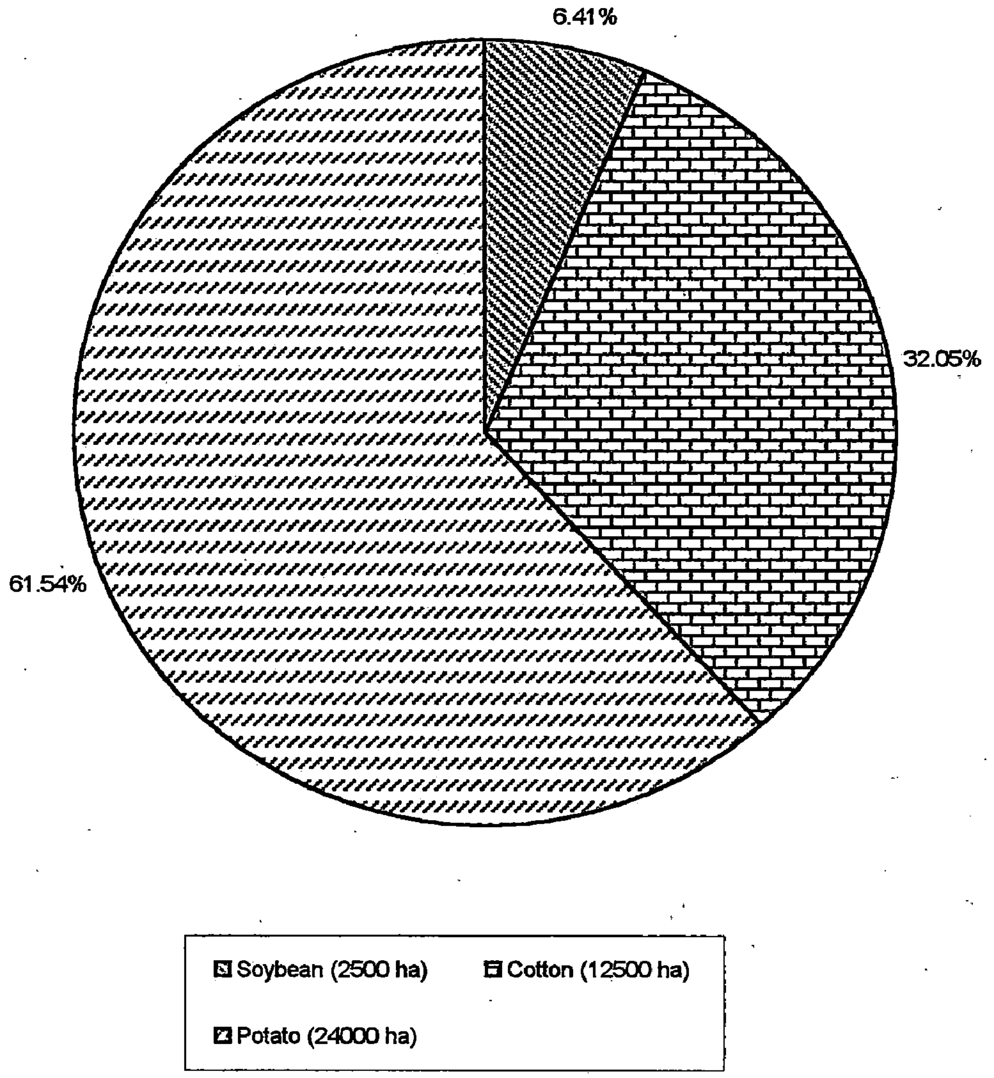


Fig. 6.4 : Proposed optimized cropping pattern for Samrat Ashok Sagar Project (M.P.)

(Run : 5)
Culturable command area = 27924 ha
Gross area irrigated = 39000 ha
Cropping Intensity = 139.66 %
Net Benefit = Rs 26.95 Crores

