been provided as a solution to the problem of perennial drinking water scarcity in the villages of western Rajasthan. The provision of tanka has been an age-old practice.

Nadi

Nadis are small excavated or embanked village ponds, for harvesting rainwater, in order to mitigate the scarcity of drinking water for human being as well as livestock. This is an ancient practice and the nadis are the most important water source of the region.

Khadin

It is a system basically innovated for runoff farming by the Paliwal Brahmin Community in Jaisalmer area, in 15th century. Khadins are earthen embankment (**Figure 1**) constructed on low-lying lands whose crops are raised by conserving rainwater received from the relatively impervious uplands with steeper slopes. These are constructed across the slope of the land to catch and store runoff and silt from the surrounding catchment.

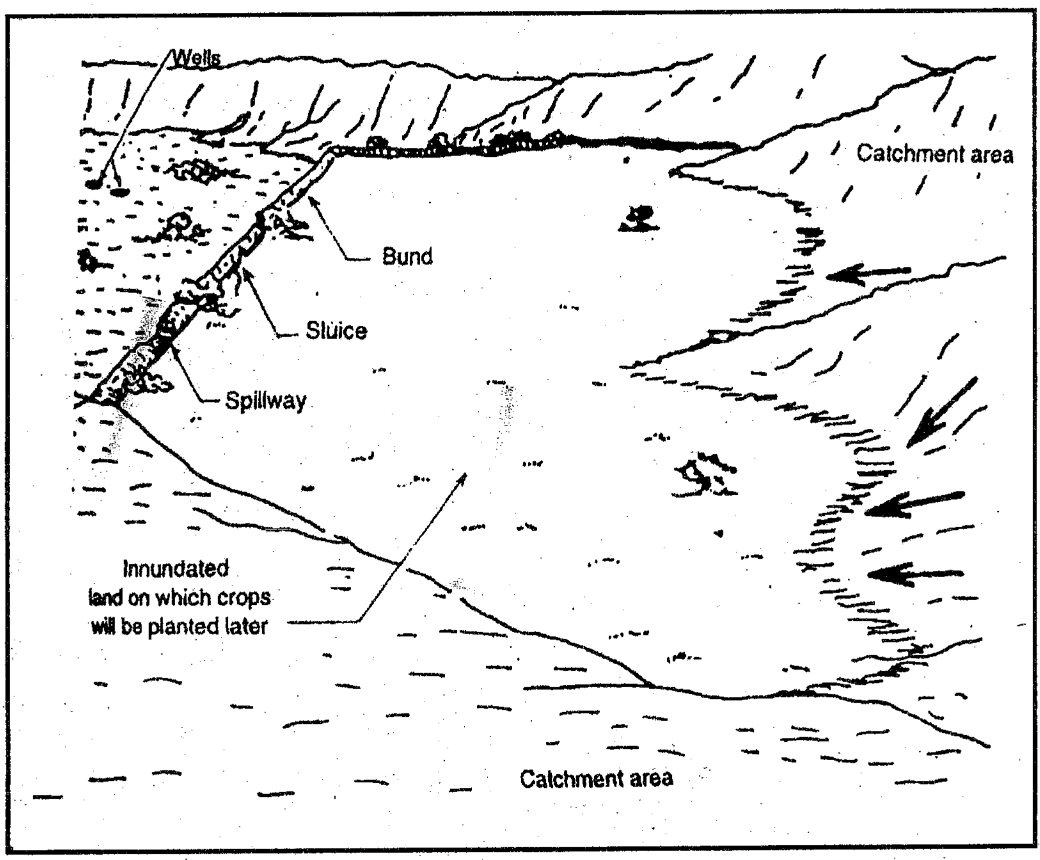

Figure 1 : Typical layout of a Khadin.

The depth of water stored varies from 0.5 m to 1.25 m and it usually disappears from seepage and evaporation by early November, when the winter crop is grown.

The land falling under submergence of the Khadin is cultivable, both in Rabi and Kharif depending upon the quantity of runoff received. If the rainfall is low and less water is received, kharif crops are taken but if the land is submerged during rainy season, cultivation of wheat and gram is done after the water is released. The stored water in khadins also helps in recharging of ground water aquifer.

7.4 WATER HARVESTING STRUCTURES

The most common way to store the harvested runoff water is by impounding. Two types of ponds viz., embankment type and excavated (dugout) type are used. Embankment types of ponds are feasible in hilly and undulating topography, where by constructing a small length of dam across a watercourse, maximum storage of water can be affected. It is advisable to take advantage of earth removed to fill in, providing additional capacity for water storage. In flat areas, embankment types of ponds are not feasible. In such area, excavated (dugout) ponds are more advantageous.

Water harvesting structures mainly comprise earthen embankments with spillways. Quite often there is sizable water storage behind such structures, and in such cases pipe outlets or sluices are provided for taking out water for irrigation. In certain cases these structures help in larger water spread to greater depths in the nallahs / streams in which case the water is often lifted for irrigating small areas. Division reservoirs can be constructed to hold and subsequently use a large volume of water. This diverted water if allowed to go downstream, may lead to flood in excessive rainfall years. These structures help in greater absorption of water on larger areas and also hold some in between dry spells, helping in moderating water stress in dry spells.

7.4.1 SOIL AND WATER CONSERVATION STRUCTURES

The land development, soil conservation methods and Afforestation methods improves the ecological, field and environmental conditions, indirectly improve ground water recharge and increase the surface water storage. Construction of different soil and water conservation structures also helps in conserving water as well as soil. They not only prevent further soil erosion but also maintain soil moisture for better crop production. Following are the various major water harvesting techniques or practices being used for soil & water conservation:

- Terracing of various types.
- Contour bunding, graded bunding & field bunding.
- Agronomical practices such as strip cropping, contour furrowing, contour grassed strips, inter row water harvesting, summer cultivation/ploughing in such areas where soil type is loamy and clayey, vegetative barriers along contours, deep ploughing etc.
- Construction of check dams, gully plugs, shrubs - checks etc.
- Construction of farm ponds, anicuts, khadins, etc.

Use of contour bunds is very successful in areas of lower rainfall particularly in western Rajasthan. With a rainfall of 250 mm or more, low contour bunds only 0.3 m high divide the canal into strips which are progressively inundated down the slope with flooding to a depth of 0.2m during the monsoon. When the rain ceases, the stored water infiltrates and a winter crop is sown (Tideman, 1996).

7.4.2 NALLA BUNDING

Nallah bunding work consists of constructing bunds of suitable dimensions across the nallah or gullies to hold the maximum runoff water to create flooding of the upstream area temporarily for some days or weeks, with surplus arrangements at suitable intervals to drain the water. The temporary storage of runoff against these bunds carries deposition of silt and the water is drained off in a controlled manner. The impounding of water facilitates the percolation of water to the deeper layers of soil profile, which otherwise will flow with intense velocity, causing erosion and silting of the natural drainage courses, lakes & reservoirs. The water released from the bunds will be free from silt and with low velocity to cause erosion. Before it can acquire erosive velocity, it will meet the next bund below in the nallah (**Figure 2**). The basin at the upstream side of the bund will be enriched by the silt deposited progressively and the general level will be raised. Construction of such bunds facilitates reclamation of gullied lands & also recharge of ground water, which in turn increases availability of ground water for irrigation, increasing command area.

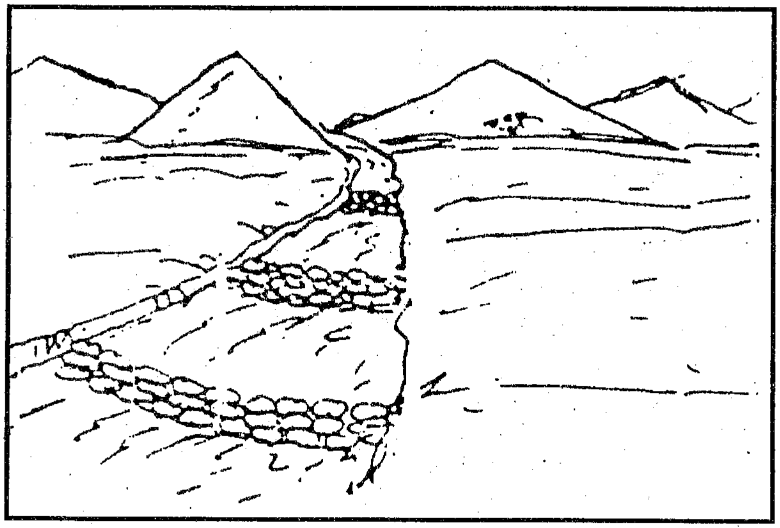

Figure 2: Series of Check Dams in Nalla Bunding.

Check Dams (**Figure 3**) are enlarged versions of gully plugs and help substantially towards increased re-charge to ground water, there by increasing or replenishing well waters in the areas of influence. These structures have been used in Gujrat, Maharashtra, Madhya Pradesh & Rajasthan. Construction of 246 checked dams (at the cost of Rs. 476 lacs) has leads to increase in 1660 ha irrigated area in IWDP Bhilwara (Nahar & Deval 1999). An increase in water table of 2039 wells from 0.85 m was also found.

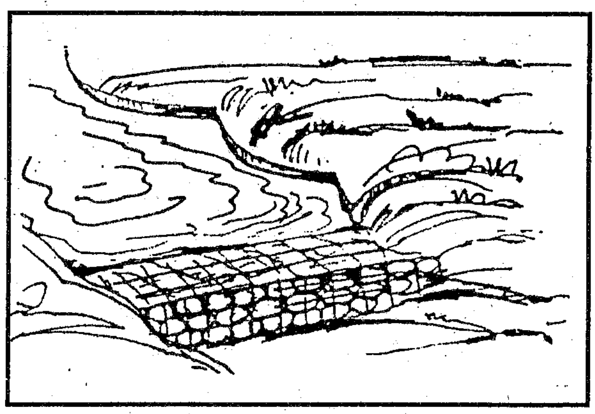

Figure 3 : A Gabion Check Dam.

Anicut (Figure 4) is a weir structure constructed across the natural drain for impounding the water in the drain. Anicuts are more suitable than earth dams when the permanent flow is too big to pass through a spillway and when the object is gully control or to tap sediment. The essential requirement for anicuts is a solid rock

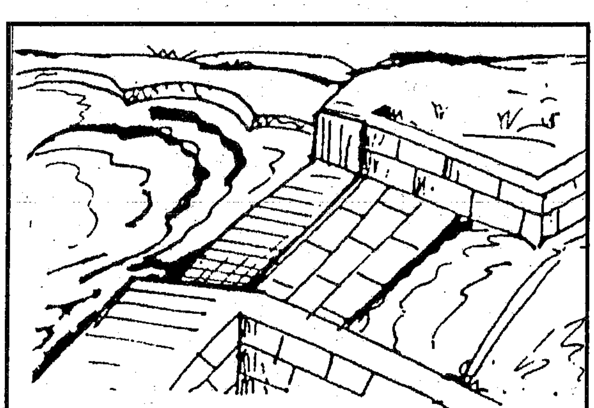

Figure 4 : Anicut.

foundations extending the full width of the stream channel. Anicuts help in recharging of surrounding wells and the stored water can also be used for lift or flow irrigation. Location of such structure should be at such place where maximum storage can be achieved with minimum cost.

7.4.3 FARM PONDS

Constructing farm ponds constitutes an important water harvesting and water conservation practices. It is a water harvesting structure to store surplus runoff water to provide life saving irrigation to the crops during dry spell. Farm ponds can serve a variety of purposes and enhance the beauty and value of rural areas. The more important uses for farm ponds are as follows:

- House hold & livestock water supply
- Fire protection
- Irrigation
- Fish production
- Recreation
- Wildlife habitat

Farm ponds can be dugout ponds or embankment cum dug out ponds (**Figure 5**). Farm ponds constructed for purposes of irrigation should be planned considering use of stored water to meet with kharif season moisture deficiencies and requirement of early rabi season. These ponds may not meet the summer needs in arid areas; ponds in semi-arid areas can be designed even for summer use especially for livestock.

Permanently flowing streams and springs provide a reliable water source for ponds. If the drainage area is small and flood flows are unlikely to occur the pond may be constructed directly in the channel of the stream or spring. Where the topography does not permit itself to embankment construction, dugout or excavated ponds can be constructed in a relatively flat terrain generally upto 4% slope. Dugout ponds can be constructed to expose a minimum water surface area in proportion to volume, they are advantageous where evaporation losses are high and water is scarce. These ponds should be constructed at the lowest portion of the area such as natural depression. The watershed must be capable of furnishing the annual runoff sufficient to fill the dugout ponds or it may be designed as per catchment area. Diversion ditches may be used to supply additional water.

In case the seepage rates of farm ponds are excessive it can be reduced by lining with natural clay soils, bentonite, bituminous materials, soil-cement mixtures, polythene, plastic etc. At locations where the water table rises to within a few meters of the ground surface, dugouts can be constructed to intercept the water, adjusting the depth to the fluctuations expected. Locations of this type may furnish supplies all the year round.

The cost of water / construction can be reduced by using the excavated soil to form a surrounding bank to contain water above the original

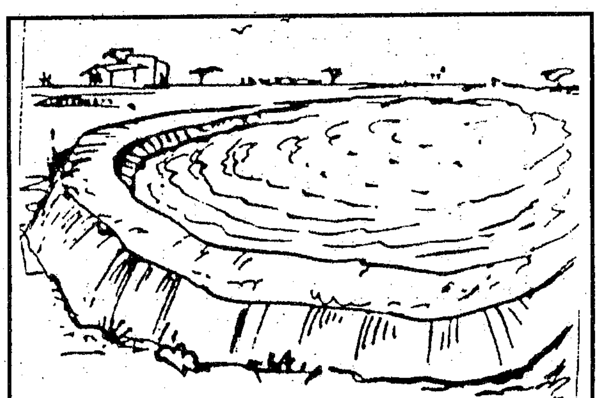

Figure 5 : Dug out farm pond.

ground level. Filling these reservoirs with flood runoff by gravity will be cheaper then pumping from a stream or borehole. In hot, arid climate, evaporation losses can be minimised by having more depth and less surface area.

Dr. Anil Agarwal, famous environmentalist and member of World Water Commission suggested that a pond of 1.25 ha in each village is sufficient to supply drinking water to all rural people of the country. As the farm ponds are often not feasible with smallholdings of 0.5 or 1 ha. They can, however, be constructed in such cases on a co-operative basis, while all farmers and rural people know about utility of farm ponds. It is proposed that farm ponds may be constructed by each farmer having land holding more than 2 hectare. These ponds may also be constructed on community basis through user's participation and contribution. In command areas also, these type of farm ponds or diggies must be promoted to store canal water during their pre-allotted time and then re-use later on for irrigation through pressurised irrigation systems, as and when actually required by crops. It has been found that construction of diggi and use of sprinkler set for irrigation in Western Rajasthan has been economical with a B.C. ratio of minimum 2.29:1 with right cropping pattern at 13% interest rate and no subsidy (Madhok & Gupta, 2000).

Farmers do not get competent advice on design, layout & construction of farm pond, therefore, proper training & guidance should be provided to overcome these deficiencies.

7.4.4 DIVERSION RESERVOIRS

In some situations it may be impractical to build storage works directly in the stream, and in such cases diversion reservoirs **(Figure 6)** may serve the purpose, these reservoirs are filled by diverting water into them or by pumping. These structures may be costly because they loses the advantage of the storage capacity in the stream channel but they are economical when the construction of ani cut or reservoir in the stream is too costly due to poor foundation, broad width, heavy flow i!1 the stream, too large submergence creating large number of resettlement, etc.

Many streams have rather high flood flows, making construction very costly. Diversion reservoirs are excavated adjacent to rivers / nallahs to store the water. These ponds permit a portion of the water flowing in the river to be diverted or by passed through the pond, while the remainder of the flow occupies the stream valley. With a continuous supply of water from rivers / nallahs, the storage can be used for several purposes.

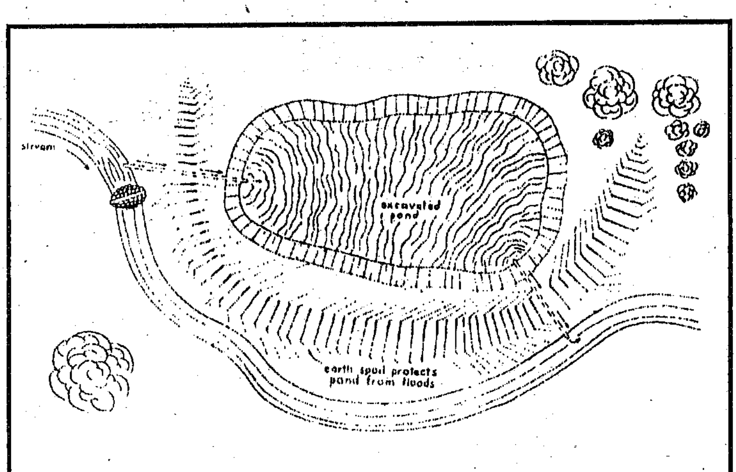

Figure 6 : Diversion reservoir.

Construction of diversion channels to divert runoff from hills & above the gullies will effectively protects the bottom land from hillside runoff and diverts water from uncontrolled areas away from buildings, fields etc.

