THE PROBLEM OF WATERLOGGING, SOIL SALINISATION AND WATER MANAGEMENT IN INDIRA GANDHI NAHAR PROJECT (IGNP) AREA:

A CASE STUDY OF RAWATSAR TEHSIL, HANUMANGARH DISTRICT, RAJASTHAN

Dissertation submitted to the Jawaharlal Nehru University in partial fulfillment of the requirement for the award of the degree of

MASTER OF PHILOSOPHY

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CERTIFICATE

I, Jyoti Chauhan, certify that the dissertation entitled **"THE PROBLEM OF WATERLOGGING, SOIL SALINISATION AND WATER MANAGEMENT IN IGNP AREA: A CASE STUDY OF RAWATSAR TEHSIL, HANUMANGARH DISTRICT, RAJASTHAN"** for the degree of **MASTER OF PHILOSOPHY** is my bonafide work and may be placed before the examiners for evaluation.

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I take responsibility for error remaining.

Jyoti

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Chapter I

Introduction

1.1 Introduction

Water is among the most precious gifts of nature to mankind. With growing requirement of water for diverse purposes, it is becoming a critical and scarce natural resource. Population growth trends and natural resource requirements in the present century in India would belong to water and land management. The development of the water resources for the well being of mankind is an inescapable necessity for raising the quality of life, which requires constant and careful monitoring of the availability of this precious natural resource in terms of time and space. The possibilities of harnessing this precious resource for optimum use, planning and development of schemes, operational maintenance and careful management of water resources is necessary on a permanent basis. In India, 70% of the cultivated area lies in the region of medium and low rainfall. Furthermore, our country utilizes only 30% of its surface water and 25% of its available ground water. As the total usable water resources of India is sufficient to irrigate about 50% of cropped area, efficient management of the water potential is of practical necessity. There is an urgent need for balanced water development projects, their implementation and optimal utilisation. The conjunctive use of the surface and ground water resources and provisions of drainage has been neglected in most of the irrigation projects in the past resulting in the cases of waterlogging and soil salinisation, besides land deterioration.

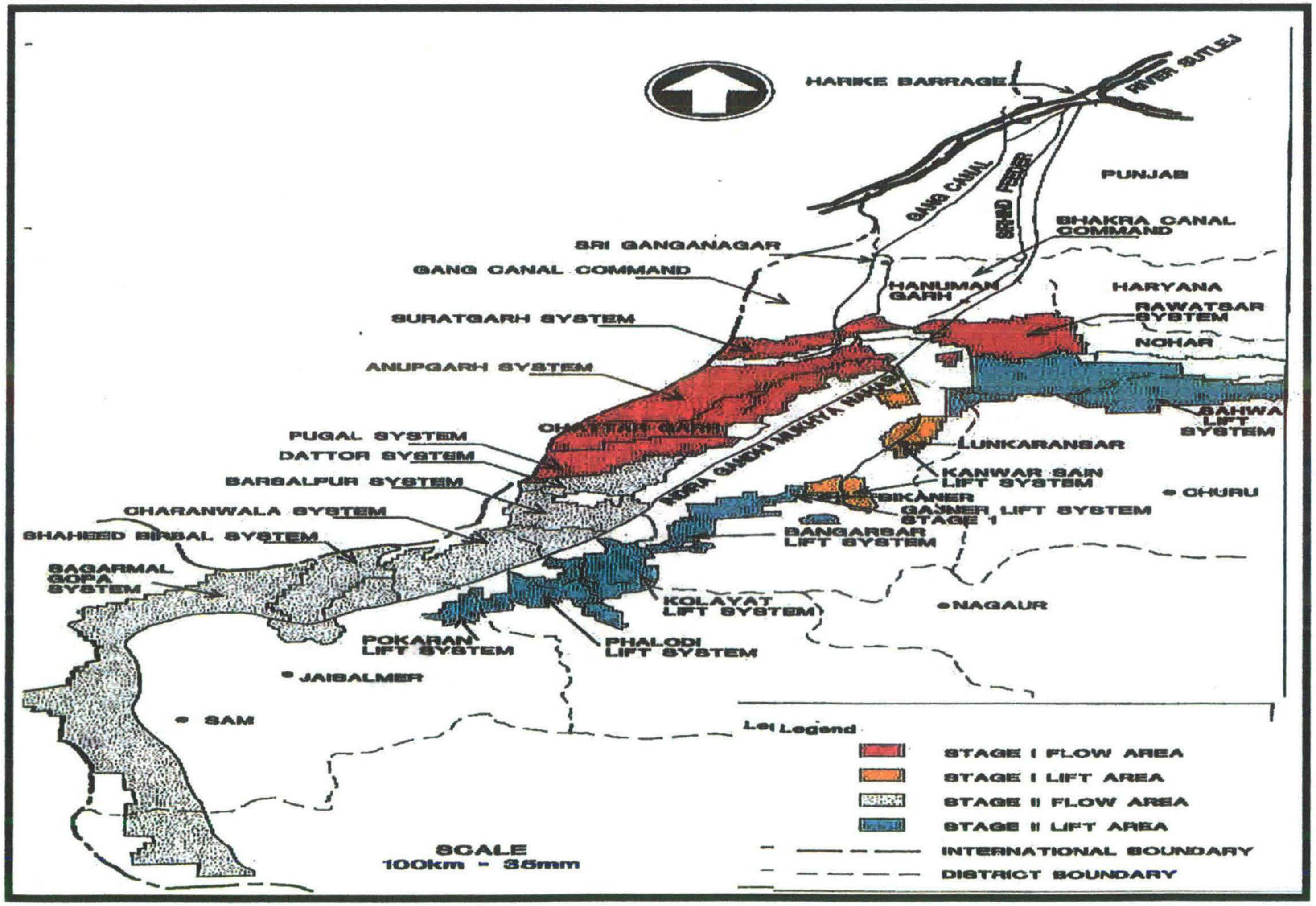
The world has experienced the soil degradation of about 2000 million hectare land. About 10 to 50% of the irrigated land is affected by waterlogging and soil salinity problems world over. In India, the area affected by soil degradation is about 200 million hectare out of which 16 million hectare land is affected by waterlogging and 15 million hectare due to loss of nutrients and salinisation. During the past three to four decade the problem of waterlogging has spread in Punjab, Haryana, Uttar Pradesh, Gujarat, West Benal, Maharashtra and Jammu & Kashmir. The problem of waterlogging in semi-arid and arid saline ground water regions is highly complex, posing serious limitations for the disposal and use of saline drainage water. This involves high and expensive technologies to tackle the problem of disposal without complicating any environmental ingredients. The waterlogging and its related problems in semi-arid canal command areas attracted more attention during 1980s. Presently, the problem has become a cause of concern for the scientists, technical experts and concerned government authorities. Therefore, the proposed water management and ecological studies with regard to the Indira Gandhi Nahar Project area, has a special significance, to address the environmental repercussion for the safety of the ecosystem. Major part of the arid zone of India (73.8%) falls in the western Rajasthan, named Thar. The Thar covers about 19.84 million hectare of land which is about 51% of Rajasthan, and 6% of the total geographical area of India, respectively. Actual area covered by the sand dunes is about 7 million hectare land (24.3%) of the affected area in Rajasthan alone. (Bhalla, 1996).

The Thar Desert is characterised by low and erratic rainfall, high evapotranspiration large temperature variation; scanty vegetation, absence of perennial rivers, sparse and a nomadic population with dependence on animal rearing. The Indira Gandhi Nahar Project (IGNP) (figure 1.1 and plate 1.1.) was approved by the planning commission in July 1957. Started on March 31, 1958 to improve the harsh desert conditions and the ecology it was developed in Stages I & II for convenience of planning, ease of construction and better administrative control. The canal takes off from Harike Barrage on the Satluj river and is meant to utilize the water of India's share of the Indus Basin rivers i.e. – Ravi, Beas and Satluj. The Stage-I of the project comprised of 204 km long feeder canal, 189 km of main canal and about 2950 km long distributaries. Stage-II consists of the 256 km of main canal and a distributaries system with a length of 5115 km. The total irrigated area is about 15.57 lakh a, i.e. 5.25 lakh hectare covered in Stage I and 10.12 lakh hectare in Stage II. Irrigation had stated in 1970 but the development of command areas of Stage – I continued right up to the end of December 1988. Hanumangarh is situated in Stage - I of IGNP. The canal network in Hanumangarh is shown in figure 1.2.

The IGNP is one of the most ambitious irrigation projects ever undertaken by any country in the world for combating hot, dry and harsh desert environments. Water has become a boon in this dry climate after the construction of this canal. Irrigation has resulted in a revolutionary change in the social and economic aspects of the population. There has been a considerable improvement in physical conditions such as micro climate, land use, soil and moisture conditions, biological status and quality of life. A slow change in the socio-economic structure and conditions has already been felt on the completion Phase-I of the project. The utilisation of the water in IGNP area needs to be viewed from the quantity of

Figure 1.1

INDIRA GANDHI NAHAR PROJECT



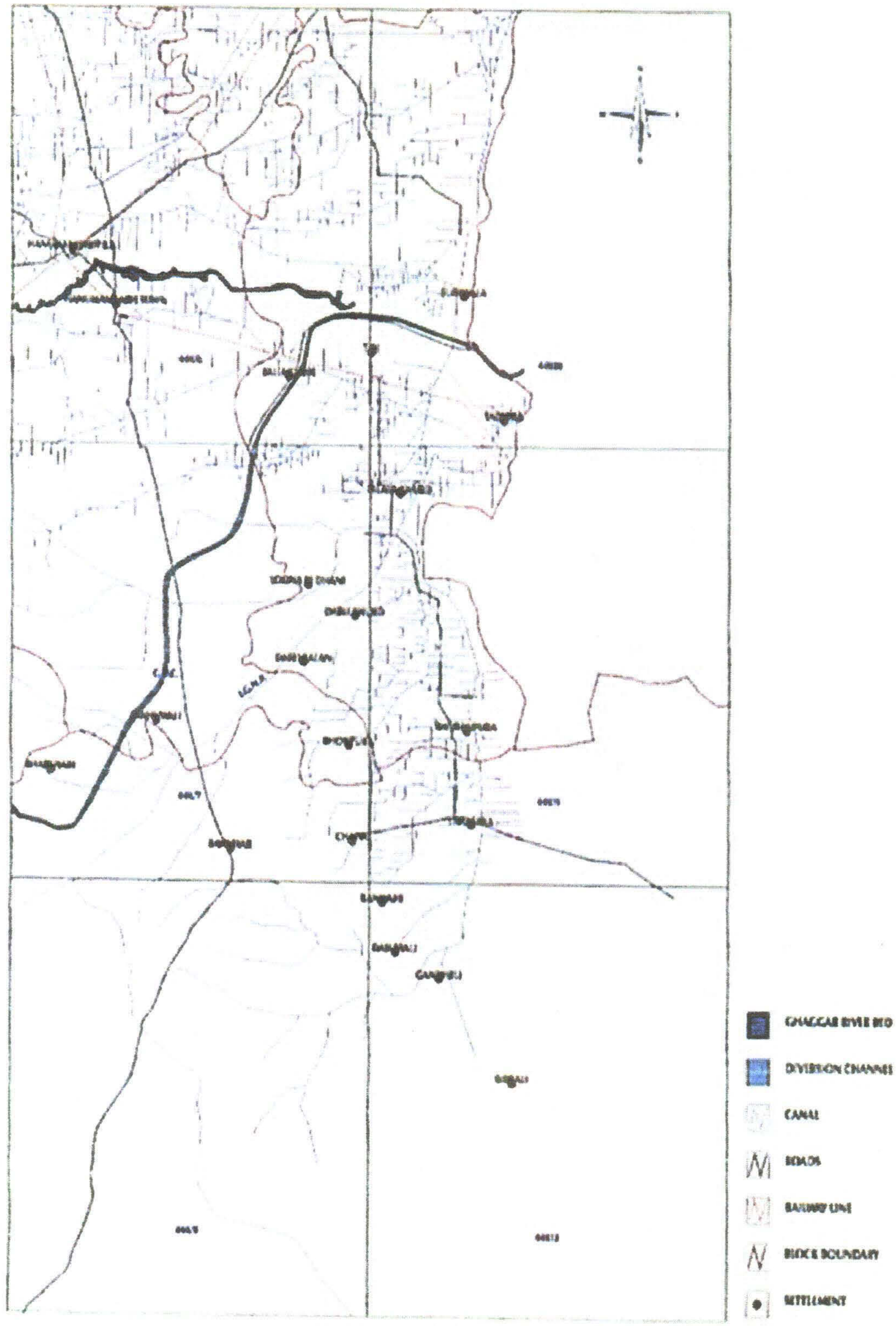
Adapted from: IGNP Studies, Govt. of Rajasthan, 1999

Plate 1.1 View of Indira Gandhi Canal Project approved since 1958.

Figure 1.2

CANAL NETWORK

HANUMANGARH DISTRICT



Adapted from : Agricultural Research Sub Station (RAU), HANUMANGARH

surface water available in the area for agricultural purpose. But intensive canal irrigation and poor canal management have created large number of adverse effects especially in respect of soil salinity, continuous rise in water table, invasion of obnoxious weeds and many health hazards affecting, the whole ecology of arid region. The change in hydrology before and after irrigation in IGNP is shown in figure 1.3.

1.2 Location

Hanumangarh is situated in the northern most region of Rajasthan and forms a part of the Indo-Gangetic Plain. It is located on $28^0$57' north latitude and between longitude $73^0$31' east. It covers a total geographical area of 9656 sq. km. It is bounded on the south by Churu district; in the south west by Bikaner district, in the west by Ganganagar district, on the north & east by Faridkot (Punjab), and Sirsa and Hissar district of Haryana.

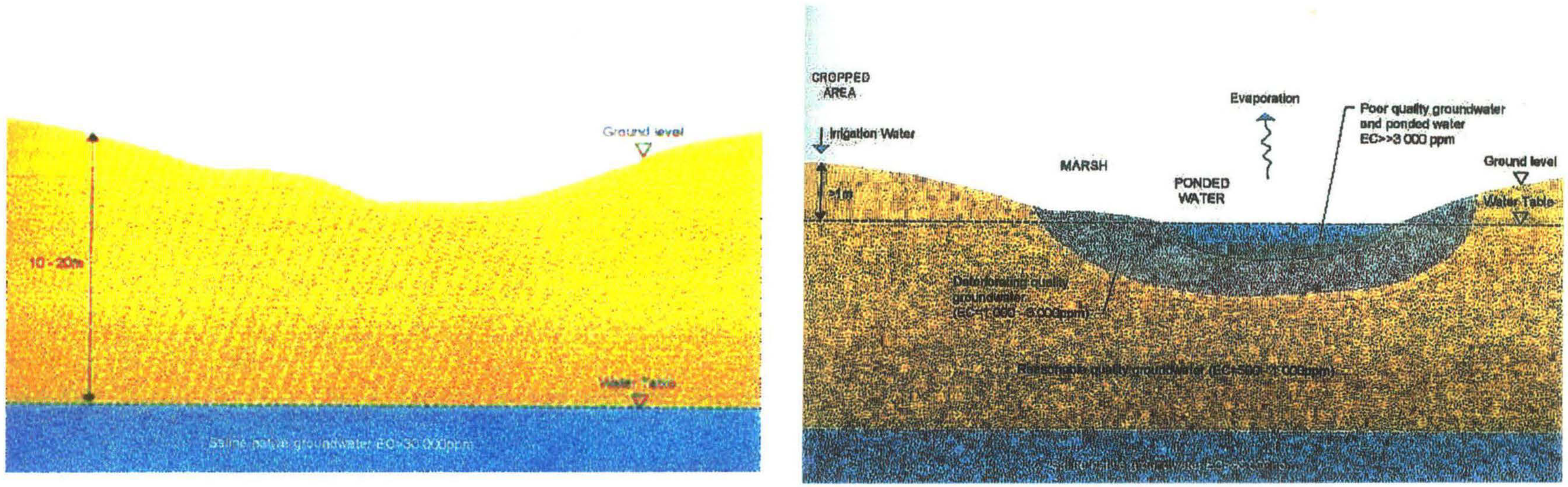
Rawatsar (figure 1.4) is a Tehsil of Hanumangarh district. It is located on $29^0$14' N to $29^0$19' N latitudes and $73^0$48' E to $74^0$20' E longitude in the IGNP Stage-I in the command area of the Hanumangarh district. The study area is irrigated by Rawatsar distributary of the IGNP main canal. Southern and eastern parts of Rawatsar is bounded by Rawatsar and the northern part is served by naurangdesar distributary. The Ghaggar diversion channel junction marks its north western boundary. Rawatsar covers a geographical area of approximately 70.75 thousand hectare and the cultivable area is about 41.8 thousand hectare, which is about 59% of the total area.

Figure 1.3

HYDROLOGY BEFORE AND AFTER IRRIGATION IN IGNP

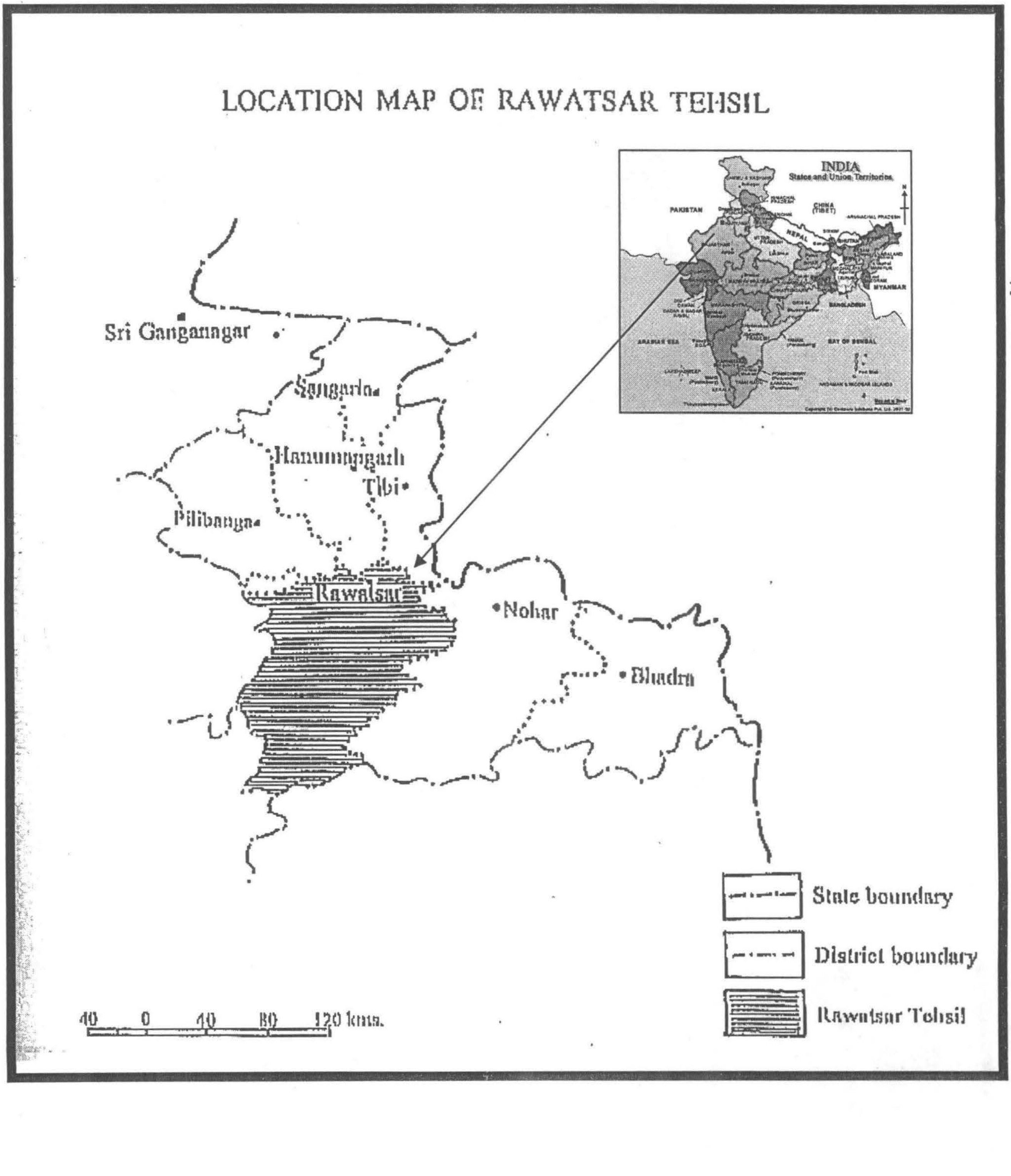
BEFORE

AFTER



Adapted from: IGNP Studies, Govt. of Rajasthan, 1999

Figure 1.4


LOCATION MAP OF RAWATSAR TEHSIL
INDIA
States and Union Territories
PAKISTAN
NEPAL
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
Sri Ganganagar
Sangaria
Hanumangarh
Tibi
Pilibanga
Rawatsar
Nohar
Bhadra
State boundary
District boundary
Rawatsar Tehsil
40 0 40 80 120 kms.

1.3 Climate

The climatic of the district is marked by a large variation in diurnal as well as seasonal temperature, extreme dryness and scanty rainfall. November to March is a cold season; followed by summer between April to June-July to mid September is monsoon while mid September to October a post monsoon period. The mean temperature remains at 23^{0}C. The normal annual rainfall of the district is 253 mm.

Table: 1.1

Annual Rainfall in Rawatsar Tehsil (in cms)

Year	Annual Rainfall
1994	19.2
1995	28.6
1996	30.9
1997	49.3
1998	32.8
1999	28.4
2000	13.7
2001	20.6

Source: Tehsil Records, 2001

Rawatsar is characterised by hot and dry desert climate condition. The area receives most of the rainfall in monsoon season and average annual rainfall varies from 243 mm to 246 mm. Summers are hot and dry and temperature in summer goes up to 43^{0}C, while, temperature in winter drops to 12^{0}C or below, dust storms are frequent in summers months. Typical scanty and xerophytic vegetation is found in this region.