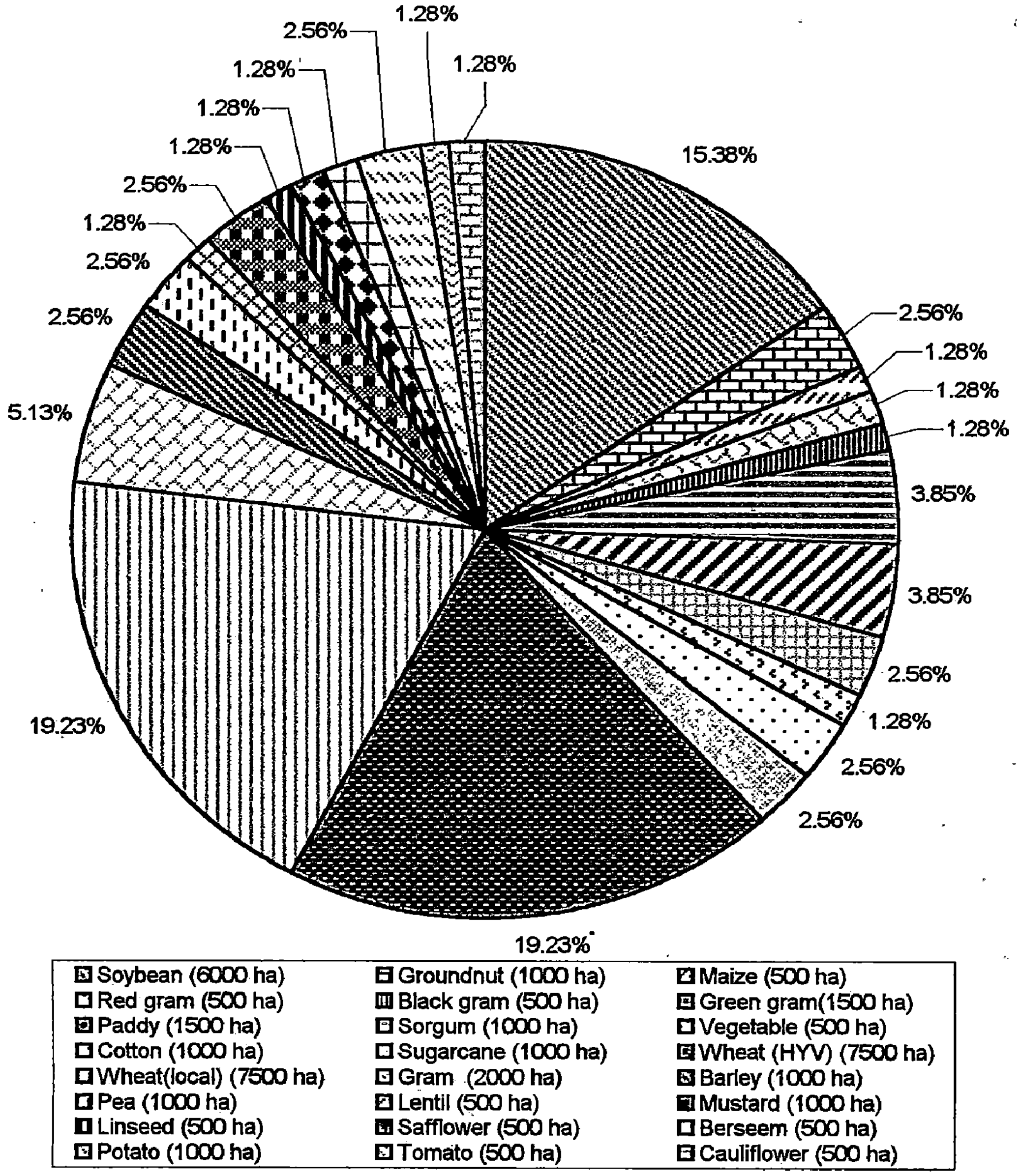


Fig. 6.5 : Proposed optimized cropping pattern for Samrat Ashok Sagar Project (M.P.)

(Run : 6)

Culturable command area = 27924 ha

Gross area irrigated = 40820 ha

Cropping Intensity = 146.18%

Net Benefit = Rs 29.33 Crores

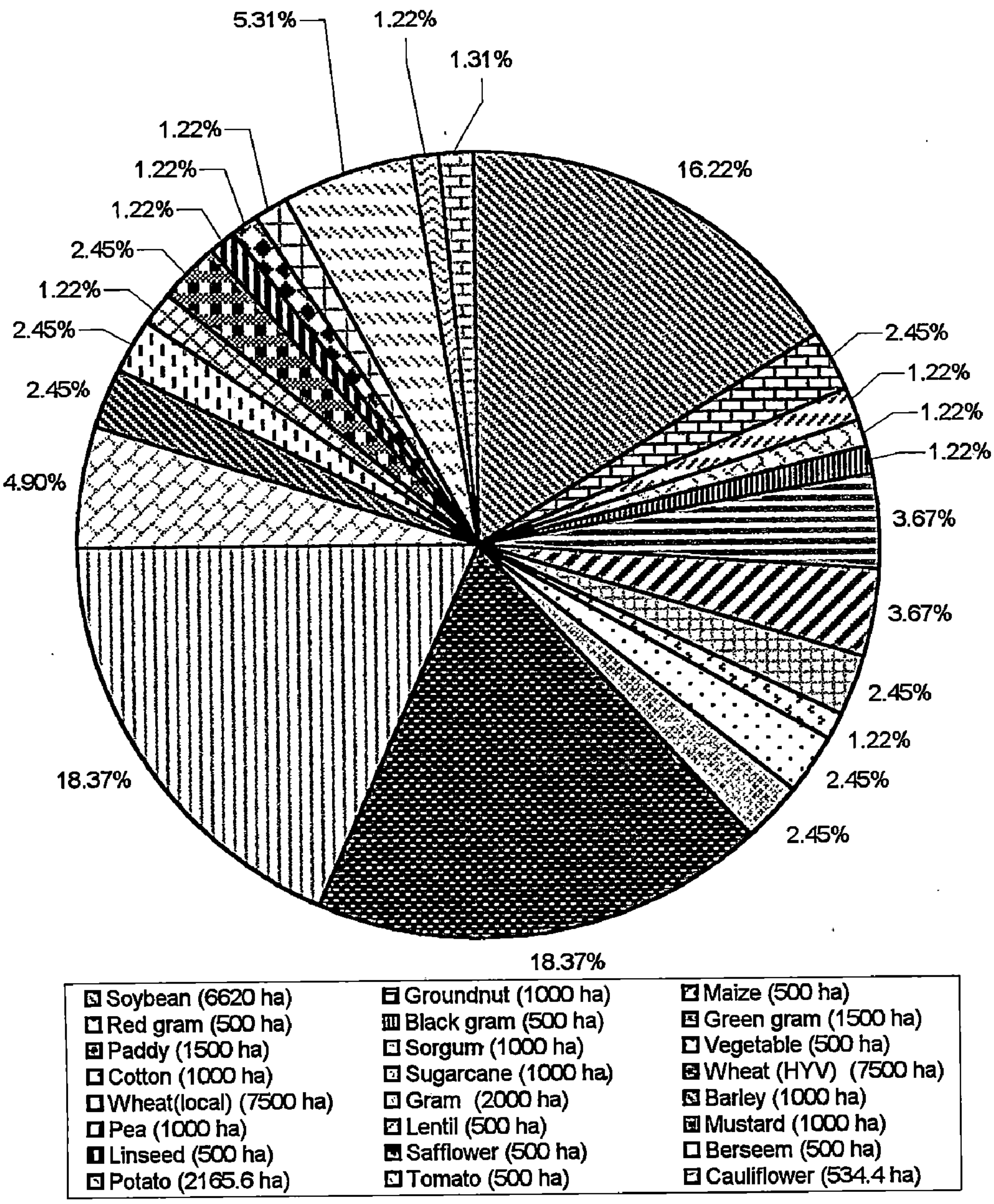


Fig. 6.6 : Proposed optimized cropping pattern for Samrat Ashok Sagar Project (M.P.)