The advantages of **Diversion Reservoirs** are:

- They are very much suited in areas where it is impractical or uneconomical to build storage works directly across the stream. As compared to other irrigation reservoirs they can be constructed with less financial requirement.
- As compared to Anicuts which are generally constructed in our state in rivers and nallahs diversion reservoirs are more economical especially where huge structures have to be constructed to heavy flows in the streams.
- Site locations where availability of hard rock for foundation is not available construction of anicuts or dams are very costly. Therefore, at such locations diversion reservoirs can be constructed with less cost.
- These structures do not require any resettlement and rehabilitation as they can be constructed in non-habitat area.
- There is no destruction to valuable flora & fauna as they can be constructed outside the forest area. Therefore, these structures are eco-friendly.
- They can be constructed in very short duration, as they don't require construction in the stream. Other structures like anicuts, etc. are constructed in the stream therefore they are generally constructed when their is no flow in the stream or water has to be diverted, which again require additional cost.
- These reservoirs are generally earthen hence more labour can be employed as compared to other structures which has more than 75% material component and hence labour employed is also very less.
- As these structures are constructed off the stream, chances of failure due to heavy rainfall are very low. As these structures don't require much strength as compared to others, their construction cost is also very low. At the same time their life is also more.
- These reservoirs can be used for several purposes like domestic, irrigation, live stock & fish production, wild life, recreation, etc.
- These structures can be constructed in wild life century also to be used by wild life.
- As these structures are generally small in size their maintenance is also easy and can be done by the users.
- These structures are of very much use in artificial recharging of wells and therefore they can serve the purpose of drinking water for a village.
- These structures can be constructed nearer to the end user as they are not limited to be constructed in stream. Therefore, the conveyance losses are also reduced.
- These structures can be constructed in hilly as well as plain area. But they are most suited to area where water can be diverted and filled into reservoir with gravity flow. In hilly area it is easy to locate such site where water can be diverted without constructing any heavy diversion structure.
- In case of stream having perennial flow these reservoir can be constructed of larger size and in case of non-perennial stream comparatively smaller size reservoir can be constructed which can be filled by the runoff received from the catchment area.
- These reservoirs can be easily lined (by plastic, clay, bitumen, etc.) if mainly required for drinking purpose otherwise they can be kept unlined to recharge ground water.

7.5 UTILIZATION OF HARVESTED WATER

The present method of harvesting and utilization of the water is by constructing big dams and store large quantity of water in the reservoirs and take this water through a network of canals up to outlets to irrigate about 10-40 ha under each outlet. Experience has shown that the overall water use efficiency in the major and medium irrigation projects is less than 30%. This is due to the fact that the water is conveyed through uncontrolled gravity flow and the farmers use as much water as possible with ill effects of over irrigation including leaching of fertilizers, unequal distribution of water, waterlogging & land becoming saline. The result is poor yields and lands becoming unproductive after some years despite huge investment on the creation of irrigation facility for this area.

The immediate need of the hour for increased production of food grains on a sustained basis is to bring more area under improved irrigation methods using the same quantity of water and causing least environmental problems. This calls for a change in the concepts of irrigation and the traditional irrigation (flooding) methods need to be replaced by more efficient methods that can be adopted by farmers with some training.

By introducing pipe conveyance system clubbed with sprinkler and drip irrigation for the crop, it is possible to expand irrigation facilities to larger area from the same quantity of water. Development in this direction has already started in the water scarce states such as Gujrat and Maharashtra. Maharashtra Government sanctions lift irrigation schemes only if the water is conveyed through pipes and use drip or sprinkler method of irrigation. The Gujrat Government is planning to bring large area under irrigation by introducing drip method in the Narmada Project. The Governments of Madhya Pradesh and Haryana have introduced Sprinkler method in the canal command area to increase the water use efficiency (Sprinkler Irrigation in India, 1998, INCID, New Delhi). In India less than 1% area has been covered with Sprinkler irrigation whereas in Libya 100% & in Saudi Arabia 64% of irrigated area has been covered with Sprinkler Irrigation.

In Rajasthan about 145000 sprinkler sets have been distributed until March, 2000. This is a very low progress despite the fact that several districts are facing the problem of falling watertable. 45 blocks have been identified as over exploited. Alwar, Jhunjhunu, Jaipur, Sikar, Nagaur, Ajmer, Pali & Jalore districts which have been classified as over exploited has about 60% sprinkler sets distributed in the state. Still other districts, which falls under over exploited zone must promote, sprinkler irrigation system instead of gravity flow irrigation.

Therefore, efficient utilization of water is of utmost importance. Need of the hour is that drip and sprinkler irrigation should be promoted in the state.

7.6 ACTION NEEDED

In Rajasthan where rainfall is scanty and drought frequency is very high, conservation of every drop of rainwater is essential, otherwise we will be facing unprecedented crisis of drinking water in years to come. To be very precise the water resource crisis is no longer a futuristic one but it appears to be the most severe crisis, which our state is going to face.

In many parts of the country and also in Rajasthan the formation and optimisation of water resources is far from being steady and continuous process. During prolonged periods intermittent stream became more intermittent and the return flow is practically

not possible, unfortunately the field of hydrology is most neglected in facing such a situation and traditionally also, it is split into surface water hydrology and ground water hydrology
7.7 with little attention devoted to the interaction of ground & surface water.

To mitigate the droughts, conserve water and to utilise available water efficiently following action is suggested:

- Water resource development, conservation, efficient utilisation and proper management should be promoted by the state government.
- A systematic exploration of water balance study in each block should be initiated, so that net water to be available for replenishment can be assessed after taking into account the evaporation, infiltration, surface runoff & deep percolation. After identifying the deficit zones possibility of inter basin transfers should be explored.
- Overall system for water supply, irrigation, flood control, erosion control & drainage can be accomplished more advantageously by considering watershed or catchment areas rather than village or district boundary. Water harvesting schemes can be taken on watershed basis comprising gully plugging in minor streams, percolation tanks along tributaries, contour bunding or trenching along hill slopes, farm ponds in the foot hill zones and wherever possible, check dam-cum-minor irrigation dams on the main stream. Land levelling (terracing) and Afforestation along hill slopes also form part of watershed development plan because they help in higher rainfall infiltration.
- Traditional water resources like khadins, tanks, Nadis, Tankas, Bawaris, etc. should be renovated, maintained and protected for future use. People participation should be encouraged in this work.
- Similarly, farm ponds may be constructed by each farmer having land holding more than 2 hectares. These ponds may be constructed on community basis through user's participation and contribution. In command areas also, these type of farm ponds or diggies must be promoted to store canal water during their pre-allotted time and then re-use later on for irrigation through pressurised irrigation systems, as and when actually required by crops.
- Construction of water harvesting structures must be taken up with people's participation and active contribution. The problem of shortage of funds, if any, can also be overcome, because close co-operation helps in people willing to come forward and take over management & offer 'Sharmadan'. Irrigation from these water-harvesting structures must be done on participatory irrigation management by formation of water user's association.
- Proper maintenance of existing recharge structures (ponds, tanks, etc.) should be carried out regularly.
- Roof water harvesting, percolation through tanks, pits, trenches, etc. should be promoted.
- Schemes like watershed development, construction of farm ponds, reservoirs, etc. must be planned in advance and must be executed during drought relief works.

7.7 SUMMARY

Our country has over 16% of population of world but has only 4% of utilizable world water resources. Rajasthan has about 11 % of geographical area of the country but has only about 1 % water resources of the country.

Due to scanty and uneven distribution of rainfall state is severely and regularly suffering from drought problem. To mitigate droughts, to counter floods and to develop water resources of the state, it is essential to harvest rainwater, which otherwise is going waste to the sea. Storage and recycling (either as surface or ground water) of this water will stabilize the agricultural production; improve ground water recharge so as to have assured supply even during droughts besides maintaining the ecological balance of the state. The rainwater harvesting can be achieved by in-Situ harvesting structures like Nadi, Tanka, Sand Filled Reservoirs, Ponds, Roof Top Collections/Hill Top Collections, etc.; by Storage of water in aquifers through Percolation Tanks, Khadins, Anicut, Check Dams, Subsurface Dams/Barriers, Injection Wells, etc.; by Soil Conservation Methods like Gully Plugging, Contour Bunding, Afforestation, Contour Trenching, Land Levelling, Terracing, and Bunding of Fields, etc. Selection of any of these structures depends on the several factors like geography, soil, climate, purpose and cost.

7.8 SELF-ASSESSMENT TEST

1. Why it is essential to do rain water harvesting in Rajasthan? Explain.
2. Which traditional rainwater harvesting structures are found in Rajasthan?
3. Define water harvesting.
4. What are the advantages of water harvesting structures?
5. What are the advantages of diversion reservoirs?

7.9 KEY WORDS

- ***Water harvesting***: collection & storage of rainwater.
- ***Tanka***: covered underground tank for collection & storage of surface runoff.
- ***Nadi***: small excavated or embanked village ponds, for harvesting rainwater.
- ***Khadin***: are earthen embankment constructed on low-lying lands whose crops are raised by conserving rainwater.
- ***Nallah bunding***: constructing bunds across the nallah or gullies to hold the maximum runoff water.

7.10 SUGGESTED READINGS

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UNIT-8

DESIGN OF WATER HARVESTING STRUCTURE

Structure

8.0 Objectives

Water and air are the two elements, which are required for survival of human. The other elements like food and shelter, which are required are derived from natural environment, which in turn require the elements of water and air to survive. It is said that water is life because the water is required from birth to death for human being and for survival for drinking, washing; irrigation and other industrial applications.

The rapid development of cities & population explosions in urban area have led to depletion of surface resources. whatever sources available now are at long distances forcing the Corporations to spend higher capital expenditure. This is the reason that the Cherapunji in Assam, which receives highest rainfall in India to the tune of I 1000 mm per year, also suffer from acute shortage of drinking water as rainwater is not consumed but allowed to drained away. This has also resulted in over exploitation of surface sources like open wells, resulting to dropping of water levels and drying of bore holes because of imbalance of inflow and outflow equation of sub surface water.

The results of man-made crisis can be seen as global warming & change in climatic conditions. The rains have become more irregular because of disturbance in natural cycle. Also the quantity of rainfall is erratic, reduced and uncertain. Hence, need for conservation has been felt much more than ever before. It is therefore necessary to conserve and augment the renewable natural groundwater resources as last chance for survival, realizing that natural resources are not unlimited if they are exploited beyond certain limit.

In past 10 years, some extraordinary efforts made by community in India to harvest rain water has shown that it not only improves the local ecology but also improves economy, agriculture, forestry & animal husbandry to improve their living standards.

8.1 Introduction

Nature replenishes the ground water resources annually- through rainfall, by way of infiltration through soil layers. Groundwater source has the benefit of availability where water is needed and during emergencies and scarity period. Thus measures should be taken to improve groundwater recharge by water harvesting structures to maintain the reliable and sustainable groundwater resource for supplementary domestic & agriculture needs by groundwater balance use.

Water harvesting may be defined as process of augmenting the natural infiltration of rainwater or surface runoff into the ground by some artificial methods. The methods may be recharge through recharge pits, trenches, bore wells shafts by directly diverting water into existing or disused wells or conserving the rain water by artificial storing and using the same for human use. Local hydrological and soil conditions and ultimate use of water govern the choice and effectiveness of any particular method. This part will be delt with water harvesting though conserving the rainwater by artificial storing.

These are popularly known as anicuts and are built across the natural water streams for storage purposes. Anicut may be defined as an obstruction constructed across the river to effect local storage and raise the water level locally.

8.2 Collection of Information

Before the actual construction of any water harvesting structure, it is necessary to properly plan and prepare full scheme, and also to design various components of the project. The proper planning will ensure an economically and efficiently functioning scheme which will serve the various objectives in view, most efficiently and with minimum expenditure and recurring operational troubles.

8.2.1 Data to be collected

- Hydrological data and data available on nearby surface water sources in the vicinity of area
- The geological data and data available on nearby surface water sources in the vicinity of area
- Data on existing projects (This will help in assessing the net present availability of water)
- Data on topography of the area. (This will indicate low-lying area and high ridges in relation to the available sources.
- Legal data on various legal laws on water rights, land holdings, administrative pattern etc.
- Data on public opinion.

8.2.2 Selection of Site

Where there is any choice, select a site:

(i) Which is situated on straight reach of the stream, sufficiently below bends

(ii) Which is far away from the confluence of large tributaries as to be beyond their disturbing influences

(iii) Which has well defined banks

(iv) Which makes approaches roads feasible on the straight

(v) Which results in maximum storage with minimum submergence & minimum length of the structure.

Intelligent inspection and local enquiry will provide very useful information's, namely, marks indicating the maximum flood levels, the afflux, scouring tendency, probable maximum floods and many other particulars. Inspection should also include notes on existing stream conditions from which the silt factor and the co-efficient of rugosity can be estimated.

8.2.3 Essential design data:

1 Catchments area: When the catchment as seen from the "topo" sheets, is less than about 1.25 sq Kn-1 in area, a traverse should be made along the watershed with a chain or compass. Larger catchments can be read from the I cm = 500 m topo maps of the Survey of India by marking the watershed in pencil and reading the included are by placing over a piece of transparent square paper.

2 Cross-sections: As a rule for a sizable stream, three cross-sections should be taken, namely one at the selected site, one upstream & one downstream of the site. Approximate distances, upstream & downstream of the selected site at which cross-sections should be taken are as under.

Catchment area	Distance (U/S & D/S of the crossing) at which cross sections should be taken.
2.5 sq Km	150 m
From 2.5 to 10 sq Km	300 m
Over 10 sq Km	400 ra to 1600 m

The cross sections at the proposed site should show levels at close interval & indicate outcrops of rocks, pools etc.

3 The Maximum H.F.L.: The maximum High flood level should be ascertained by intelligent local observation, supplemented by local enquiry, and marked on the cross sections.

4 Longitudinal Section: The longitudinal section should extend upstream & downstream of the proposed site for the distances mentioned above & show levels of the bed, low water surfaces & HFL.

5 Velocity Observation: Attempts should be made to observe the velocity during actual flood & if that flood is smaller than maximum flood, the observed velocity should be suitable increased. The velocity thus obtained is a good check on accuracy of that calculated theoretically.

8.3 Estimation of flood discharge through empirical formulae

Although records of rainfall exist to some extent, actual records of floods are seldom available in such sufficiency as to enable to calculate peak flood discharge, empirical formulae are developed. Some of the most popular empirical formulae are:

8.3.1 Dickens' Formula

$Q=CA^{3/4}$

Q = Flood Discharge in cumecs

A = Catchrrient Area in Sq. Km

C =1 1-14 for areas with annual rainfall of 600-1200 mm

= 14-19 for area in MP

= 32 in Western Ghats,

or C can be taken from figures for different pails of India

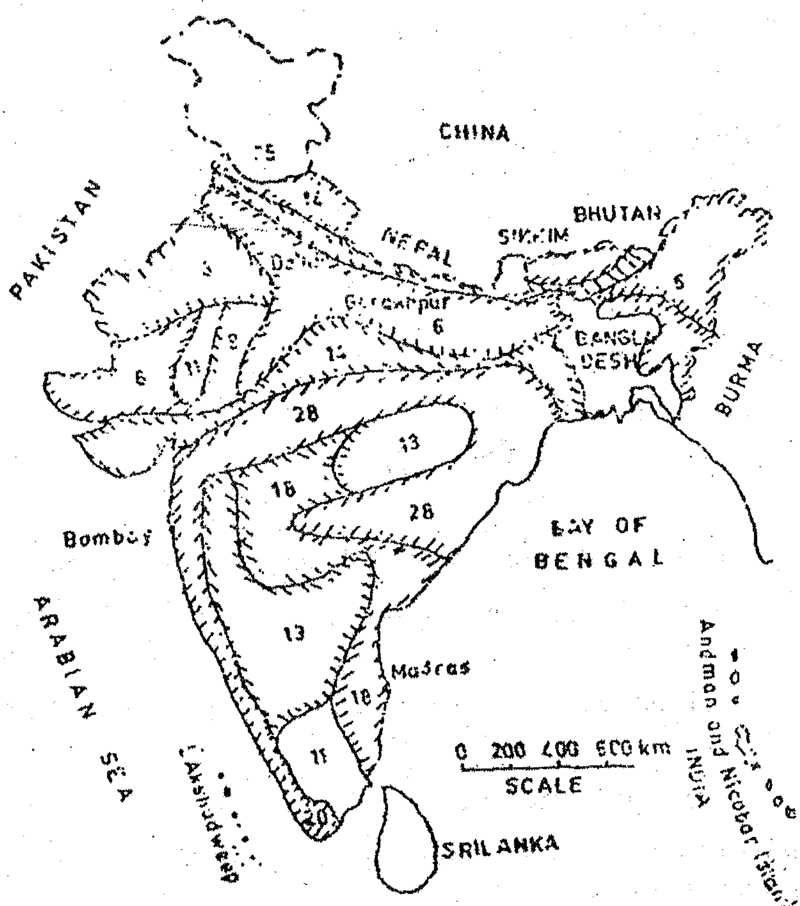


Fig: 1 a Value of IC in Dickens Formula for various parts of India

8.3.2 Ryve's' Vormula

$Q=C\ A^{2/3}$

Value of C is different & formula is applicable for South Indian Catchments

8.3.3 Inglis formula

For Fan shaped Catchments

$Q = 123\, A^{1/2}$ Q in Cumecs & A in Sq. Km

For Small & Large Catchment

$$Q = \frac{123.2\,A}{A+10.36}$$

Applicable for Basins in Maharashtra region

8.4 Estimation of flood discharge through Rational formulae

Thesize of flood depends on the following major factors

Rainfall

(i) Intensity

(ii) Distributioinn in time & space

(iii) Duration

Nature of catchment

(iv) Area

(v) Shape

(vi) Slope

(vii) Permeability of the soil & vegetable cover

(viii) Initial state of wetness

$$Q \quad \frac{CIA}{360}$$ where

Q = Peak Runoff rate in cumecs for the given design frequency of rainfall

C = Rational runoff coefficient depends upon watershed condition (Range varies from 0 to 1)

I = Rainfall Intensity (mm/hr) for the design frequency & for duration equal to time of concentration (Tc)

A = Area of watershed (Ha)

Runoff Coefficient (C)C is ratio of peak runoff rate to the rainfall intensity & depends upon Slope, Land use & Soil type

Vegetative cover & Slope (%)	Soil Texture		
	Sandy Loam	**Clay & Silt Loam**	**Stiff Clay**
Cultivated Land 0-5 5-10 10-30	0.30 0.40 0.52	0.50 0.60 0.72	0.60 0.70 0.82
Pasture 0-5 5-10 10-30	0.10 0 . 16 0.22	0.30 0.36 0.42	0.40 0.55 0.60
Forest Land 0-5 5-10 10-30	0.10 0.25 0.30	0.30 0.35 0.50	0.40 0.50 0.60

Computation of Average C

Determine the area under various land use & soils (A_1, A_2.............A_n)

Average $C = \frac{A_1C_1 + A_2C_2 + \ldots\ldots A_n\text{-}C_n}{A}$

Where $A = A_1 + A_2 + \ldots\ldots\ldots A_n$ in Hectare

Computation of Rainfall Intensity (1) (mm/Hr)

Rainfall intensity is for design frequency & for duration equal to time of concentration in mm/hr One hour rainfall intensity for 10, 25, 50 Years frequency can be available from records or can be taken from figure of one hour rainfall intensity for different frequencies in India.

