J. Indian Water Resour. Soc.,
Vol. 43, No. 1 & 2, Jan. & Apr. 2023

ENSURING EFFECTIVE SURFACE DRAINAGE THROUGH ON FARM DEVELOPMENT PROGRAM FOR MANAGEMENT OF SALINITY AND WATERLOGGING IN CHAMBAL COMMAND AREA

Upma Sharma*[1]

ABSTRACT

The aim of the paper is to explain the importance of On-Farm Development Program implemented in chambal command area. The Chambal project is one of the major irrigation project of the country. It serves both Rajasthan and Madhya Pradesh. On-Farm Development program was implemented by the end of 1970 with the objectives to ensure an equitable and reliable distribution of irrigation water to all fields, to provide efficient on-farm utilization of the available water supplies, to control excess water in the soil due to irrigation and rainfall and to construct road and other works to facilitate timely movement of farm inputs and produce. The OFD program is comprised of several components including: the construction of irrigation and drainage ditches to serve each farm, realignment of farm boundaries to permit a rational layout of irrigation, drainage and road system and land shaping to enable efficient irrigation of field crops. Detail illustration of each component of OFD program has been described. Since the inception of OFD work in the Chambal Command in 1976-77, approximately 1,58,000 ha of development work had been completed till now. Further, the use and importance of OFD program has been verified through a pre and post project evaluation report of the OFD treated area.

Keywords: *Chambal Command Area, On Farm Development Program, irrigation and drainage ditches, road system and land shaping.*

INTRODUCTION

Introduction

Several regions in this world are dealing with problems of severe salinity and waterlogging. This causes deterioration of the crop yield due to reckless agricultural activities prevailing in the affected areas. About one third of the total irrigated area in the world is estimated to be already saline and waterlogged or is likely to become so in coming years. There are several regions where salinity and waterlogging in the soil occurs naturally but irrigation practices raises and promotes its areal extension. The main reasons of irrigation induced salinization are inadequate drainage system, leakage from poorly or unlined canals and reservoirs and over application of irrigation water. In addition to this, highly concentrated poor quality irrigation water and improper drainage system are helping factors in accelerating the problem (Johnson and Lewis 1995). The spatial expansion of the problem is mainly due to fast development of irrigation facilities in different countries globally since 1950.

Due to the application of careless and faulty irrigation management practices in an area two types of saline problems are expected to arise. Firstly, salt starts accumulating in the soil due to the presence of some salt content in canal water. Evaporation and transpiration do not remove these added salts from the soil. Therefore, to remove this salt content from the root zone, excess amount of irrigation water is applied in leaching. This effort leads to the problem of waterlogging due to rise in water table depth. Mostly groundwater contains salts which significantly increases salinity level in the root zone. Thus, to avoid above two problems amount of irrigation water applied should be plenty enough to reduce salt content in the sub- surface of the soil and should be small enough to restricts water table rise in the ground water. Presence of a proper drainage system is also a support in reducing waterlogging related problems in the area.

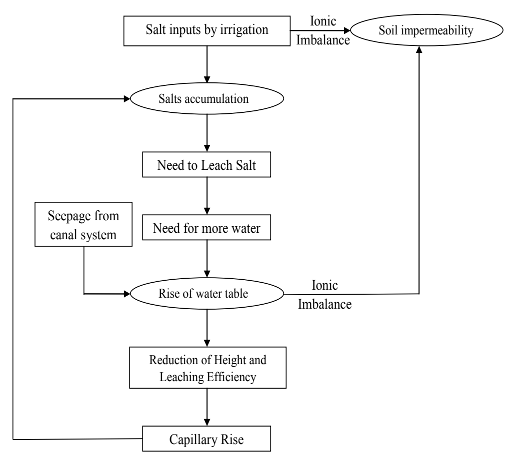

Figure 1. Flowchart of salinity induced by irrigation.

Present status in India or Indian scenario

Salinity and waterlogging problems in India are expanding year by year due to increased irrigation induced salinization. According to Abrol *et al.* (1971), approximately 2.8 Mha of salinized land lies in the Indo-Gangetic alluvial plain covering portion of Rajasthan, Punjab, Haryana, Uttar Pradesh, Delhi and Bihar. Around 8.6 Mha of area in India had been reportedly found salinized (Pathak, 2000). Majority of salinization falls in the area having canal irrigation system like Rajasthan, Gujarat,

1. *Junior Engineer, CAD, Kota-324009, Rajasthan, India.*
Manuscript No. 1595
Received : 23January, 2023 ; Accepted :27 April, 2023

Maharashtra, West Bengal, Punjab, Haryana, Uttar Pradesh, Tamil Nadu, Orissa and Kerala.