(Run : 7)
Culturable command area = 27924 ha
Gross area irrigated = 38000 ha
Cropping Intensity = 136.10%
Net Benefit = Rs 24.35 Crores

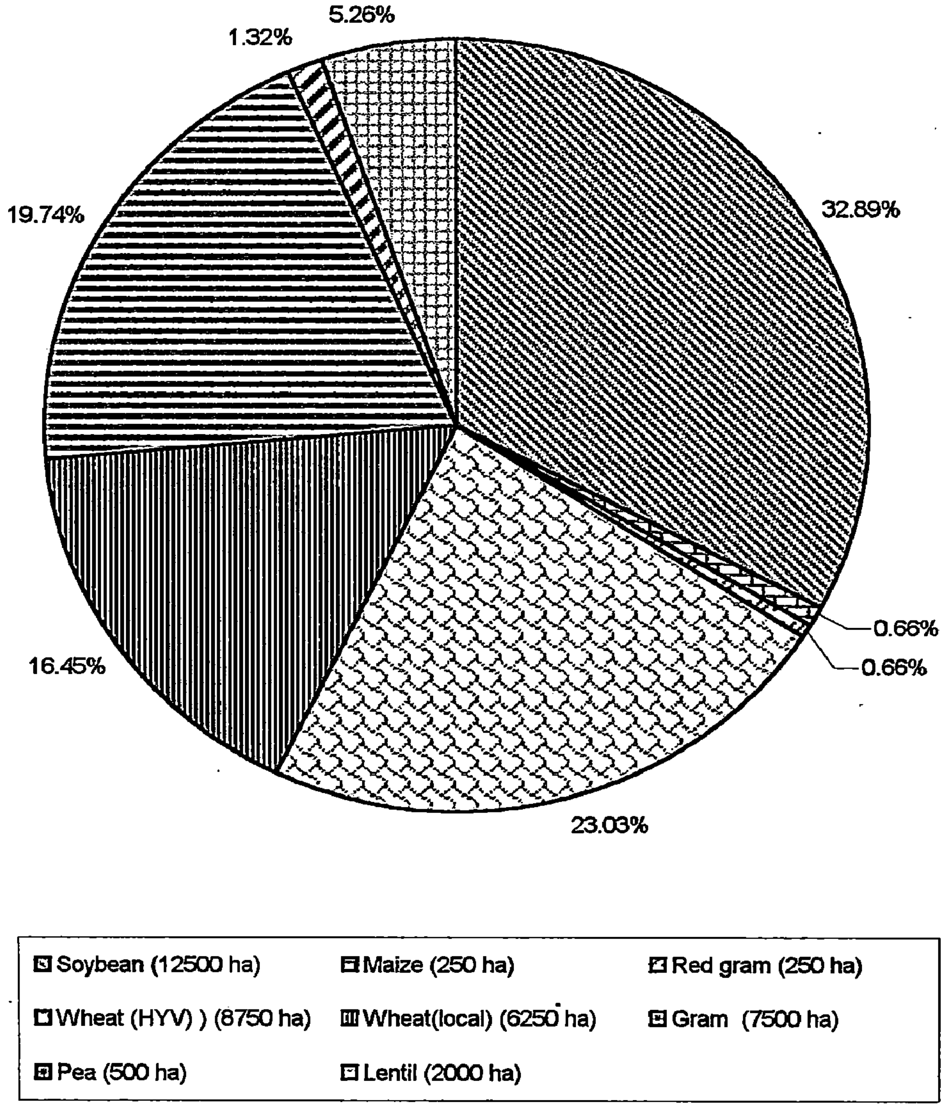


Fig. 6.7 : Existing cropping pattern of Samrat Ashok Sagar Project (M.P.)

Chapter 7
SUMMARY AND CONCLUSION

7.1 GENERAL

Command area of Samrat Ashok Sagar Project, District Vidisha, Madhya Pradesh is considered for the present study. An attempt has been made to obtain a multi objective crop planning by utilising land and water resources in order to achieve maximum returns and self-sufficiency in food production for the projected population.

The Samrat Ashok Sagar dam is located near village Khoa at the border of Raisen and Vidisha District in Madhya Pradesh. A sluice is located on the left bank 3 km away from the earthen dam and an unlined main canal 3.24 km long taking off from sluice with discharging capacity of 22.64 cumecs, bifurcating into left bank and right bank canals of 17.16 km and 23.43 km respectively to irrigate 37636 ha annually. Irrigation is started in the year 1978. The main canal including distributaries, minor and subminors are being operated at present for Rabi irrigation only. The dam is utilised in flood protection and for water supply to Vidisha township.

7.2 NATIONAL WATER MANAGEMENT PROJECT

Under NWMP, the full reservoir level of dam has been proposed to be raised from 458.40 m to 459.61 m thus increasing the reservoir capacity from 22695 ha-m to 30713 ha-m and increasing the irrigation potential from 37636 ha to 39000 ha. Lining, resectioning of canal and other protective work for Rs. 8.37 crore has been proposed in the scheme. Since this proposal has not come into force fully, present study is based on the previous reservoir capacity only.

7.3 AGRICULTURE ASPECTS

The main features of rainfall in the area is that over 90 percent of the total rainfall occurs during June to September and it is uniformly distributed both in amount and time. Minimum temperature is recorded in the month of December-January and maximum in the month of May.

The command area is covered with fertile black cotton soil and clayey soil. The area is predominantly a Rabi crop (wheat) zone. There is great scope for increasing the cropping intensity as well as for growing of labour intensive crops which will provide greater opportunity of employment for uplifting the socio-economic standard of the targetted group. By adopting a double crop pattern due to irrigation facility by the project, overruled the old pattern of single crop (Rabi) which dramatically change the socio economic status of targetted group.