Thereafter convert one hour rainfall intensity for design frequency to rainfall intensity of duration eoual to time of concentration

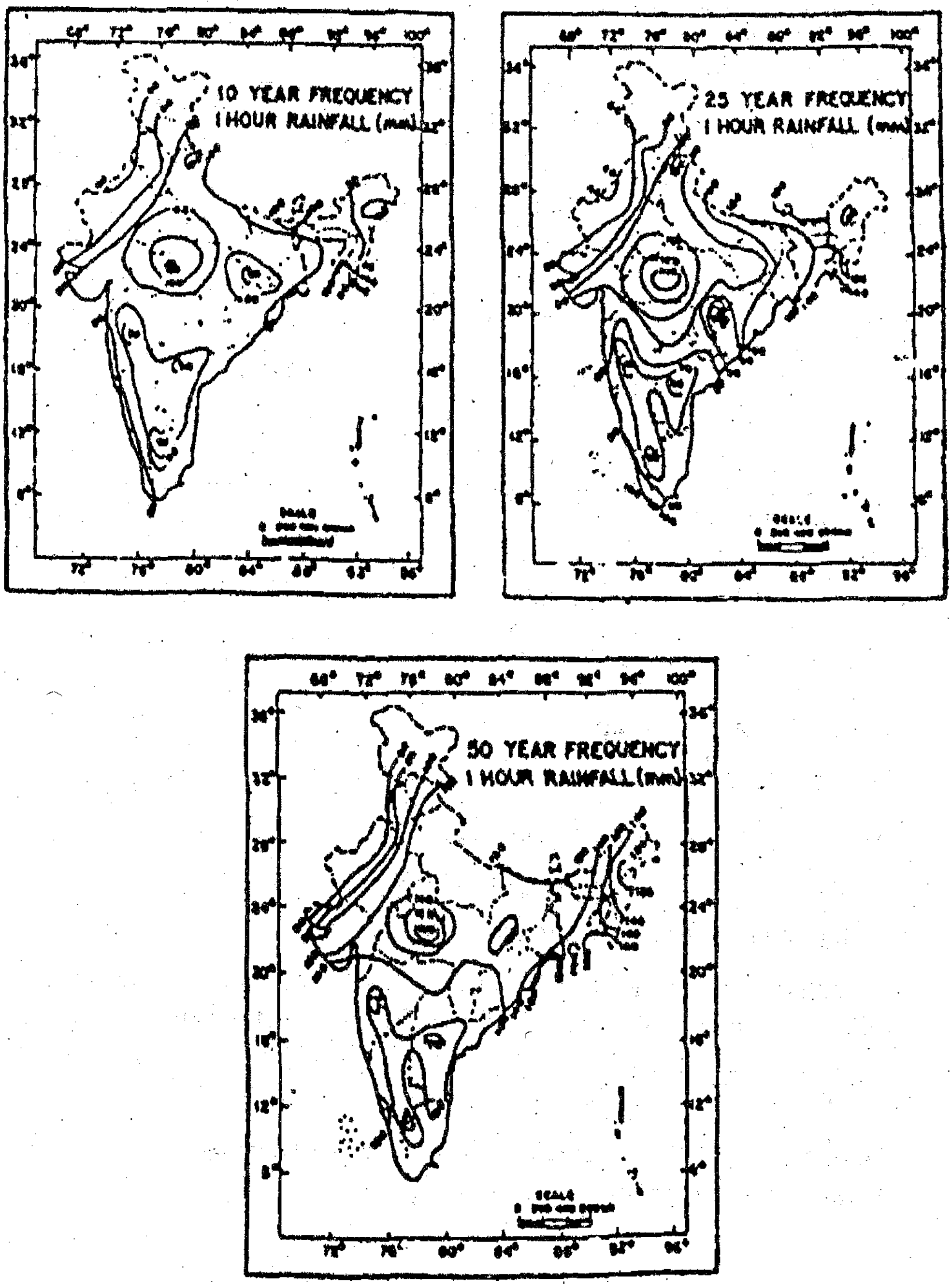
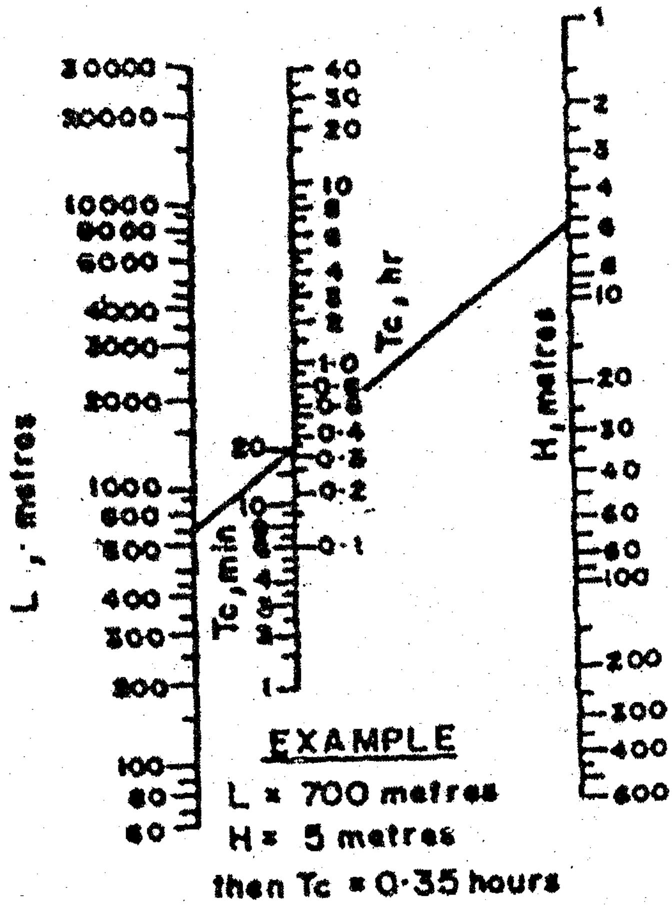


Fig. 1 b One hour rainfall intensity for different frequencies in India



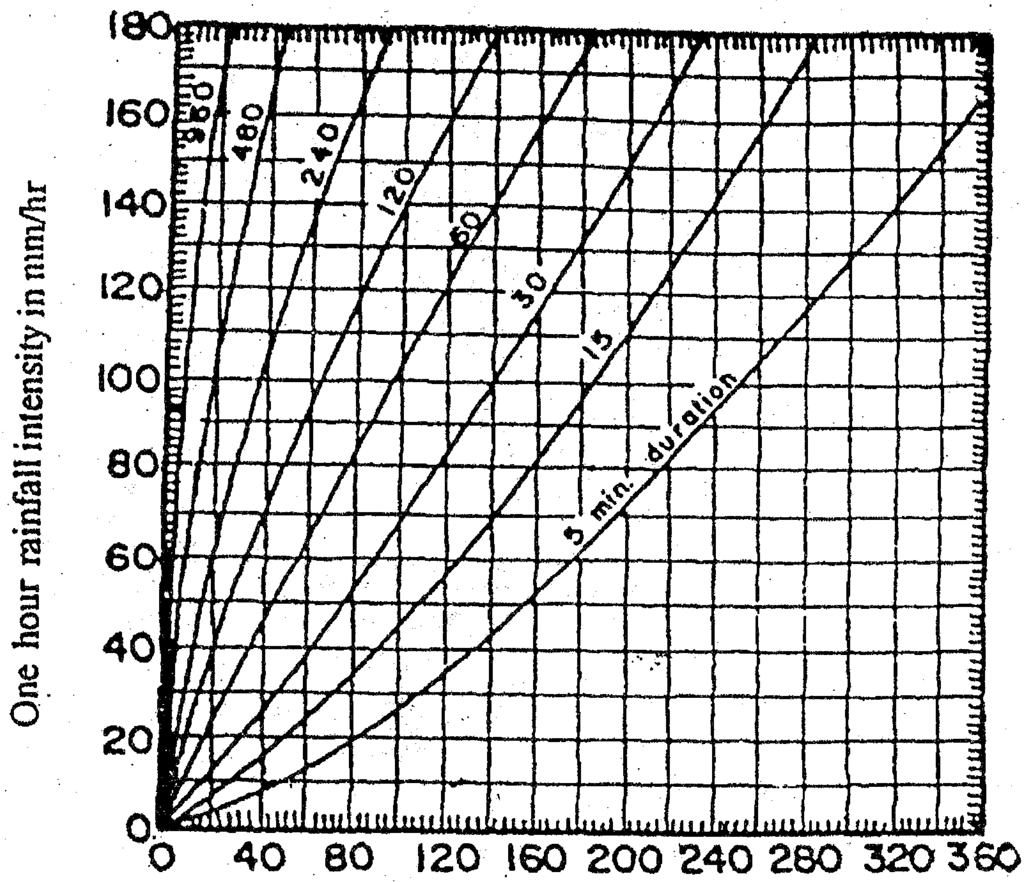
Tc Time of concentration (minute)

L Maximum length of flow (meter)

H Difference in elevation between the most remote point & the outlet (meter) Or can be estimated from nomograph

Nomograph for computation of time of concentration (Tc)

Conversion of one hour rainfall intensity to intensities at other durations



Rainfall intensity for durations indicated, mm/hr

Fig. 1c Relation of one hour rainfall intensities to intensities at other durations

A Area in Hectare

Peak Runoff Q in cumecs

Or Can be computed from Figure below

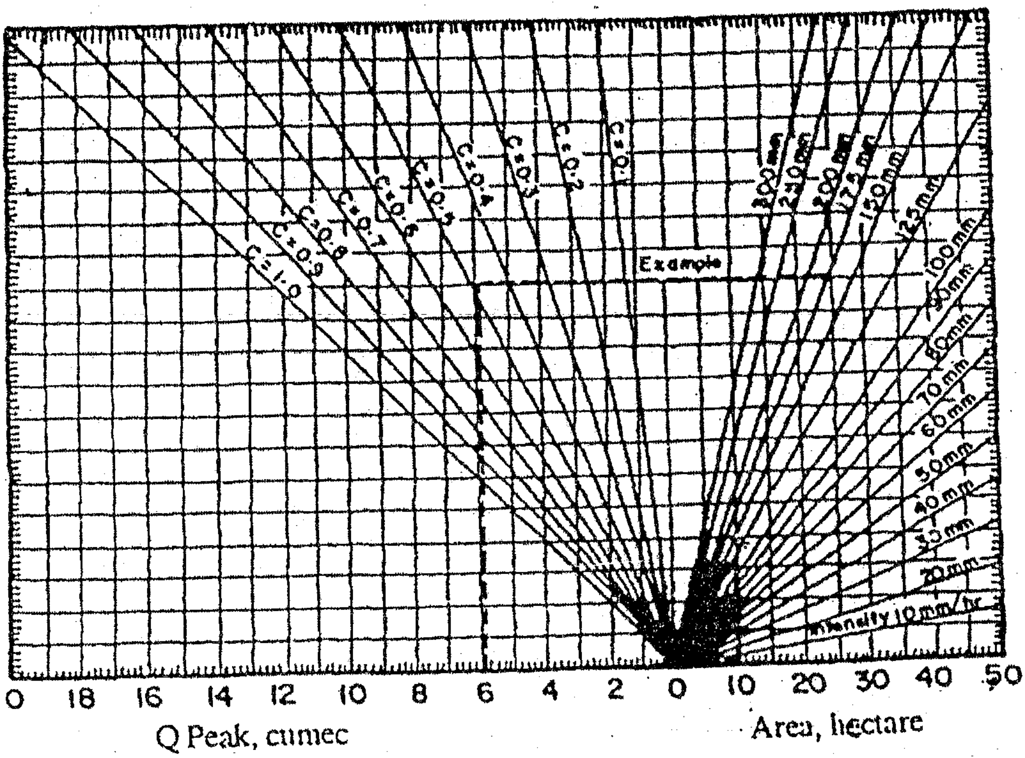


Fig. I d Chart for estimation of Q peak by Rational method

8.5 Fixing top level of Anicut & its Geomatry

Fixing the top bank level (TBL) of the structure is the most important step in planning & designing of water harvesting structure: It depends upon:

(i) Quantity of water to be stored

(ii) Availability of water at defined dependability

(iii) Conditions of banks

(iv) Submerged area

(v) Flood lift

(vi) Foundation type

Generally, the height of structure is limited to that height that avoids extra submergence of land & high flood level remains constant. i.e. TBL may be kept equal to existing HFL - flood lift due to obstruction.

Ideally & economically, the triangular profile of weir serves the purpose of water retention. However, certain top width is provided for provision of suitable footpath & drainage slope.

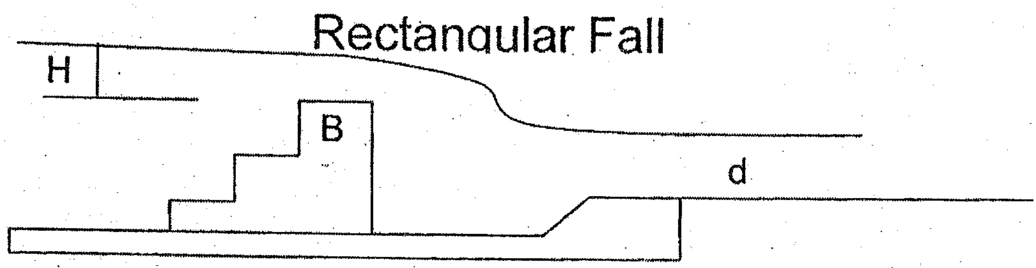
D/s Profile: The downstream profile of the structure may be kept either trapezoidal or it may be kept in Oggee shape. The Ogee shaped weirs/anicuts are much s uitable for passing high discharges. However, for construction ease, trapezoidal shape weirs/.anicuts are generally provided.

8.6 of weir/Anicut:

Steps for design of vertical d

1. Calculation of flood lift:

For vertical drop weir:



Top width of crest: $B = 0.55\ d^{1/2}$

The free fall formula is

$Q = 1.84LH^{3/2}\ (H/B)^{1/6}$

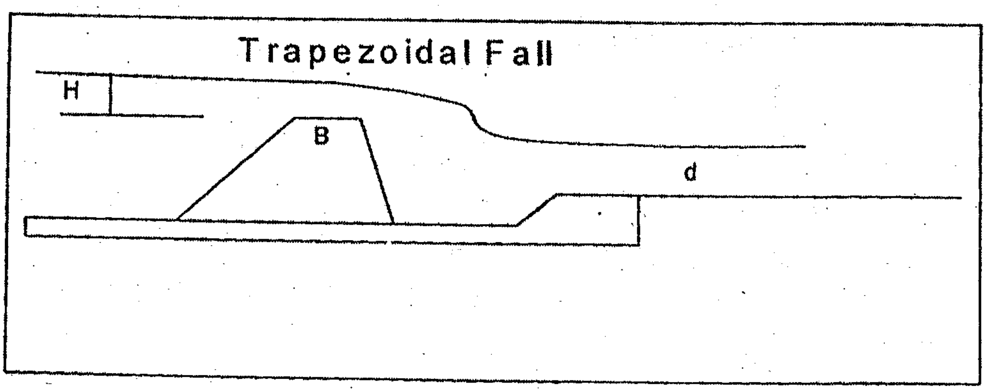
From the above formula, flood lift H can be calculated & accordingly, TBL may be decided.

For Trapezoidal weir:

Top width of crest: $B = 0.55\ [H + d]^{1/2}$

The free fall formula is

$Q = 1.99\ L\ H^{3/2}\ (H / B)^{1/6}{}_2$ Where L = Length of the Crest across direction of flow.



From the above formula, flood lift H can be calculated & accordingly, TBL may be decided.

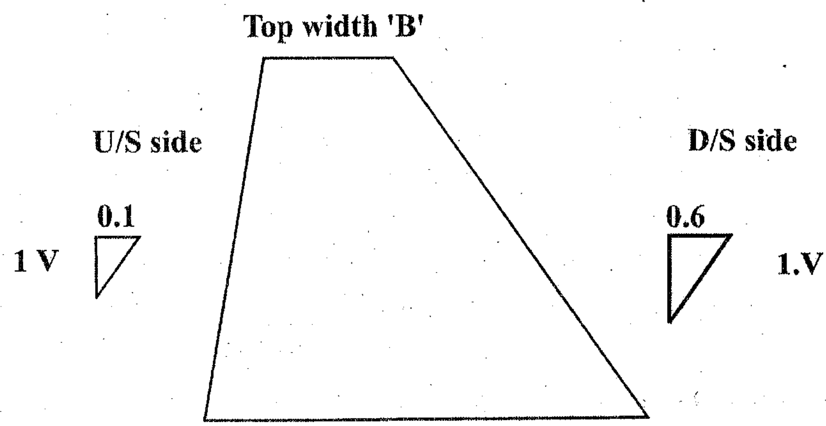
2. U/S & D/S slopes:

The upstream & downstream slopes are provided for making structure safe against disturbing forces like water pressure, uplift pressure etc.