In 1988-89, National Remote Sensing Agency (NRSA, 1995) reported 1.99 Mha area as salt affected and 1.22 Mha of land waterlogged. The estimations of NRSA are likely to be more precise as they are created using remote sensing methods covering entire area of the nation. A waterlogged area of about 8.5 Mha is estimated by the Ministry of Water Resources (MOWR) which is of the opinion is increased during 1972-90. Both over-irrigation and rise in water table depth were considered as main reasons during assessment of affected area. A rapid increase in irrigation induced salinity and waterlogging is observed in India (Smedema, 1990). In India, the area under salt-affected soils is about 6.73 million ha with states of Gujarat (2.23 Mha), Uttar Pradesh (1.37 Mha), Maharashtra (0.61 Mha), West Bengal (0.44 Mha) and Rajasthan (0.38 Mha) together accounting for almost 75% of saline and sodic soils in the country. In most of the salt-affected environments, prevalence of poor quality (saline and sodic) waters is also noted. The states of Rajasthan, Haryana and Punjab, lying in the north-western arid part of the country, greatly suffer from the problem of marginal quality waters (Singh, 2009).

In 2009, a country report (Regional Remote Sensing Service Centre, Jodhpur, Rajasthan and Central Water Commission, New Delhi) revealed that there are 91 irrigation commands in Rajasthan with 23 major and 68 medium irrigation command areas. Out of total irrigation commands, 71 commands have area under waterlogging category with highest seasonal waterlogging in Mahi Bajaj Sagar command in Banswara district and highest perennial waterlogging in IGNP (Indra Gandhi Nahar Project) stage II, in Jaisalmer and Barmer districts. Total waterlogged area in Rajasthan is 8,409 ha out of which 715 ha perennial and 7,694 ha seasonal. To determine salinity/ alkalinity in the command area around 1,748 samples of soil were collected. Salt affected area covers 0.38 Mha.

DESCRIPTION OF STUDY AREA

Location

The Chambal Command Area (CCA) lies in between 25º and 26º north latitude and 75º and 76º east longitudes in the south-eastern part (Kota, Bundi and Baran districts) of Rajasthan. The gross and net command area in Rajasthan is about 4,85,000 ha and 2,29,000 ha respectively. The non-irrigable area consists of ravines, gullies and a few high spots. The command area is extended to six panchayatsamities of Kota, Baran and Bundidistricts of Rajasthan. These panchayatsamities are Ladpura, Sultanpur, Itawa in Kota district and Keshoraipatan and Talera in Bundi district and Anta in Baran district. The total geographical area of the six panchayatsamities considered in study is about 42% of the total Kota, Bundi & Baran districts.

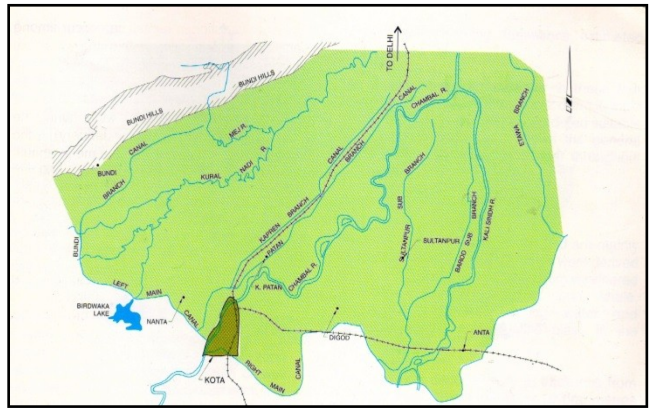

Figure 2. Chambal command Area

Climate

The climate of this area is subtropical and semi-arid, with three distinct seasons: Kharif (monsoon) from July to October, Rabi (winter) from November to March and Hot (dry) from April to June. The study area receives an average annual rainfall of approximately 800 mm based on 20 years of data (1994-2018) as given in Table 3.1.The maximum rainfall occurs in the month of July (293.7 mm) and minimum rainfall in December (3.8 mm). An average annual evaporation and evapotranspiration (ET_0) rates are reported to be around 2650 mm and 2382 mm respectively. Highest evaporation is observed in May (491.4 mm) and lowest in January (96.5 mm). July and August are the two months when precipitation exceeds evaporation rates; rest all the months are found moisture deficit as shown in Figure 3.2. An average annual relative humidity is 48.5 % with a maximum value of 81.7 % and minimum value of 17.2 %.