7.4 CROPPING PATTERN

The intensity of irrigation contemplated in the detailed project report for Kharif and Rabi crops were 45% and 90%, totalling to 135%. As against this, the crop pattern actually developed in the command area is predominantly soybean in Kharif and wheat and gram in Rabi. Due to late harvesting of soybean, sowing of wheat also get delayed, this result in reduction in yields of both soybean and wheat. Cultivators must be motivated to have irrigated soybean instead of rainfed soybean, so as to obtain higher yield.

As per the cultivation practice, with the help of NWMP fund, modified cropping pattern is proposed. In this, only soybean crop is proposed in Kharif while wheat and gram are in Rabi season. Soybean crop is stabilised because of Surya Oil Agro industry in nearby area. Farmer can dispose off the crop quickly. Other factor for soybean is that it requires less water for its growth and its growing period is during the rains, i.e., between June to September.

Wheat and Gram are the main traditional crops in Rabi season. Farmer is fully dependent on these crops because of its reliability. These crops fulfil the food requirement of projected area as well it gives good return from high yielding variety.

In the above proposal, number of crops sown in Kharif as well as in Rabi season are very less. Water available in reservoir in Kharif season is not utilised properly. Other needs of projected population is not considered such as oilfed crops, cattle need crops, vegetables etc. Looking to the above aspect of balancing crop planning, some proposals have been analysed with different combination of crops.

Proposal 1 is having soybean, rice and sugarcane as Kharif crops, while wheat(hyv), wheat (local) and gram as Rabi crops. Sugarcane crop is as introducing crop in this proposal. This crop gives more yield resulted in more benefits, and consume reservoir water in almost every month. But as for present practice nobody farmer is sowing sugarcane because of following reason.

- It is a new crop for that area
- It consumes more water throughout the year
- Growth period is maximum, it takes 10 to 12 months for its maturity.
- There is uncertainty to get water for this crop from canal system round the year.
- There is no sugar/paper industry established in nearby area
- There is no planned system to get equitable water among the farmers, only head reach farmer may get the water timely or untimely.

In proposal 2, crops proposed are rice, green gram, soybean, groundnut, sorghum and cotton in Kharif season. While wheat, gram and berseem in Rabi seasons. In this, cotton crop is introduced in small percentage of area to see the reaction of farmer. During survey of that area, the things came to know that farmer does not want to change his old tradition of farming. Cotton crop need more labour during its growth periods. But it gives good return as well consumes less water.

Proposal 3 contains good presentation of crops. 9 numbers crops in Kharif and 13 numbers in Rabi season (excluding cotton and sugarcane). Paddy crop is proposed in head reach area. Farmer is not sowing paddy because of following reasons :

- It requires more water throughout the period.
- Uncertainty of water distribution among the farmers.

- Only head reach farmer can get the water in time.
- Black cotton soil/clayey is very much sticky so it is difficult to grow crops like rice.
- A particular type of table top level fields are needed, where water can be stagnated to equal depth.
- There is acute shortage of labour at the time of sowing, weeding and harvest of crops. This may be the major reason for not coming up for paddy crop in SAS command.

Proposal 4 is having 24 numbers of crop in both the seasons. In this proposal, cotton and sugarcane are included to make it more balancing. 11 numbers of crops in Kharif with 54% cropping intensity and 13 numbers of crops in Rabi with 86% cropping intensity are analysed (overall 140%) keeping in view self sufficiency in every field.

Lastly cost of cultivation for all the crops individually per hectare is calculated fo get net benefit per hectare.

Further linear programming (LINDO) is used to achieve the maximization of benefits. In this, various optimal model are framed and run on Lindo programming considering different combinations of constraints so as to derive best crop plan.

7.5 CONCLUSION

The study entitled "**CROPPING PATTERN ANALYSIS IN COMMAND OF SAMRAT ASHOK SAGAR PROJECT IN MADHYA PRADESH**" is concluded as follows :

- The project is facing the problem of under utilization of water.
- The cropping followed is soybean based.
- The originally proposed crop plan is not being followed by the farmers.
- The NWMP recommended crop plan is not helpful in full utilization of water of project.

In view of the above, a crop plan with 24 crop combinations fully utilising the water resource has been worked out. This will fetch the monetary return of Rs. 29.33 crores and domestic need of food, fibre, oilseed, sugar, etc. can be met out of it. Further studies may also be undertaken periodically to suggest changes in crop plan.

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Annexure-1

CLIMATOLOGICAL DATA

Year – 1991

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	23.9	9.5	69	39	0.00	2.4	4.2	100.8	1.16
2	February	29.6	14.0	45	26	0.00	2.1	5.0	120.0	1.38
3	March	34.2	18.2	36	12	0.00	1.1	5.1	122.4	1.41
4	April	37.1	21.6	25	15	0.00	2.7	5.4	129.6	1.50
5	May	41.3	26.7	24	10	6.00	0.7	6.8	163.2	1.88
6	June	36.9	25.7	54	31	200.1	5.0	7.9	189.6	2.19
7	July	31.1	23.8	85	73	275.1	7.6	7.2	172.8	2.00
8	August	27.0	22.6	85	74	383.0	7.2	6.0	144.0	1.66
9	September	31.4	20.9	72	54	20.10	5.1	4.2	100.8	1.16
10	October	33.2	17.7	54	27	0.00	1.7	2.5	60.0	0.69
11	November	28.4	14.8	42	30	6.60	2.2	2.7	64.8	0.75
12	December	25.8	10.8	45	30	0.00	1.2	3.7	88.8	1.02