Generally u/s is kept around 0.1H:1V

D/s is kept around 0.6 H: I V

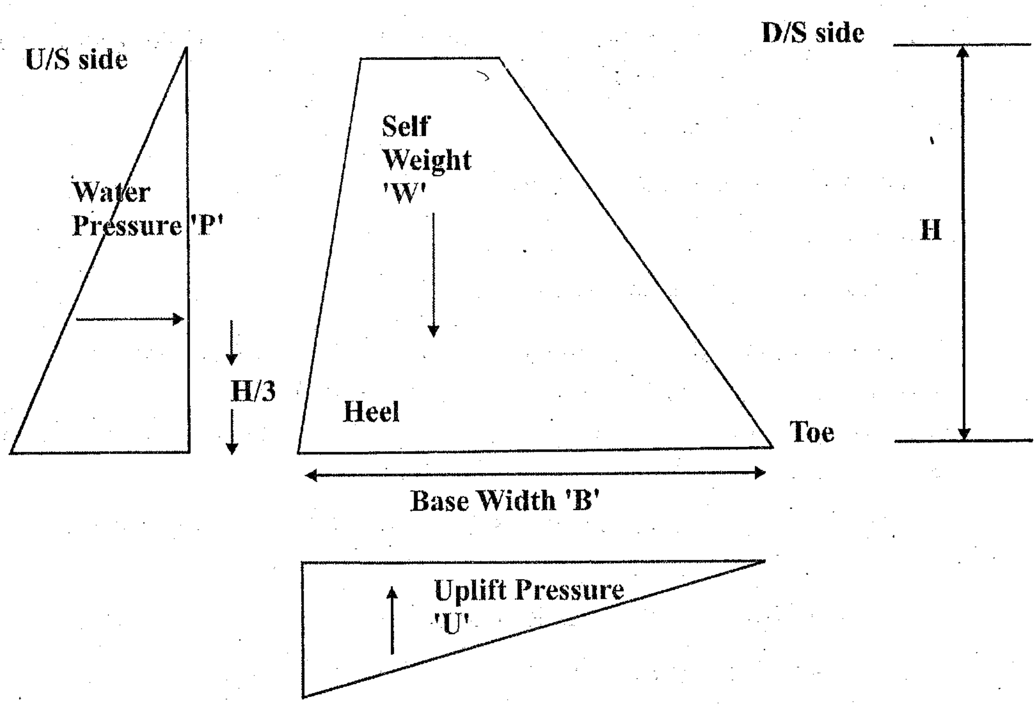
Typical shape of weir/Anicut



8.7 Stability of anicut :

Major forces acting of Anicut

- Water Pressure
- Uplift pressure
- Stabilizing forces (Self weight of anicut)



Major forces acting on structure

8.7.1 Mode of failure& criteria for structural stability

Generally failure occurs in the following ways

(i) By Overturning about the toe

(ii) By sliding of the structure By crushing of the foundation or material used for construction By development of tension at the foundation All the forces acting on the structure are resisted by its self weight.

Overturning: The ratio of resisting moment & overturning moment about the toe of structure is known as factor of safety against overturning & it should be not less than 2.0.

$$\text{FOS (Overturning)} = \frac{\text{Resisting Momen}}{\text{Overturning Momcnt}} >=2.0$$

Sliding failure: It occurs when net horizontal force above any palne in the structure exceeds the frictional resistance at that level.

The friction developed between two surface depends upon weight of structure & coefficient of friction. The value of coefficient varies from 0.65 to 0.75.

$$\text{YOS (Sliding)} = \frac{\text{Coeff, Of friction X Weight of struicture}}{\text{Total horizontal pressure}} >=1.5$$

Crushing: A structure may fail in crushing if compressive stresses produced in the body exceeds the permissible limits of foundation or construction material. The stresses may be due to direct compressive forces & due to bending forces. The stresses may be calculated as

$P1 \frac{\Sigma v}{B} [1 +6 e/B] <=$ allowable compressive stress of foundation or construction material

where ΣV is total vertical forces,

e= eccentricity of the resultant from the center of base = B/2 -X

B= total base width

$\overline{X} = \Sigma M/\Sigma V$ where ΣM= Resisting moment - overturning moment

Development of tension: A structure may fail in tension if tensile stresses are produced in the body exceeds the permissible limits of foundation or construction material. The stresses may be due to direct compressive forces & due to bending forces. The stresses may be calculated as

$P_2 = \frac{\Sigma V}{B} [1 - 6 e/B] > 0$ or allowable tensile stress of foundation or construction material

8.7.2 Combination of forces for design

Case I : reservoir full case: When reservoir if full, major forces acting are: self weight of structure, cxternal water pressure, uplift pressure & earthquake forces in serious seismic zones. The minor forces are: silt pressure, wave pressure. Normal load combinations: Water pressure upto top bank level, normal uplift pressure, earthquake (if applicable)

Case II : reservoir empty case: When reservoir if empty, major forces acting are: self weight of structure-& earthquake forces in serious seismic zones.

Normal load combinations:

Normal load combinations:

Self weight of structure and earthquake (if applicable)

8.8 Self Assessment Test

1. How you will select the site for water Harvesting structure?
2. What is dicken's formula?

8.9 Summary

For water harvesting structure, it is necessary to plan and design the structure. Planning will ensure an economically and efficiently functioning scheme which will serve the various objectives in view, most efficiently and with minimum expenditure and recurring operational trouble. Data collection for designing is very important data.

8.10 Suggested Readings

1. Discharge Measurement structures - editor M,G. Bos.
2. Weirs & Flumes for Flow measurements by P. Ackers, White etc.
3. Water Measurement manual by U.S.B.R.
4. irrigation Engineering Hydraulic structures by S. K. Garg.
5. Indian Standard Codes of Practices
6. Training modules under NMWP Project, Ministry of Water Resources, Govt. of India 1992.
7. Training modules of Irrigation Management & Training Institute Kota for middle & junior level officers.
8. Ackers, P -, White, W.&, Weirs and Flumes for Flow Measurements, John Wiley & Sons, 1978
9. Chow, V.T., Open-Channel Hydraulics, McGraw-Hill, 1959
10. French, R.H. ()pen-Channel Hydraulies, McGraw-Hill, 1986
11. Subramanya, K., Flow in Open-Channels 11 ed., Tata McGraw-Hill, 1997
12. Guidelines for the design Of small bridges and culverts, Indian Roads Congress, Special Publication 13

UNIT-9

COMMAND AREA DEVELOPMENT PROGRAMME

Structure

9.0 Objectives

Many of the irrigation projects in the country have also been under operation below their potential due to inadequate maintenance, which has been the single most important factor for reduced irrigation efficiency at project level. This has resulted in the problem of unreliability in the availability of irrigation water at farm level causing low efficiency of water usage and low productivity. Majority of the present problems include inequity in distribution of water, inefficient and over irrigation, resulting in waterlogging and salt accumulation in root zones of crops, slow pace of formation of Water User Associations (WUAs), inefficient and uncontrolled usage of surface and ground water, low water charge recoveries etc. are directly attributed to unreliability in availability of water. The Command Area Development (CAD) programme was initiated in 1974 with the objective to bridge the gap between irrigation potential created and that utilised through micro level infrastructure development and efficient farm water management; to enhance agricultural production and productivity; and to improve socio-economic conditions of the farmers.

9.1 Introduction

During the post independence period, large numbers of irrigation projects were constructed for improving agricultural production and productivity. However, it was realised that the irrigation potential created was not being utilised fully and a substantial gap existed between the potential created and potential utilised. Worried by this gap, the Irrigation Commission made specific recommendations in its report in 1972 that systematic development of commands of irrigation projects should be taken up. On the basis of this report, a Committee of Ministers (1973), which was set up by the Ministry of Irrigation and Power to suggest measures to reduce the under utilisation of potential created suggested that a broad based Area Development Authority should be set up for every major irrigation project to undertake the work of comprehensive area development. On the basis of this recommendation, the Government of India initiated a Centrally Sponsored Command Area Development Programme (CADP) in December 1974.

The Command Area Development (CAD) programme was initiated in 1974 with the objective to bridge the gap between irrigation potential created and that utilised through micro level infrastructure development and efficient farm water management; to enhance agricultural production and productivity; and to improve socio-economic conditions of the farmers. Presently, there is a gap of about 14 million hectares (Mha) between the irrigation potential created and that utilised. Taking the average cost of Rs. 10000 per ha for creation of irrigation potential, an investment of Rs. one lakh forty thousand crore thus remains under utilized. The annual interest at the rate of 7 percent would be Rs. 10000 crore. The central theme under Command Area Development and Water Management (CADWM) programme thus continues to be the efficient utilization of created irrigation potential.

Since the CAD Programme revolves around the central theme of scientific irrigation water utilisation to improve irrigated agriculture, the provision of irrigation facilities constituted the first requisite for the implementation of this Programme. In view of this the emphasis was laid on taking up primarily the activities related with irrigated agriculture. The following items were recommended to be taken up under the CAD Programme in 1976:

(1) On-Farm Development (OFD) works:

- (a) Development of field channels and field drains within the command of each outlet.
- (b) Land levelling, on an outlet command basis.
- (c) Realignment of field boundaries wherever necessary (where possible consolidation of holdings should also be combined).
- (d) Enforcement of a proper system of "Warabandi" and fair distribution of water to individual fields.
- (e) Supply of all inputs and services, including credit, and
- (f) Strengthening of extension services.

(2) Selection and introduction of suitable cropping patterns.

(3) Development of ground water to supplement surface irrigation.

(4) Development and maintenance of the main and intermediate drainage system.

(5) Modernization, maintenance and efficient operation of the irrigation system up to the outlet of one cusec capacity.

The irrigation projects included under the Programme are mostly major and medium category except in hilly regions, where minor irrigation projects were also included.

Restructured CADWM programme

Many of the irrigation projects in the country have also been under operation below their potential due to inadequate maintenance, which has been the single most important factor for reduced irrigation efficiency at project level. This has resulted in the problem of unreliability in the availability of irrigation water at farm level causing low efficiency of water usage and low productivity. Majority of the present problems include inequity in distribution of water, inefficient and over irrigation, resulting in waterlogging and salt accumulation in root zones of crops, slow pace of formation of Water User Associations

(WUAs), inefficient and uncontrolled usage of surface and ground water, low water charge recoveries etc. are directly attributed to unreliability in availability of water.

The restructured CADWM programme attempts to alleviate these deficiencies in the system above the outlet through new component of correction of system deficiencies besides the development and management activities below the outlet. Restructuring of the programme envisages rehabilitation and remodeling of existing minor irrigation tanks within irrigation project commands to enhance water availability and reduce seepage losses under medium and minor tank projects.

Increasing trend of waterlogging, salinity and alkalinity is offsetting the advantages of irrigation by rendering the affected areas unproductive or under-productive. The process of reclamation has just begun which is far exceeded by an additional area becoming waterlogged and saline/alkaline. CADWM programme, therefore, aims at reversing the trend by efficient utilisation of irrigation water and increasing the pace of tackling this problem by bringing in newer technologies like sub-surface drainage and bio-drainage under the realm of the programme.

The restructured programme considers almost all aspects of the water resources management which include development and management of the irrigation system up-stream of the outlets (up to distributaries of 4.25 cumec or 150 cusec capacity) and below the government outlet for scientific water utilisation through various developmental and management works and down to the field drainage which leads ultimately to the natural outfall through collector, intermediate and main drains. In brief these components include:

a. Operation of the irrigation system and mechanism to supply water according to the approved cropping pattern and considering the demand as per the modern farming technology in equitable manner;

b. Correction of system deficiencies at conveyance level;

c. Desilting / rehabilitation of existing MI tanks in irrigation commands and integrating the same with the system;

d. PIM to sustain the programme by handing over system for management by farmers through WUAs;

e. Assured water availability at farm gate and within outlet command with the help of WUAs;

f. Introduction of suitable technologies through advancement of knowledge of stake holders by way of training, demonstrations and adaptive trials;

g. Involvement of WALMIs and other State/Central agencies into the field oriented programmes,

h. Improving monitoring and evaluation through inbuilt system of receiving quarterly progress reports and annual administrative reports etc.

i. Greater coordination among multi-disciplinary agencies through a coordination and appraisal committee,

j. Proper drainage of surplus water from the fields directly into the drains for reuse/ recharge elsewhere and bio-drainage & sub-surface drainage and

k. Linking the programme and progress periodically considering quality and quantity aspects in view and taking action accordingly.

9.2 Command Area Development and Water Management Programme

Based on the recommendations of the Working Groups of the Planning Commission on "Command Area Development Programme" and "Private Sector and Beneficiaries Participation in Irrigation Water Management" and the views expressed by the State Governments, the existing CAD Programme has been restructured and renamed as **"Command Area Development and Water Management"** (CADWM) Programme and is hence forth called as CADWM programme.

The CADWM programme retains those components of the existing scheme, which have been found to be beneficial to the farmers. The programme includes a few new components, which have been considered necessary like correction of deficiencies in the irrigation system and providing upkeep of the drainage system. Some of the components, which have lost their utility over time, are deleted. The details of the components under the restructured programme are as under:

Continuing Components

(i) Survey, planning and designing of On-Farm Development (OFD) works;

(ii) Construction of field channels, now with a minimum of 10% beneficiary contribution of the total cost of construction;

(iii) Full package OFD works including construction of field channels, realignment of field boundaries, land levelling and shaping also with a minimum of 10% beneficiary contribution of the total cost of construction;

(iv) Warabandi (to be continued without central assistance);

(v) Construction of field drains, intermediate and link drains for letting out surplus water;

(vi) Reclamation of waterlogged areas in irrigated commands using conventional techniques as well as bio-drainage wherever applicable, now with a minimum of 10% beneficiary contribution of the total cost;

(vii) State sponsored software components such as trainings of farmers and field functionaries & officials, adaptive trials & demonstrations, action research for Participatory Irrigation Management, seminars/ conferences/workshops, monitoring & evaluation of the programme etc. through Water and Land Management Institutes (WALMI) and other institutions with seventy-five percent funding from Government of India;

(viii) Functional grant to Water Users' Associations; (ii), (iii), (v) and (vi)

(ix) Establishment cost - 20% of OFD works items at above and

(x) R & D Activities, including training of senior level officers, holding conferences, workshops, seminars etc. directly by the Ministry.

New components

a) Correction of system deficiencies above the outlet up to distributaries of 4.25 cumec (150 cusec) capacity;

b) Renovation and de-silting of existing irrigation tanks including the irrigation system and control structures within the designated irrigation commands with a minimum of 10% beneficiary contribution (of the total cost) as maintenance fund, the interest from which has to be used for maintenance in future; and

c) Use of location specific bio-drainage techniques to supplement conventional techniques for reclamation of waterlogged areas as a part of item (vi) under the Continuing Components.

Deleted Components

a) Land levelling & shaping (subsidy);

b) Sprinkler & Drip irrigation (subsidy);

c) Conjunctive use of surface and ground water (subsidy); and

d) Crop compensation and introduction of suitable cropping patterns.

Thus the scheme would encompass all aspects of water management for efficient and equitable distribution of water in the commands of irrigation projects for optimal utilisation and augmentation of water use in a participatory manner.

9.3 CADWM Programme Components

The old programme was in operation on 50:50 funding pattern basis between Centre and States. In view of recurring shortage of funds with the States to provide matching share, enhanced funding had been proposed for some of the existing key components. However, the Government of India has retained the existing financing pattern of 50:50 between Centre and States in the CADWM programme except in case of State Government sponsored software components, in which case the funding pattern would now be 75:25 between the Centre and States.

In case of certain select activities such as construction of field channels and full package OFD works and reclamation of waterlogged areas, 10% minimum mandatory contribution (of the total cost) by farmers through WUAs shall form a part of the state share.

The 10% mandatory contribution (of the total cost) by farmers through WUAs in case of rehabilitation and remodelling of Minor irrigation tanks will not become part of State share but shall be deposited in the corpus fund of the WUAs and the interest accrued thereon can be used by WUAs for future maintenance of tanks and its control structures. Thus, both Central and State governments have to provide full 50% share for this activity.

In case of continuing software items such as (i) adaptive trials and demonstrations, (ii) action research, (iii) courses organized/sponsored by States/Projects/CADAs for officers, field functionaries and farmers, (iv) monitoring and evaluation sponsored by the States, (v) seminars, conferences etc. the financing pattern shall be 75:25 between Centre and State respectively. These activities are necessarily to be carried out by the States through WALMIs and/or other State/Centrally sponsored institutions only in consultation with the Ministry of Water Resources.

Continuing software activities, such as training of senior level officers through National level training courses, workshops, seminars and conferences, evaluation, monitoring and other special studies sponsored by the Centre, shall continue to be funded at 100% by the centre.

Participatory Irrigation Management

Participatory programme is, the central theme of the CADWM programme and a minimum of 10% contribution (of the total cost) on selected items is to be paid by all farmers through their WUAs so that these associations get inspired and willingly own the systems. Henceforth, the CADWM programme is to be implemented only in those project areas where the legalized associations are formed and are effective and willing to take over the system up to distributaries of 4.25 cumec (150 cusec). The beneficiary contribution through WUAs should be either in cash or through labour. The States may devise suitable mechanism in this regard and inform the Ministry about the same. The component on correction of system deficiencies shall be implemented only after WUAs are willing to take over the system. A MoU is to be signed between the WUAs and the State departments in this regard and the distributaries are to be handed over immediately after they are corrected of their deficiencies. The State departments may have to ensure timely supply of water at the head of these distributaries.