1.4 Relief Characteristics

Relief of the Indira Gandhi command area in Hanumangarh district is characterised by alluvial plains and sandy plains, inter-dunal depressions or deflation basins and sand dunes. The command area of Hanumangarh district is an extension of the Punjab Plain, which consist of alluvium laid down by the Ghaggar river. The Ghaggar is a fertile plain consisting of recently deposited alluvial sediments along with old alluvium. Parts of Nohar and Bhadra district of hanumangarh district are mostly rainfed. Though canal has reached these areas, the agricultural patches of land are at higher elevations where canal water cannot reach. The area comprises of longitudinal and transverse sand dunes.

Hanumangarh district is located in the low rainfall zone with acidic moisture regime. The soils of the district have developed through both aeolian and fluvial sedimentation processes. The physiographic evidence suggests that the southern part of Rawatsar, Nohar and Pilibanga Tehsil have remained characterised more by high wind activity. This part has high density of medium to high dunes and narrow, highly hummocky inter-dunes with coarse textured soils and abundance of freelime in the form of concretions. The north and north western parts of the district have evolve through fluvial sedimentation and belong to both old and recent alluvial plains of the Ghaggar river and its old tributaries Saraswati and Drishitadwati.

1.5 Geology

The area is covered by wind blown sands and alluvium except for a few patches of recent calcareous and sandy sediments associated with gypsum. The oldest rocks of the area belong to the Aravalli Super Group which includes phyllite, shale and quartz veins, overlain by the rocks of the upper Vindhyan which are entirely made up of bright to pale red fine and medium grained sandstone and siltstone.

Geology of Rawatsar area is completely obscured under a thick blanket of sand dunes, and alluvium of the Quaternary age. Sand dunes consists of silt and fine sand, yellowish to brownish in colour; and heaped up long time in the form of mounds and hills in heights of 30 meters in southern part, forming longitudinal ridges. Soils with light texture having small grains with smaller intergranular spaces resist percolation of water and helps in creating waterlogging conditions in the area. Occurrence of lime is very common, which is generally in a powdered form. The amount of lime increases with depth; with heavier textured soils found in the low lying area of river beds. The area is composed of mainly former flood deposits and aeolian sands. Flood plains are more common in the northern part. The alluvium is mostly fluvial in origin and comprises of unconsolidated to loosely consolidated sediments consisting of an alternate sequence of sand, silt and clay with frequent lenses of silt clay and kankar with occasional gravel horizons. These sediments are heterogeneous in nature and vary both laterally and vertically in character.

1.6 Hydrogeology

Ground water generally occurs in unconsolidated to loosely consolidated alluvial sediments of the Quaternary. In central part of the study area along the main canal, water table is high and ground water occurs under unconfined to semi confined conditions. Thickness of the water table aquifer varies from a few meters to more tan 30 meters. Semi confined conditions are overlain by clay and kankar beds. Therefore, water holding capacity of soils is less, resulting in water table to rise. A continuous rise in water table causes waterlogging and soil salinity in the study area. As the ground water is saline or brackish and soils are also rich in soluble salts, it causes problems of salinity along with waterlogging.

The earlier studies by the Rajasthan Agriculture Department reveal that the depth of water table varied between 40.0 to 46.0 mbgl (1952). Monitoring of water table was started in 1973 in the present study area. The finding of the agency shows a continuous rise in water table. The rise in water table varies from 0.20 m to 1.85 m per annum.

1.7 Soils

Soils in the IGNP area of Hanumangarh district are mainly sandy except in some parts where they are alluvial. In the upper command area near the head of main canal these sandy soils of recent origin. In some areas gypsum accumulation also occurs at shallow depth. The soil in the southern part is dominantly coarse textured, underlain by varied type of the sub-strata at variable depth exposed to severe wind activity.

1.8 Natural Vegetation

In the IGNP area Vegetal cover is generally sparse due to moisture deficiency and arid conditions. Although after the construction of canal land under cultivation has increased. The areas where natural vegetation consists of thorny scrubs and bushes withstand high rate of evaporation from the surface of leaves. Command area in Hanumangarh district in Stage-I comprises of *Acacia Senegal* while command area of stage II has *Prosopis, Acacia Senegal* type of plants. The region does not have much forest cover, yet degraded patches could be visible in few areas.

1.9 Overview of Literature

In India, agricultural development mainly depends on Southwest Monsoon, which is uncertain, uneven and erratic. In order to overcome the deficiency of natural water, irrigation has been assigned a key role in the strategy for agricultural development. Despite many loopholes in the development of irrigation resources, it has emerged as an effective mechanism to combat the adverse effects of weather. In the desert area of Rajasthan, irrigation has been very successful. It has helped in improving the socio-economic condition of the people of Rajasthan. Before the incoming of the Indira Gandhi Canal it was a barren area, with no water and poor economy. Conditions completely changed after the construction of IGNP. Agricultural production increased substantially and change in cropping pattern and land use is observed. Since the ecosystem in the desert area is fragile, canal irrigation brought with it the problem of waterlogging and soil-salinisation. When the intensity of the problem increased it attracted the attention of scientists and administrators belonging to various disciplines, ranging from geographers, economists to engineers. A brief review related to available literature on canal irrigation and problem there of such as waterlogging and salinisation is presented below.

Verma (1983) examines the policy issues about water use in the command area of Rajasthan canal. The author emphasises the use of high level of technology i.e. fertilizers, high yielding variety of seeds etc. He also advocates the practice of intensive irrigation in canal area. This is proposed for maximizing the profit and production.

Dandikar (1983) explains the importance of irrigation in the arid zone with special reference the Indira Gandhi Command Area. The author suggests that intensive irrigation may be economically good and profitable but it will benefit mainly the rich farmers and create a gap in the society in respect of resource distribution. He proposes the development of livestock, pastures and extensive irrigation in order to benefit the people of this region. The author argues that excessive use of irrigation water may cause the problem of soil salinity and waterlogging.

Dhir (1983), highlights the soil characteristics of Stage - I where command area of Stage II are different from those in the upper parts of Stage I.

Bithu (1983) discusses that intensive irrigation introduced in the command area without considering the fragile ecosystem of the area is one of the cause of waterlogging and salinisation. He suggests that proper planning should be done to reclaim the affected areas.

Roy (1983) studied the impact of irrigation on social, economic and environmental conditions. He has drawn conclusion from primary data of the households with and without irrigation. The villages are chosen from the command area.

Jha (1984) explains the use of irrigation projects to control floods. His study is based on the region of Bihar. He has also compared between planned and unplanned irrigation.

Pant (1984) edits the proceedings of the workshop on "productivity and equity in irrigation systems", organised by the Giri Institute of Development Studies. This book deals with theory, concepts and issues; empirical case studies of irrigation management and administrative experience in Andhra Pradesh and Gujarat.

Gupta (1987) evaluates the irrigation induced environmental degradation (waterlogging and soil salinity) and has suggested certain measures for its amelioration. The author estimates that about 12 million hectares of land in India is affected by waterlogging and soil alkalinity and salinity.

Dhawan (1988) has done an extensive work on the impact of irrigation on agricultural development in India. The study is mainly based on secondary data and covers a wide range of influence of irrigation on agricultural development in the country. The empirical enquiry mainly focuses on protective, productive and stabilising role of irrigated agriculture. The study also analyses inter-source differences in productivity of irrigated agriculture, income generation through irrigation and equity in sharing gains from irrigation.

Dhawan (1989) discusses various resource involved in water resource management including waterlogging and drainage, wastage of irrigation water, prevention of groundwater depletion, conjunctive use of irrigation water, improvement in the level of irrigation utilisation and achieving economy in water use.

Vohra (1987), in his article on "Issue in Water management" observed the failures of big irrigation projects due to lack of water management strategies and administration. Looking to the large financial investment of the projects the gap between water potential created and utilised must be minimised. The emphasis is to evolve a rational policy of water management. Saxena (1996) recommended lining of water courses of personal fields be encouraged for conservation of water. By adopting water management measures, waterlogging and soil salinisation can be controlled.

WAPCOS (1992) and Central Water Commission, in their studies on the IGNP Canal command areas, reviewed the development, water balance and conjunctive use of surface and ground water. Technical aspect regarding drainage, i.e. methods and techniques are also explained in the report. The report of the CWC stresses on ecological balance of the area, afforestation and monitoring of waterlosses in rational manners by adopting better water management strategies. The final report "IGNP studies for the state of Rajasthan" (1999) of Government of Rajasthan emphasizes on a pilot programme on drainage and possible drainage system in the area. It also highlights the problem of waterlogging and salinity in the IGNP area. The effect of waterlogging on the socio-economic conditions of people, and possible drainage methods to overcome the problem as biodrainage, open drains and subdrains has also been explained.

Rathore (2001), studied fluctuation soil and water quality over the at Lakhuwali Pilot Area to highlight the different aspects of the problem of waterlogging and salinisation. The pilot area is Lakhuwali in Hanumangarh district where Indo-Dutch Project has been started for installation of sub surface drainage system. Periodical assessment of water quality and soil salinity is done and effect of sub surface drainage system on production of barley is analysed.

Rathore (2001), has given a methodology for mapping waterlogged and saline areas in part of Hanumangarh district along with remedial approaches to explain the objective and methods of making maps in saline areas, satellite images and ground checks through soil sampling in a grid system.

Singhvi (1990), in her report has explained the geology, climate and rainfall pattern of Rawatsar Tehsil of Hanumangarh district. The problem of waterlogging & soil salinisation and the main causes and solution of problem are explained. Change in landuse and cropping pattern is also reported in the affected areas.

Sahni (1990) explains the nature of soil in irrigated command area with a view to maximize the crop yields per unit of cultivable area and per unit of available water, and to avoid or minimize irrigation related problem such as soil erosion; waterlogging; soil salinity etc. This article discusses the major emerging issues related to improved irrigation system management in such command areas and appropriate package of management practices suitable for various field situation.

Sharma and Hiran (1990) discusses the problem encountered with CAD projects as well as suggestions for improving CAD performance. They suggest the development of head water tanks, soil conservation structures, optimum land use based on capability classification and conservation farming practices should form an integral part of an irrigation system.

J.F. Cerrcia (1990) highlights the existing lacunae in the irrigation projects, optimisation of irrigation water along with other inputs and operating policy options for maximize from small number of farms or smaller yields from a large number of farms.

Deo and Verma (1990) discuss on water table, ground water quality and soil salinity during 1984-86 in the command area of the Indira Gandhi Canal, indicating large differences, which varied with location, season and irrigation management. Studies are mainly carried out in Wenkaransar and Seelwala.

Sharma (1990) in his article explains the problem of irrigation scheduling which needs consideration of two aspects i.e. availability of water and cropping pattern in the command area. The paper suggests that the problem of uncertainty in availability of water may be dealt by using different models. Paper points out the need for identifying homogenous part of the command area and preparing separate optimal crop plan for these. It suggests that optimal cropping pattern and irrigation scheduling should be determined simultaneously.

Sharma et.al. (1995) explain the problem of salinity in Chambal Command Area by studying the pH and EC values of soil and water. They suggest that in order to sustain and improve the crop production, soil salinity and waterlogging must be controlled.

Devadattan (1995) in a study in canal area of Kultanad, Kerala where typical acid saline extends over an area of 7000 hectare, has recommended to wash the field many a times before sowing the seeds.

Gupta (1995) highlights the importance of leaching for controlling soil salinisation. He suggests the strategies which one should adopt while leaching.

Joshil et.al (1995), highlight the serious nature of the problem causes and solutions of waterlogging and salinisation.

Tideman (1996) brings together the technical and some of the socio-economic knowledge available for successfully implementing watershed management. The multi-disciplinary approach involving all factors influencing the well being of the people of the watershed has been highlighted.

Keeping in consideration the available knowledge through above articles and books, an attempt has been made in this dissertation to look into various issues concerning waterlogging and salinisation. Additional literature has been referred to wherever necessary.

1.10 Hypothesis

The problem of waterlogging and soil-salinisation in Rawatsar is the outcome of absence of any proper natural drainage, presence of hardpan effect at shallow depths, consequent rising of water table due to mismanagement of irrigation facility, lack of water management strategies unplanned land use.

1.11 Objectives

1. Examine the water resources in respect of various aspect of natural ecosystem which on account of its long interaction with environment has gone through fragile changes in Rawatsar area of the IGNP.

2. To study the landuse changes after large scale canal irrigation in this arid tract.

3. To understand the magnitude and extent of the adverse environmental impact with special reference to waterlogging and salinisation.

4. To highlight various development and management schemes to solve the problem of waterlogging and any impact of these schemes there of.

5. To study the changes in water table, change in soil composition, cropping pattern in Rawatsar area.

6. To suggest remedial measures to protect the fragile ecosystem of the study area.

1.12 Methodology

The source of information is mainly secondary data collected from various published and unpublished sources like the Census Reports, Agriculture, Statistics, Tehsil Records, Report of IGNP, Command Area Development (CAD) and Ground Water Board.

1. In order to know about the water and soil quality, samples from various sites and chaks (villages) were collected and tested in Lab at Hanumangarh, affiliated to Indo-Dutch Project.

2. The data for area irrigated and water utilised were taken from irrigation office, established to analyse and reach at solutions for the waterlogging.

3. Primary information, mainly to know the socio-economic effects of waterlogging and salinisation was collected by talking to farmers, engineers, administrative officers and residents. Photographs were taken of the affected sites in order to highlight the intensity of problem.

4. Data analysis was done in order to highlight the spatial and temporal dimension of the problem, attempt has been made to show the results.

5. Various books, articles & projects studies were helpful in analysing the problem and drawing conclusion.

1.13 Data Source

The study is mostly based on secondary data and field observation. Secondary data has been obtained from various Departments, Government of Rajasthan, reports published by Command Area Development (CAD) and WACOS. Information has also been obtained from agricultural sub stations, important departments dealing with the Ground Water Board, Bikaner, Irrigation Office, Agriculture Extension Office, Revenue Records etc.

Further, this information has been collected from different books, articles, journals, seminar proceedings, brochers, booklets, other published and unpublished sources.

1.14 Chapterisation Scheme

The first chapter deals with the introduction of the problem, physical characteristics of the study area as relief, climate, soils etc, hypothesis, objectives, literature review, methodology and data source is also discussed.

Second chapter deals with te drainage characteristics and methods.

Third chapter gives detailed information about the problem of waterlogging and salinisation. It discusses the causes and solutions for the problem.

Chapter IV highlights the effect of waterlogging and salinisation on land use pattern; production of important crops etc.

Chapter V discusses important methods to combat the problem of waterlogging and salinisation. Water management techniques are discussed in detail.

Last chapter gives the summary of the above chapters along with conclusion.

1.15 Limitations

Though sincere efforts were made to highlight the causes and consequences of problem in detail but there were certain limitations which handicapped the presentation of certain issues.

First and foremost limitation was that Rawatsar is situated near Pakistan. At the time of field observation and verification there was tension prevailing between the two countries. Toposheets of the restricted area were not available for drawing the topographical details etc.

Secondly Hanumangarh district has been newly carved out from Ganganagar in the year 1994. A comprehensive data regarding crop production, irrigated area etc are not available.

Thirdly, some patches of land were severely waterlogged and were not accessible complete data regarding production, landuse etc. of waterlogged areas was not available.

Chapter II

Drainage Characteristics and Methods

2.1 Concept of Drainage

Drainage condition in Stage-I of Hanumangarh district is poor. It does not have any perennial river. The Ghaggar, which is a seasonal river, originates from Shivalik range of the Himalayas, enters the region in Ganganagar district near Hanumangarh and flows westward through Suratgarh and Anupgarh Tehsils. This river is lost in sandy plains but its course is easily traceable upto Anupgarh town. The Ghaggar river causes occasional flash-floods. Floodplain of this river is known as *Nalli Land/Nali Bed.* There has been a great controversy regarding Ghaggar river. Some scholars believe that it had been a perennial river and carried a large volume of water in historical times. The hydrogeographic changes were more likely to have occurred due to neo-tectonic movements both in the Himalayan catchment and basin of the Ghaggar river or a major climatic change towards aridity.

During medieval times some interchange might have taken place between the easterly affluent of the Indus and the westerly tributaries of the Yamuna by minor shiftings in watershed. The River Yamuna during early historic times is said to have discharged into Indus system through now neglected bed of the Saraswati River. (Dikshit, 1977). Others believe that from the configuration of the sites in the area, particularly those on the River Saraswati and from the results of scientific studies carried out it appears that the climatic and hydrological conditions during the past three thousand years have not undergone any major changes. The conditions in the area covered by the Saraswati and the Drishadvati, represented by the Ghaggar, Hakra and Chautang – were not radically different from those prevailing in the recent times. The behaviour of these rivers may have been the same as it is now. (Pandey, 1997)

2.2 Methods of Drainage

Artificial Drainage is removal of excess rain or irrigation water from the land surface or sub-surface. Though, in addition to the natural phenomena of rain, there is a man made phenomena of irrigation, such as construction of dams, canals anicuts etc. In almost every canal irrigation system, it has been found that large scale artificial drainage works are essential, if intensified agriculture in semi-arid and arid areas is to be of permanent nature. Drainage problems result from the fact that it is hardly ever feasible to achieve full efficiency. In the process of irrigation, loss by seepage from canal system, use of excess irrigation water and incidence of rainfall particularly during irrigation season contributes to the ground water and consequent drainage problems. Even if full efficiency were possible, there is often a need to use a certain amount of excess water for leaching out residual salts from the irrigation water present in soil. As the soils of arid and semiarid areas often contain soluble salts which are redistributed by a rising water table, appearing at the surface. It may merely be mentioned that the transformation of the Mesopotamia plains, those vast areas in Babylonian times were once the granary of the world are now a salty desert because of improper use of irrigation water. The

Imperial Valley in California was brought under irrigation at the beginning of the last century (1910). Only fifteen years later, the productivity of this area was severely threatened and large part of the agricultural land of the valley went out of crop production.

Excess salt accumulating in the root zone either from irrigation water containing salt or from saline ground water at shallow depth or the salt present in the top soil should be leached out to maintain a favourable salt balance in the soil profile.

The objective of artificial drainage is to prevent the occurrence of an excessive moist condition in the root zone which either directly or indirectly has a harmful effect on the growth of the crops, and to prevent the accumulation of salt in the root zone or the leach-out accumulated salts of the soil profile. The main aspect of drainage is necessitated by irrigation to discharge capacity and should correspond to the quantity of irrigation water supplied in excess of crop requirement. On the other hand, drainage necessitated by rain depends upon the intensity of rainfall, the natural surface and infiltration characteristics of the soil.

When natural drainage is inadequate to handle the water reaching the land by natural means, man made or artificial drainage is required. Selection of a drainage system is arrived at after careful examination of various alternative methods. Important drainage methods are mentioned as follows:

1) Surface drainage, including land grading and smoothing.

2) Sub-surface drainage or pipe drainage.

3) Tube-well drainage.

4) Bio Drainage.

a) Surface Drainage

Surface drainage is the evacuation of water over the ground surface, sometimes in part through the top soil to an open drainage system with an adequate outlet. The need for the surface drainage is the result of a combination of certain climatic, hydrologic, topographic and land use characteristics.

The water may be produced from excess precipitation, water applied for irrigation, losses from conveyance channels and storage elevation. The surface drainage generally comprises of open drains and their capacities are determined to drainoff a specified storm water. Such open drains not only drain off the surface flows but also intercept the seepage water or shallow ground water. Such drains are economical for carrying large volumes of water. However, surface drains have the following disadvantages:

1. The area covered by the drains is lost for cultivation or any other use.
2. The open drains require frequent cleaning and heavy maintenance expenditure.
3. Such drains during non-operating period give rise to the growth of weeds.
4. The land is split up into separate parcels which may considerately hamper efficient farming if drain spacing are narrow.

Water is likely to remain stagnant on the land in pockets or shallow depression. Therefore, in addition to the construction of drains, the micro-topography of the land has to be changed. This operation is called land farming. The time over which excess water has to be removed from the soil surface, the specific cultivation needs of various crops or crop rotation, the soil structure and natural soil fertility are considered for planning land farming operations. In land farming operations two processes are recognised i.e., land smoothing and land grading. Land smoothing means the flattening of land surface without changing its general topography, whereas, land grading for surface drainage consists of cutting, filling and smoothing to continuous surface.

Surface drainage system for flat areas (maximum slope 2%) can be in the form of bedding system, parallel field drain system, the random drain system and the parallel open ditch system. The different surface drains are designed on their functional behaviour and are termed as under:

1. On farm field drainage system – comprises graded channels that collect excess water from fields.

2. Main drains are principally excavated for natural drains collecting water from link drains or directly from field drains.

3. Seeping drains – are located along channels and intercept surface and/or subsurface flows. These drains help in arresting of excess discharge/seepage from the fill reaches of canals to the adjacent fields.

b) Sub-Surface Drainage

A drainage system for removal of excess ground (GW) water below the soil surface is termed as sub surface drainage. It is to ensure that GW is below the effective rooting depth of crops grown in the area. It should not aim to separate the capillary fringing from the root zone in case quality of water is fresh as it would mean depriving the crop of 10 to 30% of its water requirement. Such drains are also provided to maintain salt balance by the application of excess water to leach the salt and drain them outside the area through the drainage. The various sub surface drainage methods generally adopted can be explained as under:

1. Vertical drainage

2. Horizontal drainage

3. Bio drainage

c) Vertical Drainage – Well Drainage

One of the methods of drainage is to lower the water table by pumping from wells. Well is constructed by drilling a hole into a saturated aquifer; the hole is cased and is equipped with a screen over those parts of the aquifer that have most favourable water transmitting properties. The annular space around the screen is generally gravel packed. The well is equipped with a pump to lift the water from the aquifer to lower ground water table. A hydraulic gradient is established in the surrounding area and ground water flows towards the well from all directions (radical flow).

d) Open wells/dug wells

Making conjunctive use of ground water for irrigation directly or by blending with the fresh water, if the salinity of ground water is within acceptable limits.

e) Skimming wells

The ground water quality data has shown that the salinity of ground water increases with depth and in many areas due to the presence of excessive salts in the soil profile. The rise in water table caused by the recharge from good quality rain water and irrigation losses does not show corresponding improvement on the ground water quality. But it has been found that with the passage of time, the excessive salts in the soils have leached and the shallow GW gets accumulated by percolation of good quality rain/irrigation water over the deeper GW which is more saline. Thus by proper layout of skimming wells, the top layer of fresh water can be used for irrigation.

f) Tubewell Drainage

The following conditions singly or conjunctively contribute to the feasibility of a tubewell drainage scheme.