CLIMATOLOGICAL DATA

Year – 1992

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	26.4	10.50	51	29	0.60	2.2	5.0	120.0	1.38
2	February	27.0	11.1	44	27	0.00	2.4	4.2	100.8	1.16
3	March	34.3	17.1	28	18	0.00	2.3	5.4	129.6	1.50
4	April	38.2	21.7	20	10	0.00	1.1	5.5	132.0	1.52
5	May	40.6	25.3	26	11	19.60	2.4	7.3	175.2	2.02
6	June	39.9	26.5	56	34	55.20	5.3	7.7	184.8	2.13
7	July	33.2	24.5	87	75	210.30	7.7	6.1	146.4	1.69
8	August	28.5	22.9	88	79	389.90	7.1	6.4	153.6	1.77
9	September	30.3	20.6	84	70	71.40	5.8	5.0	120.0	1.38
10	October	31.1	18.5	49	28	66.40	1.0	2.7	64.8	0.75
11	November	28.6	14.4	58	43	0.00	4.1	2.5	60.0	0.69
12	December	26.5	11.1	53	34	0.00	2.4	3.8	91.2	1.05

CLIMATOLOGICAL DATA

Year – 1993

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	26.3	10.6	70	39	2.90	1.7	5.2	124.8	1.44
2	February	28.0	12.0	58	27	8.90	2.5	4.7	112.8	1.30
3	March	31.5	16.3	40	21	1.30	1.7	5.4	129.6	1.50
4	April	38.1	22.1	19	11	0.00	3.0	5.8	139.2	1.61
5	May	42.0	27.2	33	19	0.00	1.8	7.0	168.0	1.94
6	June	36.6	25.9	75	52	95.50	6.6	7.6	182.4	2.11
7	July	31.5	23.3	82	67	366.10	6.7	6.0	144.0	1.66
8	August	28.8	22.5	90	82	239.80	7.7	6.2	148.8	1.72
9	September	28.9	21.7	86	73	368.50	7.0	5.2	124.8	1.44
10	October	32.1	19.7	54	36	39.9	0.9	3.1	74.4	0.86
11	November	29.1	13.8	39	25	0.00	0.4	3.3	79.2	0.91
12	December	26.0	10.1	46	26	4.60	0.2	3.6	86.4	1.00

CLIMATOLOGICAL DATA

Year – 1994

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	26.0	12.6	57	30	21.20	2.5	4.3	103.2	1.19
2	February	26.9	11.8	35	19	17.80	1.2	4.5	108.0	1.25
3	March	35.2	17.5	23	11	0.00	1.2	4.9	117.6	1.36
4	April	36.3	21.0	30	16	40.70	0.9	5.0	120.0	1.38
5	May	41.4	26.7	42	22	0.40	1.6	6.9	165.6	1.91
6	June	34.5	25.2	81	59	352.50	6.4	7.8	187.2	2.16
7	July	28.1	23.0	88	78	273.50	7.7	6.6	158.4	1.83
8	August	30.2	20.8	87	80	601.10	7.7	5.2	124.8	1.44
9	September	30.2	20.8	79	66	123.50	5.1	4.3	103.2	1.19
10	October	32.2	17.6	71	49	11.70	3.5	3.0	72.0	0.83
11	November	28.9	13.9	48	30	15.00	1.5	2.9	69.6	0.80
12	December	26.2	9.1	51	29	0.00	0.9	4.0	96.0	1.11

CLIMATOLOGICAL DATA

Year – 1995

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	22.9	9.1	53	25	53.20	2.3	4.1	98.4	1.13
2	February	27.9	11.8	44	21	0.60	1.7	5.0	120.0	1.38
3	March	31.0	16.5	29	17	65.50	1.7	5.2	124.8	1.44
4	April	37.3	20.5	28	20	11.40	1.6	5.2	124.8	1.44
5	May	40.3	25.7	33	17	0.50	2.7	7.1	170.4	1.97
6	June	40.5	27.5	77	27	17.60	7.0	7.7	184.8	2.13
7	July	32.1	23.7	81	66	330.00	6.3	6.66	158.4	1.83
8	August	29.2	23.2	88	79	209.10	7.6	5.4	129.6	1.50
9	September	31.7	21.8	72	54	126.80	3.8	4.1	98.4	1.13
10	October	33.5	19.3	53	37	48.90	3.3	2.8	67.2	0.77
11	November	29.4	13.6	59	41	0.00	0.9	2.8	67.2	0.77
12	December	26.7	12.1	59	36	20.80	1.8	4.1	98.4	1.13

CLIMATOLOGICAL DATA

Year – 1996

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	24.4	11.9	50	29	6.50	1.3	4.4	105.6	1.22
2	February	28.8	12.7	47	23	18.10	2.4	4.4	105.6	1.22
3	March	35.0	18.2	25	14	3.40	0.4	5.3	127.2	1.47
4	April	39.0	21.3	22	14	0.30	1.2	5.6	134.4	1.55
5	May	41.2	25.7	31	13	0.00	0.9	7.2	172.8	2.00
6	June	38.9	26.4	61	42	59.70	6.3	8.2	196.8	2.27
7	July	32.2	23.9	81	71	517.90	7.8	7.0	168.0	1.94
8	August	28.3	22.5	90	80	532.30	7.6	5.8	139.2	1.61
9	September	31.0	22.1	88	78	207.20	6.8	4.4	105.6	1.22
10	October	30.8	18.5	61	40	51.30	2.7	2.9	69.6	0.88
11	November	29.9	13.8	45	27	0.30	0.4	3.0	72.0	0.83
12	December	26.3	9.6	65	46	0.00	3.1	3.3	79.2	0.91