Physiography

The command area elevation ranges from 60 to 170 m above mean sea level. The mean slope is about 0.08 %. The area includes free flowing rivers and with adequate conveyance channels. These rivers and the network of meandering gullies (nallas) feeding them from the primary drainage system of the area. Approximately sixty separate drainage zones have been identified within the command areaas displayed in Figure 3.

Prior to irrigation development in the command area in the sixties, these nallas generally remained dry and were occasionally flooded during the kharif season. They now remain wet because of irrigation and related drainage requirements.

Good groundwater aquifers are present in the deeper alluvial deposits but diminish towards the south western portion of the basin as the clay content of the soil increases (Darra, 1993). The regional groundwater gradient is towards the chambal river.

Three major physiographic units constitute the chambal command area. The main units are accumulative plain, eroded plateau and bundi hills.

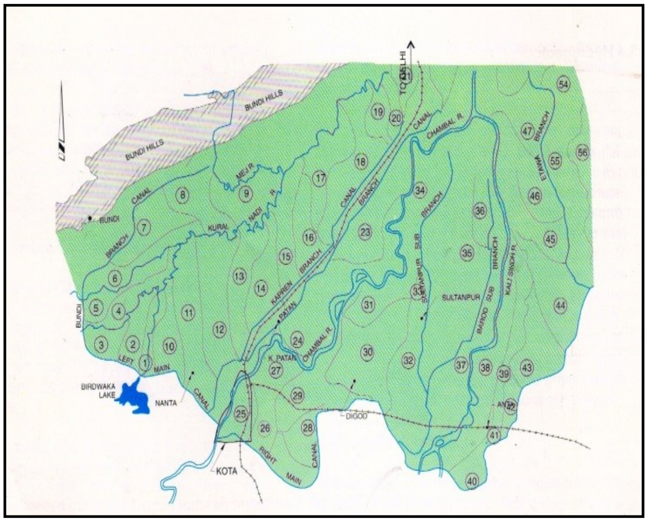

Figure 3. Chambal Command Area Drainage Zones.

HYDROGEOLOGY

The main geological formations of the CCA are of the upper vindhyan system to recent alluvium system. This is a cambarian system, believed to be some 4000 m thick. It has little structured displacement or disturbance and is generally rich in calcium carbonates. The main rock types (Vaya, 1980) are limestone shales and sandstone. Figure4 gives an overview of geological formations and Figure 5 shows values of aquifer thickness in the study area.

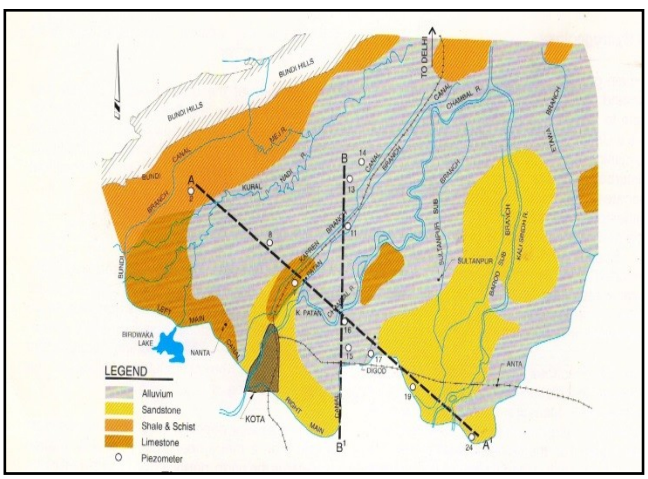

Figure 4. Chambal Command Area Surficial Geology.

The thickness of alluvium in the command area occurs from few meters to about 40 meters. Alluvium formation occupies the central and north-eastern part of the command area. Wells installed at 40-60 m deep are expected to yield 20-30 m^3/hr. Limestone formation occurs throughout the command area either in isolated patches or followed by alluvium. The expected yield of wells installed 80-150 m deep may range from 60-90 m^3/hr. The study area is majorly covered by alluvium followed by limestone and very slight area of sandstone.