- Large area of flat lands with extensive high water table with or without salinity problem.

- Well defined continuous thick pre-aerated aquifer with a good hydraulic conductivity. Aquifers should permit an efficient well. The soils should have a high infiltration rate.

- Ground water quality should be good enough to be used for irrigation with or without mixing with the fresh surface waters. Care should be taken that highly saline water does not enter into the well while pumping.

- When the ground water lowering beyond 2.5 to 3 meters is desired and a shallow impervious layer (soil is considered impervious if the permeability is less than 20% of the permeability of strata above) does not exist.

- When the pipe drainage is difficult or costly because of inadequate gravity outlets or unstable soils which make the digging of deep trenches difficult.

- Ground water is under artesian conditions.

- Power is available at reasonable costs.

Before a tubewell drainage scheme is conceived, a careful engineering investigation should be carried out to evaluate the feasibility of drainage. The inter-connection of the under-ground water in the upper layers to that of pumped aquifers should be ascertained. The well drainage system are classified generally according to the function for which they are constructed.

g) Systematic Drainage

Well drainage are provided for systematic drainage. Wells in the drainage area are located more or uniformly over the entire area proposed to be drained off. The wells may be located to that spacing of the wells in a multiple well system that their individual zones of influence do not overlap, each well will not interfere with other wells. But if the discharge and draw down of each well in the system is effected by neighbouring wells for speedy drainage or lowering of ground water table (GWT) a system of interfering wells are provided and discharge is computed by method of superposition.

h) Selective Drainage

The system of the drainage by wells located in a small problematic areas like depressions or saline tract is termed as selective drainage. The spacing of wells will be generally interfering to lower the GWT in a short time.

i) Interceptor Drainage

The surface of the water in a semi-confined aquifer is not always level. Areas along embanked rivers with high water level, water impoundages like tanks, filling reaches are suitable. The surface may have a slope and wells installed in such aquifer will intercept the subsurface flows. Such well may be installed in one or more lines along with the front of flow. In case where such wells are installed in a linear system along the shore of a river or reservoir to lower the GWT, it is termed as shore drainage.

j) Advantages of Vertical Drainage

Vertical drainage or well drainage has certain advantages over gravity drainage and these are:

1. On undulating land with local depressions not having natural outlets, the pumped water is generally disposed off through pipe lines connecting the various wells. Excessive earth moving is thus avoided as no deep canals need to be dug through topographic ridges. Also without such canals and ditches more efficient farming operations can be introduced.

2. Well drainage enables the ground water table to be lowered to a much greater depth than does the gravity drainage. This means that a greater portion of the excess water can be stored before it has to be removed. In arid and semi-arid regions, a deeper ground water table will reduce salinisation of soils.

3. The deeper layers or substrata may be much more pervious than the layers near the surface. Pumping from these layers may reduce the artesian pressure that it often presents, creating instead a vertical downward flow through the upper layers. If the pervious strata are found at a depth of 5m or more, it is only with the well drainage that full benefit can be desired from these favourable hydrological conditions.

4. If the water in the pumped aquifer is of good quality it can be used for irrigation on demand.

k) Limitations

1. Well drainage is not technically feasible on small areas because too large a portion of water is drainage out of the area that consists of 'Foreign' water i.e., ground water inflowing from the surrounding areas.

2. Well drainage can only be applied successfully if the aquifer characteristics are favourable i.e., if the transmissivity of the aquifer is fairly high only then the wells be widely spaced or the aquifer is confined (i.e., an upper layer of clay overlying a sandy aquifer). An additional criterion is the value of the hydraulic resistance of the upper clay layer. This value must be low enough to ensure an adequate percolation rate. The decision in favour of vertical drainage should only be taken after careful hydroecological investigations has proved its suitability.

3. The operations and maintenance of a well drainage requires electricity or fuel and is more costly than gravity of tile drainage.

4. A pumped drainage (well drainage) is more complex engineering structure than gravity drainage or tile drainage. Its successful implementation is dependent on detailed hydrological investigation including hydrological investigations, including transmissivity, storability, aquifer characteristics and GW quality.

l) Vertical Drainage by Causing Deep Percolation

In some areas under study, hydrological barriers are met with at shallow depths. The excessive irrigation and water recharge create perched water table conditions where the soils below the hydrological barriers are all porous and unsaturated. The perched water conditions can be drained by puncturing the hydrological barriers and allowing the water to percolate in deep aquifers. This can be practical only if the thickness of hydrological barriers is not excessible (say more than 10m) and the storability of the deep soils below the hydrological barriers is substantial.

This method would provide immediate relief and can protect the area being waterlogged.

m) Horizontal Drainage

Installation of a system of a buried pipe drains or pipeless (mole) drains, interception of GW and a system of open or collection drains for disposal of the drainage water is termed as horizontal drainage or pipe drainage. The primary aim of pipe drainage is not to control the GWT which may be deep but is to remove excess water from the top soil where it may contribute to perched water table or the excess water from the area above the horizontal drainage.

n) Pipe Drains

The areas under study are predominantly sandy with an irregular topography. The horizontal drainage will be effected by pipe drains. The most common materials used in the manufacturing of drain pipes are clay, concrete and plastic.

1) Clay Pipes

Clay pipes (often referred as clay tiles) are usually made in length of about 30 cm and have a range of internal diameter from 5 cm to 15 cm; 5 cm being the standard sized for lateral drains. The pipes may be straight or they may have color, Collored pipes may provide some extra safeguard against mis-alignment. The water enters the pipe line through the gaps between the tiles. Porosity of the wells is of no practical significance, clayware pipes are highly resistant to chemical attacks and do not deteriorate in the soil. Some important aspects are shape (straight, square ends) absence of crack, homogeneity (well mixed clay), etc.

2) Concrete Pipe

Concrete pipes are used if clay tiles are not readily available or if greater diameter (e.g. more than 15 or 20 cm) of pipes are required. Manufacturing of concrete pipes is a much simpler process than that of clay pipes & their installation is also much simpler. A disadvantage of concrete pipes is its susceptibility to disintegration in acidic and sulphate soils which can be overcome by using sulphate resistant cement. Concrete tubes or pipes are specially designed to permit water entry through their porous walls. The pores, however, are likely to become clogged by silt and clay particles or other materials. The porosity also makes the pipes more vulnerable to attack by cement destroying agents.

3) Plastic Pipes

The most common plastic material for drain pipes are polyvinyl chloride (p.v.c.). With equivalent weight and size P.V.C. is less impact resistant and the brittleness of P.V.C. pipes may lead to damage in handling. Plastic pipes are available in smooth and corrugated varieties of which corrugated varieties have become more popular. The smooth pipes are rigid and their length usually does no exceed 5 m, where as the corrugated pipes are flexible and are delivered in coils whose inner diameter is about 0.80 m or more. The total length of pipe in one coil decreases with increasing diameter and is approximately 200 m for 10 cm pipes.

The corrugated pipes require less plastic material per unit length and thus are cheaper. Even so they have much greater resistance to outside pressure. Due to their flexibility, corrugated pipes are the only type of pipe that can be used with special drainage techniques but the corrugated pipes have considerably higher hydraulic resistance than smooth pipes and thus large sized pipes are needed for the same quantity of water. The out side diameter of corrugated pipes needs to be about 25% more than that of a smooth pipes.

The entry of water in a smooth pipe is with saw sits, usually longitudinally, sometimes transversal. Corrugated pipes generally have small opening preferably in the valley of the corrugation. Perforations on the tops of the corrugation make considerable weakness in the pipes.

A new development in material of drainage is the plastic strips. A plastic strip equal in thickness of smooth plastic pipe is carried on roll, by means of an apparatus as the drainage machine, shaped to a rigid pipe by punches in the overlap. These punches also serve for water entry. Additional opening can also be made in the strip. The plastic strip pipes are cheaper to transport than the ready made plastic pipes and these may be appropriate in area where saving in transport costs can be considerable. The plastic strip can be installed with a normal trench excavating drainage machine.

In the drainage functions, there is not much differences between the various types of pipes currently being used. The ultimate choice will be dictated by economics and working efficiencies. The advantage of plastic over clay and concrete pipes is that these are considerably lighter weight and their production in longer lengths involved lower cost, thus cheaper in installation.

The pipe drains may be classified as:

- Field drains or field laterals, usually parallel drains, whose functions is to control GW depth.
- Collector drains whose function is to collect water from the field drains and to transport it to the main drains.
- Main drains, whose function is to transport the water out of the area.

The water table is usually curved, its elevation being highest midway between the drain. The factors which influence the height of the water table are:

(a) precipitation and other sources of recharge

(b) evaporation and other sources of discharge

(c) soil properties

(d) depth and spacing of the drains

(e) cross-sectional area of the drains

(f) water level in the drains

Thus, for the design of a pipe drainage system the following elements must be determined.

- Spacing and depth of laterals; primary factors n the control of GWT.
- Diameter and gradients of lateral and collector pipes; ensure the proper evacuation of the water taken up by the laterals.
- Layouts (alignment) of laterals and collectors.

In Rawatsar there is an absence of natural drainage as there is no perennial river. On the other hand there is a layer of hardpan in the soil profile which makes the soil impervious. If the above techniques as suggested by WAPCOS in 1992 are applied, drainage condition in Rawatsar can be improved to a large extent.

Chapter III

Waterlogging and Salinisation

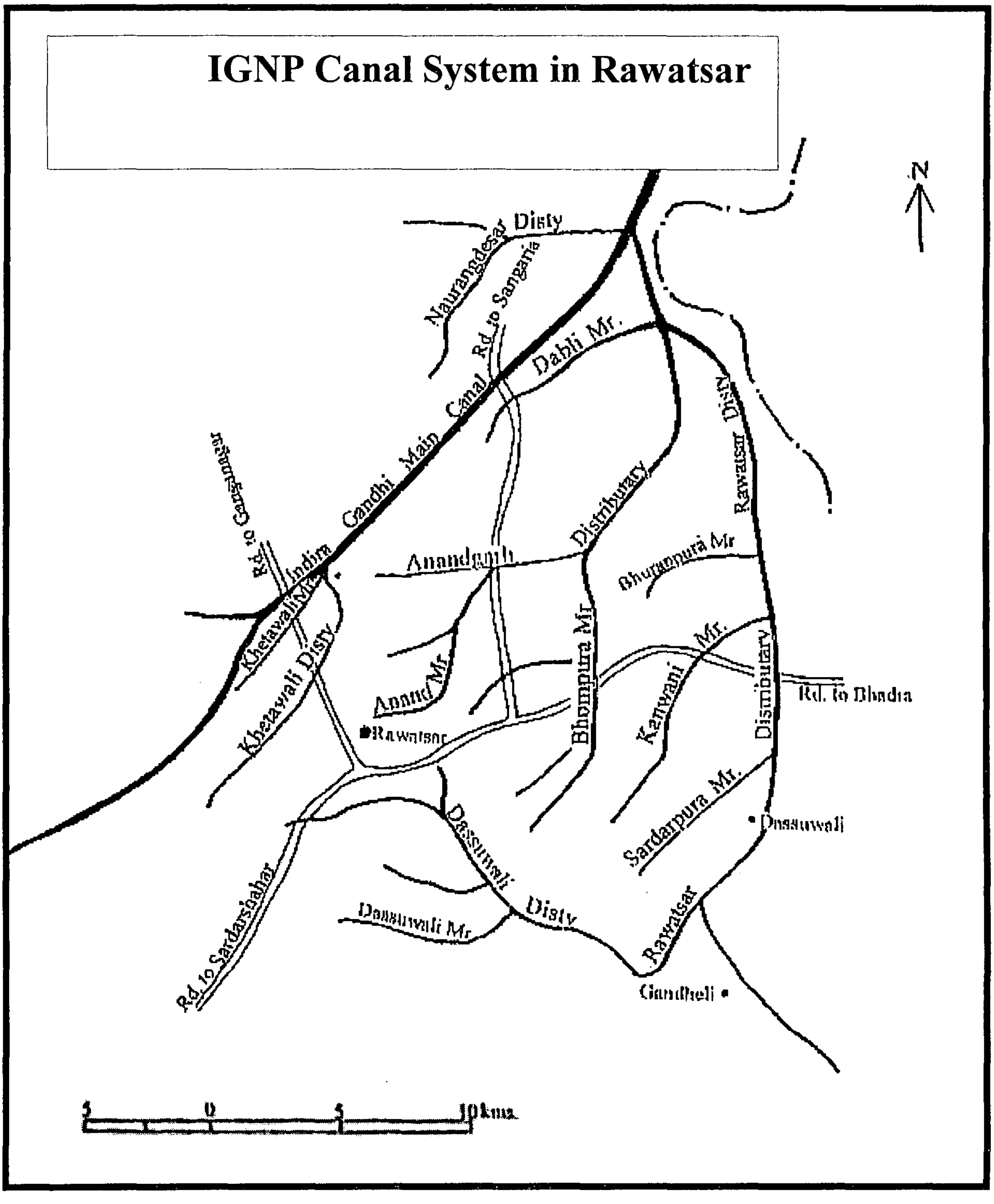
3.1 Concept of Waterlogging

The problem of waterlogging arises from the rapid increase in the ground water table and saturations of soil profile, and thereby inhibiting the plant growth. The problem of waterlogging was first initiated in Stage I and was more pronounced in this Stage. The areas adjoining Ganganagar and Hanumangarh were severely effected. Rawatsar is situated in Hanumangarh district which also is situated in Stage I. (figure 3.1)

According to a special committee of the Central Board of Irrigation "an area is said to be waterlogged when the water rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of air, decline in level of oxygen and increase in the level of Carbon-dioxide" (Ministry of Agri and Irrigation, Government of India, 1976).

There is a difference of opinion about the depth of ground water which may have negative effect on plant growth. It depends on a variety of factors, including the type of crop, length of root, quality of ground water, pH value of soil in the profile. The actual depth of water table, when it starts adversely affecting the yield of the crops, may vary from 0 to rice to about 1.5 m for other crops.

Figure 3.1



Adapted from: CAD, Ground Water Board, Bikaner

According to a report of the United States Government "Land and Water Development in Indus Plain", water table is likely to affect the crop production if it comes up to 5 or 6 metres. A water table less than two to as much as five metres from the surface may be interpereted as indicative of waterlogging. (Stepperdson, 1981).

3.2 Causes for Waterlogging

The rapid increase of salinity and waterlogging problems in canal command areas is posing a serious threat to the agricultural production. The presence of excess water and salts in subsurface soil layers not only cause severe physiographic crop damage, but also increase cost per unit of crop production and decrease the farm income.

The defective water management technique causes steep rise in the groundwater level. Sometimes water rises to such an extent that the root zone of the crop get saturated. This causes decrease in the level of oxygen and increase in the level of CO_2; resulting into plant death. Improper use of irrigation water and improper drainage facilities cause waterlogging and soil salinity hazards.

The important causes of waterlogging are as follows:

1. **Absence of Natural Sub-drainage:** In Rawatsar command area there is a total absence of any natural outlet, as a result water is locked in the depressions. Stagnant water in these depressions results in recharging ground water in near

by area. This raises the groundwater level to pose the problem of waterlogging in this area.

2. **Hydrological Barrier at Shallow Depth:** Non-porous barrier layer exists beneath the surface in depth range of 0-20 metres which impedes percolation of excess water due to clay and Kankar material, causing the rise of water table.

3. **Overuse of Irrigation Water:** Farmers, since the introduction of irrigation, applied high water allowance in IGNP State I, at the rate of 0.37 cusecs per 1,000 hectare (WAPCOS – 1992). There was uncontrolled supply from direct outlets on the main canal which cannot be run in rotation like the branches, distributaries, minors and sub minors channels. Increase in number of waterings was done as recommended by Agriculture Extension and Research Wing of CAD IGNP. Non use of sprinkle and drip systems of irrigation and lack of field drain or land shaping highlighted the problem of waterlogging. (CAD Report – 1990).

4. **Seepage from Main Canal:** Water is lost through seepage from the canal network which causes waterlogging conditions in areas adjoining the main canal distributaries and minors. It is due to constructional bottlenecks.

5. **Seepage from the Ghaggar:** Number of depressions were constructed to receive the water during rainy season from the Ghaggar Diversion Channel to check the surface flow of the Ghaggar river into Pakistan.

6. **Lack of on farm development:** There is a lack on farm development facilities such as field drain, land shaping, consolidation of land holdings, afforestation, banking, warehouses etc.

7. Unplanned land use and cropping pattern also aggravates the waterlogging and soil salinity problem.

8. Introduction of irrigation without taking into consideration the irrigation capacity of lands and soil profile, and lack of water management strategies and better administration.

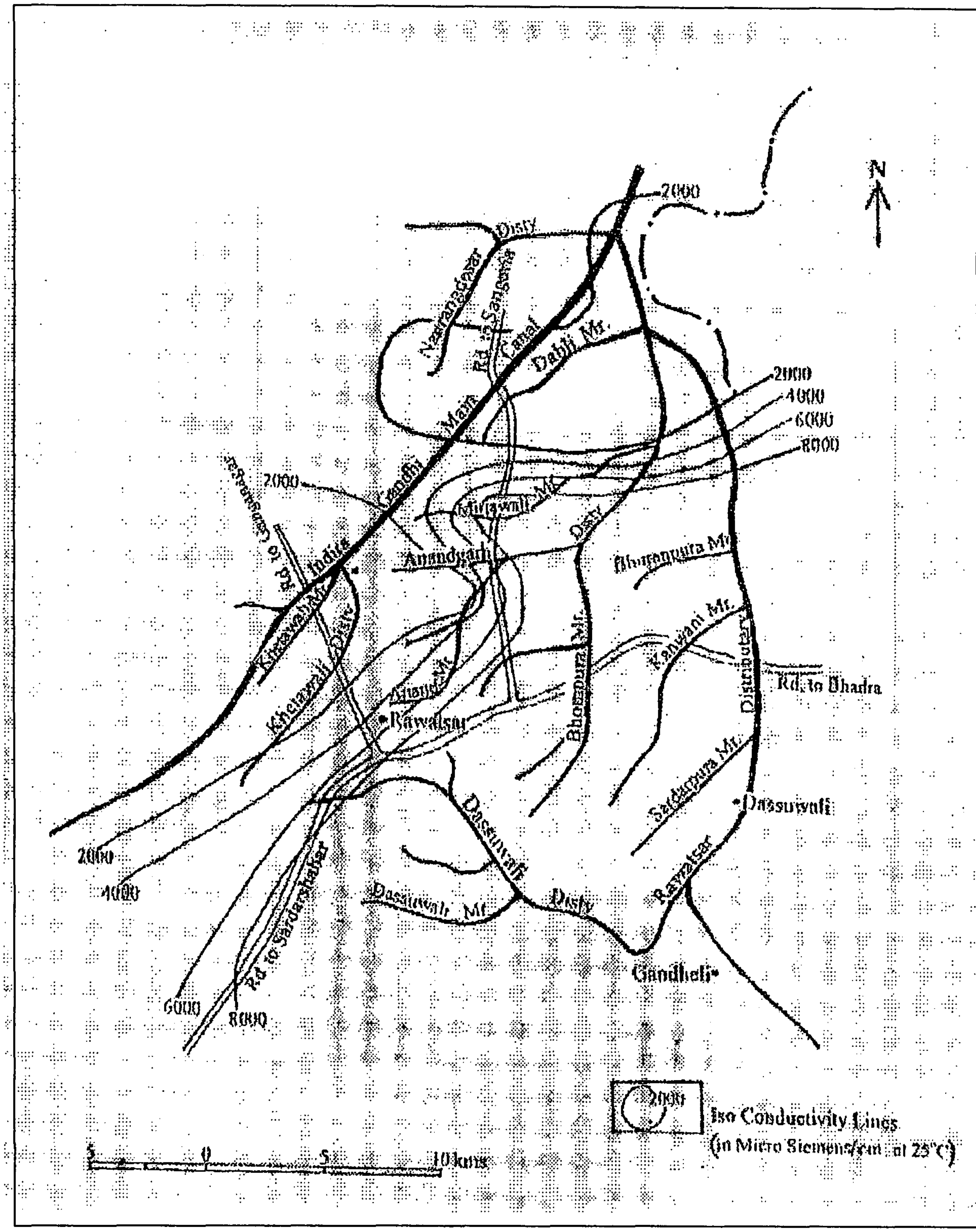
These are the major causes of waterlogging in the Indian Gandhi Command Area. Besides this, local farmer do not adopt sprinklers and drip irrigation techniques and cropping pattern according to the topography and environment of the area. They generally cultivate high water requiring crops.