- TOPOGRAPHIC AND SOIL SURVEY, PLANNING AND DESIGN OF OFD WORKS

Topographic survey is meant for proper planning and designing of OFD works so as to ensure their quality. Soil survey is meant for land capability classification so as to understand their capability for crop planning and undertake proper treatment measures to realize their full potential. Proper topographic and soil survey maps of the project should be maintained in CADA records.

- **CONSTRUCTION OF FIELD CHANNELS**

Construction of field channels to the last field/ each holding is to be ensured under the programme. Twenty per cent lining has been advocated in general, considering that the lining of main field channels, where irrigation water flows for longer duration, reduces seepage to a great extent.

In some States, where topography and soil type induces wastage in different ways, field channels require more length of lining. Sometimes, this may be beyond 20%. Lining beyond 20% can be done but no additional Central assistance beyond the prescribed cost norms will be provided for the same. It has also been observed that in some States only earthen channels are constructed without lining, which are liable to be ploughed or damaged. The concerned officials are to ensure that each holding is connected by the field channel for enforcing proper Warabandi system. In some undulating areas, conveyance system through open channels may not be workable and in such areas laying of underground pipelines can be resorted to. In many areas although outlets were fixed in the minors / distributaries at the time of commissioning of the projects, later these have been removed and are not yet fixed. It is desirable that such outlets are in position before any field channel is constructed. Cost of such repairs used to be charged to the component on enforcement of Warabandi earlier. The same may now be charged to the component of correction of system deficiencies.

Area specific designs of field channels are considered more appropriate than standardized designs, though the later seem to be more economic. As far as possible, field channels may be designed to run on full supply discharge. This ensures lower seepage losses.

The role of legalized Water Users' Associations is being strengthened further by making a provision for mandatory contribution to extent of 10% (of the total cost) in cash or in the form of labour by the beneficiary farmers in the construction of field channels. Such a provision is considered essential to ensure involvement of beneficiary farmers in the construction and maintenance of field channels and imbibe in them a sense of ownership of the assets created. The Associations, which collect contributions from the beneficiaries in advance and deposit the same with the CAD Authority or promise contribution in the form of labour in writing, shall be entrusted with the task of construction of field channels under the overall supervision and guidance of CADA staff. The CADA staff will prepare the design and plan for construction of field channels in the outlet command in consultation with WUAs, provide them technical guidance at the time of construction of field channels, inspect and authenticate the details of expenditure incurred by the WUAs and also periodically monitor and review the progress of works. The cost norms of Rs. 6000/- and Rs. 10000/- per ha. respectively for plain and hilly areas including special categories areas have now been revised to Rs. 10,000/- and Rs. 15.000/- per ha. in the restructured CADWM Programme.

- **WITHDRAWAL OF COMPONENT ON LAND LEVELLING**

It has been our experience that the farmers prefer to execute the land levelling component themselves rather than going in for a subsidy. Despite efforts, disbursement of funds on this component had been minimal. While this activity remains an effective and integral part of the scheme, the subsidy component on Land levelling is henceforth withdrawn.

The component of land leveling and shaping, which was financed as a subsidy item under the old CAD Programme has been withdrawn in the restructured CADWM Programme due to insignificant progress made and lack of interest on part of the farmers.

- **FULL PACKAGE OFD WORKS IN HILLY / SPECIAL CATEGORY AREAS**

Terracing and land levelling in hilly terrains is an important activity requiring large funds for mechanized handling, which is beyond the limits of small and marginal farmers. At the request of certain States, a new component on Full package OFD works is being introduced at higher cost norms in special category States. This component shall enable the hilly and special category States to go in for mechanized terracing at Government cost and covers the cost of construction of field channels and land levelling. Similarly some of the other States prefer to perform land levelling and realignment of field boundaries at Government cost. In case of these States, the component on full package OFD has been retained but at no extra cost and it is anticipated that additional cost if any on that account shall be borne by those States. The component on full-package cover all costs associated with construction of field channels and land levelling /terracing /realignment of boundaries at Government cost.

This would include construction of field channels, realignment of field boundaries and land levelling/shaping at a cost norm of Rs. 10,000/- per ha. in plain areas and Rs.18000/ - per ha in case of hilly areas. The financing pattern for this component will be 50:50

between the Centre and State/ farmers, with at least 10% contribution (of the total cost) of farmers through their WUAs.

- **ENFORCEMENT OF WARABANDI**

Warabandi comprises of deciding the day and time of delivery of water as per size of holding in consultation with the farmers. This activity is initiated immediately after the field channels are constructed. Generally, Warabandi schedules are prepared by agencies implementing the CAD Programme and these roasters are handed over to Irrigation Department. In these cases, it is not known whether Warabandi schedules are in conformity with the canal roasters. It is always desirable that Warabandi schedules conform to the canal roasters and monitoring of the schedules is done for at least two seasons to ensure proper working of the planned system for Warabandi.

This component will be continued for ensuring equitable distribution of irrigation water among the beneficiaries but without any Central Assistance.

- **CONSTRUCTION AND MANAGEMENT OF FIELD, LINK AND INTERMEDIATE DRAINS**

Under the old CAD Programme, only field drains within the outlet command could be constructed with Central Assistance as there was no provision for construction of intermediate drains and link drains to connect them to main drains. Under the restructured CADWM Programme, this deficiency has been corrected by expanding the scope of this activity for construction of intermediate drains and link drains to connect them to main drains. For this purpose the existing cost norm of Rs 1000 per ha and Rs 2000 per ha respectively for plain and hilly areas has been revised to Rs 4000 per ha and Rs 5000 per ha respectively. The financing pattern for this component will be 50:50 between the Centre and States.

- **RECLAMATION OF WATERLOGGED AREAS**

In spite of many precautionary measures, the irrigation has created the problem of waterlogging and soil salinity alkalinity in some of the areas

An area is said to be waterlogged when the water table rises to an extent that soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of the air, decline in the level of carbon dioxide. The depth of water table which is considered harmful would depend upon the type of crop, type of the soil and the quality of water which may vary from 0 m for rice to about 1.5 m for other crops.

Central Board of Irrigation and Power adequately describes the water logging as under:

"An area is said to be waterlogged when the water table rises to an extent that soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of the air, decline in the level of oxygen and increase in the level of carbon dioxide. The water table, which is considered harmful, would depend upon the type of crop, type of soil and the quantity of water. The actual depth of water table, when it starts affecting the yield of the crops adversely, may vary over a wide range from zero for rice to about 1.5 m for other crops".

The Report of the Working Group (1991) on "Problem identification in irrigated areas with suggested remedial measures" setup by the Ministry of Water Resources (MOWR), defined waterlogged areas as under:

(i) Water logged areas (due to rise in water able)	Water table with in 2 meters of land surface
(ii) Potential areas for water logging	Water table between 2-3 meters below land surface
(iii) Safe areas	Water table below 3 meters of land surface

The problem of water logging can be mitigated by efficient water management and through taking up preventive measures. In some cases, remedial measures in the form of reclamation are necessary for bringing the lands back to their original productivity. Ministry of Water Resources has recognized this aspect and it has taken several initiatives in this regard.

Conventional drainage/ sub-surface drainage

A prerequisite for sustainable agriculture is maintenance of proper balance of water, air and salts in the root zone of plants. In some of the canal commands, irrigation has disturbed this balance resulting in rise in ground water table, waterlogging and secondary salinisation of soils. Apart from being an ecological disaster, it has a very adverse effect on agricultural production, which can seriously jeopardize food security.

The balance of water, air and salts in the root zone of plants can be achieved by adequate drainage. Drainage can be either natural or artificial. Most lands have some natural surface and subsurface drainage. When natural drainage is inadequate, artificial drainage is required to increase the drainage capacity.

Artificial drainage is essential to sustain irrigated agriculture. Often, subsurface drainage is needed in irrigation commands to control the rising water table and avoid waterlogging and salinisation. Conventional subsurface drainage systems are of two types- subsurface vertical and subsurface horizontal drainage. When properly designed, installed and maintained, these systems are efficient in lowering the water table and preventing salinisation of irrigated lands. However, these systems have two drawbacks-namely they are costly and generate drainage effluents, which will have to be either carefully reused or safely disposed off.

So far reclamation of waterlogged areas was being done entirely through Government funds. A minimum 10 % contribution (of the total cost of construction) from the beneficiaries will now be mandatory. The existing cost norm of Rs. 12000 per ha. is revised to Rs. 15000/- per ha. for surface drainage and also for bio drainage, which was not included under the old Programme. The sub-surface drainage has also been included at cost norm of Rs. 40,000/- per ha. The financing pattern for this component will be 50:50 between the Centre and State/ farmers.

Water logging may be broadly divided into the following three different categories:-

(i) <u>Water logging caused by stagnation of water because of rain accumulation, over irrigation in the absence of proper draining system</u> - the most feasible solution to such type of water logging is the construction of field drains connected with the main drain through the collector/inter-mediate drains. Under the CAD programme, financial assistance was provided to the States for construction of field drains. The scope of the drainage item has been enhanced and new financial assistance is also provided for the construction of intermediate and link drains. Cost norms have also been enhanced appropriately.

While forwarding proposals for works for reclamation of waterlogged areas, such works should not be included under reclamation, which are covered under the item of construction of intermediate and link drains.

(ii) In another type of waterlogging, the land gets water logged due to the water coming into the land due to upland seepage, sheet flooding from top etc. causing tals. Massive flood-control schemes are required for protection of such areas, which are beyond the scope of the CADWM Programme.

(iii) Water logging in which the water in the root zone obstructs the aeration of soil/ (please see definition above) and is caused due to application of irrigation water/ action of farmers is covered under the third category. Schemes for reclamation of areas affected by such water logging comes under the purview of this item and the proposals should mainly include crop/soil/water management schemes, bio-drainage schemes or sub-surface drainage schemes etc. For more details manual on water logging published by the CAD wing of MOWR may be referred.

New component of Bio-Drainage

An alternative to these conventional subsurface drainage systems is bio-drainage, which is less costly and more environment friendly. It is a combined drainage-cum-disposal system. Bio-drainage relies on vegetation, rather than mechanical means, to remove excess water. The driving force behind the bio-drainage concept is the evapo-transpirative power of plants especially of trees to lower ground water table. Bio-drainage is economically viable because it requires only an initial investment for afforestation and when established, the system could generate economic returns by means of fodder, fuel wood and small timber.

The concept of bio-drainage is new and evolving. So far, it has been tried on a limited scale under experimental conditions. Some practical experience on bio-drainage has been gained in Indira Gandhi Canal project of Rajasthan and a few irrigation projects in Maharashtra. Necessary technical guidance with regards to suitability of tree species for a particular Agro-ecological situation will have to be ascertained form ICAR Institutes, State Agricultural Universities, State forest department etc.

- **ENHANCED INSTITUTIONAL SUPPORT TO WUAs**

The functional grant to Water Users' Associations has been enhanced to Rs. 600 per ha. which will be shared in the ratio of Rs 270:270: 60 per ha among the Centre, State and the farmers.

- **ADAPTIVE TRIALS AND DEMONSTRATIONS**

Adaptive trials involve evolution of suitable soil-water-crop relationships and management techniques suitable to the condition of farmers' field. This requires knowledge of a number of aspects such as agro climatic conditions, land development, crop varieties, proper doses and method of fertilizer application schedules, irrigation practices etc. consistent with the economic capabilities of the farmers. The focus of the adaptive trials should be on bringing about a switch over from traditional low risk, low input and low yield crops to high risk, high input but high yield and profitable crops.

Demonstrations of scientific technology, covering scientific water management and land development practices, introduction of suitable crops and varieties, proper dose and methods of application of fertilizers, irrigation practices, etc. are very important for increasing productivity. These are taken up extensively under the Programme on farmers' fields and the farmers are provided practical training on these aspects.

Dissemination of technical know-how among farmers, being planned through adaptive trials, demonstration and training of farmers is not getting sufficient attention. The need for training of farmers and functionaries continues as a critical requirement. To organize trainings, demonstrations and adaptive trials on regular basis for dissemination of know-how among the farmers it is proposed to strengthen the extension/ training activities through WALMIs and other institutions. The funding for this component is 75:25 between the Centre and the State.

- **ACTION RESEARCH PROGRAMME FOR PIM**

It has been observed that not much activities under action research on PIM has been undertaken either by the CADAs or the WALMIs. Efforts under CADWM therefore need to be intensified to initiate action research on various aspects of PIM such as creating awareness on PIM, stress on equity, rights and duties of farmers, enforcement of Warabandi, collection of water charges, O&M of the system, running of societies etc. The funding for this component is 75:25 between the Centre and the State.

- **NEW COMPONENT ON CORRECTION OF SYSTEM DEFICIENCIES**

A number of irrigation projects in the country have been operating much below their potential due to shortage of funds for O&M related activities such as cleaning of the channels by de-silting and weeding, raising earthwork in embankments or dressing the side-slopes to the design standard and removing undercuts in hard strata, strengthening of banks in filling sections, restoring bed gradients, replacing and painting metal parts in gates and hoists, making control and measuring devices fully functional etc. Lack of timely O&M has resulted in complete deterioration & dilapidation of canals and its structures. This has been by and large responsible for unreliability in availability of irrigation water at farm level and consequently the reduced irrigation efficiency. The scope of the Command Area Development Programme has therefore, been expanded to take care of system deficiencies occurring above the outlet up to distributaries of 4.25 cumec (150 cusec) capacity. This would eventually improve the output of Command Area Development (CAD) activities below the outlet as well.

With a view to ensure sustainability of the system deficiencies undertaken, before accepting the proposals for up gradation of the system, the State Governments will be required to ensure that distributary Committees (on distributaries of upto 4.25 cumec (150 cusec) are formed, which can take over these distributaries for operation and maintenance, after these have been rehabilitated. The financing pattern for this component is 50:50 between the Centre and States.

- **NEW COMPONENT ON RENOVATION OF MINOR IRRIGATION TANKS IN IRRIGATED COMMANDS**

Majority of tanks constructed in the past are in need of urgent repairs. It is not unlikely that a number of disused tanks have been encroached upon and are being used for other purposes. Irrigation potential through Minor Irrigation tanks have been declined due to poor maintenance and other factors. However, they are still serving useful purpose. It will be necessary to see that they are restored to their original capacity and the necessary repairs to be carried out.

It is reported that, in the last 40 years the irrigated area by tanks is coming down steadily at an increasing rate. According to government statistics published by the Planning Commission, around 17 lakh ha of net area has been lost under tank irrigation measuring a capital loss of Rs. 5100 crore (Planning Commission 1999). Many of these are within the existing commands and can be easily integrated with the systems.

This new component will upgrade and bring the level of services to the beneficiaries envisaged in the Project Report. Also beneficiaries will be involved in the implementation of this scheme and maintenance functions will also be transferred to Water Users Associations (WUAs). This will improve the overall management of tank irrigation and help in regaining the lost irrigation potential of minor irrigation tanks. The objectives of the scheme would be achieved for selected tanks through low cost infrastructure improvement designed to support improved operation plan responsible for checking deterioration of the system. Thus, not confining the objective to the rehabilitation of the system alone, it has been extended to improve management of the system by making farmers increasingly responsible for maintenance of the tank schemes.

The cost norm for this item is Rs. 15,000 per ha of areas irrigated by the tank. The cost for rehabilitation is to be shared by Centre and the State Government in the ratio of 50:50. The 10% (of the total cost) mandatory contribution (cash or labour) by the farmers will be deposited with the Water Users Associations (WUA) as maintenance fund, the interest from which will be used for maintenance of the system. This component can be taken up only after other activities in the command have been completed.

- **CENTRALLY SPONSORED TRAINING OF SENIOR LEVEL OFFICERS (TOTs)**

The need for ensuring proper implementation of the Programme has resulted in making "training" a very important activity under the CADWM Programme. The Ministry of Water Resources provides Central assistance for training of officials and farmers for implementing the CADWM Programme and Participatory Irrigation Management. Training activities were initiated during the Sixth Plan for functionaries of CADAs in the form of orientation training through seminars and workshops organised by the Ministry of Water Resources. During the Seventh Plan, central assistance was provided for these activities and training programmes were organised for middle, senior and top level officers at State and the Central levels. The training of middle level officers both from the Agriculture and Engineering disciplines were also taken up through WALMIs.

The National level training programmes are to be organised by this Ministry through Central/ State level organisations/ Institutions, WALMIs/ IMTIs and other leading institutions.

The purpose of the training programmes on PIM is to assist officers to appreciate legal, financial, administrative and motivational issues involved in farmers' participation and evolve strategies for implementing the concept. The training programmes are designed to study the organisation and performance of CAD Authorities, problems in the implementation of the Programme, inter-departmental co-ordination, and approaches to better utilisation of water etc.

- **COURSES ORGANISED BY STATES/ CADAs FOR OFFICERS, FIELD FUNCTIONARIES, AND FARMERS**

As the National level Training courses are meant for Senior level officers of CADAs/ State Governments, and cover very small part of the target group, the training courses for middle & junior level officers & farmers have to be organized by State Governments themselves at CADA/ Project level either directly or with the assistance of WALMIs/ IMTIs' and other Central/ State level Institutions/ Organisations. There is now a need to strengthen WALMIs to take up this activity on a wider basis. The financing pattern for this component will be 75:25 between the Centre and States.

- **INCLUSION OF MI SCHEMES UNDER THE NEW PROGRAMME**

In the old programme, minor irrigation schemes or their clusters with a CCA of at least 500 ha. in hilly areas were eligible for inclusion under the programme. As hilly areas do not have any medium or major irrigation schemes, to ensure better management of irrigation water in the hilly areas, Minor Irrigation scheme or cluster of Minor Irrigation schemes of the CCA of 100 ha are included under the restructured CADWM Programme.

- **CONJUNCTIVE USE**

Conjunctive use of ground water and surface water will serve the dual purpose of increasing the area under irrigation on the one hand through supplementing canal water for irrigation and reduce waterlogging on the other. Conjunctive use of surface and ground water now form an integral part for irrigation and its integrated development and management is a crucial factor in increasing agricultural production in command areas.