CLIMATOLOGICAL DATA

Year – 1997

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	24.0	9.8	47	26	6.60	0.5	4.2	100.8	1.16
2	February	27.5	11.6	38	20	0.00	0.8	5.2	124.8	1.44
3	March	33.8	17.6	30	15	0.00	0.9	5.0	120.0	1.38
4	April	35.8	20.5	21	13	11.60	1.6	5.4	129.6	1.50
5	May	39.0	24.4	33	20	20.30	1.9	6.8	163.2	1.88
6	June	35.7	24.2	61	30	129.10	4.7	7.2	172.8	2.00
7	July	29.6	23.6	84	71	251.80	7.1	6.2	148.8	1.72
8	August	29.5	22.7	88	75	244.80	7.0	5.9	141.6	1.63
9	September	30.8	22.1	69	51	162.40	4.5	4.2	100.8	1.16
10	October	31.2	18.2	67	54	149.30	3.8	2.5	60.0	0.69
11	November	28.6	19.2	46	33	0.00	0.3	2.7	64.8	0.75
12	December	21.1	12.9	57	38	137.20	1.6	3.4	81.6	0.94

CLIMATOLOGICAL DATA

Year – 1998

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	23.6	10.8	62	32	0.00	2.0	4.0	96.0	1.11
2	February	27.6	12.4	51	29	0.20	2.0	4.7	112.8	1.3
3	March	31.9	15.9	33	15	40.90	2.2	4.8	115.2	1.3
4	April	38.4	22.3	18	12	13.10	0.7	5.8	139.2	1.61
5	May	42.1	26.8	31	15	0.40	1.7	7.0	168.0	1.94
6	June	37.9	26.4	64	27	138.50	4.7	7.8	187.2	2.16
7	July	30.6	23.7	87	76	336.40	7.1	6.6	158.4	1.83
8	August	30.2	23.7	85	74	237.00	7.4	5.7	136.8	1.58
9	September	31.2	23.2	83	72	222.70	5.9	4.3	103.2	1.19
10	October	32.3	21.2	75	57	19.60	3.6	3.3	79.2	0.91
11	November	28.9	15.4	49	32	4.40	0.6	3.1	74.4	0.86
12	December	27.6	10.0	53	38	0.00	1.0	4.0	96.0	1.11

CLIMATOLOGICAL DATA

Year – 1999

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	25.4	9.3	59	37	0.00	0.98	6.20	148.8	1.72
2	February	27.1	14.7	73	49	33.60	3.10	7.80	187.2	2.16
3	March	34.5	16.6	35	20	0.00	0.60	5.50	132.0	1.52
4	April	40.8	21.9	22	11	0.00	0.55	6.00	144.0	1.67
5	May	41.0	26.6	41	20	14.70	2.35	9.20	220.8	2.55
6	June	35.3	24.3	70	51	98.80	5.15	9.60	230.4	2.67
7	July	29.9	23.4	84	71	433.20	7.00	9.70	232.8	2.69
8	August	28.5	22.4	86	78	193.20	7.00	10.00	240.0	2.77
9	September	29.0	21.7	94	82	460.20	6.95	8.30	199.2	2.30
10	October	30.1	18.50	74	62	87.00	3.40	5.90	141.6	1.63
11	November	29.9	14.0	50	38	0.00	1.50	4.00	96.0	1.11
12	December	25.4	9.30	65	41	0.00	0.85	4.25	102.0	1.18

CLIMATOLOGICAL DATA

Year – 2000

Station : Bhopal
Latitude : 23°17'N

Height above M.S.L. : 523m
Longitude : 77°21'E

S. No.	Month	Temperature in °C		Humidity %		Rainfall in Month in mm	Cloud Cover in Oktas	Wind Speed in 24 hrs		
		Maximum	Minimum	at 8.30 hrs	at 17.30 hrs			km/hr	km/day	m/sec
1	January	25.8	9.8	65	37	0.00	0.73	4.87	116.8	1.35
2	February	26.0	10.5	51	33	0.80	1.38	8.55	205.2	2.37
3	March	32.7	15.6	32	16	2.00	0.16	7.00	168.0	1.94
4	April	40.2	22.8	27	13	0.00	0.83	7.70	184.8	2.13
5	May	38.4	25.1	52	36	64.20	3.40	7.20	172.8	2.00
6	June	35.8	24.9	69	51	86.80	5.50	10.00	240.0	2.77
7	July	29.3	23.1	87	77	568.70	7.43	9.10	218.4	2.32
8	August	30.3	23.0	83	70	229.70	6.00	7.80	187.2	2.16
9	September	31.6	21.70	74	58	24.80	4.12	6.90	165.6	1.91
10	October	35.2	18.90	47	27	0.00	1.42	3.00	72.00	0.83
11	November	31.2	15.40	46	32	0.00	1.25	3.00	72.00	0.83
12	December	21.7	10.20	49	29	0.00	1.00	2.90	69.60	0.80

Annexure - 2

ABSTRACT OF RAINFALL DATA (1991-2000)

(Unit in mm)

S. No.	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1	1991	0.00	0.00	0.00	0.00	6.00	200.1	275.1	383.0	20.10	0.00	6.60	6.00	890.90
2	1992	0.60	0.00	0.00	0.00	19.60	55.20	210.30	389.90	71.40	66.40	0.00	0.00	813.30
3	1993	2.90	8.90	1.30	0.00	0.00	95.50	366.10	239.80	368.50	39.90	0.00	4.60	1127.50
4	1994	21.20	17.80	0.00	40.70	0.40	352.50	273.50	601.10	123.50	11.70	15.00	0.00	1457.60
5	1995	53.20	0.60	65.50	11.40	0.50	17.60	330.00	209.10	126.80	48.90	0.00	20.80	884.40
6	1996	6.50	18.10	3.40	0.30	0.00	59.70	517.90	532.30	207.20	51.30	0.30	0.00	1397.00
7	1997	6.60	0.00	0.00	11.60	20.30	129.10	251.80	244.80	162.40	149.30	0.00	137.20	1113.10
8	1998	0.00	0.20	40.90	13.10	0.40	138.50	336.40	237.00	222.70	19.60	4.40	0.00	1013.20
9	1999	0.00	33.60	0.00	0.00	14.70	98.80	433.20	193.20	460.20	87.00	0.00	0.00	1320.70
10	2000	4.00	0.80	2.00	0.00	64.20	86.80	568.70	229.70	24.80	0.00	0.00	0.00	977.00
	Total	90.00	80.00	113.10	77.10	126.10	1233.80	3563.00	3259.90	1787.60	474.10	26.30	162.60	10994.70
	Average	9.1	8.0	11.31	7.71	12.61	123.38	356.30	325.99	178.76	47.41	2.63	16.26	1099.47