3.3 Condition of Waterlogging in command areas

Ground water table is rising at an alarming rate in the command area of Stage-I. In Rawatsar block of Hanumangarh district the water table has risen at very fast rate. The increase in pH and EC values was also recorded (figure 3.2). The rise of water table in Rawatsar in 1996 is shown in figure 3.3. In 1970s the rise of water table was about 1.7 metres (CAD, Bikaner). It was mainly due to excessive use of irrigation water initially provided to farmers in the area which was devoid of natural drainage and consisted of hardpan of gypsum layer. The waterlogged and saline areas of Hanumangarh are shown in figure 3.4 and 3.5 The presence of the Ghaggar diversion channel in the vicinity of Rawatsar has also caused the rise in

Figure 3.2

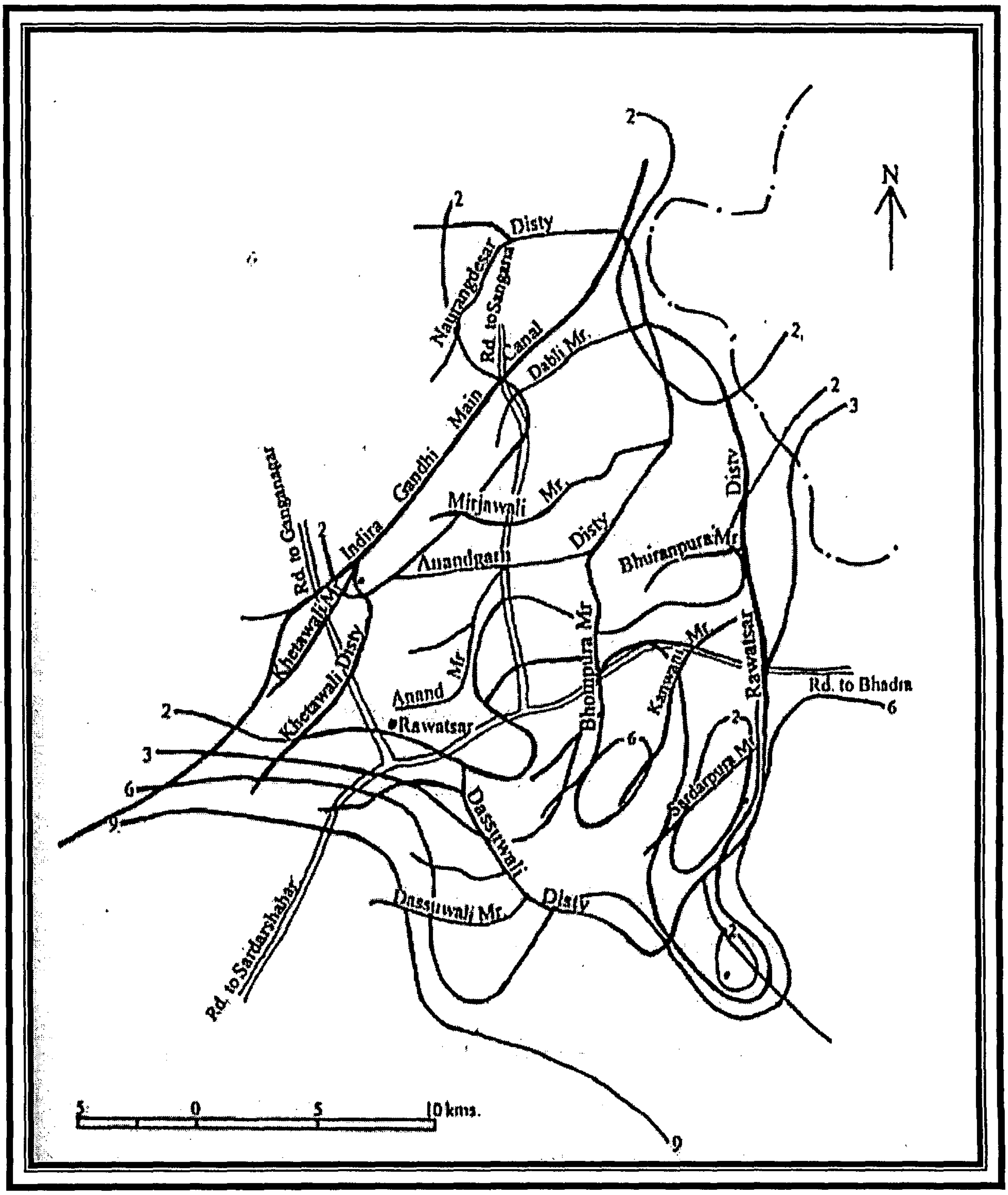
ELECTRICAL CONDUCTIVITY IN RAWATSAR



ADAPTED FROM: C.A.D. GROUND WATER BOARD , BIKANER(1992)

Figure 3.3

RAWATSAR: DEAPTH TO WATER TABLE (mbgl*), 1996



ADAPTED FROM: C.A.D. GROUND WATER BOARD, BIKANER

(mbgl : metre below ground level)*

Figure 3.4

WATERLOGGED AND SALINE AREAS OF HANUMANGARH

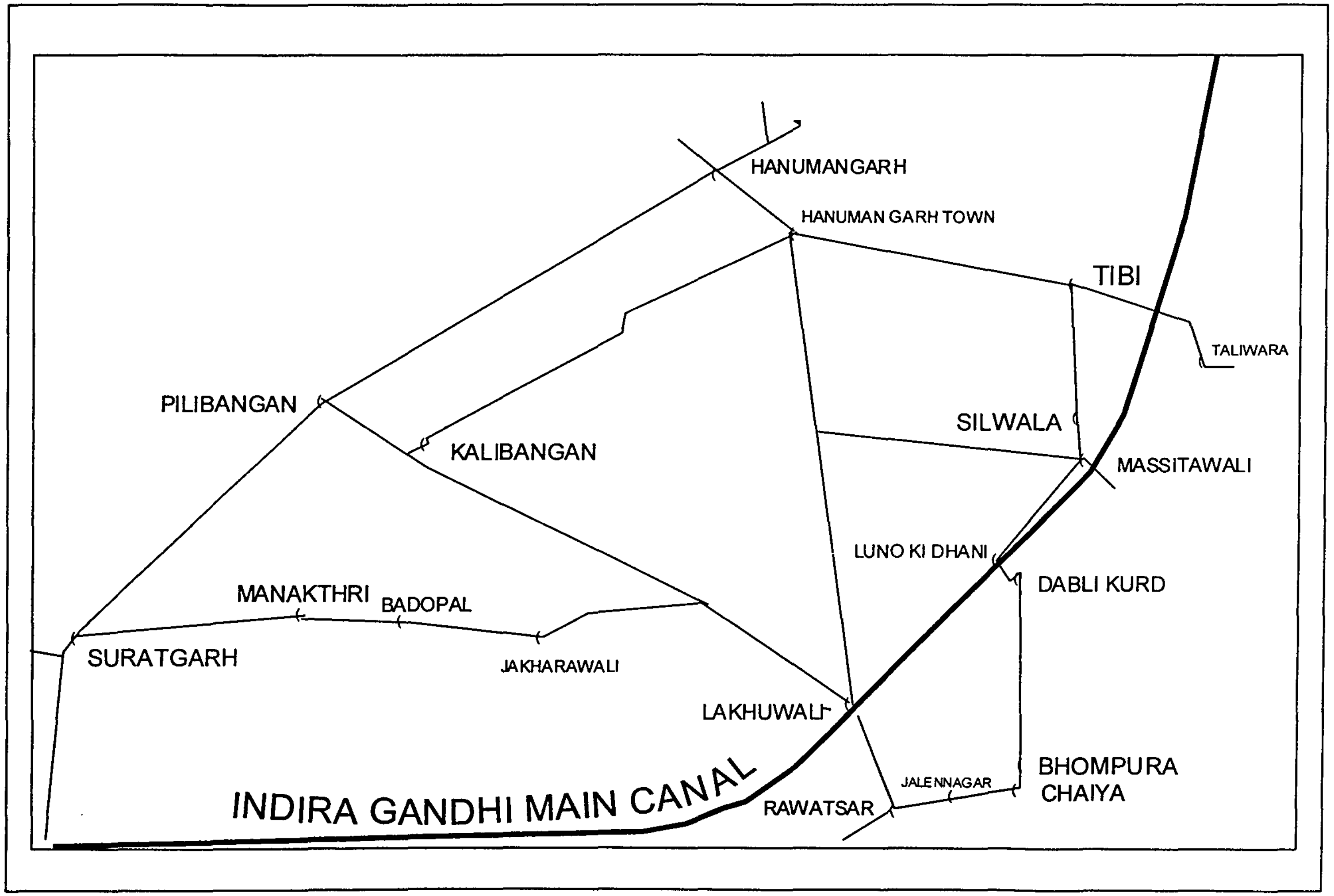
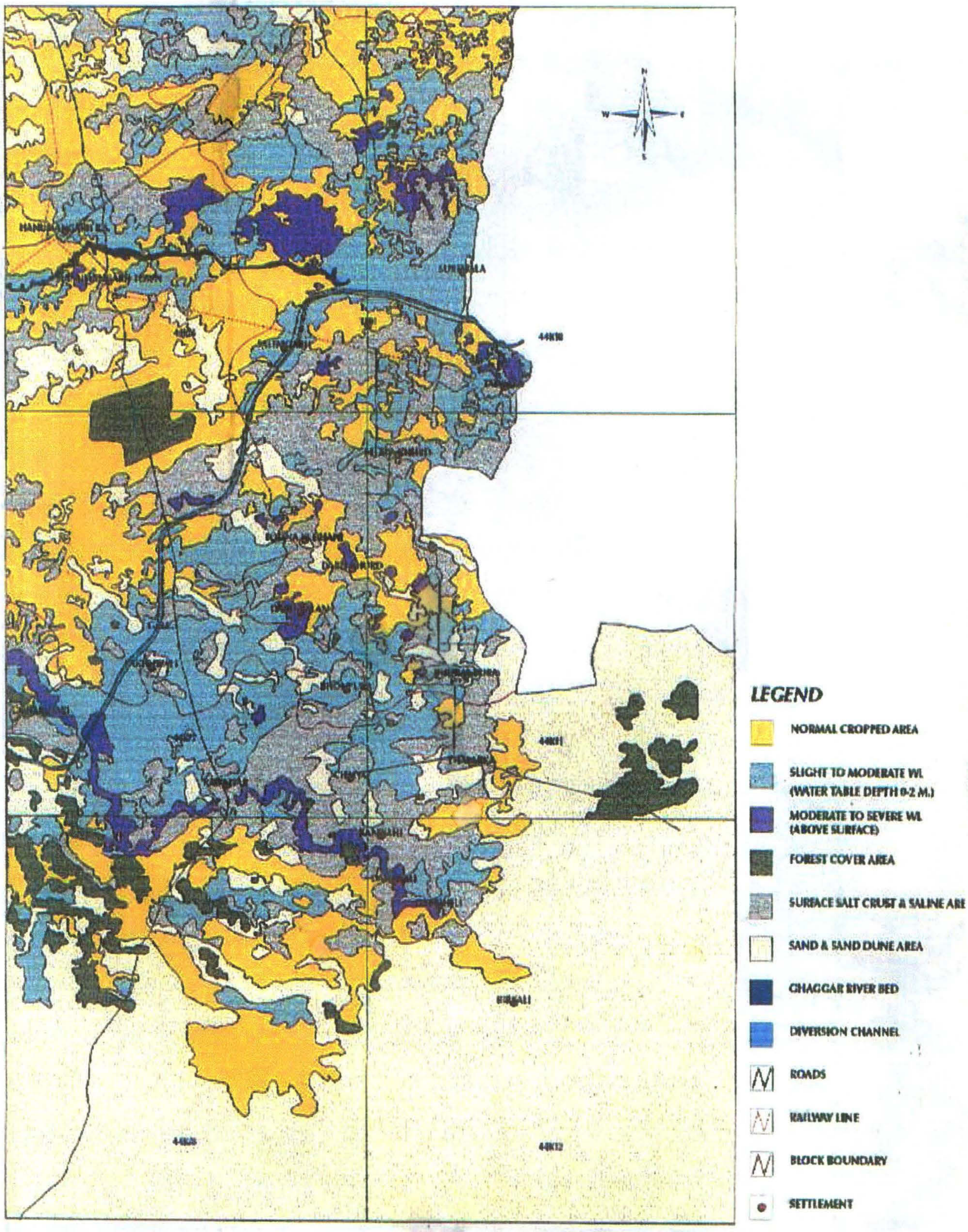


Figure 3.5

WATERLOGGED AND SALT AFFECTED AREAS PART OF HANUMANGARH DISTRICT



Adapted from : Agricultural Research Sub Station (RAU), HANUMANGARH

water table. Discharge in this channel remains high during rainy season, resulting occasional floods in the Ghaggar river. The condition of waterlogging in IGNP command area in 1996-97 (Table 3.1). It shows that severity of the problem is more pronounced in Stage-I. (Table 3.2 and figure 3.6 to 3.9) shows the rise in ground water level from 1995 to 1998 in Rawatsar area of Hanumangarh. The negative effect of waterlogging in Rawatsar, Dassuwali and 2SPM are shown in plate 3.1 to 3.7. In Dassuwali village, the condition is very severe. By the end of 1998 complete area had been waterlogged. This condition might arise within few years in 2S PM where rise in ground water table (GWT) was 0.34 metre by June, 1998. In rest of the villages as Gandheli, 2SPM, 3BPM, 2DWN water table has risen consistently, and the gap between ground surface and water table is reducing continuously.

Realising the seriousness of the problem the Ground Water Department has launched a project, "monitoring of water table" since 1980-81 with financial assistance of canal authorities under CAD programme in Stage-I of the Indira Gandhi Canal Command Area and Ghaggar basin in Ganganagar district. This project covers an area about 8,000 km^2. According to the status report of the project, annual rise in ground water table varies from 0.20 metres to 2 metres. Average rise in water table is 0.8 metres in this region.

According to this report, in the Indian Gandhi Canal Command area, Stage I depth of groundwater table in IMBD of Hanumangarh district, at the time of introduction of irrigation scheme i.e. in 1962 was 38 metres. By the end of 1990 it was mere 4.5 metre. The annual rate of change recorded works out to be

Table 3.1

I.G.N.P Command Area
Conditions of waterlogging (1996-97)

S.No.	Categories of waterlogging	Water level (mbgl)	Area (in Hec)	
			Stage – 1	Stage - 11
1	Potentially sensitive area	1.5-6.0	297820	17303
2	Critical area	1.0-1.5	24140	3610
3	Waterlogged area	0.0-1.0	17220	1243

Source: CAD, Ground Water Board, Bikaner

Table 3.2

Rawatsar Area
Rise of Ground Water Level (mbgl*) (1995 - 98)

Area	YEARS												
	1995		1996				1997				1998		
	Sep	Dec	Mar	June	Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun	Sep
Dassuwali	0.38	0.31	0.25	-	0.30	-	-	0.42	0.21	0.08	Waterlogged		
2SPM	1.74	1.53	1.55	1.46	1.32	1.27	1.12	0.89	0.83	0.83	0.69	0.34	0.73
Gandheli	5.28	5.01	4.79	4.71	4.52	4.43	4.37	4.29	4.20	4.20	4.85	3.95	3.90
4AM	5.32	5.11	4.97	-	-	-	-	-	-	-	-	-	2.53
3BPM	2.67	2.51	2.04	2.30	2.30	2.31	2.39	2.39	2.41	2.41	1.91	1.57	2.25
2DWN	4.06	3.99	3.70	3.62	3.62	3.48	3.01	3.01	2.95	2.95	1.93	2.55	2.44