This component was covered under the old CAD Programme as a subsidy item but financing for this has been withdrawn in the restructured CADWM Programme due to poor response from farmers. There are several schemes run by the Ministries of Agriculture and Rural development, convergence with which can be built into CADWM Programme to promote conjunctive use of surface and Ground water.

The revised funding pattern and revised CADWM norms are available at **Annexure - I.**

9.4 SUMMARY

During the post independence period, large numbers of irrigation projects were constructed for improving agricultural production and productivity. However, it was realised that the irrigation potential created was not being utilised fully and a substantial gap existed between the potential created and potential utilised. The Command Area Development (CAD) programme was initiated in 1974 with the objective to bridge the gap between irrigation potential created and that utilised through micro level infrastructure development and efficient farm water management; to enhance agricultural production and productivity; and to improve socio-economic conditions of the farmers. The central theme under Command Area Development and Water Management (CADWM) programme thus continues to be the efficient utilization of created irrigation potential.

The restructured programme considers almost all aspects of the water resources management which include development and management of the irrigation system up-stream of the outlets and below the government outlet for scientific water utilisation through various developmental and management works and down to the field drainage which leads ultimately to the natural outfall through collector, intermediate and main drains.

9.5 SELF-ASESSMENT TEST

- Why Command Area Development Programme was initiated?
- What are the objectives of the Command Area Development Programme?
- Which items were taken up in Command Area Development Programme?
- Which items have been taken up in restructured Command Area Development & Water Management Programme?

9.6 KEY WORDS

- ***Command Area:*** Area irrigated by an irrigation project.
- ***On Farm Development:*** Works executed on the field for the efficient water management.
- ***Warabandi:*** Warabandi is a system of equitable water distribution by turn in proportion to the land holdings within an outlet command.
- ***Participatory Irrigation Management:*** Involvement of water users in all aspects of irrigation management at all levels.

9.7 SUGGESTED READINGS

- Command Area Development and Water Management Restructured Programme of Ministry of Water Resources, Revised Guidelines 2005. Ministry of Water Resources, New Delhi
- Dr. Veer Pal, Lecture note on CADWM programme, 200.., in Training courses on PIM organised

Annexure I

The restructured Command Area Development and Water Management Programme will be implemented with effect from 1.4.2004 with components, financing pattern, cost norms and condition of release as given below:

Activity	Financing Pattern (Central Share)	Cost Norms
1. Correction of System deficiencies above outlet upto distributaries of 150 cusec capacity (New Component).	50%	Rs 2000/- per ha or 50% of actual expenditure whichever is less as central assistance (assumed cost for Correction of System deficiency Rs.4000/- per ha)
2. Survey, Planning and designing of OFD Works (Ongoing Component).	50%	50% of actual expenditure on survey, planning and designing of OFD Works. (No change from IX Plan)

Activity	Financing Pattern (Central Share)	Cost Norms
3. Construction of Field Channels (ongoing component).i) North Eastern States Himachal Pradesh, Jammu & Kashmir, Hilly areas of Uttranchal & West Bengal, Indira Gandhi Nahar Pariyojana of Rajasthan and other similar areas in the State, Kerala, Goa, DVC of West Bengal, Districts of Haryana & Punjab States bordering IGNP.	50% *	Rs.7500/- per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost of construction is Rs.15000/ -per ha).
ii) For States and Areas other than given at item 3 (i) above.	50% *	Rs.5000/- per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost of construction is Rs.10000/- per ha).
4. Full Package OFD Works including Field channels, realignment of field boundaries, land levelling/ shaping (ongoing component with enhanced scope);i) For Hilly States/ Areas as mentioned in 3 (i) above	50% *	Rs 9000/- per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost for full package OFD works in hilly areas is Rs 18,000/- per ha).
ii) For plain areas	50% *	Rs 5000/- per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost for full package OFD works in plain areas is Rs 10,000/- per ha).
5. Construction of Field, intermediate and link drains (ongoing component with enhanced scope).		
i) North Eastern States Himachal Pradesh, Jammu & Kashmir, Hilly areas of Uttranchal & West Bengal, Indira Gandhi Nahar Pariyojana of Rajasthan, Kerala, Goa, DVC of West Bengal, Districts of Haryana & Punjab States bordering IGNP	50%	Rs.2500/- per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost of construction is Rs.5000/- per ha).
ii) For States / Areas other than given at item 5 (i) above	50%	Rs.2000/- per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost of construction is Rs.4000/- per ha).

Activity	Financing Pattern (Central Share)	Cost Norms
6. Reclamation of waterlogged areas/ drainage - for all the States (ongoing component with enhanced scope to include bio-drainage)	50% *	Rs. 7500/- per ha or 50% of actual expenditure whichever is less for execution of surface drainage, bio-drainage etc. (total cost assumed @ Rs.15000/- per ha); and Rs.20,000/- per ha or 50% of actual expenditure whichever is less where sub-surface drainage is envisaged (the total cost assumed @ Rs.40,000/- per ha).
7. Establishment (Ongoing component)	50%	20% of Expenditure on items at S. No. 3 (i) & (ii) / 4 (i) & (ii), 5 (i) & (ii) and 6.
8. Institutional support to Water Users' Associations (Ongoing Component)	270:270:60 **(Centre: State: Farmer)	Rs 600 per ha in the ratio of 270:270:60 per ha. among Centre, State and Farmers (No change in old ratio of 225:225:50 on Rs. 500/- per ha).
9. Adaptive trials , demonstrations, action research , etc. through WALMIs and other institutions (ongoing component)	75%	As per location specific needs.
10. Training (ongoing component) (i) Courses for senior level officers sponsored by Central Government.	100%	As per location specific needs.
(ii) courses organized by States / Projects for officers, field functionaries and farmers etc. through WALMIs and other institutions.	75%	As per location specific need
11. Monitoring and Evaluation (ongoing component)		
(i) To be sponsored by Central Government	100%	As per need
(ii) To be sponsored by State Government	75%	As per need

Activity	Financing Pattern (Central Share)	Cost Norms
12. Renovation and de-silting of existing irrigation tanks and control structures within the irrigated Commands (New Component)	50% #	Rs 7500/-per ha or 50% of actual expenditure whichever is less as central assistance (the assumed cost for renovation of tanks is Rs.15000/- per ha)
Note: * A minimum of 10% contribution (of the total cost) by the beneficiary farmers, as a part of the State share, is mandatory for these activities. **The institutional support is to be given where farmers associations are formed under PIM act or registered under Societies Act/ Cooperative Societies Act and actually engaged in distribution of water at the outlet level. A minimum of Rs 60/- per ha is to be realized from the beneficiary farmers. # A minimum of 10% contribution (of the total cost) by the beneficiary farmers is necessary for this activity. This money shall be deposited in the accounts of WUAs as maintenance fund, the interest from which will be used for maintenance of the tanks and the system.		

UNIT-10

PRECISION LAND LEVELLING

Structure

10.0 OBJECTIVES

The success of any surface irrigation method depends to a very great extent on the degree of smoothness of the field surface. High irrigation efficiencies are absolutely unattainable on a field surface having low and high spots. A carefully prepared and smoothly shaped field surface either graded to a desired slope or level (with no slope in either direction) is a prerequisite for efficient irrigation. Thus the main objective of the land preparation is to provide a well graded shaped smooth plane surface to help the irrigator to achieve uniform application of water throughout the field. Reshaping the surface of land to a planned grade with smooth surface is called land grading. Land grading and smoothing permit uniform and efficient application of irrigation water and removal of excess water without erosion. Land grading in combination with surface drainage system provides adequate surface drainage protection.

10.1 INTRODUCTION

The success of any surface irrigation method depends to a very great extent on the degree of smoothness of the field surface. High irrigation efficiencies are absolutely unattainable on a field surface having low and high spots. A carefully prepared and smoothly shaped field surface either graded to a desired slope or level (with no slope in either direction) is a prerequisite for efficient irrigation. Thus the main objective of the land preparation is to provide a well graded shaped smooth plane surface to help the irrigator to achieve uniform application of water throughout the field.

10.1.1 Land Grading and Smoothing

Reshaping the surface of land to a planned grade with smooth surface is called land grading. Land grading and smoothing permit uniform and efficient application of irrigation water and removal of excess water without erosion. Land grading in combination with surface drainage system provides adequate surface drainage protection.

Land levelling operations may be grouped into three phases: rough grading, land levelling and land smoothing. Rough grading is the removal of abrupt irregularities such as mounds, and ridges, and filling of pits, depressions and gullies. Rough grading is followed by land levelling which reshapes the land surface to a planned grade. (The terms land levelling, land grading, land forming and land shaping are synonymous). Land levelling requires moving large quantities of earth over considerable distances. Levelling operation leaves an irregular surface due to dumping the loads. These irregularities are removed and a plane surface obtained by land smoothing which is the final operation in land levelling.

10.1.2 Advantages and Benefits of Land Grading and Shaping

The main advantages and benefits of land grading and shaping can be summarised as below:

(a) Uniform and efficient application of irrigation water throughout the field, as there are neither low spots where excess water can accumulate, nor any high spots which will not receive enough water to meet full crop requirement. This results in water saving and better plant growth.

(b) Better, quicker and efficient removal of excess irrigation and runoff water without any soil erosion.

(c) Proper placement of seed and fertilisers at the desired depth, thus ensuring better germination, resulting in optimum plant population and uniform plant growth.

(d) Ease in operation and movement of crop production machinery, resulting in less repair and maintenance cost as well savings in power requirements.

(e) Less weed problems as there is no water stagnation at low spots.

(f) Facilitates leaching of salts.

The above factors have a cumulative effect on improving crop yields and net returns. Proper land grading, coupled with surface drainage measures, can reclaim unproductive poorly drained areas.

Land grading is also beneficial in un irrigated areas to conserve moisture, reduce soil erosion and provide for surface drainage. In low rainfall areas, land grading will result in a smooth uniform land surface, which reduces runoff and induces a greater amount of the rainfall to infiltrate the soil and assures even moisture distribution.

10.1.3 Factors Affecting Land Grading

Factors affecting design of land grading slopes, cuts and fills are influenced by the soil type and depth, topography, climate specially rainfall, crops to be grown, method of irrigation, drainage requirements and other special features of the site including the preference of the farmer.

(a) Soils

Before undertaking land grading operations, a careful study of the soil characteristics is very essential, as some soil properties have direct bearing on the grading operations. Therefore, it is always better to conduct a detailed soil survey of the area before planning for land grading/shaping operations.

Soil Depth

The major problem with grading is the effect of removal of the top soil and its influence on the plant growth. The plant growth is affected both on fill and cut areas. The exposure of subsoil in the cut areas is very serious problem, as it renders the area infertile for a long time. Therefore, it is essential to have complete information on soil depth to enable the designer to decide maximum cut. Usually, shallow soils, which put a limit on the depth of cut do not provide much choice to the designer. These soils, therefore, pose a difficult problem when combined with undulating topography. Under such situations sprinkler/drip systems may be preferable.

Soil Texture and Structure

Other soil properties, which influence levelling design, are texture and structure, as these affect infiltration or intake rate of water into the soil profile. If the infiltration rate is high, length of run for irrigation water should be kept shorter than if it is low

(b) Topography

The existing topography also affects the land grading operations. If the land is very steep and undulating, it may not be economical to develop it for surface irrigation methods. In such area an sprinkler/drip methods may be more suitable. The development of a uniform grade in the direction of irrigation and the removal of slopes at right angles to it should be the aim of a high quality-levelling job. Safe limits of longitudinal slope of fields, based on soil types are given in Table 1. Usually, excessive cuts are necessary to eliminate cross slopes. To reduce the extent of the cuts, the field is divided into parts and the levelling is done in strips at different elevations, separated by low ridges or borders.

Table 1 Recommended safe limits of land slope for efficient irrigation.

Type of Soil	Longitudinal Slope (%)
Heavy (clay) soils	0.05 to 0.25
Medium (loamy) soils	0.20 to 0.40
Light (sandy) soils	0.25 to 0.65

(c) Crops

The precision of land grading operation also depends on the crops to be grown. For high value crops, more expenditure to achieve a high degree of precision may be justified. But for lower value crops it may not be economical to incur heavy expenditure to achieve high degree of precision in land grading operation.

(d) Source of Water Supply

If water is costly and in short supply, which is true in most cases, it is necessary to use every drop efficiently. In such a case more expenditure on precision levelling may be justified.

(e) Climate

Rainfall out of all other climatic characteristics is the most important factor in determining maximum and minimum slopes and length of the field. The rainfall intensity, duration, and season also affect the maximum allowable slope for controlling soil erosion.

(f) Irrigation Methods

Each method of irrigation has its own limitations as to the permissible cross slope and down field slope. While border strips and check basins do not permit any cross slope within the strip, furrow and corrugation methods of irrigation permit a certain degree of cross slope within a field.

(g) Desire and Preference of the Farmers

The desire and preference of the farmer should be clearly known before undertaking any land grading operations. He should always be taken into confidence. The cultivator should be consulted about various constraints, and different alternative plans, as he is the best judge and knows his field better than anybody else.

10.2 LAYOUT AND PLANNING

Prior to levelling design, the land development programme must be planned so that the location of the field boundaries, irrigation water supply system, drains and farm roads are known. An integrated on-farm development plan consists of the following activities:

- Orientation and alignment of fields/plots on the basis of existing topography and soil.
- Layout of field irrigation channels with location of turnouts.
- Layout of field drains with location of outlets.
- Layout of farm roads.

An accurate contour plan on a scale of 1:1500 along with a soil map are the two basic tools for proper planning and deciding layout of the fields for precision grading/shaping operations.

10.3 LAND GRADING SURVEY AND DESIGN

Once the fields/plots have been laid and demarcated, land grading/shaping is carried out within individual plots, by doing cutting and filling with earth moving machinery. The earth movement is restricted to individual plots only. Following procedure is used to carry out the survey and design for land grading.

10.3.1 Survey and Stacking

To carry out the survey for land grading, the general practice is to establish a grid system over the field and set wooden stakes at the grid points (Figure 1). The usual grid spacing is 25 m in each direction. Other spacing such as 30*30 m, 20*20 m, and 15*15 m are also sometimes used, depending on the nature of surface relief of the area and the precision required in levelling. Each grid point is at the centre of the grid square and represents nearly equal area. For convenience in identification, the row lines are lettered and the column lines numbered.

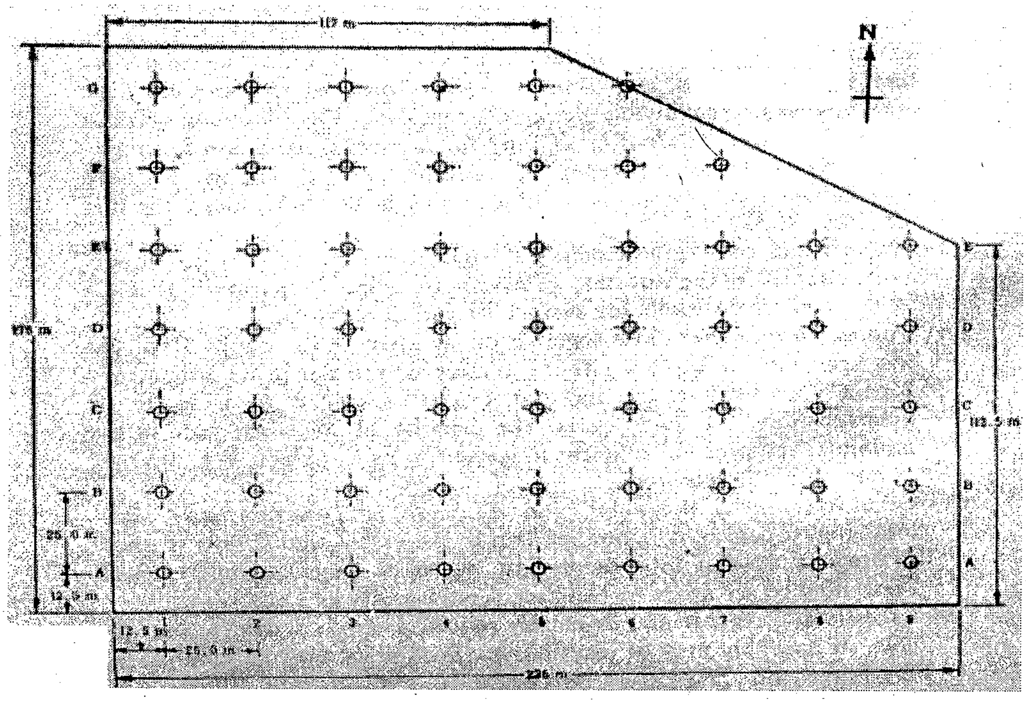


Figure 1 Grid pattern used for stacking a field which is to be graded.

Whole field is divided into suitable grids and wooden stakes (usually of size 1 cm by 4 cm by 1 m) are fixed on each grid point. Extra stakes may be fixed on the points where topography changes abruptly. First grid lines in the X and Y directions are at a distance of half the grid spacing, Figure 1. Stakes are driven into the ground far enough to ensure that they will withstand strong wind.

After all points have been staked, levels are run to determine the ground elevation at each stake and recorded on the grid map. A temporary bench mark, located on a nearby pucca structure, may be used for calculations of elevations. To make the survey information more readily understood and studied, contour lines are drawn at suitable intervals. The recommended contour interval for land slope ranging between 0 to 1%, 1 to 2%, 2 to 5% and 5 to 10% are 6 to 15 cm, 15 to 30 cm, 30 to 60 cm and 60 to 150 cm, respectively.

With the help of the contour map the land is divided into fields that can be graded and irrigated individually to the best advantage.