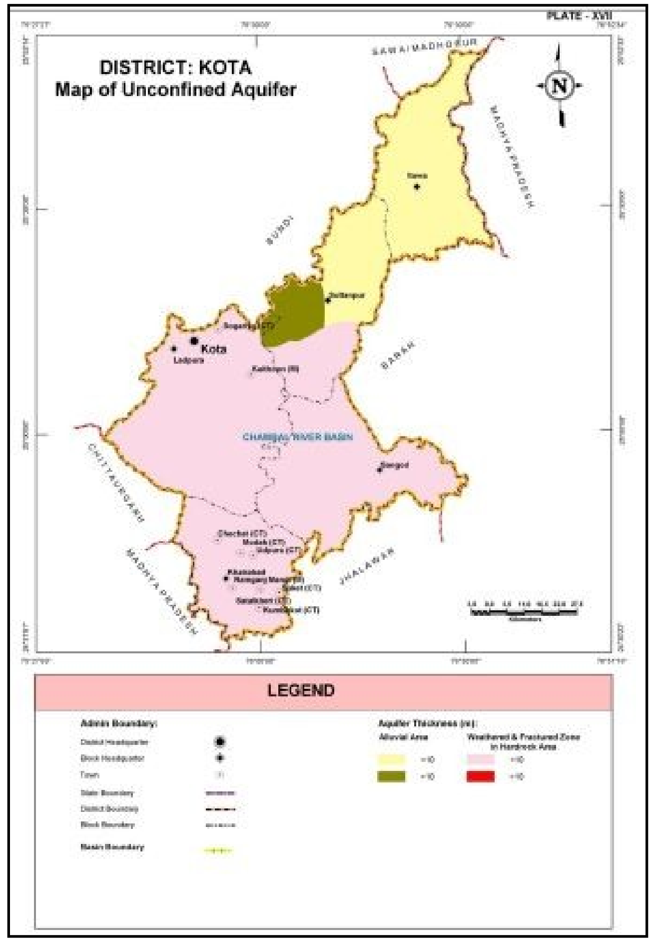

Figure 5. Chambal Command Area Aquifer thickness Map.

Soils

The main soils found in the command area are alluvial sand, silt and clay. The thickness of the alluvial deposits changes from less than a meter near Kota to several meters towards the north, north-east and north-west of the command. The parent material of sand, silt and clay conformation may vary in texture, depending on the kind of deposition of the alluvium. It may also vary in its characteristics, depending on the source of the material, which is often rich in calcium carbonate and lesser amounts of other elements mainly sesqui-oxides. This parent material commonly consists of sand lenses and sand layers. These may be restricted to small areas or may spread over large areas, which may occur deeper in the profile below 1m.

Most of the soil series have a layer with high calcium carbonate concretions, known as “kanker”, at varying depths. Bhatnagar (1990) described kanker as a layer of calcium carbonate concretions comprised of silicate particles held tightly together by calcium and magnesium carbonate, and a small fraction of alluvium, iron, sodium, potassium and different trace elements. These layers are generally believed to be restrictive to the movement of water, air, and root penetration due to dense nature of the materials.

During 1968-81, a detailed soil classification of the command area was carried out based on texture, soil colour, depth and presence of 'kanker' layer. The soils were categorized into eight series given in Table 1 and presented in Figure 6.

Table 1. Soil classification series in the chambal command area

S. No.	Soil Series	Per cent
1.	Chambal	62
2.	Chambal Variant	6
3.	Kota	5
4.	Kota Variant	23
5.	Sultanpur	1
6.	Bundi	<1
7.	Guda	<1
8.	Alod	<1

Source: RAJAD (1995)

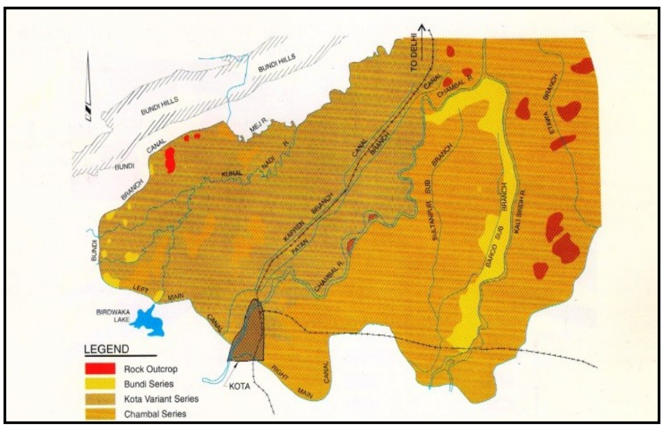

Figure 6. Chambal Command Area Soil Series.

Irrigation

In 1960, two dams Gandhi Sagar Dam and Kota Barrage were constructed to initiate irrigation facility in the command area. Later on two other dams Rana Pratap Sagar and Jawahar Sagar were also constructed. Kota Barrage provides irrigation water to the command area through two canal system. One is left main canal which runs in Rajasthan with approximate length of 2.74 Km and other is right main canal flows both in Rajasthan and Madhya Pradesh, its length in Rajasthan is 124 Km. The length of branches, distributaries and minors of left and right main canal is 966 Km with design discharge of 42 m^3/s and 1367 Km with design discharge of 188 m^3/s respectively. The irrigation water quality is good with an average electrical conductivity (EC) of 0.3 ds/m and total dissolved solid of 200-250 ppm. Figure 7 represents canal system of Chambal Command Area in Rajasthan.