* mbgl – meter below ground level
Source: CAD, Ground Water Board, Bikaner

Figure 3.6

RISE OF GROUND WATER LEVEL IN 2SPM
1995-98

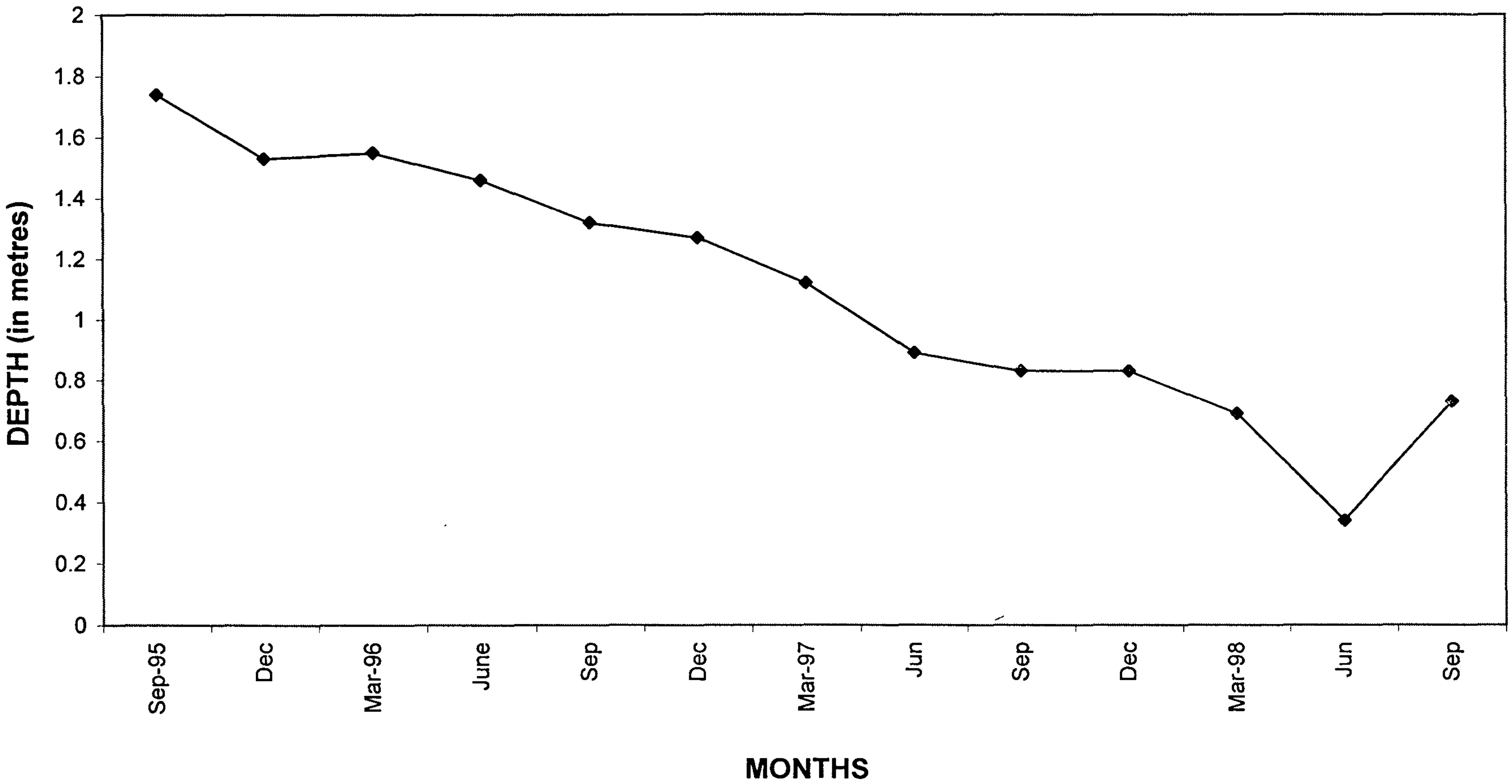


Figure 3.7

RISE OF GROUND WATER LEVEL IN GANDHELI
1995-98

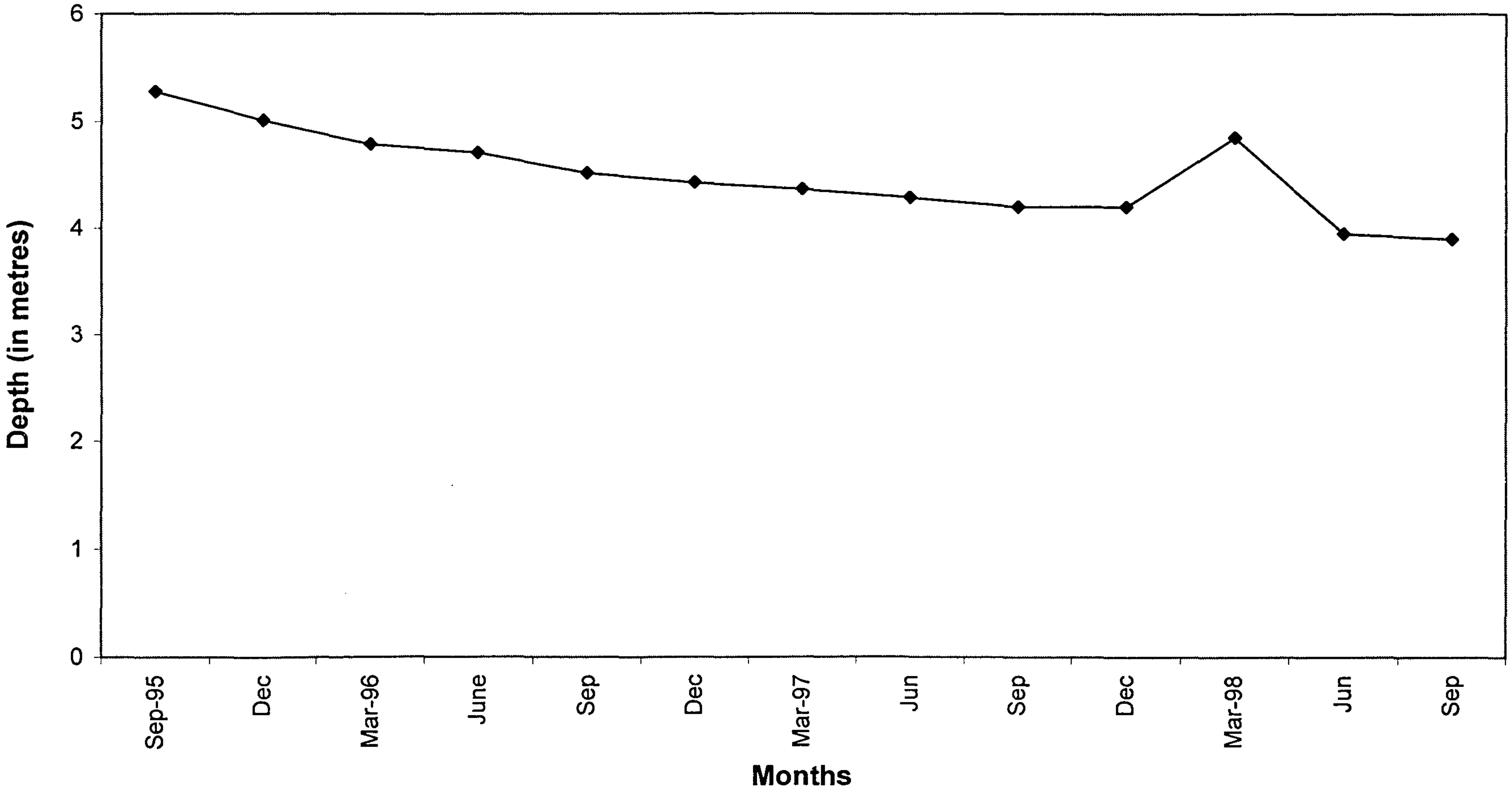


Figure 3.8

RISE OF GROUND WATER LEVEL IN 3BPM
1995-98

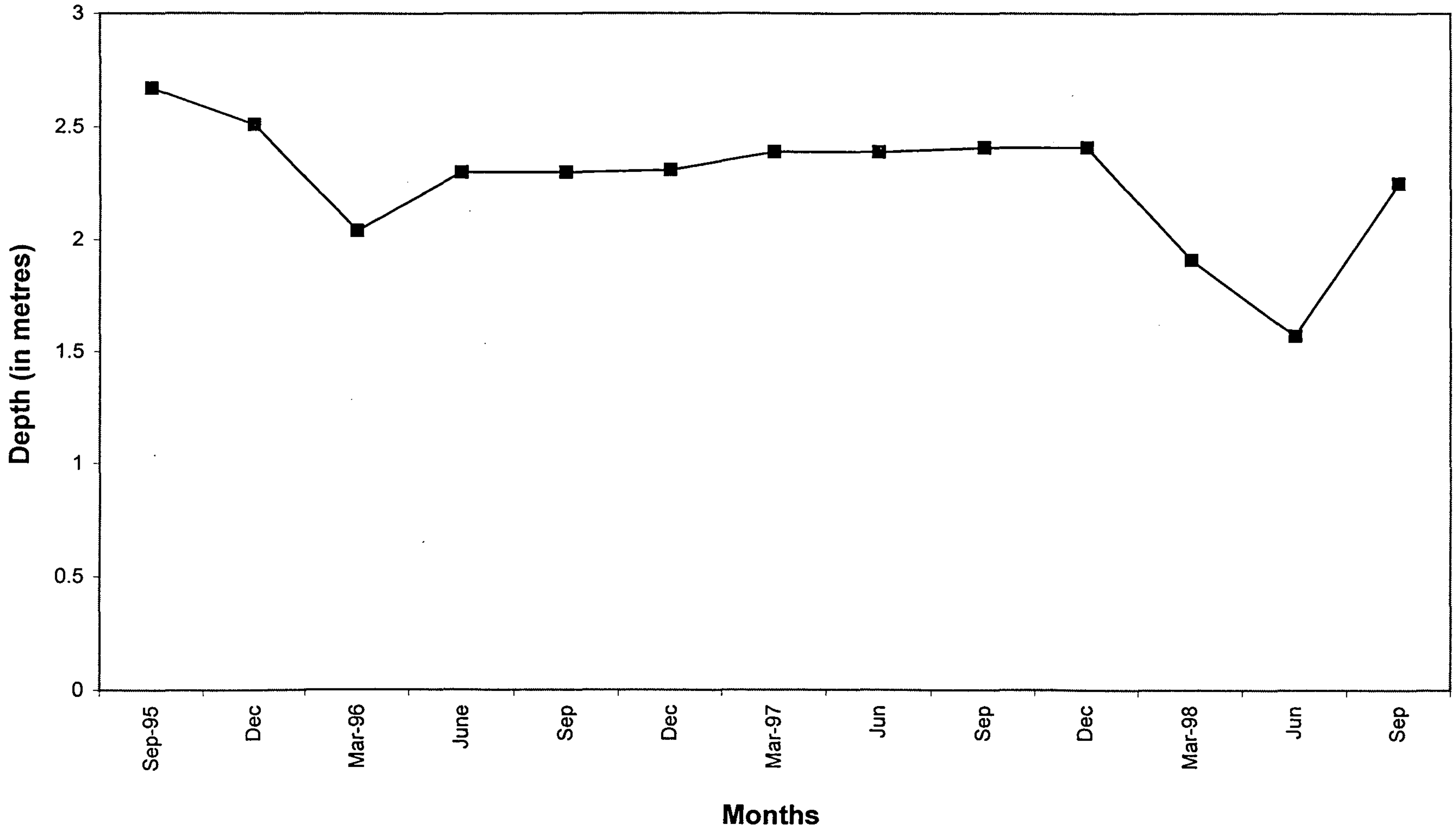


Figure 3.9

RISE OF GROUND WATER LEVEL IN 2DWN
1995-98

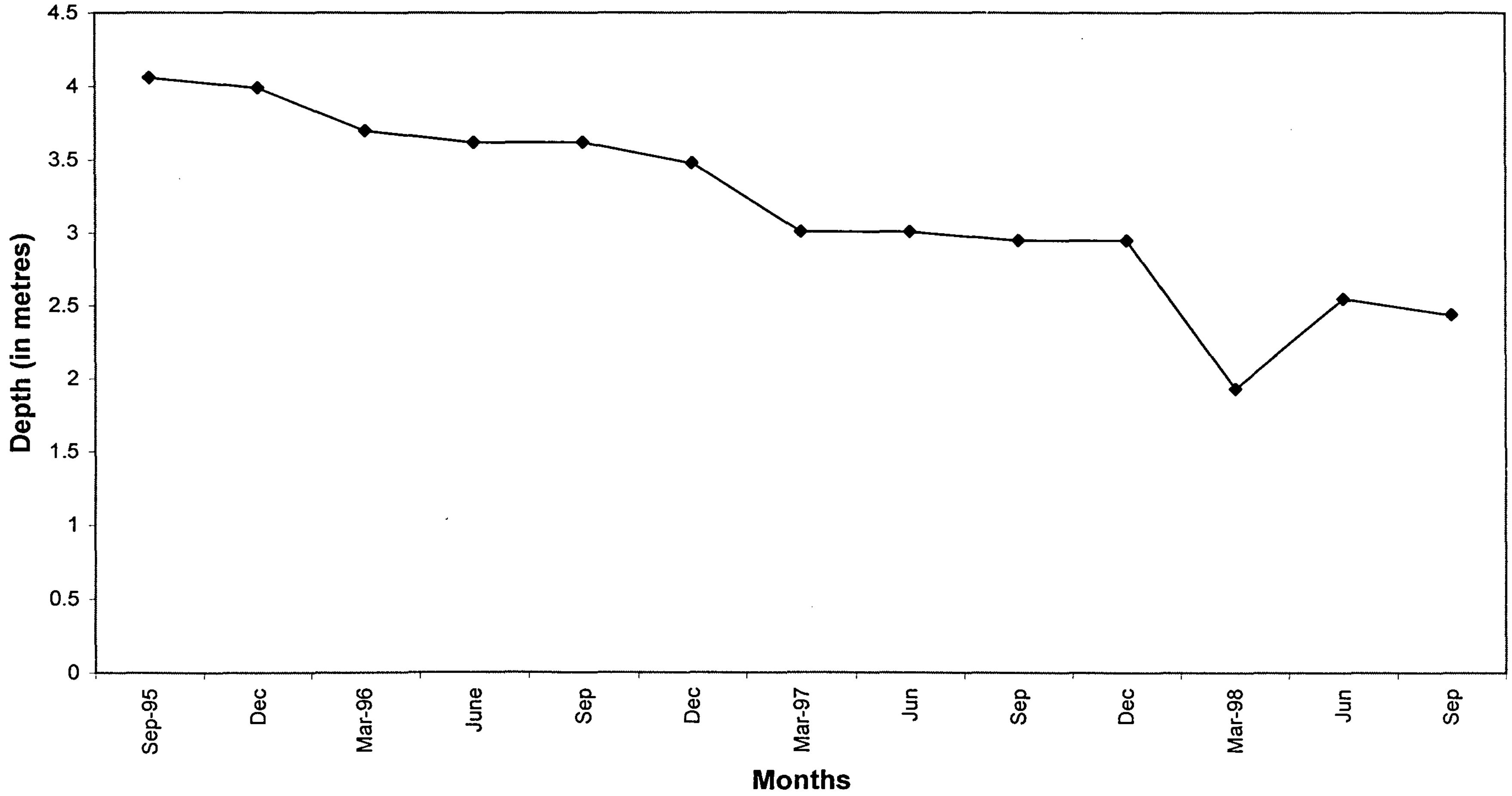


Plate 3.1 Dassuwali: The picture shows flooded area and loss of vegetation.

Plate 3.2 Dassuwali: The picture shows ruined village, nursary due to waterlogging.

Plate 3.3 Dassuwali: Ruined temple and houses due to waterlogging and salinisation.

Plate 3.4 Rawatsar: Residential area affected due to waterlogging and salinisation.

Plate 3.5 Rawatsar: Sub merged part of RICCO warehouse area about 3 feet water has accumulated here. [redacted].

Plate 3.6 Rawatsar: Growth of *ERA* grass (wildspecies) in the salty water, inside the open drain. Plantation of trees like 'Poplar' is recommended in order to stop silting into drain (Bio-drainage).

Plate 3.7 2SPM: Waterlogged and endangered area.
This field is at higher level than the waterlogged field. This is used for paddy cultivation. Some patches of salt are seen on it. Leaching is required before cultivation in such cases.

1.2 metres. By the end of year 2000 depth of groundwater level has been less than 2 metres. The critical areas are situated last of Rawatsar near the Sardarpura Minor at Gandheli and Dassuwali. Moreover, new critical areas have emerged in nearby Rawatsar as 4 AM and 2 DWN in the last decades. If the present rise in water table is not arrested immediately, then about 70 percent area of the Rawatsar Tehsil would come under critical area by end of 2002.

Sharp rise in water table in this region is the result of excessive deep water percolation because of intensive irrigation in the command area of the Indira Gandhi Canal and other canals, and seepage from the floods of the Ghaggar. The inter-dunal depressions lying south and south-west of Suratgarh town, to the west of Rawatsar Tehsil have been converted into artificial barrage and taken to prevent flooding by the Ghaggar on the cultivated land.

The quality of water in waterlogged areas is also poor. Water samples analysed recently from the effected areas show a clear picture of the present scenario which is shown in Table 3.3.

Table 3.3
Analysis of water samples in Rawatsar

June 2002

S.No.	**Sample Area in Rawatsar**	**EC (ds/m)**	**pH**
1.	14 km main drain standing	4.1	8.9
2.	Rawatsar Seepage Main drain 14.5 km	2.8	9.5

Source: Laboratory of Agricultural Research Sub-station Hanumangarh Town (2002).

Table 3.3 suggests that the quality of water is very poor for irrigation purposes. Salt content is high which is indicated by the pH values. The EC is also high. It was 4.1 in the main drain area and about 2.8 in seepage areas

Table 3.4 shows the quality of water in waterlogged areas in 1997, 1998 and 1999. pH is nearly 8 in 1997 and 1998 in important affected areas of Rawatsar. The EC and pH values for the year 1997 is shown in figure 3.10 and 3.11. In 2S-PM water was 10 in 1997, which shows it to be highly alkaline. Although in 1998, with several reclamation measures taken up by the government, alkmanity reduced to a small percentage, yet it was not enough to completely get rid of salts from the soil.

3.4 Concept and Causes of Salinisation

The process of soil salinisation is another adverse effect induced by irrigation on physical environment. It is generally associated with the rise in the groundwater table. Soluble salts accumulate in the soil and form hardpan which is impervious, as a result, water is unable to percolate. Saline soils are formed from the accumulation of water soluble salts or exchange sodium in the absorbing soil complex (Zonn 1986). The soluble salts that accumulate in the soil consist principally of cautions of calcium, magnesium, sodium, chloride and sulphates ions. Potassium, bicarbonates, and nitrate ions occur in smaller quantities. Borates occasionally occur in small amounts but receive considerable attention because of their exceptionally high toxicity to plants (Thorne and Seatz, 1955).

Table 3.4

Rawatsar
Water Quality in Water logged Area (1997-99)

AREA	Years					
	1997		1998		1999	
	EC	PH	EC	PH	EC	PH
Dassuwali	550	8.0	-	-	-	-
2SPM	500	10.0	690	8.2	360	6.9
Gandheli	10700	8.0	4000	8.2	4100	8.2
4AM	5000	8.0	4100	8.0	27500	9.2
3BPM	2400	8.0	2100	8.2	-	-
2DWM	1530	8.0	1900	8.2	1900	8.0

Source: C.A.D., Ground Water Board, Bikaner

Figure 3.10

RAWATSAR
EKECTRICAL CONDUCTIVITY IN WATERLOGGED AREA
1997

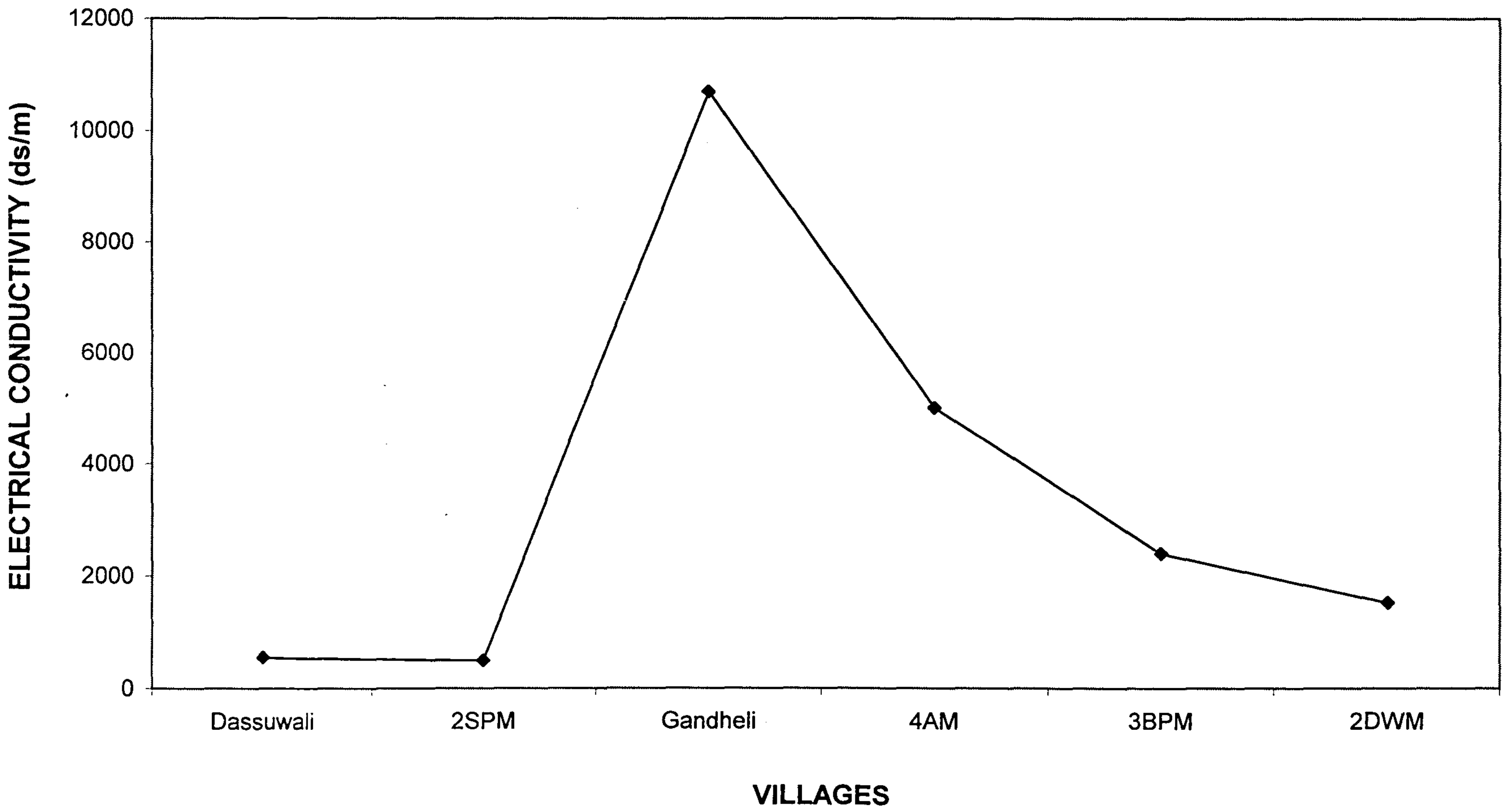
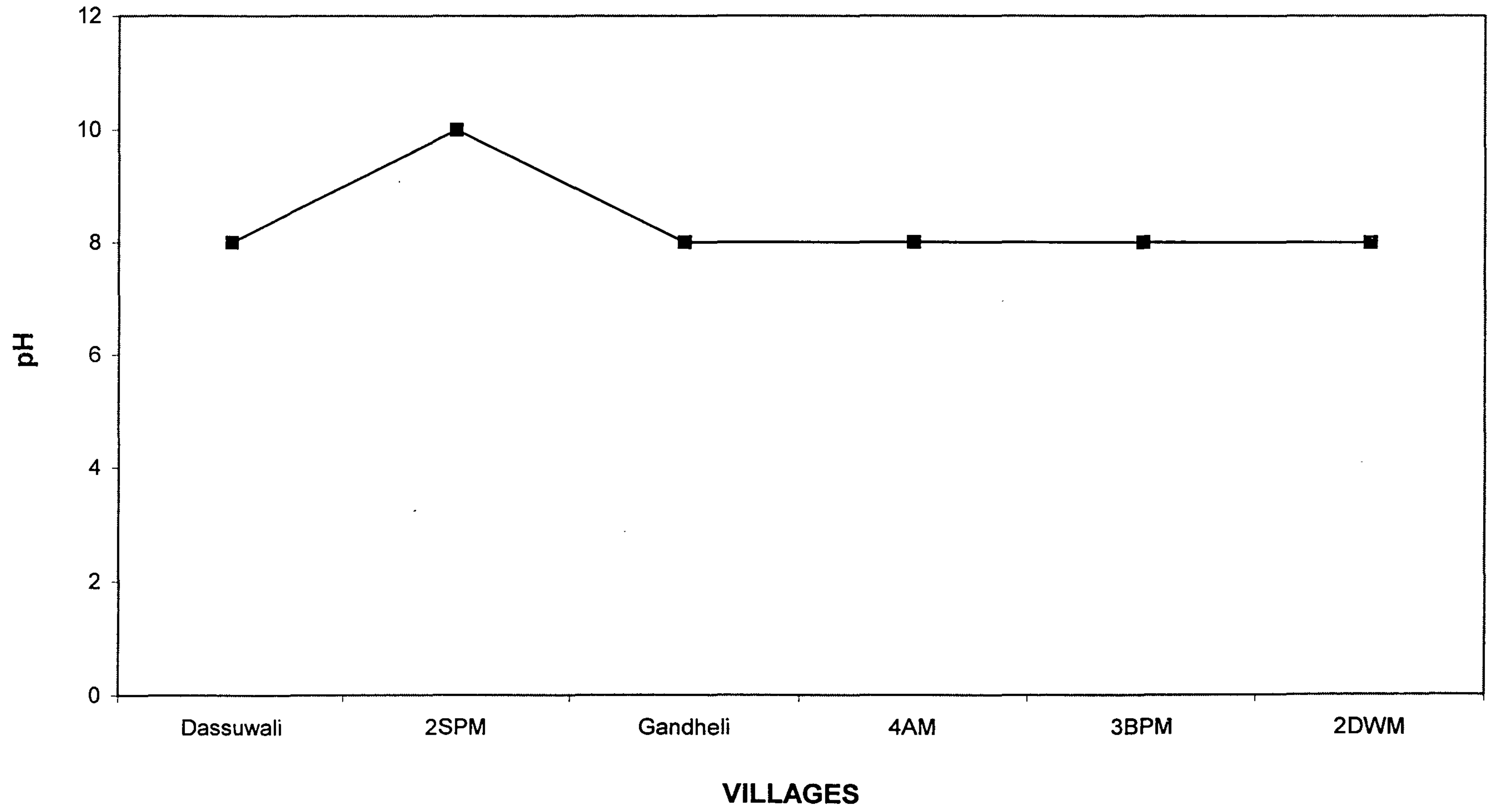


Figure 3.11

RAWTSAR
pH VALUES IN WATER LOGGED AREA
1997



As the water table rises the salts get accumulated near the surface. During sunshine when evaporation takes place, these salts get accumulated near the surface. Water reaches to the ground surface through capillary action. Toxic materials get concentrated near the root zones which hampers the growth of plant.

When irrigation is carried out in the areas having poor water quality i.e. saline in nature, having high pH, soil salinisation occurs. Owing to water and dissolved salts in a waterlogged soil, salt may accumulate on the soil surface in toxic amounts even though the salt content of the irrigation water is low. The process of soil salinisation and alkalinisation is similar but alkali soils have very high concentration of sodium salts by virtue of which soil structure become unstable and dispersion of clay particals occur. This results in plugging of soil pores and reducing the permeability of soil profile (Dhegens, 1983).

The problem of soil salinity and alkalinity is generally associated with waterlogging and strong salt concentration. The pH value of the soil samples indicate that soil salinity is very high in irrigated areas.

Table 3.5 shows the present status of soil contents in some important areas in Rawatsar Tehsil of Hanumangarh District. The salinity hazard status of the soil could be easily seen in Table 3.5.

Table 3.5
Salinity Hazard Status of soils

(June-2002)

S.No.	Sample Area of Rawatsar	Moisture %	EC (ds/m)	pH
1.	1 KM	4.70	80.0	8.6
2.	2 NGM	7.6	5.6	9.6
3.	3 KKM	8.67	7.6	9.0
4.	11 KM	13.54	8.8	8.9
5.	8 KM	3.46	8.8	9.0

Source: Laboratory of Agricultural Research Sub Station, Hanumangarh Town. (2002).