FORMULATION OF L.P. MODEL

CASH CROP ORIENTED CROP PLAN

(RUN 4)

```
max 5825 x1+6350 x2+3780 x3+6030 x4+5030 x5+5030 x6+6178 x7+4190 x8+4405 x9
   10960 x10+24450 x11+6375 r1+4170 r2+9750 r3+3980 r4+6150 r5+5130 r6
   +7950 r7+7950 r8+8210 r9+12780 r10+16880 r11+8560 r12+14760 r13
subject to
   x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11<=15000
   r1+r2+r3+r4+r5+r6+r7+r8+r9+r10+r11+r12+r13<=24000
! water constraints
  0.125 x1+0.156 x2+0.125 x3+0.349 x4+0.473 x5+0.435 x6+0.628 x7
  +0.142 x8+0.125 x9+0.359 x10+1.185 x11<=4800
0.811 r1+0.700 r2+0.629 r3+0.629 r4+0.423 r5+0.556 r6+0.624 r7+0.624 r8
  +0.624 r9+1.071 r10+0.667 r11+0.560 r12+0.321 r13<=17600
end
```

RESULT OF RUN 4

LP OPTIMUM FOUND AT STEP 5

OBJECTIVE FUNCTION VALUE

1) 0.5566825E+09

VARIABLE	VALUE	REDUCED COST
X1	2499.999756	0.000000
X2	0.000000	155.277863
X3	0.000000	2045.000000
X4	0.000000	4710.555664
X5	0.000000	8431.666992
X6	0.000000	7597.777832
X7	0.000000	10685.055664
X8	0.000000	2008.055664
X9	0.000000	1420.000000
X10	12500.000000	0.000000
X11	0.000000	4636.110352
R1	0.000000	10505.000000
R2	0.000000	12710.000000
R3	0.000000	7130.000000
R4	0.000000	12900.000000
R5	0.000000	10730.000000
R6	0.000000	11750.000000
R7	0.000000	8930.000000
R8	0.000000	8930.000000
R9	0.000000	8670.000000
R10	0.000000	4100.000000
R11	24000.000000	0.000000
R12	0.000000	8320.000000
R13	0.000000	2120.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	3081.944336
3)	0.000000	16880.000000
4)	0.000000	21944.445312
5)	1592.000122	0.000000

NO. ITERATIONS= 5

Annexure-5

FORMULATION OF L.P. MODEL

(RUN 5)

```
max 5825 x1+6350 x2+3780 x3+6030 x4+5030 x5+5030 x6+6178 x7+4190
x8+4405 x9
   10960 x10+24450 x11+6375 r1+4170 r2+9750 r3+3980 r4+6150 r5+5130 r6
   +7950 r7+7950 r8+8210 r9+12780 r10+16880 r11+8560 r12+14760 r13
subject to
   x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11<=15000
   r1+r2+r3+r4+r5+r6+r7+r8+r9+r10+r11+r12+r13<=24000
! water constraints
  0.125 x1+0.156 x2+0.125 x3+0.349 x4+0.473 x5+0.435 x6+0.628 x7
  +0.142 x8+0.125 x9+0.359 x10+1.185 x11<=4800
0.811 r1+0.700 r2+0.629 r3+0.629 r4+0.423 r5+0.556 r6+0.624 r7+0.624
r8
  +0.624 r9+1.071 r10+0.667 r11+0.560 r12+0.321 r13<=17600
 x1>=6000
 x2>=1000
 x3>=500
 x4>=500
 x5>=500
 x6>=1500
 x7>=1500
 x8>=1000
 x9>=500
 x10>=1000
 x11>=1000
 r1>=7500
 r2>=7500
 r3>=2000
 r4>=1000
 r5>=1000
 r6>=500
 r7>=1000
 r8>=500
 r9>=500
 r10>=500
 r11>=1000
 r12>=500
 r13>=500
 end
```

RESULT OF RUN 5

LP OPTIMUM FOUND AT STEP 30

OBJECTIVE FUNCTION VALUE

1) 0.2695770E+09

VARIABLE	VALUE	REDUCED COST
X1	6000.000000	0.000000
X2	1000.000000	0.000000
X3	500.000000	0.000000
X4	500.000000	0.000000
X5	500.000000	0.000000
X6	1500.000000	0.000000
X7	1500.000000	0.000000
X8	1000.000000	0.000000
X9	500.000000	0.000000
X10	1000.000000	0.000000
X11	1000.000000	0.000000
R1	7500.000000	0.000000
R2	7500.000000	0.000000
R3	2000.000000	0.000000
R4	1000.000000	0.000000
R5	1000.000000	0.000000
R6	500.000000	0.000000
R7	1000.000000	0.000000
R8	500.000000	0.000000
R9	500.000000	0.000000
R10	500.000000	0.000000
R11	1000.000000	0.000000
R12	500.000000	0.000000
R13	500.000000	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	24450.000000
3)	0.000000	16880.000000
4)	77.500015	0.000000
5)	788.500061	0.000000
6)	0.000000	-18625.000000
7)	0.000000	-18100.000000
8)	0.000000	-20670.000000
9)	0.000000	-18420.000000
10)	0.000000	-19420.000000
11)	0.000000	-19420.000000
12)	0.000000	-18272.000000
13)	0.000000	-20260.000000
14)	0.000000	-20045.000000
15)	0.000000	-13490.000000
16)	0.000000	0.000000
17)	0.000000	-10505.000000
18)	0.000000	-12710.000000
19)	0.000000	-7130.000000
20)	0.000000	-12900.000000
21)	0.000000	-10730.000000
22)	0.000000	-11750.000000
23)	0.000000	-8930.000000
24)	0.000000	-8930.000000
25)	0.000000	-8670.000000
26)	0.000000	-4100.000000
27)	0.000000	0.000000
28)	0.000000	-8320.000000
29)	0.000000	-2120.000000