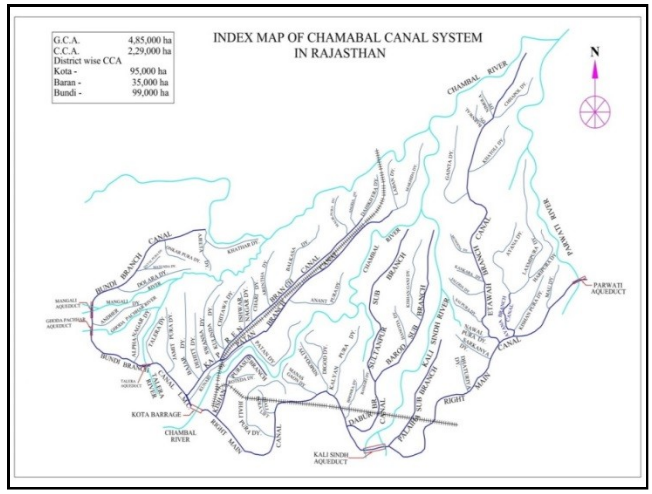

Figure 7. Chambal Command Area Canal System.

Salinity and Waterlogging

Before the commencement of irrigation, some area was found saline and waterlogged in the chambal command. Figure8 shows salinity profile from year 1951-58 in the Digod tehsil before irrigation, indicating less evidence of salinity in the area.

Around 10 year after irrigation development, approximately 20,000 ha of land had a water table within 1.5 m below ground surface and 1,61,000 ha within 3 m (Darra, 1993). Based on the 1972 soil survey, an overview of the saline area in study area is shown in Figure 9. It was interpreted from the map that saline and waterlogged conditions occurred in irrigated areas. It was found mostly near main and branch canals due to leakage and seepage from the canals leading to about 5% of the land gone out of production. The affected area was increasing 1 per cent per annum. Also the natural drainage system was not adequate to remove excess monsoon rainfall.

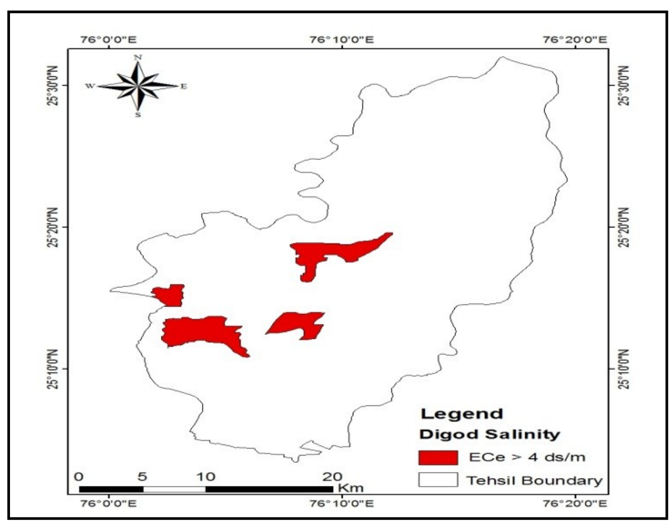

Figure 8. An overview of Salinity Profile from 1951-58 in Digod Tehsil.

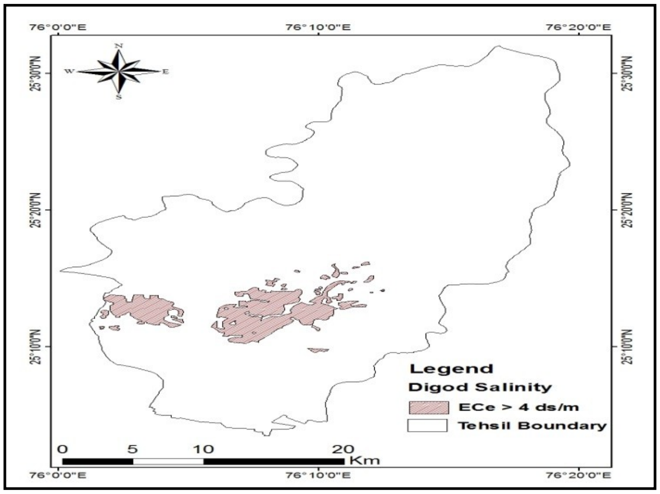

Figure 9. Layout Map showing Saline Area of Study Area in 1972.

Command Area Development Projects

Since the introduction of irrigation in 1960, severe problem of salinity and waterlogging had been observed in the command area which was worsened by undulating nature of the terrain, improper water management and conventional farming practices. The irrigation water was not reaching to the field's adequately due to lack of knowledge among farmers regarding proper utilization of the irrigation water and ineffective field distribution system to receive and drain water.