Table 3.5 also shows that the percentage of soil samples having pH between 8.5–9.0 is high. This is because of the presence of strong salt regime and shallow *Kankar Pan* in this region. It is suggested after the field observation that these soils require reclamation practices before Kharif sowing, otherwise cultivation would suffer under field condition, saline soil can be recognised by the patchy growth of crops and often by the presence of white crust of salts plate The extent and frequency of bare white spots is normally an indication of the concentration of salts in the soil plate.

3.5 Measures to control waterlogging and salinisation

A. Abotic Measures: Salinity has been an important historical factor and has influenced the life span of agricultural system. A significantly large areas of the Indian subcontinent have been rendered unproductive by salt accumulation due to management of irrigation system.

Most of the traditional agricultural crops on majority of such soils either fail to grow or would give very poor return unless substantial investment is made on the reclamation of these lands. Sometimes, the problem of secondary salinisation becomes more serious, since it usually represents loss of productive agricultural lands. The vast occurrence of soil salinity and alkalinity is a serious factor adversely affecting crop production and economic utilisation of land resources. In view of growing demand for food to support ever growing population, it has become important to use every centimeter of the land according to its capability. In an attempt towards reaching this objective, utilisation of salt affected soils and barren lands have been given priority. The salt affected soils are problematic soils because of their high salt content, with little scope for redemption.

These soils can be reclaimed provided there is an adequate arrangement for drainage. If the provision of adequate drainage is economically and technically not feasible, the soils can be put to other alternative uses. However, as far as possible, attempt can be made to reclaim them. A technological improvement to cope with hazards seem to be nearly improbable in the near future. Scientists are more concerned with the viable biological approach viz. breeding tolerant varieties of traditional crops or searching for the crops, which are tolerant and remunerative.

Whether it is a reclamation of saline soil or alkali soil, arrangement for leaching and drainage has to be made. Without adequate drainage there is hardly any possibility for permanent relief in case of salt affected soils. Reclamation of saline soils should result in the reduction of soil salinity to a specified level and also waterlogging caused by irrigation. The removal of soluble salts can be done by following three methods.

(a) Scrapping is the removal of salts from the surface by mechanical means. This can be followed only where there is a serious problem of salinity having encrustation on the surface. This procedure can be followed on a very small scale because it involves a huge expenditure. Moreover, all within the profile and not removed.

(b) Flushing is the surface washing out of salts with runoff water which is collected at the sloppy end of the fields. Flushing is occasionally restored to supplement leaching in the reclamation process. This is particularly useful when the permeability of the soil is very low and there is some hard layer in the soil profile. The major drawback with the flushing is that it is unable to remove salts from the inner depth of the soil. Secondly, enough slope gradient in the field is required and there must be a source where the salts of the field can be disposed off.

B. Leaching (Plate 3.8 and 3.9) is the method of solubilising and transporting the soluble salts by downward movement of water through the soil. Leaching is an integral part of the reclamation process. Whether the soil is saline or sodic, leaching is a must for their reclamation. In case of saline soil, leaching is done directly after levelling and bunding the field. Leaching is also very effective in the reclamation of saline soils. Before going for leaching, bunding and leveling of the area in question is done. Then deep ploughing with a tractor implement is done. If the soil is very heavy, having low permeability, then it could be advisable to mix sand. It would be better if the electrical conductivity of the soil is monitored from time to time to know the progress of salt removal.

C. Cultural practices can often be modified to suit the adverse soil conditions for obtaining optimum crop yield. Evidence from the researches being carried out in recent past reveal that some medicinal and aromatic plants are well suited to the saline and alkali soils than the traditional agricultural crops because of their more tolerant/ameliorative effect and high benefit cost ratio.

From the preliminary studies conducted at the Central Institute of Medicinal and Aromatic Plants, Lucknow; Regional Research Laboratories and CSIR

Plate 3.8 Rawatsar: Field near Rawatsar where white patches due to accumulation of salts are visible.

Plate 3.9 Rawatsar: Field after leaching process to get rid of salinity problem.
Though leaching is done on the field,[redacted] but it is not much successful.

sponsored research projects, it has been observed that some aromatic grasses and medicinal plants are tolerant to soil salinity with minimum or no efforts on reclamation. It shows no adverse effect on the quality of the produce. Most of these crops as some species of rice, wheat, barley etc. have been found to tolerate higher salinity level as compared to arable agricultural crops such as gram, groundnut, etc.

D. Green manuring: Green measuring is the practice of turning into the soil undercomposed green plant material for improving the physical condition of the soil. The incorporation of green manure crop provides a large amount of organic matter, improves soils' physical condition besides increasing supply of essential plant nutrients. Compared gypsum and manuring for reclamation of saline alkali soils and found increase in permeability, nitrogen and organic carbon content of soil with green manuring (Aggarwal and Pandey, 1971).

Similarly, common field crops in different categories were classified according to their alkali tolerance (Abrol and Bhumbla, 1971).

Relative tolerance of crops of salts:

(a) Salt tolerant crops: Dhaincha, sugarcane, paddy, barley, tobacco, cotton, teramira, babbar grass, sugarbeet, spinach, date-palm, phalsa.

(b) Semi-tolerant crops: Rice, wheat, oats, jowar, maize, castor, turnip, senji, metha, banseem, cowpeas, tomato, cabbage, pumpkin, cucumber, bitter gowrd, grapes, sig, guava, mango, palm and citrus.

Santosh Rathore (2000) observed that barley was the most salt tolerant crop. Followed wheat. If the proper package of practices is followed, the barren alkali lands can be utilised to the benefit of farmers and a precious resource can be preserved and utilised for the welfare of human beings.

The research work done in Indian and abroad has generated enough data to prove that salt-affected soils are no more unproductive. These soils could be put to productive use but choice of crops, their varieties and use of different agro techniques in such soils are of paramount importance.

Chapter IV

Land Use and Agriculture

Land Use refers to the classification of land according to its quality for a particular purpose. The total geographical area of Rawatsar is 1,87,519 hectare. The land use pattern in Rawatsar is shown in the Table 4.1.

4.1 Land use in Rawatsar

(a) Forest

The available data given in table 4.1 (Figure 4.1) reveals that area under forest has increased from 63 hectare in 1986-87 to 211 hectare on 1998-99. By the end of 2000, area under forest was 275 hectare. It has increased from 0.033% in 1986-87 to 0.112% i.e. less than 1% an increase of 0.08%. This is not because of the irrigation expansion, but the CAD programme which is responsible for afforestation. Afforestation and sand dunes stabilization is particularly emphasised in the canal command area. When the afforestation programme was started, emphasis was given to plant Eucalyptus trees but since it made the land barren; it was decided to plant another species of trees, named 'Poplar'. After the problem of waterlogging and soil salinisation rose, it was decided to construct open drain called locally as 'sem-nala'. Trees were planted on both side of the open drain which represented biodrainage. This helped to increase forest cover in Rawatsar Tehsil.

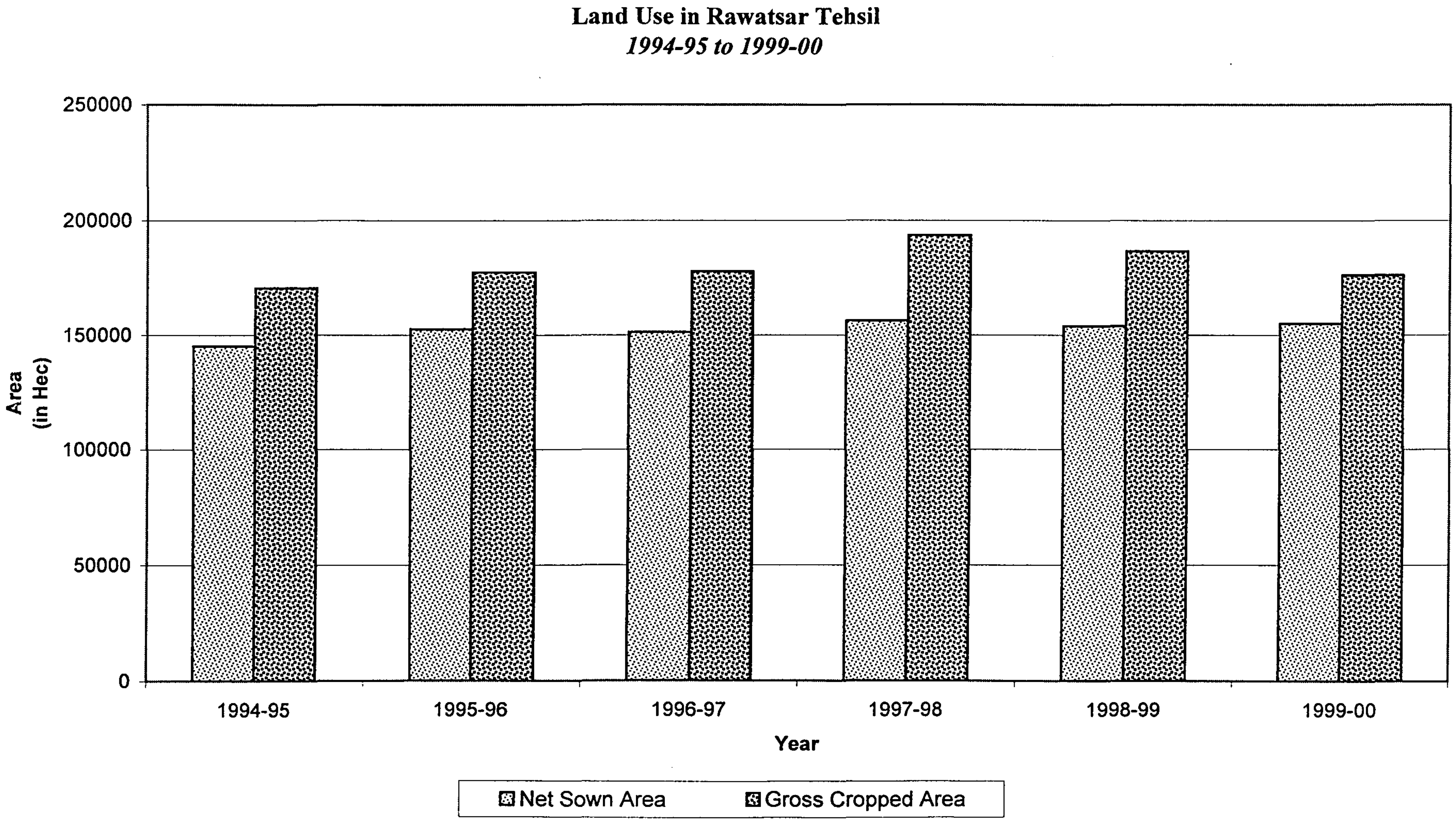
Table 4.1

Land Use in Rawatsar Tehsil (in hectares)

Year	Total Geographical Area	Forest	Land Not suitable for Cultivation		Uncultivable Land		Fallow Land		Net Sown Area	Gross Cropped Area	Land cultivated more than once
			Land used other than cultivation	Usar Land	Gochar & Chargah Land	Banjar Land	Other fallow	Current fallow			
1986-87	187519	63	12143	93	2875	4613	9237	14271	144224	161226	17002
1987-88	187519	63	12289	93	2772	4459	17666	18969	50105	58455	8350
1988-89	Data not available										
1989-90	-do-										
1990-91	-do-										
1991-92	187519	63	9959	379	2713	548	9945	18746	138487	158025	19538
1992-93	187782	63	12143	-	2555	4774	7527	15311	145138	167537	22393
1993-94	187782										
1994-95	187782	63	11599	926	2451	14749	6981	5917	145096	170452	25356
1995-96	187782	63	11464	1181	2313	12022	5118	3081	152540	177279	24739
1996-97	187782	63	11267	927	2784	13382	3414	4763	151182	177754	26572
1997-98	187782	63	10879	1401	2772	4392	6300	5863	156172	193548	37376
1998-99	187782	211	11315	905	2624	6276	6901	5713	153837	186548	32711
1999-00	187782	275	11315	905	2560	4506	5434	7849	154938	176154	21216

Source:- Revenue Records, Rawatsar

Figure 4.1



Land Use in Rawatsar Tehsil
1994-95 to 1999-00
250000
200000
150000
100000
50000
0
Area
(in Hec)
1994-95
1995-96
1996-97
1997-98
1998-99
1999-00
Year
Net Sown Area
Gross Cropped Area

b Barren Land

Barren land is also known as Usar in the command area. Though this category of land accounted for about .05% of the total area, it appears to be increasing during the last two decades (Table 4.1). It was 93 hectare in 1986-87 which increased to 379 hectare in 1991-92, in 1997-98 it was only 141 hectare. The main cause of increase in the proportion of barren land with irrigation expansion is salinisation and alkalinization in the areas where Kanker bed formation is very near to land surface or Gypsiferous layer is found. After introduction of various schemes such as leaching, artificial drainage etc the area under barren land has reduced substantially. By the end of 2000 it was 905 hectare which was 0.48% of total area, compared to 0.75% in 1998-99.

c. Land put to Non Agricultural Use

The proportion of Area under this head has slightly come down in Rawatsar Tehsil, from 12,143 hectare in 1992-93, which was 6.4% of total geographical area, to 11,599 hectare in 1994-95, about 6.2% of the total area. In the last decade area under non agricultural use has mostly remained constant i.e., between 11,000 hectare to 11,500 hectare, (6% of the area). By the end of 2000 it was 11,315 hectare. The increase in the proportion of land under this category is attributed to colonisation and establishment of new settlements, and construction of canals and roads.

d. Permanent Pastures and Grazing Land

The area under permanent pasture and grazing has been fluctuating in the last two decades but has remained between 2,500 hectare to 3,000 hectare which is about 1.4% of the total geographical area. The increase within the two decades has been mainly attributed to the development of the cultivable command area.

e. Culturable Wasteland

The area under culturable wasteland consists primarily of unstable and shifting sand dunes which remains uncultivated because of acute deficiency of moisture and severe wind erosion. However, growth of some xerophytic grasses such as 'sewan' and thorny scrubs on this land during rainy season is the mainstay of the livestock of the region. It is evident from Table 4.1 that the area under culturable wasteland has declined in 1980's. It was 4,613 hectare in 1986, and by the end of 1982 it was about 4,459 hectare. This decline may be due to irrigation expansion. With the expansion of canal irrigation, the uneven and duny land is being leveled and brought under cultivation. The engineers, before the construction of canal observed that in Hanumangarh district being relatively plain land, had low proportion of culturable wasteland even before the introduction of irrigation (WAPCSO Report, 1992).

Under Culturable wasteland increased tremendously during the initial irrigation years of 1990. It increased from 14,741 hectare to 13,382 hectare. It was mainly attributed to the problem of waterlogging and soil salinisation in the command area. After the remedial measures were undertaken to combat this problem, the area under culturable wasteland declined from 13,382 hectare in 1996-97 to 4,352 hectare in 1997-98. It was 2.3% of the total geographical area. Culturable wasteland remained only 4,506 hectare by the end of year 2000.

f. Fallow Land

Under this type of land use, land is left uncultivated for a period of less than 5 years in order to regain its fertility. If any cultivated land is left without cultivation upto one year, it is termed as "current fallow". If the duration of fallow exceeds one year but is less than five years, it is termed as "other than current fallow". But under rainfed conditions, land under plough is also left uncultivated due to inadequate rainfall in the Western Rajasthan. Moreover, farmers in this region also leave piece of land uncultivated for using it as grazing land.

The area under current fallow has decreased in the last two decades. In 1986-87 the current fallow was 14,271 hectare which increased to about 15,311 hectare. From 1990 onwards the area under current fallow has declined from 5,917 hectare in 1994-95 to 5,713 hectare in 1998-99.

On the other hand, land under other than current fallow has declined from 9,237 hectare in 1986-87, to 7,527 hectare in 1992-93. After 1990's, up to 2000, the area under other than current fallow category has been almost constant between 5,000 hectare to 6,000 hectare which is about 2.9% of the total area.

g. Net Area Sown and Gross Area Sown

Net area sown has remained almost stagnant about 79% of total area. It was 1,44,224 hectare in 1986, and about 1,54,938 hectare by the end of year 2000. Net sown area was 50,105 in 1987-88 which was 27% of the total area. Sharp decline in net sown area in 1987-88 was due to severe drought in Rajasthan. Gross area sown has also remained constant in the last decade, though it has shown declining trend Gross cropped area was 1,61,226 hectare in 1986 which declined to 58,455 hectare in 1987-88 due to drought. It again increased to 1,93,548 hectare in 1997-98. At the end of 2000 it was 1,76,154 hectare. This small decline in sown area may be due to the area which has become waterlogged over the last few years.

h. Area Sown more than once

Area sown more than once has been fluctuating in the last two decade in Rawatsar. One of the causes, is the problem of waterlogging and soil salinisation which has made soil unsuitable for cultivation. Though it has shown an increasing trend. It may be due to increasing practice of intensive irrigation in order to increase profit and production. It was 17,002 hectare in 1986-87 which became 22,393 hectare in 1992-93. By the end of 2000 it was 21,216 hectare, about 11.3% of the sown area.

4.2 Production of Important Crops in Rawatsar Tehsil (1994-2000)

Table 4.2 (Figure 4.2) shows the production of crops wheat and rice has increased during the last decade. Production of wheat has increased manifolds from 26,166 metric tones in 1994-95 to 89,835 metric tones in 2000. Similarly, the production of rice has increased from 291 metric tones in 1994-95 to 10,273 metric tones in 2000. Although, rice is not a significant crop in this region, in terms of agricultural production, it is mainly concentrated in the flood basin of the Ghaggar river, where both river flood water and canal irrigation drain.

Table also shows the production of cotton, sugarcane, groundnut, which, on the whole have declined in the last decade. The decline in cotton was from

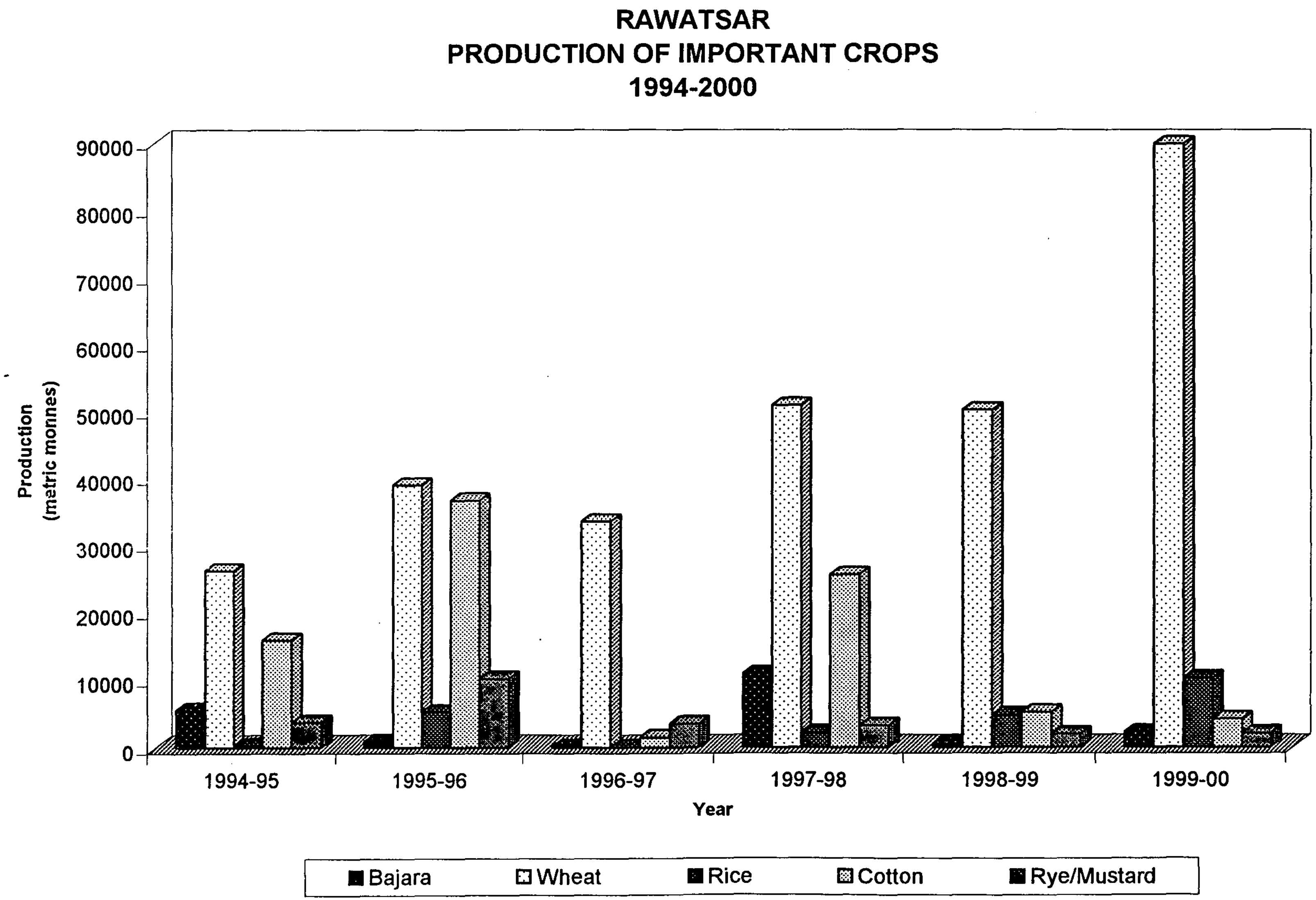
Table 4.2

Production of Important Crops in Rawatsar Tehsil (in metric tonnes)

Year	Food Grain						Cash Crops				Pulses				Others		
	Bajara	Jowar	Wheat	Maize	Jo	Rice	cotton	Sugarcane	Groundnut	Rye/Mustard	Tur	Rabi pulses	Kharif pulses	Gram	Til	Chilli	potato
1993-94																	
1994-95	5481	***	26166	***	1689	291	15863	***	212	3711	***	49	1	27124	56	***	***
1995-96	848	1.4	38915	***	2052	5191	36633	548	8	10146	***	***	***	12637	27.1	2	7
1996-97	151	***	33473	***	1026	15.5	1504	105	32.4	3518	***	79	***	28310	14	***	***
1997-98	10940	1	50928	***	4198	2208	25531	2280	371	3279	***	270	1	1E+05	154	***	***
1998-99	544	1	50198	2	1913	4764	5214	1620	195	1912	1	73	***	80493	146	1	8
1999-00	2239	2	89835	***	1762	10273	4167	330	46	2066	1	3489	***	2E+05	343	***	4

Source: Revenue Records, Rawatsar

Figure 4.2


RAWATSAR
PRODUCTION OF IMPORTANT CROPS
1994-2000
Production
(metric monnes)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1994-95
1995-96
1996-97
1997-98
1998-99
1999-00
Year
Bajara
Wheat
Rice
Cotton
Rye/Mustard

15,863 metric tones in 1994-95 to 4,167 million tones in 2000. The decline in sugarcane has been from 548 metric tones in 1995-96, to 330 metric tonnes in 1999-2000. The production of gram was 27,124 metric tonnes in 1994-95 which increased from 80,493 metric tonnes in 1998-99 to 1,94,628 metric tonnes by the end of 2000.