10.3.2 Land Levelling Design Methods

The basic methods of land levelling design are given below:

i) Plane method

ii) Profile method

iii) Plan-inspection method

iv) Contour adjustment method

- **Plane method**

This is the most widely used method. It assumes that the area is to be graded to a true plane. In this method the average elevation of the field is determined and this elevation is assigned to the centroid of the area. The following is the procedure for land levelling design:-

Determination of the Centroid of the field: The centroid is located by taking moments about two perpendicular reference lines, at right angles to each other as shown in Figure 2. The distance of the centroid of the field from any line of reference is equal to the sum of the products obtained by multiplying the area of each part times the distance from the line of reference to its centroid, divided by the area of the entire field.

Determination of the Average Elevation of the field: The average elevation of the field is determined by adding the elevations of all the grid points in the field and dividing the sum be the number of points. The average elevation of the field is assigned to the centroid. Any plane passing through the centroid at this elevation will produce equal volume of cut and fill. With the elevation of the centroid known and the downfield grade and cross slope selected, the elevation required at each grid point can be calculated.

Determination of the Slope of the Plane of best fit: The slope of any line in the X or Y direction on the plane, which fits the natural ground surface, can be determined by the least-squares method. The least squares plane by definition is that which gives the smallest sum of all squared difference in elevation between the grid points and the plane. It is called the '*plane of best-fit*'.

The slopes of this plane can be calculated, using the following two equations:

$$(SX^2 - n X_c^2)Sx + \{\Sigma(XY) - n X_c Y_c\}S_y = \Sigma(XE) - (nX_c E_c) \quad \text{............(1)}$$

and

$$(\Sigma Y^2 - n Y_c^2)Sy + \{\Sigma(XY) - n X_c Y_c\}S_x = \Sigma(YE) - n(Y_c E_c) \quad \text{..........(2)}$$

For rectangular fields, the slopes are:

$$Sx = \frac{\Sigma(XE) - n X_c E_c}{\Sigma X^2 - n X_c^2} \quad \text{..................................(3)}$$

$$Sy = \frac{\Sigma(YE) - n Y_c E_c}{\Sigma Y^2 - n Y_c^2} \quad \text{..................................(4)}$$

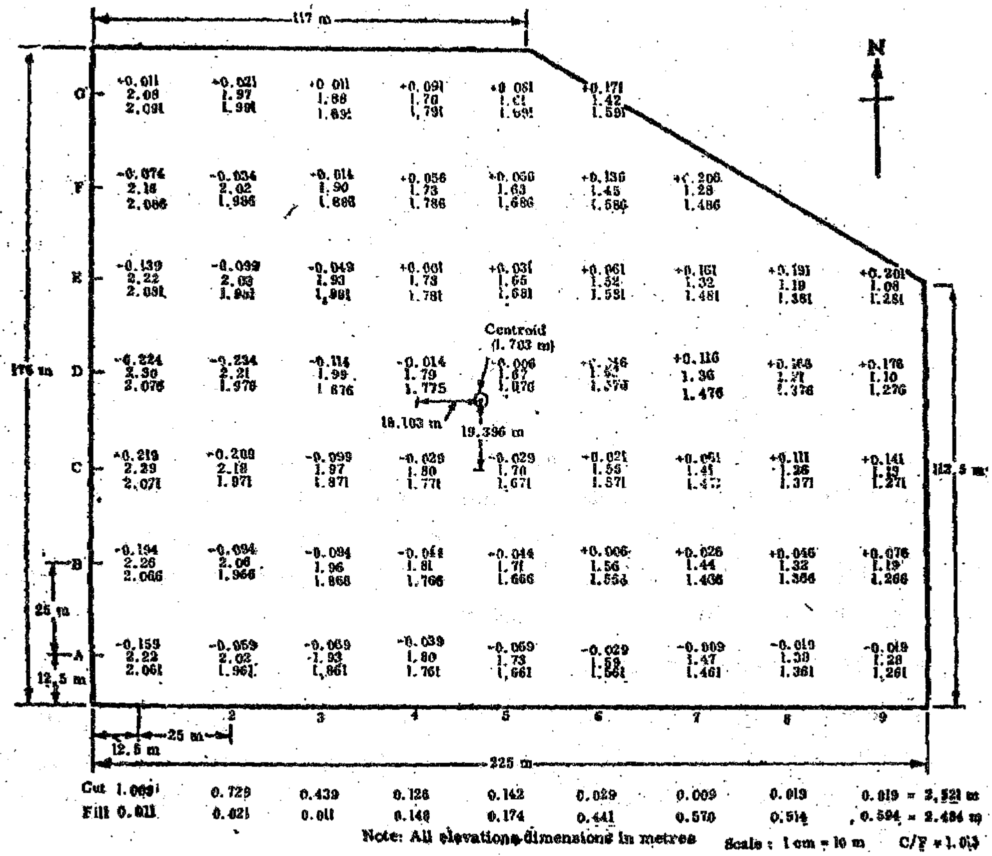


Figure 2 Land levelling design using the plane method.

Where,

n	=	total number of grid points
Sx	=	Slope in the X-direction
Sy	=	Slope in the Y-direction
X_c	=	distance of centroid along X-axis
Y_c	=	distance of centroid along Y-axis
E	=	elevation at any grid point
E_c	=	elevation of the centroid (average elevation of all points)

Generally, the slopes are fixed by the designer and therefore above equations are not used. However, if the grading/shaping is to be done at the existing average slope in order to reduce earthwork, then above equations should be used.

Determination of the Formation Levels, Cuts and Fills: With the elevation of the centroid determined, the formation level of any point (the elevation which the point should attain after land grading operation) may be determined, using the computed or assumed values of S_x and S_y. Then cuts and fills at the grid points is calculated.

If designed elevation is less than the original elevation, it is a cut point, similarly if designed elevation is more than the original elevation, it is a fill point. Mark cut/fill at each stake. This is not necessary, if laser controlled levelling equipment is used.

Determination of Cut-Fill Ration: Experience in land grading with modern earthmoving equipment has shown that the cut-fill ratio should be greater than one. This means that a greater volume of cut than fill must be allowed. ΣCut and Σ Fill give the ΣC/ΣF (ratio), which generally varies from 1.1 to 1.6, depending on the soil texture and type of machinery used in land grading/shaping. For each situation, it is necessary to work out local criterion. If ΣC/ΣF is less than 1.1, then elevation of the centroid should be lowered and cut fill should be workout at each grid point again and recalculate ΣC/ΣF. This process is undertaken till desired ΣC/ΣF is obtained.

- **Profile method**

The profile method of land levelling design consists of plotting the profile of the grid lines and then laying the desired grade on the profiles. In this method adjustments are made in such a way that the designed grade provides an approximate balance between cuts and fills. The haulage distance is also kept minimum as far as possible. The method is especially adapted to levelling design for very flat lands or land with undulating topography on which it is desired to develop a fairly uniform surface relief. **Figure 3** illustrates this procedure for the field shown in **Figure 2.**

- **Plan inspection method**

In this method, the elevations of the grid points are recorded on the plan, and the designed elevations are determined by inspection after a careful study of the topography. It is largely a trial and error procedure. This method is adapted for moderate to flat land slopes.

- **Contour adjustment method**

Under this method, a contour map is drawn and proposed ground surface is shown on the same map by drawing in new contour lines. The new contours are properly spaced to get uniform slope. Like Plan-Inspection method, it is also a trial and error procedure. The proper balance between cuts and fills is estimated graphically at the grid points by interpolating between contour lines and by taking the difference in elevation between the original and new surface. The method is especially adapted to the smoothening of steep lands that are to be irrigated.

10.4 EARTH WORK VOLUME CALCULATIONS

A common procedure for calculating earth-work volume is known as 'Four Point' method, which is sufficiently accurate for land levelling. Volume of cut, V_c, for each grid square is given by the formula:

$$V_c = \frac{L^2(\Sigma C)^2}{4(\Sigma C + \Sigma F)} \qquad \text{.....(5)}$$

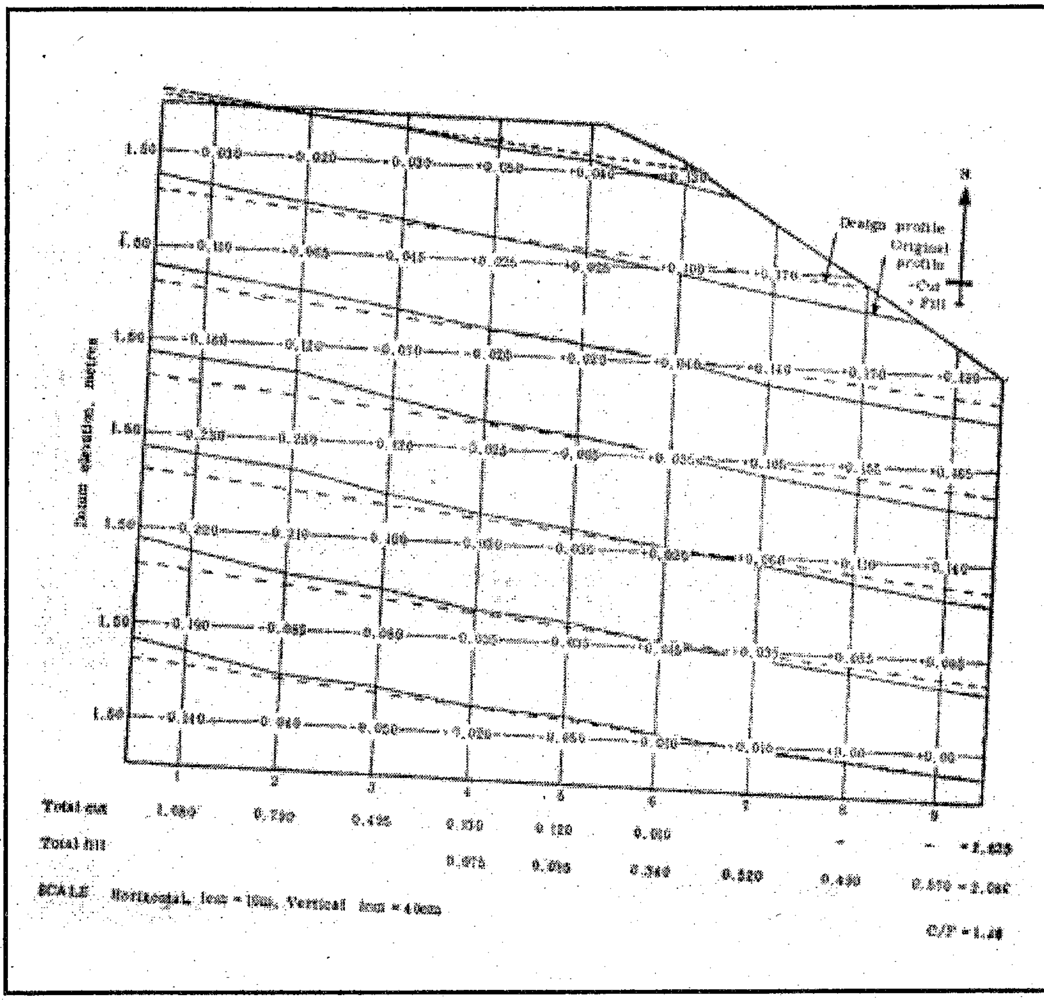


Figure 3 Profile method of land levelling design.

Similarly, the volume of fill, V_f, can be calculated by the formula:

$$V_f = \frac{L^2 (\Sigma F)^2}{4\ (\Sigma C + \Sigma F)} \qquad \text{.......(6)}$$

where

V_c	=	volume of cut, m^3
V_f	=	volume of fill, m^3
L	=	grid spacing, m
C	=	cut on grid corners
F	=	fill on grid corners

For incomplete grids, appropriate multiplication factors are used.

As a simple 'thumb rule', the following formula is also used for earthwork volume:

$$\Sigma V_c = L^2\, \Sigma C$$

where, ΣV_c and ΣC refer to the total volume and total cuts for the entire plots.

10.5 EQUIPMENT FOR LAND GRADING

Land grading is done by tractor-drawn and bullock-drawn equipment. Rough grading is done by bulldozers, tractor-drawn carrier-type scrapers, and small scrapers drawn by tractor-drawn land planes or bullock-drawn wooden floats.

While selecting the equipment, factors such as characteristics of the soils to be handled, value of work, required precision, size of the field, earth-work involved, haulage distance, local availability of machinery & spares, equipment, skill of the operators, repair and maintenance facilities available in the area and the draught power (human, animal and mechanical) required to operate the equipment have to be considered, along with alternative combinations of equipment and techniques to be employed for the proper planning and execution of the works. The applicability, performance and mechanical features of the equipment are of relevance in their selection.

10.5.1 Mechanical Equipment for Land Grading

Following type of mechanical equipment are generally, used in land grading/shaping operations:

i) Crawler tractor, with front blade (bulldozer)

ii) Crawler tractor, with carryall scraper (mechanical or hydraulic)

iii) Wheel tractor with carryall scraper

iv) Wheel tractor with drag scraper

v) Wheel tractor with leveller

vi) Wheel tractor with land plane

vii) Crawler tractor with land plane

viii) Motor grader

(a) Bull Dozer

The front blade bulldozer **(Figure 4)** is a very inefficient piece of equipment for earth moving operations. They are frequently employed in cutting and pushing earth to short distances only, where haulage is less than 50 meters. However, for removing old bunds, embankments, channels, etc., a bulldozer may be very satisfactory.

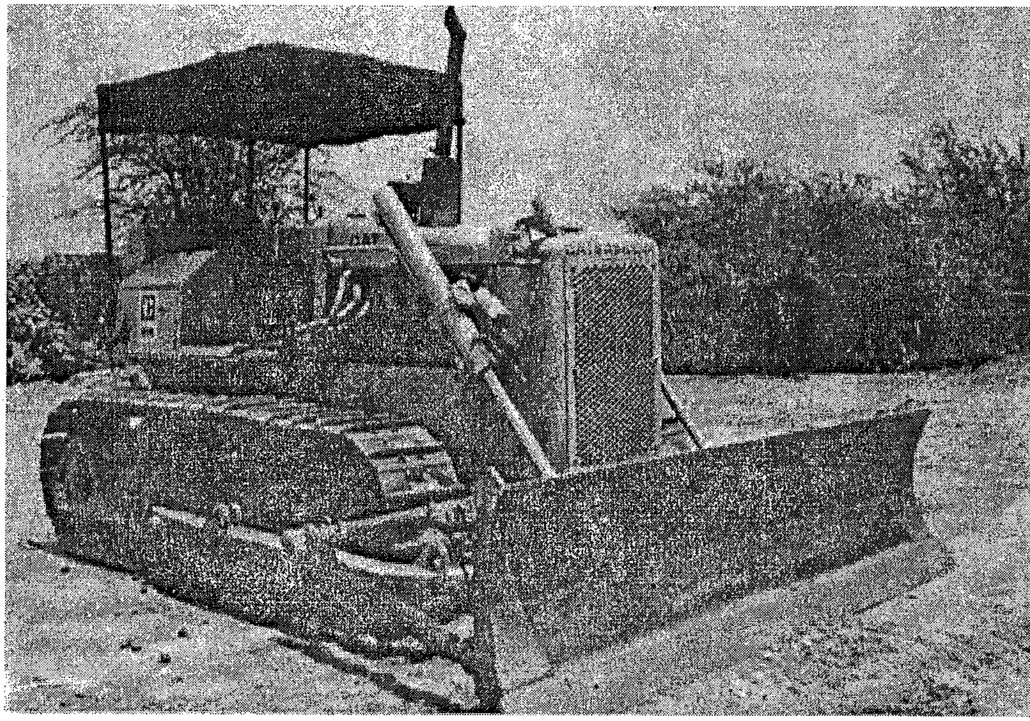


Figure 4. Bulldozer.

(b) Carryall Scraper

Mostly the main earthwork involved in land levelling operation is done with earth moving scrapers, known as carryall. These scrapers are widely used for large scale land grading operations. It consists essentially of a bowl or bucket mounted on rubber-tired wheels with a blade and apron across its front end for cutting, scooping and retaining a load of earth. To load, the bowl is lowered and the apron is partially lifted. In hauling position the apron is closed and the bowl is lifted clear of the ground. To dump or spread, the apron is lifted and the load is pushed forward through the open end of the bowl. The machine cuts to grade, hauls the load economically for fairly long distances and spreads the soil evenly at the desired location.

Scrapers are available in wide range of size from 1.5 to 19 cu m capacity. Most of the lands levelling jobs are now being done with scrapers pulled with wheel tractors. Their speed and manoeuvrability make them well suited for this type of work. Small scraper units 1.5 to 6.0 cu m are available, which can be pulled with farm tractors of 40 to 120 HP. The larger units of 6 to 19 cu m capacity usually are equipped with their own power units. These large units often require a pusher especially while making heavy cuts. However, in the elevating or self-loading type scrapers, pushers are not needed, as the loading is assisted by a rotating chain elevator **(Figure 5).**

Figure 5. Elevating Scrapper.

(c) Drag scraper, leveller and land plane

Also known as bottomless scrapers are mainly used for land smoothing operations. As the name implies, the bowl or bucket has little or no bottom and earth moving is accomplished by scraping soil from the high areas and dragging it to the low areas. To operate these scrapers, it is necessary to loosen the ground with a plough or harrow. If used with laser control system, very high degree of accuracy can be obtained with a drag scraper.