In 1967, a project of Land and Water Use Management was introduced with the help of Government of India, the United Nation Development Program (Special Fund Sector) and FAO (Food and Agriculture Organization of the United Nations) with the objectives of: Finding various mean to protect the area against salinity and water logging, development of proper water management practice and giving recommendations for proper land and water management.

By the end of 1970, a land development system evolved which was subsequently supported by World Bank and known as On-Farm Development (OFD). The main objectives of the OFD program were: to ensure an equitable and reliable distribution of irrigation water to all fields, to provide efficient on-farm utilization of the available water supplies, to control excess water in the soil due to irrigation and rainfall and to construct road and other works to facilitate timely movement of farm inputs and produce.

The OFD program is comprised of several components including: the construction of irrigation and drainage ditches to serve each farm, realignment of farm boundaries to permit a rational layout of irrigation, drainage and road system and land shaping to enable efficient irrigation of field crops.

Since the inception of OFD work in the chambal command in 1976-77, approximately 1,58,000 ha of development work had been completed till now. Figure 10 shows OFD work completed in the area and Figure 11 shows layout of OFD system.

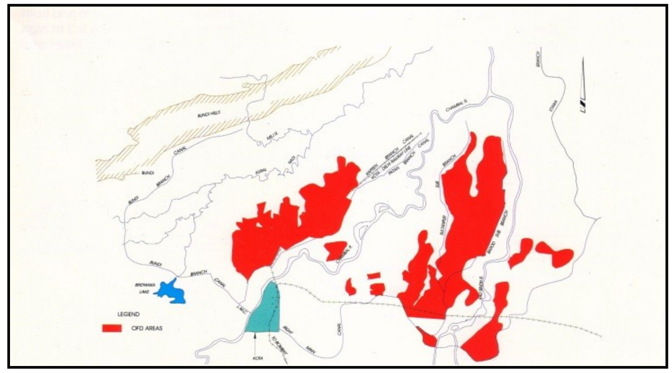

Figure 10. On Farm Development Program completed in Chambal Command Area.

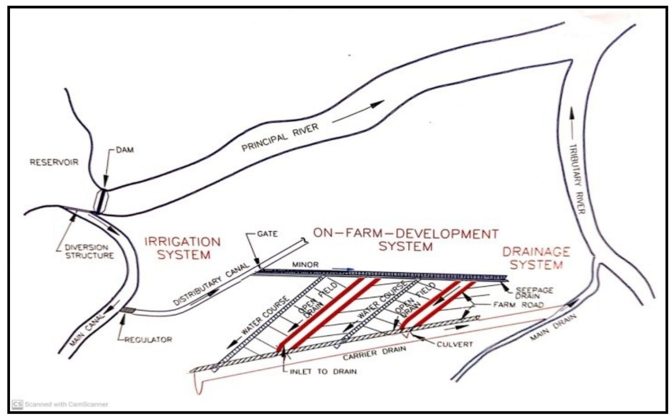

Figure 11. Layout of On Farm Development System.

On Farm Development Program

The items of on farm development are realignment of the field, field channels and drains with approach road planned on topographical consideration. Following are treatment work performed during program:

Irrigation System

The irrigation system is based primarily on the contours and not on the sazra map. The water runs down the top of natural ridges with field drains in the intervening depressions. Strips of fields are laid in herringbone fashion at such an angle to the existing contours that the slope of their long axis conforms to that required for most efficient irrigation.

All the fields which have been receiving irrigation water even by putting obstructions and raising FSL artificially are to be kept under commend by surface flow. To achieve this the canal FSL may have to be raised, if required. This will have to be done with caution in view of increased seepage losses with raising of FSL. Areas commanded by lift at present will be tried to be brought under flow irrigation, however, abnormally high patches will continue to receive only lift irrigation else the concerned cultivators will feel deprived of the facility being enjoyed at present.

The water delivery from the watercourse to fields will be through turn-outs initially but the watercourse will be designed for ultimate use of syphons for which the minimum working heads of 10 cm will have to be provided through endeavor will be made to have more working head.

The outlet should generally be of 30 l/s capacity but may vary between 20 l/s to 40 l/s capacity depending on the area and topography. All such outlets with discharge below 20 l/s and above 40 l/s should be examined in special cases and provided, if absolutely necessary.

Desirable working head in the canal at off-taking point of water course should be 30 cm. However, if topography does not permit it may be reduced to 15 cm too.