The table reveals that after the decline of cash crop production, the production of bajra and jowar has shown an increasing trend. Bajra production has increased from 544 metric tonnes in 1999, to 2,239 metric tonnes in 2000. This is due to the shift from cash crops to rainfed crops like barley etc., as a result of the problem of waterlogging etc.

Significant increase in grain yield as well as on fodder yield of the crop is due to reclamation of saline and waterlogged patches caused by the sub drainage system. But this marginal yield is a substantial increase and financial relief to the cultivators owning this waterlogged and saline lands where cultivation was out of question in the past years (Rathore, December 2001).

4.3 Area under important crops in Rawatsar Tehsil

Table 4.3 (Figure 4.3) gives an idea of decline in area under traditional crop like bajra and jowar. This is due to introduction of irrigation which is mainly responsible for the shift in the cropping pattern. The area under wheat has recorded increase from 15,222 hectare in 1986-87 to 21,589 hectare in 1992-93, but the area under crop remained almost constant up to 1996-97 since more and

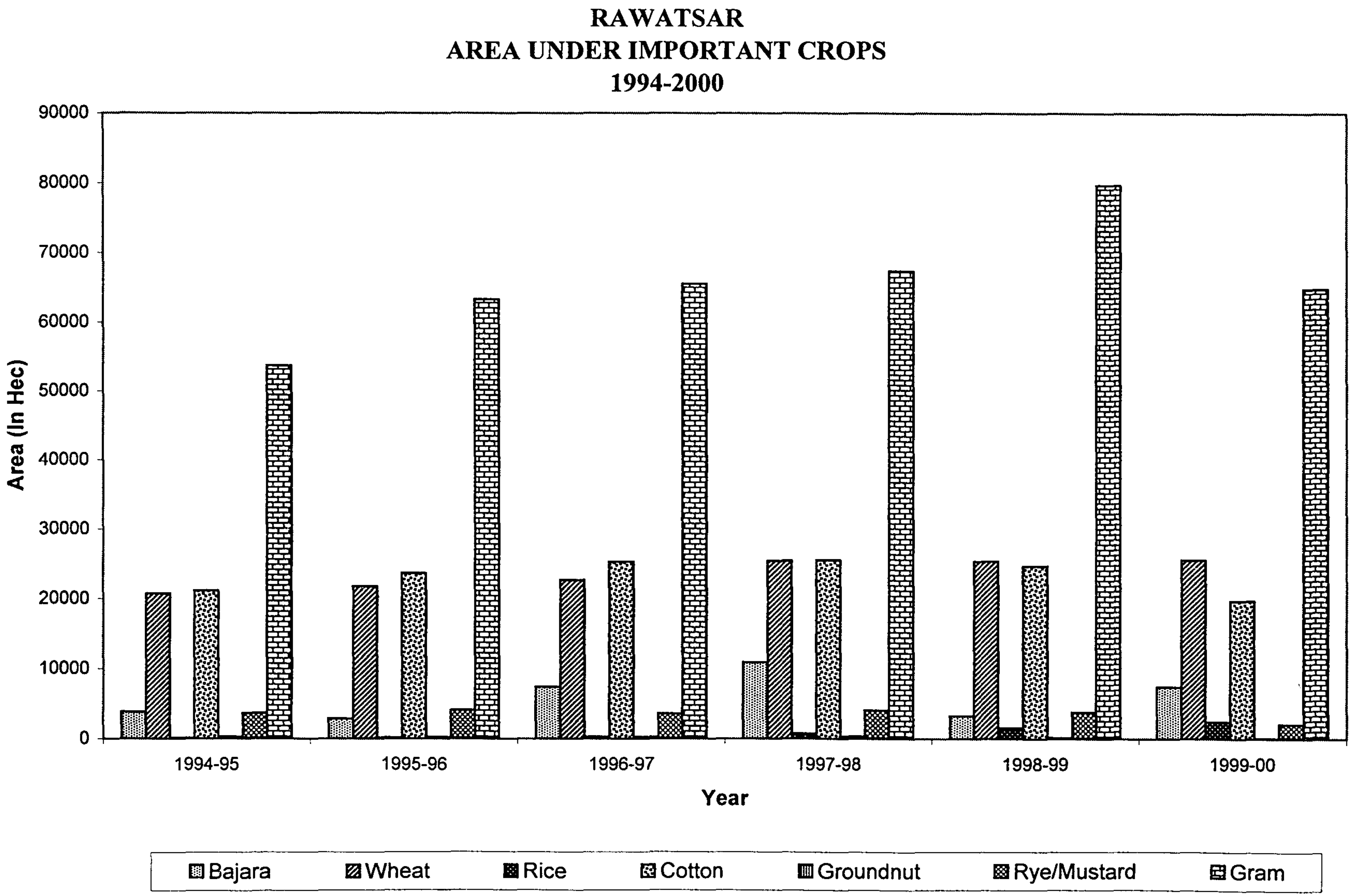
Table 4.3

Area Under Important Crops in Rawatsar Tehsil (in hec.)

Year	Food Grain							Cash Crops				Pulses				Others		
	Bajara	Jowar	Wheat	Maize	Jo	Chote Dhan	Rice	cotton	Sugarcane	Groundnut	Rye/Mustard	Tur	Rabi pulses	Kharif pulses	Gram	Til	Chilli	potato
1992-93	7413	6	21589	-	1059	-	209	19863	-	782	3299	-	2	4303	56905	21	1	5
1993-94																		
1994-95	3879	-	20761	-	1344	7658	97	21150	1	283	3676	-	1	99	53667	158	-	6
1995-96	2871	-	21744	-	755	-	163	23629	5	243	4125	-	-	127	63290	443	-	4
1996-97	7435	-	22684	-	802	-	313	25324	21	270	3595	-	1	3886	65547	369	-	-
1997-98	10940	1	25464	-	2099	6954	736	25531	76	371	4099	-	1	270	67383	307	-	-
1998-99	3321	1	25437	2	1037	6617	1588	24710	54	195	3824	2	-	146	79754	292	1	2
1999-00	7471	3	25667	-	881	-	2446	19748	11	77	2066	-	-	3489	64876	857	-	1

Source: Revenue Records, Rawatsar

Figure 4.3


RAWATSAR
AREA UNDER IMPORTANT CROPS
1994-2000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Area (In Hec)
1994-95
1995-96
1996-97
1997-98
1998-99
1999-00
Year
Bajara
Wheat
Rice
Cotton
Groundnut
Rye/Mustard
Gram

more area was affected by waterlogging and salinisation. Area under wheat has marginally increased since 1996-97, which was about 25,667 by the end of 2000.

Area under rice is very little compared to wheat. It is mainly sown in the Ghaggar flood area. It was 312 hectare in 1986-87, which had once declined from 209 hectare in 1992-93 to just 97 hectare in 1994-95. But in the past 4 or 5 years area under rice has recorded an increase from 736 hectare in 1997-98 to 2,446 hectare by the end of 2000. The increase in area shows the shift towards growing rice as it is a salt-tolerant crop and can thrive for a longer period in waterlogged and saline areas.

There has been a wide fluctuation in the area under cash crop such as cotton, sugarcane, and groundnuts. Cotton which occupied maximum area among the three showed an increase from 10,314 hectare in 1986-87 to 21,150 hectare in 1994-95. Thereafter, it remained almost constant for some years before declining in the late 1990's. It is mainly attributed to the problems of waterlogging and salinity in the area due to irrigation.

Area under sugarcane also has shown a decline from 52 hectare in 1986-87 to 11 hectare in 2000. Similarly, area under groundnut has also declined from 2,389 hectare in 1986-87 to just 77 hectare in 2000. Area under gram increased in 1980's but in the late 1990s it has shown a decreasing trend from 79,754 hectare in 1998 to 64,876 hectare by the end of 2000.

Rapeseed and mustard is mainly grown as a rainfed crop. Its area has declined from 1999 hectare in 1986-87 to 1816 hectare in 1987-88 but afterwards showed an increase and than remained almost constant till mid-1990's. Thereafter, it shows a declining trend. Area decreased from 4,099 hectare in 1997-98 to 2,066 hectare by the end of 2000.

Area under pulses has also declined. Area under Kharif pulses has declined from 8908 hectare in 1986-87 to 146 hectare in 1999. Though an increase was recorded in the year 2000, the area under pulses in the year 2000 was only 3,489 hectare. Pulses like Moong, Moth, Ashar are mostly grown as rainfed crop in most areas in Rajasthan.

4.4 Water utilised and area irrigated in Kharif and Rabi Season

Table 4.4 (Figure 4.4 and 4.5) shows water utilised and area irrigated in Kharif and Rabi season. It shows that on an average 340.37 microsemens (mcm) water is utilised and 48,583 hectare area is irrigated in Kharif season. Water utilised in Rabi season is 264.55 hectare. Average area irrigated in Kharif is less than Rabi season but water utilised is more in Kharif than in Rabi season. Water utilised in Rabi season is less, because after rainfall, or irrigation water percolates less and moisture is retained in the soil for a longer period.

Area irrigated has remained almost constant from 1984 to 1987 in Kharif season i.e. 44,477 hectare in 1984 to 44,074 hectare in 1987 but afterwards it has shown an increasing trend; though the increase recorded in irrigated area is not significant. It has risen from 50,881 hectare in 1990 to 56,895 by the end of 1994. Area under irrigation during Rabi season has also shown fluctuations. It was 47,200 hectare in 1984, which increased to 55,661 hectare in 1986, with a sharp fall in the year 1987 when it was 27,860 hectare. It may be due to the drought

Table 4.4

Rawatsar Area : Water Utilized and Area Irrigated (1984-94)

Year	KHARIF		RABI	
	Water utilized (in mcm)	Area irrigated (in hec)	Water utilized (in mcm)	Area irrigated (in hec)
1984	350.82	44477	214.85	47200
1985	226.96	40199	300.97	52110
1986	296.03	44961	312.93	55661
1987	315.77	44074	153.50	27860
1988	323.91	47397	388.05	55793
1989	370.54	48159	228.81	52951
1990	405.75	50881	342.97	57838
1991	397.93	52692	244.91	56440
1992	-	-	-	-
1993	340.81	55598	141.05	48803
1994	375.23	56895	317.49	55273
Total	**3403.74**	**485333**	**2645.53**	**509929**
Average	**340.37**	**48533**	**264.55**	**50993**

Source: Irrigation Department, Hanumangarh

Figure 4.4

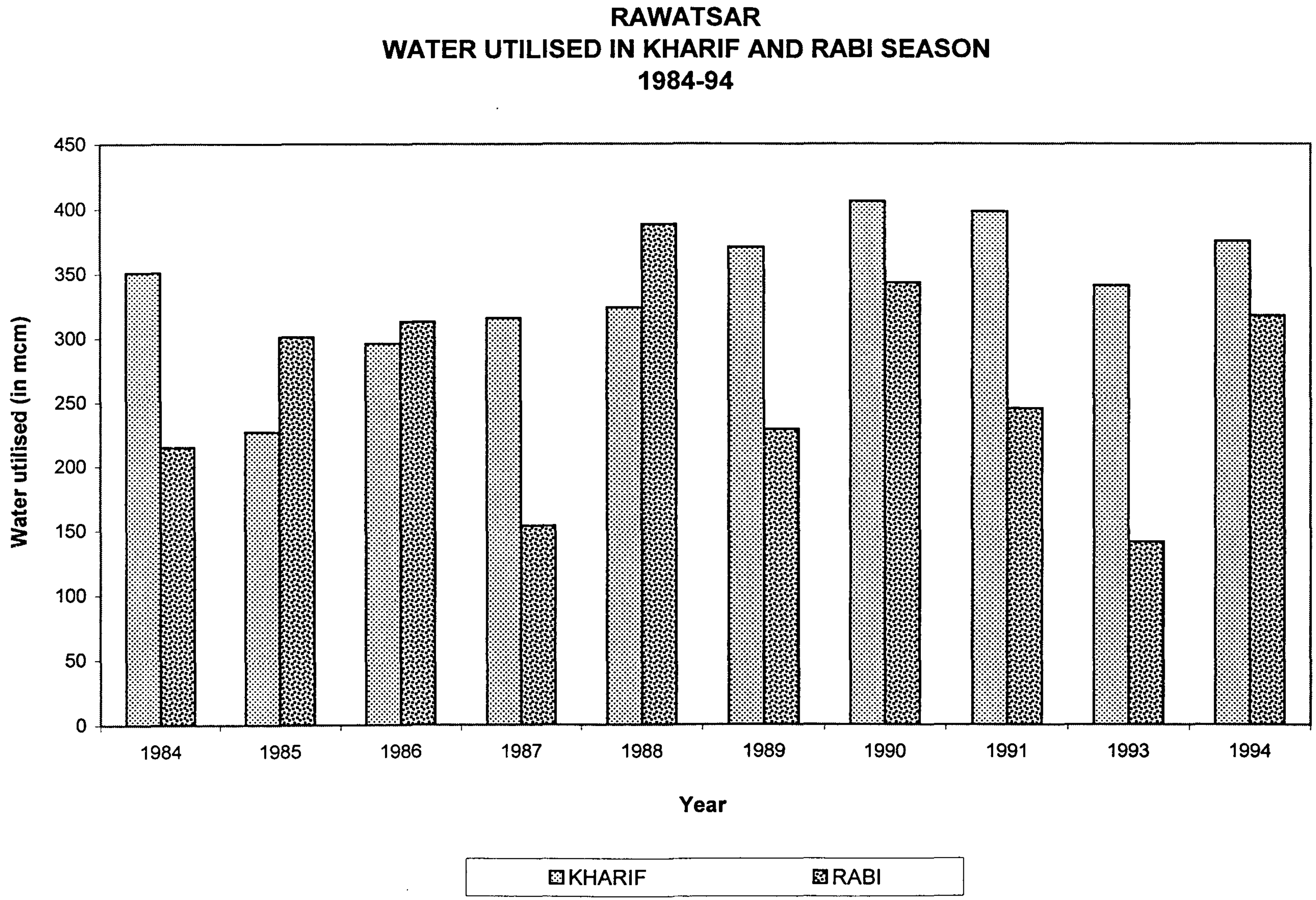
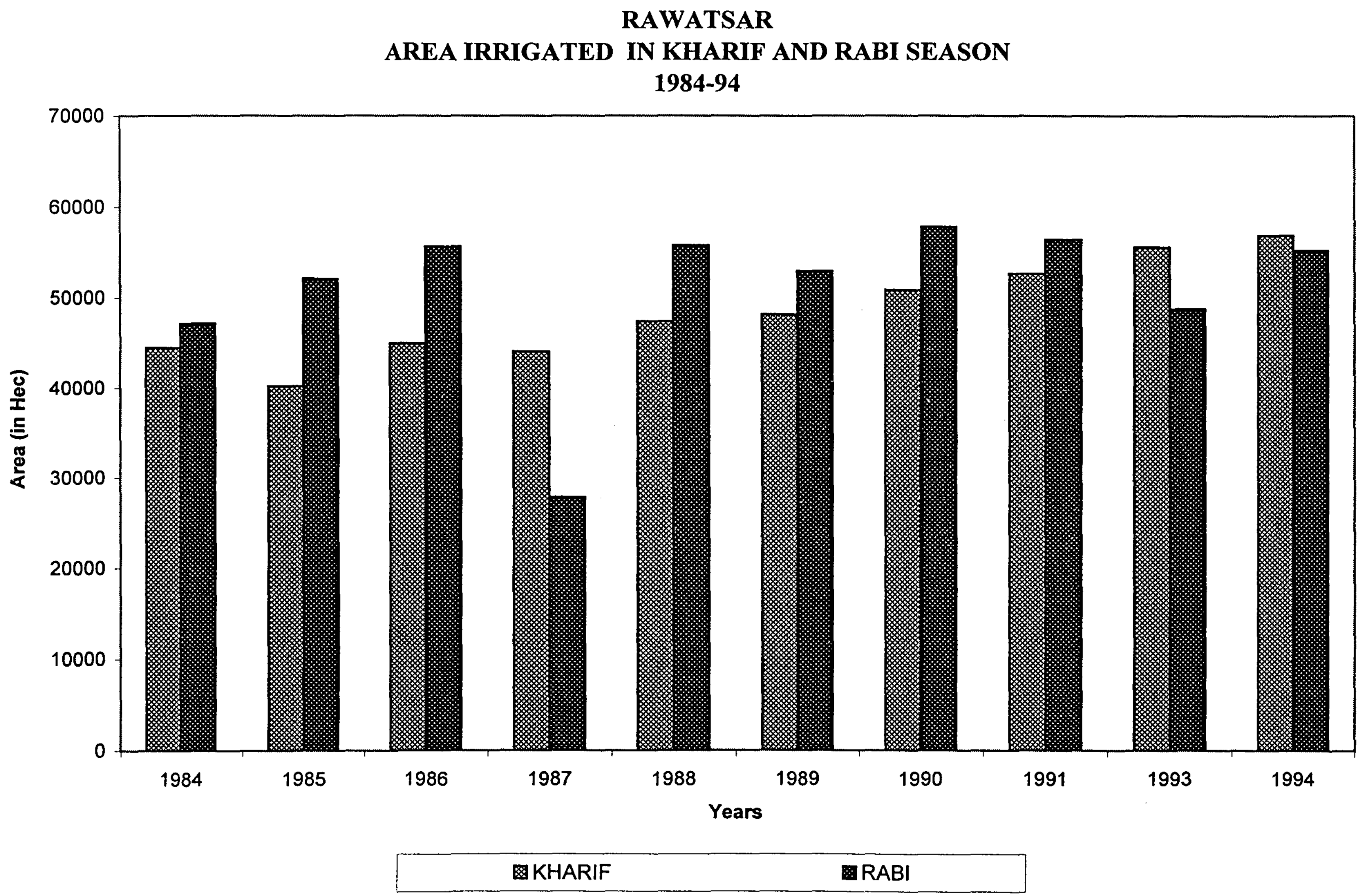

RAWATSAR
WATER UTILISED IN KHARIF AND RABI SEASON
1984-94
450
400
350
300
250
200
150
100
50
0
Water utilised (in mcm)
1984
1985
1986
1987
1988
1989
1990
1991
1993
1994
Year
KHARIF
RABI

Figure 4.5



RAWATSAR
AREA IRRIGATED IN KHARIF AND RABI SEASON
1984-94
70000
60000
50000
40000
30000
20000
10000
0
Area (in Hec)
1984
1985
1986
1987
1988
1989
1990
1991
1993
1994
Years
KHARIF
RABI

condition and low availability water supply for irrigation Purpose. The area irrigated increased to 56,440 hectare in 1991, dropping to 48,803 hectare, and later increasing again in 1994 to 55,273 hectare. Water utilised in irrigation has also shown fluctuations in Rabi season. It was 214.85 mcm in 1984 which decreased to 153.50 mcm in 1987. In this period area irrigated was also the lowest. Water utilised again increased to 342.97 mcm in 1990 and thereafter declined to 141.05 mcm in 1993. In 1994 water utilised was only 317.49 mcm.

All the above analysis show that there has been decrease in the area and production of important crops, especially cash crops and pulses. Area and production of groundnut, cotton and sugarcane has declined. On the other hand, pulse production has also declined like gram, tur etc. Production and area under wheat and rice, although shows increase, but this increase is mainly attributed to the use of salt tolerant species of rice and wheat. As a result of the problem of waterlogging and salinity more land is becoming Usar and Banjar. Data reveals the severeness of the problem of waterlogging and soil salinisation.

Chapter V

Schemes, Projects and Water Management Techniques

5.1. Details of Measures Undertaken

After the outcome of the problem of waterlogging and salinisation in IGNP command area several measures were undertaken by different departments such as Agriculture, Irrigation, Command Area Development Board etc. Economist, Geographers, Agriculture and Extension officers were all concerned about the problem and worked in groups or individually to find out the possible remedial measures.

In 1974, waterlogging was first observed near Badopal and Manaktheri. This area is adjoining the depressions of the Ghagar Diversion Channel (Constructed in 1966). Waterlogging sign appeared in Rawatsar (Khetewali Dhani) in 1984. The report suggested the construction of skimming wells in Dabli Khurd and Luna ki Dhani and pilot schemes for pumping water in the main canal. Secondly, it was decided to construct tubewells along Suratgarh Branch near the waterlogged area of Dolatwali and Badopal in the year 1997. This Report mentions that the standing water near Manktheri was pumped in the Ghaggar river during flood period of 1998. (Irrigation Department, Rawatsar, 2000).