NO. ITERATIONS= 30

FORMULATION OF L.P. MODEL
UTILITY BASED CROP PLAN
(RUN 6)

```
max 5825 x1+6350 x2+3780 x3+6030 x4+5030 x5+5030 x6+6178 x7+4190 x8+4405 x9
   10960 x10+24450 x11+6375 r1+4170 r2+9750 r3+3980 r4+6150 r5+5130 r6
   +7950 r7+7950 r8+8210 r9+12780 r10+16880 r11+8560 r12+14760 r13
subject to
   x1+x2+x3+x4+x5+x6+x7+x8+x9+x10+x11<=15750
   r1+r2+r3+r4+r5+r6+r7+r8+r9+r10+r11+r12+r13<=25200
! water constraints
  0.125 x1+0.156 x2+0.125 x3+0.349 x4+0.473 x5+0.435 x6+0.628 x7
  +0.142 x8+0.125 x9+0.359 x10+1.185 x11<=4800
0.811 r1+0.700 r2+0.629 r3+0.629 r4+0.423 r5+0.556 r6+0.624 r7+0.624 r8
  +0.624 r9+1.071 r10+0.667 r11+0.560 r12+0.321 r13<=17600
 x1>=6000
 x2>=1000
 x3>=500
 x4>=500
 x5>=500
 x6>=1500
 x7>=1500
 x8>=1000
 x9>=500
 x10>=1000
 x11>=1000
 r1>=7500
 r2>=7500
 r3>=2000
 r4>=1000
 r5>=1000
 r6>=500
 r7>=1000
 r8>=500
 r9>=500
 r10>=500
 r11>=1000
 r12>=500
 r13>=500
 end
```

RESULT OF RUN 6

LP OPTIMUM FOUND AT STEP 28

OBJECTIVE FUNCTION VALUE

1) 0.2933716E+09

VARIABLE	VALUE	REDUCED COST
X1	6620.000000	0.000000
X2	1000.000000	0.000000
X3	500.000000	0.000000
X4	500.000000	0.000000
X5	500.000000	0.000000
X6	1500.000000	0.000000
X7	1500.000000	0.000000
X8	1000.000000	0.000000
X9	500.000000	0.000000
X10	1000.000000	0.000000
X11	1000.000000	0.000000
R1	7500.000000	0.000000
R2	7500.000000	0.000000
R3	2000.000000	0.000000
R4	1000.000000	0.000000
R5	1000.000000	0.000000
R6	500.000000	0.000000
R7	1000.000000	0.000000
R8	500.000000	0.000000
R9	500.000000	0.000000
R10	500.000000	0.000000
R11	2165.606934	0.000000
R12	500.000000	0.000000
R13	534.392944	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	129.999847	0.000000
3)	0.000000	12793.178711
4)	0.000000	46600.000000
5)	0.000000	6127.167969
6)	620.000122	0.000000
7)	0.000000	-919.600159
8)	0.000000	-2045.000000
9)	0.000000	-10233.400391
10)	0.000000	-17011.798828
11)	0.000000	-15241.000000
12)	0.000000	-23086.800781
13)	0.000000	-2427.200195
14)	0.000000	-1420.000000
15)	0.000000	-5769.399902
16)	0.000000	-30770.998047
17)	0.000000	-11387.312500
18)	0.000000	-12912.196289
19)	0.000000	-6897.167480
20)	0.000000	-12667.167969
21)	0.000000	-9234.970703
22)	0.000000	-11069.884766
23)	0.000000	-8666.532227
24)	0.000000	-8666.532227
25)	0.000000	-8406.532227
26)	0.000000	-6575.375488
27)	1165.607056	0.000000
28)	0.000000	-7664.393066
29)	34.392956	0.000000

NO. ITERATIONS= 28

FORMULATION OF L.P. MODEL

BASED ON EXISTING CROPPING PATTERN

(RUN 7)

```
!run 7
max 5825 x1+3780 x3+6030 x4+6375 r1+4170 r2+9750 r3+6150 r5
   +5130 r6
subject to
 x1+x3+x4<=13000
 r1+r2+r3+r5+r6<=25000
!water constraints
0.125 x1+0.125 x3+0.349 x4<=4800
0.811 r1+0.700 r2+0.629 r3+0.423 r5+0.556 r6<=17600
x1>=12500
x3>=250
x4>=250
r1>=8750
r2>=6250
r3>=7500
r5>=500
r6>=2000
end
```

RESULT OF RUN 7

LP OPTIMUM FOUND AT STEP 13

OBJECTIVE FUNCTION VALUE

1) 0.2435688E+09

VARIABLE	VALUE	REDUCED COST
X1	12500.000000	0.000000
X3	250.000000	0.000000
X4	250.000000	0.000000
R1	8750.000000	0.000000
R2	6250.000000	0.000000
R3	7500.000000	0.000000
R5	500.000000	0.000000
R6	2000.000000	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	6030.000000
3)	0.000000	9750.000000
4)	3119.000000	0.000000
5)	87.750038	0.000000
6)	0.000000	-205.000000
7)	0.000000	-2250.000000
8)	0.000000	0.000000
9)	0.000000	-3375.000000
10)	0.000000	-5580.000000
11)	0.000000	0.000000
12)	0.000000	-3600.000000
13)	0.000000	-4620.000000

NO. ITERATIONS= 13