The bed slope in water course should generally be 1:1000 but may vary from 1:500 to 1:2500 depending upon the natural topography, soil type and availability of working head in the canal. However, it will be preferable to have velocity more than non-silting velocity as worked out by:-

$$V_0 = 0.3092\ Y^{0.5}$$

Where V_0 = Non-silting and non-eroding velocity in m/sec

Y = Depth of flow in meters.

In case of flatter slopes more than 1 in 3000, lining will have to be provided in the water courses.

For calculations of discharges, CCA will be the entire area served by the water course and will be calculated @0.424 litre per second per hectare (Assumed maximum irrigation demand 0.53 l/s/ha at Barrage Head and canal system efficiency 80% as provided in IBRD Report No. 430-IN page 12 & 45 respectively. Accordingly the flow requirement = 0.53*0.80=0.424 l/s, required at water course head). The discharge so obtained and as provided under 2.3 will be compared and whichever is higher will be adopted for all purposes.

The minimum bed width of 30 cm, will be adopted so as to facilitate the water course cleaning by local spade. Side slope 1.5:1 will be kept 30 cm. for better stability. In case of flatter slopes, bed width is to be restricted to 22 cm in order to develop higher velocity. A free board of 15 cm is to be provided in order to reduce frequent maintenance, operations and to encroach upon the same to some extent whenever required to irrigate isolated higher patches if possible.

Drainage System

The Chambal command area is criss-crossed by many natural nalas which will be trained so as to form the main lateral drain to remove excess water from the catchment areas. To these main/laterals drains all the fields drains will be connected which will be constructed in the natural valleys occurring between the two water courses which are constructed on natural ridges as far as possible.

Field drains arechargeable to farmers account under On-Farm Development Program. All drains running along the canals (Distributaries, minors etc.) and link or collector drains are constructed on Government account.

Open surface drainage system is to be adopted within the OFD areas. The run off from all fields will be collected in the field drains which will ultimately discharge into lateral/main drains. It is assumed that the main drainage system would have already been constructed by the drainage circle in the OFD areas and in case it has not been constructed/designed then the drainage circle will adopt the system as proposed by Land Development Circle and the required outfalls and structures will be incorporated/provided by them.

The farm roads/tracks are being provided along the field drains rather than along the water courses on account of reasons like avoiding of head loss from water course to farm turnouts in view of long pipe crossings, continuous weathering of farm roads/tracks due to traffic and non-availability of earth for its maintenance near water courses and chances of earthen water courses section becoming unstable due to disturbance of soil on account of traffic.

The field, intermediate and link drains are aligned on the valley lines. The drainage system has been designed on the basis of technical report No. 7 (July, 72) published by the water management division of the Ministry of Agriculture New Delhi. The 24 Hrs storm of statistical recurrence period of five years has been taken in to consideration for working out run off. The maximum submergence period has been taken as 72 Hrs for paddy and fallow lands where as for other crops it is 48 Hrs. Optimum depth of field drains has been kept about 1.2 m with a side slope 1:1, top width of 3.15 m and bottom width 0.75 m. It will provide sufficient soil for the construction of field approach roads on both the sides of the drain and shall drain water up to the root zone of the crop.

Realignment and Land Shaping

All the farm properties are necessarily required to be rectangular due to realignment of watercourse and construction of drainage system. Some of the fields which used to get irrigation water earlier get reverse grade due to realignment of water courses and as such the grade correction is also done. Since the realignment and reverse grade correction which is also referred as regrading is done to new system of irrigation and drainage, therefore the cost of these items of woks are charged from the farmers on prorate basis.

Land leveling and shaping for irrigation necessarily means modifying the surface of a field to a planned grade to provide more suitable surface for receiving irrigation water more efficiently. Normally land leveling requires movement of earth over several meters wherever land shaping or grading means removal of minor undulations and cause no change in the general topography of the land surface.

To rationalize and straighten the field boundaries it becomes necessary to realign them. The consolidation of holding may be undertaken to possible extent if farmers are agreed. While realigning the field boundaries due care shall be taken by CAD Revenue Wing to ensure that the newly allotted holding do not differ from the old one in quality of land and that the permanent assets also do not get alienated or exchanged. Fields are laid along the contours in herringbone fashion. To achieve proper longitudinal grade in the fields the boundaries are slanted between contours. This reduces earthwork involved in shaping/ grading of fields. The length of field is usually kept within 210 m for both side irrigation. This work shall be done by the department but minor correction in the individual fields for efficient irrigation shall be done by the farmers/beneficiaries against their contribution.