But these schemes were not much successful in evolving a permanent solution. A workshop was conducted at Hanumangarh, and attended by the technocrates, bureaucrats and public representatives to tackle the waterlogging problem. The engineers from Irrigation Department visited the works carried out by the states of Punjab and Haryana which also faced the similar problem. Afterwards, they prepared proposal according to the guidelines of Subrahmanyam Scheme. The new Scheme suggested to construct *Rawatsar Main Drain* (Plate 5.1 to 5.4) for dewatering waterlogged area. This proposal now covers broader aspect of wasteland management and it provides guidelines for bio drainage, desalinisation of saline/alkaline soil, mapping of water table by remote sensing satellite and sitting up of hydrological/meteorological station to calculate crop water requirement. The project also established a centre for monitoring the salinity level and reclamation of saline land.

Before this in March 1992, WAPCOS had prepared a Revised Feasibility Report for IGNP State II which contain a major chapter on problems of drainage and salinity and possible remedial measures similarly in June 1993, the Area Development Commission Office prepared an Integrated Development Project for IGNP Area Stage I Phase II and Stage II for 1993-98. Earlier in May 1993, a settlement project for the Indira Gandhi Canal Area under WFP Project 2600 Expansion II was prepared for 1994-99. A project for construction of left out canals in stage I was also prepared in 1992. A separate annual action plan to prevent and control waterlogging are being made each year, according to CAD – IGNP annual action plans.

Kapoor and Kavadia (1994) suggest the following recommendation for tackling the problems:-

Plate 5.1 Rawatsar: Open drain or 'Sem Nala'.

Plate 5.2 Rawatsar: Construction of sub drains to join main drain.

In order to solve the problem of waterlogging open drain is constructed, called as 'Sem Nala' Sub drain joins one main drain, which is connected to big pipes to pour water into main canal. This project is of Irrigation Department costing about 4.5 crores.

Plate 5.3 Rawatsar: Main drain joined by number of sub drains.

Plate 5.4 Rawatsar: Big pipes connected to main drain (above) to pour water into main canal.

1. Minimise use of water for irrigation according to land capabilities.

2. Depletion of the Ghaggar depressions.

3. Maximum use of biodrainage to offset the high cost of drainage in the absence of natural drainage.

4. In the absence of natural drainage, vertical drainage should be resorted to wherever possible, and drain water should be blended with canal water in appropriate doses, suitable for irrigation. If blending of drainage water is not possible, it should be carried to local neighbouring depressions and used for manufacturing of salt. It would require cautious approach because of associated salts.

5. In areas of hydrological barriers at shallow depth, horizontal drainage may be tried if vertical drainage is not possible.

6. Puncturing of hydrological barrier where subsurface drainage is not possible.

7. Better water management on the field through use of conservation practices viz irrigation in alternative furrows, use of optimum size of border strips, basins, drip and sprinklers etc. and right doses of irrigation.

8. Better control and management of irrigation network to minimize loses of water and assured dependability of deliveries.

9. Strengthening and monitoring of ground water system to eliminate the information gaps.

10. Pilot studies for remedial measures and research on drainage.

Kapoor and Kavadia (1994) also caution that any absence of natural surface drainage and formidable distance from a suitable location for disposal of saline drainage also poses a major restrictions on feasible solutions.

The November, 1992 report of the ICAR technical group on the problems of seepage and salinity in IGNP has suggested the following measures:

1. Reduction in delta.

2. Developing drip system based alternative agriculture.

3. Control of seepage from canal network:

   (a) Repair of dam and aged/vulnerable reaches and lining.

   (b) Ensuring clearance deposition of drifting sands and weeds to avoid water congestion.

   (c) Provision of interceptor drains.

   (d) Pumping of ground water.

4. Management of pond water in the Ghaggar depression – it could be utilised by developing irrigated agriculture and afforestry in non-command areas lying south of the depression.

5. Provision of biodrainage – fragile areas may have to be assigned to pasture and forestry. Use of under ground brackish water to raise salt resistant trees in non-command areas.

6. Special drainage, measures in critical areas, horizontal drainage, system, skimming wells, inverted tube well drainage be considered.

7. Conjuctive water utilisation

8. Systematic reclamation of salt affected soils

9. Long term measures for salt disposal from the eco-system

The experience of Punjab and Haryana had provided opportunity to foresee some possible subsequent benefits and consequences of canal irrigation. The Command Area Development Agency (CADA), has thus initiated certain measure to address the problem of waterlogging and secondary soil salinisation. The Groundwater Wing of Rawatsar has been asked to conduct the following studies comperehensively:-

1. Mornitoring of water table.

2. Hydrological barrier layer investigations.

3. Drainage trial and demonstration.

Other anti-water logging programmes include Work Programme started in 1994-95 under Drainage Trial and Demonstration Programme and are approved by the Government of Rajasthan with an outlay of 0.72 crores.

1. Near Rawatsar, additionals skimming well would be constructed at Lunio Ki Dhani. The wells will be provided with infiltration galleries.

2. Chakwise investigation in the critical areas was also taken up during the financial year 1994-95.

An Interim Action Plan in 1993-94 was started to mitigate the problem of waterlogging. The Commissioner Area Development, IGNP has prepared an "Interim action plan for remedial and preventive measures for waterlogged areas of Jhakharwali – Baropal – Haraktheri region", Hanumangarh in April 1993.

The following measures were proposed and are being implemented to combat the menance of waterlogging conditions in the area.

(a) Reduction in Delta: Reduction in number of days of running of canal. The present water allowances in the command is 0.37 cusec / 1000 hectare. In the areas where stagnant water bodies and waterlogged conditions have developed, the allowance is proportionately reduced to 0.21% cusec/1000 hectare. This may not only reduced the ponded areas, but has resulted in the net saving of 48 cusecs of water.

(b) Incentive Scheme for Conjuctive use of Water and Farmers Participation: Motivation assistance of Rs. 15,000 per electric connection to Rajasthan State Electricity Board to energize the well is being provided by the Command Area Development Agency (CADA). In the non electrified area, a motivation assistance Rs. 10,000 per well will be provided to the farmers for the procurement and installation of Diesel Pump set in the waterlogged areas.

(c) Bio drainage: The seedlings of suitable trees are being raised by the Forest Department at its nurseries and supplied to farmers free of cost. It is proposed that 1,00,000 seedings will be distributed to farmers in the current financial year, under bio drainage programme. Approximately, 0.67 lakhs seedlings have already been provided by the Forest Department to the farmers.

(d) Pilot Projects have been prepared by the groundwater wing of Command Area Development (CAD) after conducting pre-feasibility studies. The groundwater management and salinity protection through vertical drainage was initiated in Tibi sector in Hanumangarh District of Stage I in June 1990. In the project report, 24 tube wells and 15 skimming wells were proposed and the Government of Rajasthan accorded the administrative & financial sanctions for the construction of six tube wells and five shallows skimming wells at villages Masilawali and Lunio Ki Dhani respectively.

(e) Vertical Drainage through wells: Five shallow skimming wells of 3 m diameter at a spacing of 125 m in a single row were constructed in Chak MSTN village Lunio Ki Dhani, in the year 1992. The wells were constructed above the hydrological barrier layer and within the permeable horizon without infiltration galleries. To reclaim the adjoining affected areas ten addition skimming wells with infiltration galleries to enhancing the flow, needed to be constructed with an active participation of farmers. The technical and financial assistance is being provided by CADA, and the required pumping done solely by the farmers.

(f) Vertical drainages through tube wells: For the purposes of vertical drainage six tubewells have already been constructed in a grid, by the Ground Water

Department. Out of the six two tubewells have already been constructed and two could not be constructed due to marshy conditions in the area. Now efforts are being made to construct the remaining two tube wells by hand boring.

(g) Horizontal subsurface pipe drainage: This project titled, "Trial and demonstration of horizontal subsurface pipe drainage for restoration and preservation of irrigated lands, mainly for Lunkarnsar District in collaboration with the Central Soil salinity Research Institute, Karnal has been initiated.

5.2 Present Technincal Installations in Rawatsar to control problems:

The absence of natural drainage and presence of gypsiferous barrier layer at shallow depth are important factors in increasing the complexity of the problem in Rawatsar area. The findings of the studies done by the Command Area Development (CAD – 1998) shows that the low lying areas started to become water logged by 1985, and waterlogging problem became more severe from 1991 onwards. The water logged areas of the chaks of Rawatsar distributary are located in the low lying areas from tail of Prempura minor to Rawatsar, into Baropal.

Presently, vertical subsurface drainage has been undertaken by the CAD in which shallow tubewells all constructed at Mastawali, Rawatsar in Hanumangarh. About 120 tubewell have been installed as a part of the Chief Minister's Anti waterlogging Programme.

Horizontal subsurface drainage has been taken over by the Rajasthan Agricultural University under the Indo-Dutch Drainage Project. Water levels in 25 peizometres and drain flow in laterals are bring manually monitored daily. A new larger lined evaporation pond has been constructed in 1998.

Dewatering ponds (Plate 5.5 and 5.7) have been started at Luno ki Dhani and Dabli Khurd and the decrease in standing water levels achieved by pumping been nullified with inflows during the seasonal rains. After about six weeks of dewatering the ponded water at Dabli Kalan, et showed a decrease 0.5 m (CAD – 1996).

Biodrainage programme has been started by the CAD, by planting trees in 600 hectare, of biodrainage with additional 300 hectare being around the Ghaggar depressions.

Interceptor drains have been constructed as an anti waterlogging plan. There is a proposal to construct open collector drain along Rawatsar Branch (R.D. 12.5 to RDO) and along IGMN (RDO to RD 2). The drain water is to be carried to Dabli from where it can be pumped into the Indira Gandhi Main Nahar (IGMN).

5.3 Water Management Practices:

Waterlogging and soil salinisation are the problematic aspect of facility water management practice in India. Defective planning at conceptual level, defective construction at the field level, lack of on farm development, ineffective training to farmers and managerial staff, defective irrigation practice are the main bottlenecks in the objective of optimisation of land and water resources. The different water management practices which could be followed are explained below:-

Plate 5.5 Rawatsar: Reclaimed field patches after construction or open drain and evaporation ponds.

Plate 5.6 Cultivation of Rabi crops on reclaimed land.

Plate 5.7 Rawatsar: Water decrease after construction of evaporation ponds and open drain.

Plate 5.8 Rawatsar: Cultivation or barley as salt tolerant crop.

(I) Change in Water Application Methods:-

The success of the conventional gravity methods, namely, border basin furrow and combination thereof, largely depends on precise land shaping and grading. But shallow soil cover becomes a constraint in land development operation.

In such condition even a moderate land leveling would remove the soil and expose underlying rocks. Gravity irrigation systems are, thus, not suited to such conditions. Due to their adaptability to a wide range of soil, topographic, climatic conditions and crops, sprinkle and drip irrigation systems are popular in the developed countries. In these methods soluble fertilizers, herbicides etc can be easily applied along with irrigation water and labour costs remain generally less as compared to gravity irrigation. (Sahni, 1999).

In recent studies conducted at Rahuri, Maharashtra have indicated that the sprinkler irrigation gave about 2 percent higher yield compared to surface irrigation method.

(II) Command Area Development

Efforts should be made for increasing water-use efficiency in CAD Projects. Lack of interdisciplinary approach in irrigation management has been one of the major factors which has contributed to the poor performance of irrigation system. Irrigation efficiency can be achieved by a shift from traditional method to modern scientific planning and managements.

(a) Development of head water tanks, soil conservation structures and optimum land utilisation in the catchment area should form an integral part of irrigation project.

(b) The water storage capacity of the reservoir should be increased to conserve the maximum possible monsoon runoff for irrigation of Rabi and Kharif crops.

(c) Canal releases should be regulated to match with the critical dry spells in the command area. Seeing the present conditions, reduction in water allowance could be done. Suitable schemes for conjunctive use of surface water release from canal system and groundwater available in the command area should be developed.

(d) Unfavourable monsoon situations like onset, prolonged dry spells and early withdrawal etc should be taken care of in advance by developing contingent plans.

(e) Water conveyance and distribution at the outlet level and within the field can be improved by adopting lining of water courses and field channels, and adoption of underground pipelines keeping in view, the economic constraints.

(f) More and more farmers should be encouraged to participate in the improvement of the command area such as formation of cooperative societies, banking purposes and distribution of water etc.

(g) Land shaping and consolidation of land holdings should be adopted to the extent possible.

(h) To meet the additional requirement of crop production, inputs and infrastructure facilities in extension irrigation farming namely, farm power, seeds/seedlings, fertilizers, insecticides and pesticides, crop processing, storage, transport, marketing and rural credit etc. should be developed.

(i) Farmers should be encouraged to collect and reuse their own deep-percolation water systems.

(III) Selection of suitable crops

Cropping pattern in the command area should be according to the available water supply, as groundnut and wheat give best returns under low water supply. With limited water supply, short duration, paddy, followed by wheat can be recommended. For late Rabi cropping patterns, late variety of wheat like sonalika grown under limited water supply and fertilizer have proved successful (Hiran, 1990).

The selection of crops and cropping pattern sequences (Plate 5.6 and 5.8) to be followed in saline soils is of paramount importance, since crops vary in their tolerance to salinity, and are either too sensitive or semi-tolerant to tolerant, to a given level of salinity (Mass and Hoffman, 1977). Appropriate cultivation practices and growing of suitable crops help in leaching of salts. In the saline soil of arid and semiarid areas of North Western India, cotton, serghum, millet, castor been and moth bean should be grown during Kharif, and wheat, barley, mustard, sunflower and sugarcane during Rabi, depending upon the availability of water. The crop production as a function of soil salinity under field conditions has been studied by Sharma et. al. (1990). They found that the threshold tolerable soil salinity levels for wheat, barley and mustard are 4, 7 and 6 ds/m respectively. The yield of wheat, barley and mustard can be increased by 28, 30 and 13 percent, respectively, after reducing the salinity in the affected areas. Singh and Sharma (1993) reported that pearl millet and cotton can be grown in saline soil up to EC value of 6.5 and 7.5 ds/m, respectively, without significant reduction in yield.

The recommended cropping sequences for saline soils are pearl millet-mustard, sorghum-wheat or barley, sorghum-mustard, castor bean-wheat or barley and cotton, wheat or barley. Singh and Sharma (1992) reported that pearl millet – wheat, pearl-millet mustard, sorghum (fodder), wheat sorghum (fodder), mustard cropping sequences were more remunerative in saline soils. Since, the saline soils vary considerably in their nature and characteristics, it is imperative that only location specific management practices are developed and adopted.

(IV) Increase in Social, Political and Legal Interaction

Besides, the technical aspects and administrative aspects, importance of social and political aspect of irrigation management is also important. Looking at the social scenario, the farmers in a village are generally divided into heterogeneous groups, headed by some powerful persons. The farmers are entrapped in local politics and debts. Farmers have their land fragmented, of irregular shape and at scattered locations which make it a difficult task for irrigation agencies to supply water proportionately to each farmer, according to his requirement. Present laws on land reforms and land consolidation could not be implemented properly due to more powerful local politicians and their influence upon implementing authorities. Lack of education and social awareness among the farmers is also a great bottleneck. Farmers do not participate in the decision making process of canal delivery and canal water supplies are uncertain.

All these problems could be tackled by effective administrative and legal efforts. The existing legislation, irrigation practices and agricultural institutions in India have a great deal to say about mismanagement and poor efficiency of irrigation network and water use by the farmers, particularly, beyond the canal outlet. The second irrigation commission (1972) had recommended that law relating to irrigation should be unified and simplified. All the important laws and regulation should be effectively executed by the administrative officials. Accountability of Project managers towards farmers should be fixed.

The above factors show that there is need for sincere efforts to control the problem of soil salinisation and waterlogging. Besides, technical aspects administrative, legal and political aspects should also be properly looked into. Farmers should be encouraged to participate in training programmes, providing them with Bank facility, formation of cooperatives etc. All these measure will be helpful in irrigation management, water management and also help in solving the problem of waterlogging and soil salinisation.

Chapter VI

Summary and Conclusion

The Indian agriculture is highly dependent on south-west monsoon which is characterised by high spatial and temporal variation, uncertainty in onset and withdrawal, prolongation of dry and wet spells and frequent occurrence of droughts and floods. Realising the hardships faced by the people, mainly by farmers, a number of major and medium irrigation projects were initiated after post independence period. The Indira Gandhi Canal Project (IGNP) is one of the most ambitious project in the Thar desert of Rajasthan. It is an effort to transform the semi-arid and arid region of northwestern Rajasthan into one of granaries of India. This irrigation project, launched on March 31, 1958 has already been completed in Stage-I, and is in progress in Stage-II.

The ecology of the desert is highly fragile, as a result the construction of canal has posed serious problems. The presence of hardpan, high concentration of salts in soils, seepage from canal, over utilisation of irrigation resources and absence of any natural drainage are the important factors resulting the problem of waterlogging and salinisation. These problems are hurdles in the optimum utilisation of irrigation resources. Ever since the introduction of canal, ground water has risen sharply in Stage-I of the canal development. By the end of 1997, about 17,220 hectare of area was completely waterlogged; 24,140 hectare was critical and 2,97,820 hectare was potentially sensitive. On the other hand, in Stage-

II, 1,243 hectare was completely waterlogged, 3610 hectare critical and 17,303 hectare potentially sensitive.

According to the Ground Water Board Bikaner, the rise in groundwater level is highly alarming in Dassuwali, 4 AM, Gandheli villages in Rawatsar Tehsil of Hanumangarh district. The fact that waterlogging has posed a serious threat in the Indira Canal Command Area is also substantiated by the data provided by the project, the "Monitoring of Water table, Groundwater Department, Bikaner. It suggests that in 1981 about 9 percent of the project area; located in two regions around Tibi and Baropal villages (Hanumangarh) was critical areas.

It has also adversely affected the area occupied and production of important crops. Land use pattern has changed after the onset of the problem. Salty and marshy land (Usar) has increased, on the other hand area irrigated and water utilised has shown wide constant, fluctuations (Table 4.4.) proportions of area under follow is almost, however, area under current fallow has declined. Production of conventional and traditional crop like jawar, bajra, and pulses has declined as more and more area is brought under cash crops, wheat, rice, etc.

Although detailed information regarding the ground water table of the sown part of stage I command area are not available, waterlogging problem in this region is expected to be further accentuated due to impeded drainage, incidence of calcareous and clay layer near the surface and sandy texture of soils.

Soil salinity is another widespread irrigation environmental hazard in the command area of Stage-I of the Indira Gandhi Canal. Among irrigated soils, incidence of salinity is competitively how is upper part of the command area of Stage-I. The pH value of soil has been between 8.5 and 9.0 in most of the villages as Darsuwali, Gandheti, 4 AM, 2S PM during end of 1990's.

Samples of soil and water taken from the field recently show that the quality of both soil and water is very poor. The presence of strong salt regime and calcareous and clay pans near the surface are the main determinants in developing soil salinity in the irrigated area of the command area.

After the beginning of the problem during 1980's in Rawatsar area several steps were undertaken by various departments to control the problem. Many projects were initiated including subsurface drainage system in collaboration with the Dutch Govt. named as 'Indo-Dutch' Project in Lakhuwali, Hanumangarh. Irrigation department has constructed open-drains, evaporation pond etc. [redacted] Water is poured from open sub drain to main drain, subsequently pumped into the main canal.

Besides these technical steps undertaken, it has been adviced to move to Ecodrainage, Biodrainge, Green Manuring and growing salt-tolerant crops. All this will minimize the use of water and also help in water management. Above all, it is necessary to take sincere steps for command area development. Training of farmers, formation of cooperatives, banking facilities, land-levelling etc. should be intensively initiated. In addition, checks should be put on heavy allowance of water given to farmers.

Efforts have been made in the dissertation to highlight the severity of the twin problems of waterlogging and soil salinisation. On analysis, the data shows that the problem of waterlogging and salinisation is the outcome of absence of any natural drainage, presence of hardpan; consequent rising of water table due to mismanagement of irrigation resources, lack of water management strategies and unplanned land use.

Various data literature, field observation, and reports suggest that both natural and manmade factors are responsible for the development of such environmental hazards in the study area.

There is an absence of natural drainage and technical methods have not been very successful in the field in removing excess surface or subsurface water from soil or land. The techniques of biodrainage and surface drainage are most suitable measures for reclamation of the waterlogged areas. Experts and scientists are of the view that there should be a shift from Border Irrigation Techniques to Sprinkler and Drip Irrigation. This will allow the judicious use of water. Water allowance must be fixed according to the irrigation capacity of land and soil profile. Seepage losses from canal irrigation system which has lead to rise in water table should be checked by proper lining of unlined water courses in personal fields.

Farmers should be trained about irrigation management practices. The training of land users must be provided free of cost. They should be acquainted with knowledge of formation and nature of their fields, irrigation capacity of soils and a suitable land use and cropping pattern by the trainers and field experts.

For reclaiming inundated areas, surface water pumping can be most effective measure, but may prove a temporary solution of the problem. The permanent waterlogged or ponded areas, where reclamation is neither possible nor economically feasible, these as may be developed as marine ecosystem.

Farmers should be encouraged to use salt tolerant species of crops which can withstand the adverse environmental condition.

Above all, there should be healthy interaction among the people in political, legal and administrative arenas should not make the problem as a political issue. Technocrates and beaureucrates should sincerely and honestly work together in finding an appropriate solution to the problem. Efforts should be taken for effective and sincere implementation of laws and regulations.

These issues can be solved by mutual understanding and cooperation among the public representative, decision makers and land users of the affected regions. The only remedy appears to be an integrated approach which would include water management strategies and judicious land use planning of the region. This study proposes an integrated approach for irrigation and drainage management so that already heightened problems of waterlogging and soil salinity in the command area can be effectively prevented and controlled to maintain the ecological balance. Ecological feasibility should be the priority of planning and concept of sustainable resource management also be adopted.

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