It is considered very essential to have farmers participation and looking to the fact that the period available for execution of OFD words is very limited the land leveling works takes place in two phase. Land leveling operations will be taken up along with the normal infrastructure works in first phase where it is considered that land leveling operations are beyond the capacity of farmers. Leveling in the fields which requires very minor work and which can be taken up by the farmers themselves, is left to be done by farmers in phase two.

Pre-Project and Post-Project Comparative Layout

On-Farm Development Works make the field suitable for attaining sustainable crop production. The percentincrease in crop yield in OFD treated area is expected from 200-250% in class I and II land.Class III land becomes cultivable and expected to give good crop yield. It provides gentle slope for free flow of water to each and every field for irrigation and removal of excess water from the fields. Treated field facilitate leaching of salts to improve soil structure and drainage conditions. A pre and post layout map of OFD treated area is presented in Figure 12 and 13 respectively.

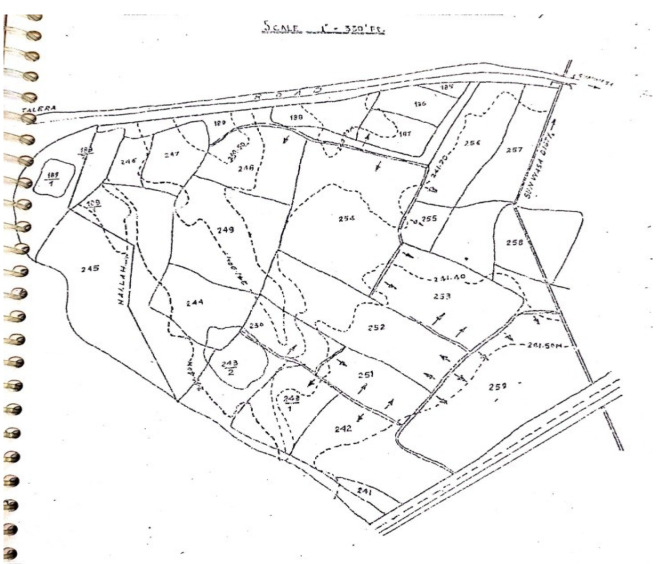

Figure 12. Pre-Project Layout of On Farm Development Works

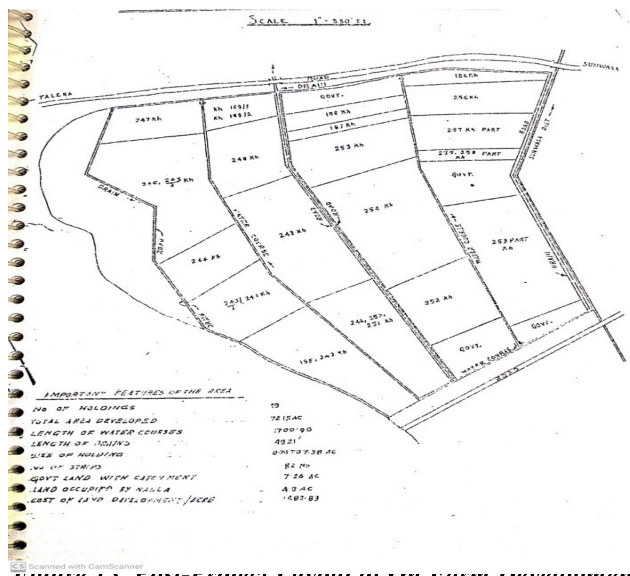

Figure 13. Post-Project Layout of On Farm Development Works

REFERENCES

1. Abrol, J. P.; Yada, J. S.; Pal and Massoud, F. J. 1971. Salt effected soils and their Management. FAO Soil Bulletin 39. Food and Agriculture Organization, Rome
2. Johnson, D. L. and Lewis, L. A. 1995. Land degradation: creation and destruction. Cambridge, Blackwell.
3. Ministry of Agriculture. 1990. Status of land degradation in India. Directorate of Economics and Statistics. Ministry of Agriculture. New Delhi, India
4. NRSA. 1996. Mapping salt-affected soils of India on 1:250,000. National Remote Sensing Agency. Balanagar, Hyderabad, India.
5. Pathak, P. S. 2000. Agro forestry: A tool for arresting land degradation. Indian Farming. 49(1).
6. RAJAD, 1996. Analysis of sub-surface drainage design criteria, Rajasthan Agricultural Drainage Research Project (RAJAD). Chambal Command Area Development, Rajasthan, India, Canadian International Development Agency, 1995 Edition.
7. Smedema, L.K., 1990. Irrigation performance and waterlogging and salinity. Irrigation and Drainage System. 4: 367–374.
8. Singh, G. 2009. Salinity-related desertification and management strategies: Indian experience. Land Degradation and Development. 20: 367-38