(d) Motor grader

Though costly, motor grader is a very versatile machine. It is quick, highly manoeuvrable and economical for making farm roads and shallow drains. sometimes, it is also used for final smoothing operation **(Figure 6).**

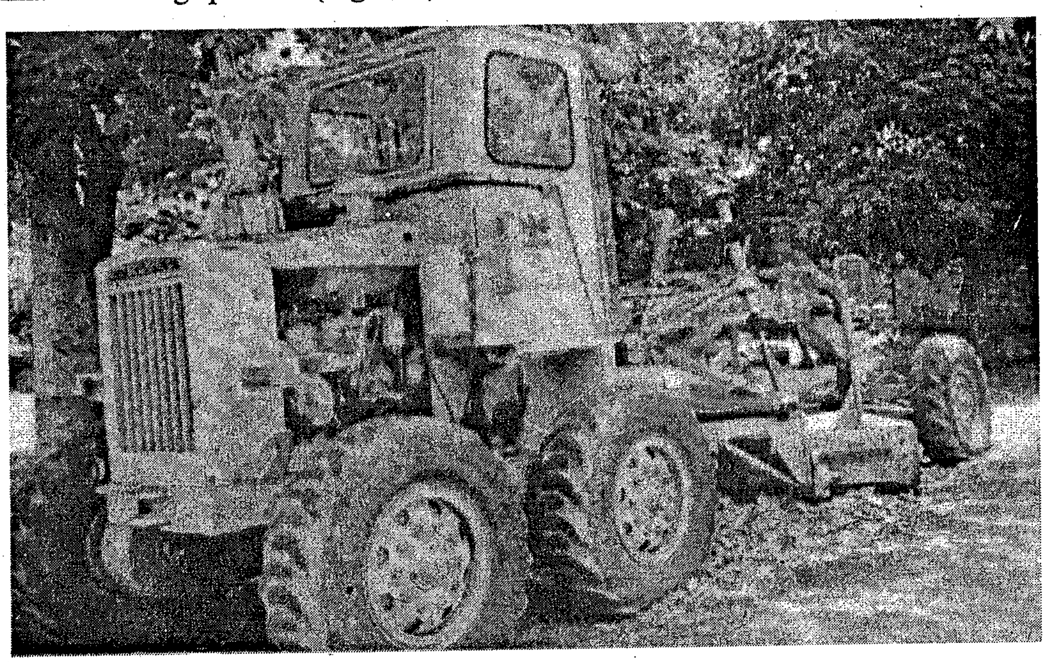


Figure 6 Motor grader.

10.5.2 Use of Laser Controlled Land Grading/Shaping Equipment

With the development of rotating head laser beam and its use for guiding the operation of land grading and shaping machinery, it has been possible to attain very high degree of precision. Both manual control and automatic systems are available. In a manual set up the signals are picked on a light display panel in front of the operator, and he knows whether he is on-grade, above the grade or below the grade.

Accordingly, he adjusts the blade/bucket to bring it back to the desired grade line. While, in the automatic system the laser beam signals are meshed with the hydraulics of the grading/shaping equipment and the control of blade/ bucket is done automatically. Hydraulic controls on the machine automatically raise and lower the blade using the laser beam as a reference. The operator needs only drive the machine and see that the laser and other mechanisms are working. The laser beam is produced by a rotating laser (transmitter) that produces a 360-degree plane that is level or tilted **(Figure 7).** The laser is set up like any surveying transit or level and rotates one revolution every few seconds. Although the beam spreads slightly with distance from the transmitter, the detector on the machine is designed to pick up the centre of the beam. An accuracy of 0.005 m in 400 m distance is possible.

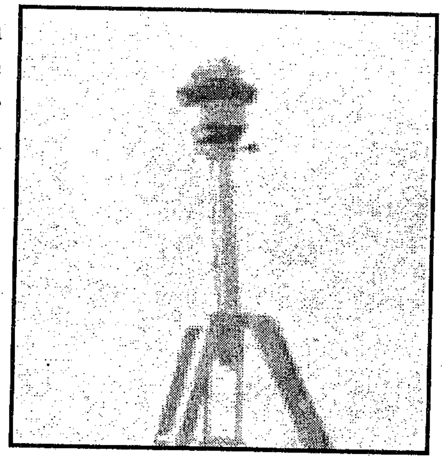


Figure 7. Laser Transmiter.

For laser operation the transmitter may be set at any convenient location in the field within the range of operating equipment. The grade is established in both the directions by making necessary adjustments in the transmitter.

Table 2 gives the list of equipment for different types of land grading/shaping jobs.

10.5.3 Bullock Drawn Farm Implements for Land Grading and Shaping

Small and marginal farmers can do their own land preparation, namely, land grading and shaping, land smoothing, etc., with the help of simple bullock drawn implements described below:

i) Plows and harrows to open up the field, turn the soil, break the clods, and prepare a firm seed bed.

ii) Scrappers for rough land levelling and grading.

iii) Wooden floats and U-levellers for land smoothing.

Table 2 Guide for proper selection of equipment

Degree of precision	Equipment	Typical soil movement	Average haulage (m)
Rough first land grading/levelling	Track type bulldozer	High spots only	<50
	Tractor Scraper	400 - 1200 m^3/ha	>50<500
	Heavy tractor carryall scraper	400 - 1200 m^3/ha	>50<350
Medium first land grading/ levelling	Track type bulldozer	400 - 600 m^3/ha	<50
	Elevating Scraper	400 - 700 m^3/ha	>50<500
	Heavy tractor dual carryall scraper	400 - 700 m^3/ha	>50<350
	Heavy tractor carryall scraper	200 - 500 m^3/ha	>50<350
Final and maintenance grading/shaping	Heavy tractor drag scraper	100 - 350 m^3/ha	NA
	Agri. Tractor drag Scraper	100 - 350 m^3/ha	NA
	Motor grader	100 - 200 m^3/ha	NA

(a) Plows

Good plowing contributes greatly to the uniform distribution of irrigation water. Lands that are irrigated by ordinary flooding methods especially require good plowing because owing to the lack of specially prepared levees there is no means of spreading water over the higher portions of fields.

Disc or mould board plows are primary tillage implements which open up the compacted soil, loosen it and turn it over, to facilitate the other follow-on equipment to work effectively to form basins, borders or furrows. Good tillage by appropriate plows also help to maintain the infiltration capacity of soil and aeration. Some bullock driven mould board plows are shown in **Figure 8.**

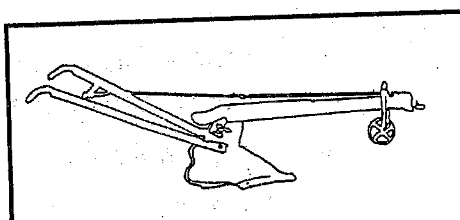


Figure 8. Bullock driven mould board plow.

(b) Harrows

Many varieties of harrows are in use as secondary tillage implements. Of these, disc harrows are useful for, breaking the large clods brought out while the soil is plowed and turned. Spike toothed harrows comb the soil, collect the trash and facilitate rough levelling.

(c) Buck scraper

Animal drawn buck scraper **(Figure 9)** is a very efficient implement for land grading when the fields are small to medium in size and when only animal draught power is available with the farmer. It can be used to move the soil loosened by plows. It is very economical when the haul distance is less than about 50 meters. The essential components of the buck scraper are the front board, the tail board, joints, handle and hitch. The implement incorporates a number of automatic features when constructed and operated properly. As indicated in Figure 8, the important features of the implement are the location of the hinge point of the tail board at the back (set the centre of hinge pin 11 cm from the bottom of the front board) and the position of 'eye bolt' or hitch of the chain on the front board (set the hitch points on either side 6.5 cm from the bottom of the front board).

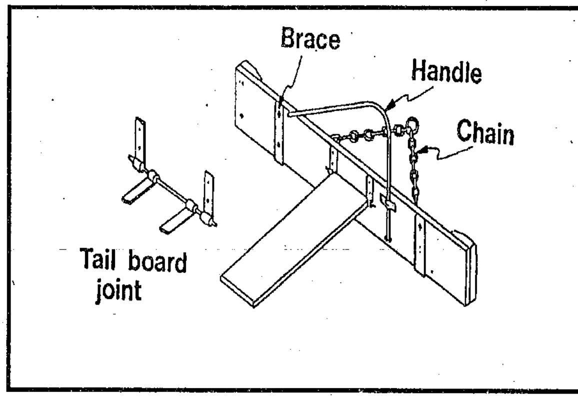


Figure 9 Animal drawn buck scraper.

(d) Wooden float

The float is a long sled-like drag, **Figure 10,** which is used for land smoothing with bullock power. Large size floats are sometimes used with tractors also. The equipment operates on the principle of a carpenter's plane. It has three blades, the cutting blade in the front, the spreading blade in the centre and the covering blade at the back. As the float is pulled forward, the cutting blade removes the high spots and pushes the soil into the low areas ahead.

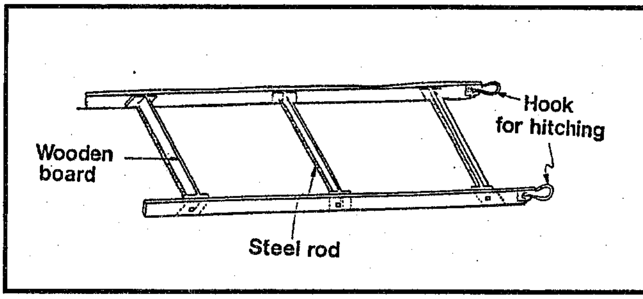


Figure 10 Wooden float.

(e) U-leveller

A wooden U-leveller, **Figure 11,** is another useful implement for smoothing small fields for check basin method of irrigation. It works on the same principle as a wooden float. its short length facilitates levelling small field plots.

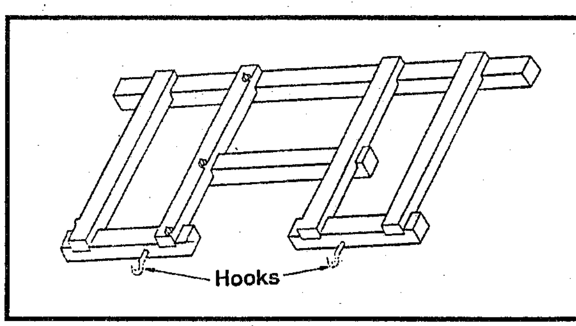


Figure 11 Wooden U-leveller.

10.6 CONSTRUCTION AND PRECISION

After the land levelling design is complete, the desired cut and fills are marked on the grid stakes. The levelling job is done with a set of suitable equipment and adopting the techniques for obtaining high efficiency in levelling operation.

10.6.1 Construction Procedure

Cut and fill stakes for construction purposes must be established to guide the equipment operator. When a grid type system exists, the stakes indicating cuts and fills are located at the grid points. Some times the cut or fill may be marked directly on the grade stake. The following are the common methods of setting grade stakes:

- Each stake may be driven such that its top is at grade.
- Each stake has two lines marked on it-one blue and the other red. The blue line indicates the formation level and the red line the ground level at the stake point. The distance between the red and blue lines indicates the amount of cut or fill, as the case may be. The desired grade is obtained when the formation coincides with the blue lines.

Fields should be scarified prior to construction if there are hard pans. The field surface should be firm when surveyed so that staff reading taken at stakes will reflect the true elevations.

Fields should not be graded when wet, because this impairs the physical condition of the soil. A construction map is useful aid in deciding the best approach to a levelling operation. To keep the haul distance a minimum, it is important to construct the fills from the nearest excavation available. In performing the levelling operations, care is taken not to disturb the grid stakes. When the depth of fill is more than 15 cm, it is necessary to build them in layers of 15 cm deep, to avoid excessive settling.

Normally, earthwork operations have a permissible tolerance of ± 3 cm. It is impractical to accomplish a high finish with scraper equipment. The finishing job is always done with land floats or land planes.

10.6.2 Grading Precision

Grading should be checked prior to and following the finishing operations. A tolerance of 30 mm may be allowed in checking, provided there are no reverse grades in row direction. Generally, the precision of land grading is measured by a factor, known as '*Levelling Index* (LI)', which is defined below:

$$LI\ (cm) = \frac{\Sigma I \text{ Existing grade levels - designed grid level/cm} I}{\text{Number of grid points}}$$

The concept of LI was introduced by Aggarwal and Goel (1981). Based on the research done by them, a maximum LI of 3.0 cm. has been recommended. However, researchers at Pantnagar University recommended a LI of 2.0 cm. **Table 3** gives the savings in irrigation water for different L.I.

Table 3 Effect of grading precision on depth and irrigation efficiency in wheat crop at Pantnagar.

Levelling Index (cm)	Total irrigation applied (cm)	Additional depth of Water over minimum irrigation (cm)	Relative application efficiency (%)
		1982-1983	
1.30	19.3	0.0	100
1.49	25.9	6.6	74
1.87	27.3	8.0	71
2.15	32.0	12.7	60
2.36	33.0	13.7	58
2.65	38.3	19.0	51
		(1983-1984)	
1.19	10.0	0.0	100
1.28	11.1	0.7	94
1.53	12.9	2.4	81
1.77	15.0	4.5	70
2.09	15.1	4.6	70
2.44	16.9	6.4	62
		(1984-1985)	
1.25	18.8	0.0	100
1.62	22.8	4.0	83
2.03	25.5	6.7	74
2.25	27.0	8.2	70
2.80	31.3	12.5	60

(Source - Research on Water Management - Progress Report, ICAR, 1983 - 85)

10.7 MAINTENANCE

There are several reasons as to why a field does not stay level once a correct levelling has been accomplished. The three main reasons are:

i) Uneven settlement of the fills particularly spots with heavy fills.

ii) Improper use of tillage equipment.

iii) Flooding of the area.

Maintenance is needed to restore proper level at each location particularly after a heavy rain or after several irrigations when fills have thoroughly settled. Maintenance is critical during the first year or two after construction. The stepwise procedure for maintaining a graded land is given below:

- Identify high spots after a heavy rain or several irrigations.
- Disc or chisel high spots to loosen the soil.
- Level the field with a land plane or leveller. Make several rounds in all directions to get proper level. Another useful suggestion to maintain the land in proper shape is to use a leveller of smoothener each time in between crops. Smoothing operation, particularly, may be required for several years after the land has been graded.

10.8 COST ESTIMATES

The cost of earth work on land shaping will vary with number of factors. The topography, field conditions, length of haul, total volume and volume of earth movement per hectare, type of equipment used and the operator's skill all effect the cost of construction. National commission on Agricultural (1976) while reviewing the cost of land expressed similar opinion while suggesting that cost is not proportional to initial levels or the final levels or the final levels achieved. In Chambal Command, Rajasthan, the percentage of time spent on various operations could be of the order shown in Table 4. It is clear that scraping and chiselling take 70 per cent of the time and will therefore form the major component of the total cost.

Table 4 Relative time spent on various operations in precision land levelling

Operation	Percent time spent
Scraping	56
Chiselling	13
Land Plane	11
Idle	10
Change of Equipment	6

When earthwork for land grading exceeds 350 cu m per ha alternative measures should be considered including changing the field width. Financial analysis of land grading vis-à-vis cost analysis of pressure irrigation systems (sprinkler and drip method) should also be undertaken to arrive at the best alternative for each case.

10.9 SUMMARY

Reshaping the surface of land to a planned grade with smooth surface is called land grading. Land grading and smoothing permit uniform and efficient application of irrigation water and removal of excess water without erosion. Land grading in combination with surface drainage system provides adequate surface drainage protection. Land grading have a cumulative effect on improving crop yields and net returns. Proper land grading, coupled with surface drainage measures, can reclaim unproductive poorly drained areas. Land grading is also beneficial in un irrigated areas to conserve moisture, reduce soil erosion and provide for surface drainage. In low rainfall areas, land grading will result in a smooth uniform land surface, which reduces runoff and induces a greater amount of the rainfall to infiltrate the soil and assures even moisture distribution.

10.10 SELF-ASSESSMENT TEST

- Explain land grading, leveling and smoothing.
- What are the benefits of land grading?
- Which factors affect land grading?
- Explain plane method of land levelling.
- How earthwork volume can be calculated for land grading?
- Describe use of laser controlled land grading/shaping equipments.

10.11 KEY WORDS

- ***Land Grading***: Reshaping the surface of land to a planned grade with smooth surface is called land grading.
- ***Plane Method***: In this method it assumes that the area is to be graded to a true plane. In this method the average elevation of the field is determined and this elevation is assigned to the centroid of the area.
- ***Plane of best fit***: The least squares plane which gives the smallest sum of all squared difference in elevation between the grid points and the plane is called the 'plane of best-fit'.

10.12 SUGGESTED READINGS

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UNIT-11

NETWORK PLANNING BELOW OUTLET

Structure

11.0 OBJECTIVES

Irrigation water plays an important role in agriculture and it is generally believed that crop yields can be increased manifold with it. But if the irrigation system are not planned properly, then it can result in severe waterlogging and increase in salinity, too. It is realised all over the world that irrigation and drainage must be planned and executed simultaneously. Good planning calls for maximum coverage of the irrigable lands at minimum construction cost, operation and maintenance expenses. Desirable location should therefore be determined principally on topographic consideration and therefore adequate information on topographic conditions, soil characteristics, intended irrigation methods and water delivery arrangements, etc. be collected. This article describes various types of lay out method, their advantages, disadvantages etc.

11.1 INTRODUCTION

Irrigation water plays an important role in agriculture and it is generally believed that crop yields can be increased manifold with it. But if the irrigation system are not planned properly, then it can result in severe waterlogging and increase in salinity, too. It is realised all over the world that irrigation and drainage must be planned and executed simultaneously and hence Dr. Hitoshi Fukuda of Tokyo University, Japan, coined a new word "IRRINAGE", synonymous with Irrigation and Drainage. The small size and scattered nature of holdings coupled with social and economic conditions of farming pose a severe restraint on the irrinage layout. The right approach is probably the common sense application of advanced science and practice to local farming conditions.

An irrigation system consists of Dam (head works), reservoir, main canals, branch canals, distributaries, minors, outlets and watercourses (Figure 1). Watercourse is a network of small irrigation channels from canal outlet to the individual farm which carries water to the fields in a chak. Chak is a piece of command area of a canal which receives irrigation from a single outlet in the canal. It may generally comprise of few hectares to about 40 hactares.

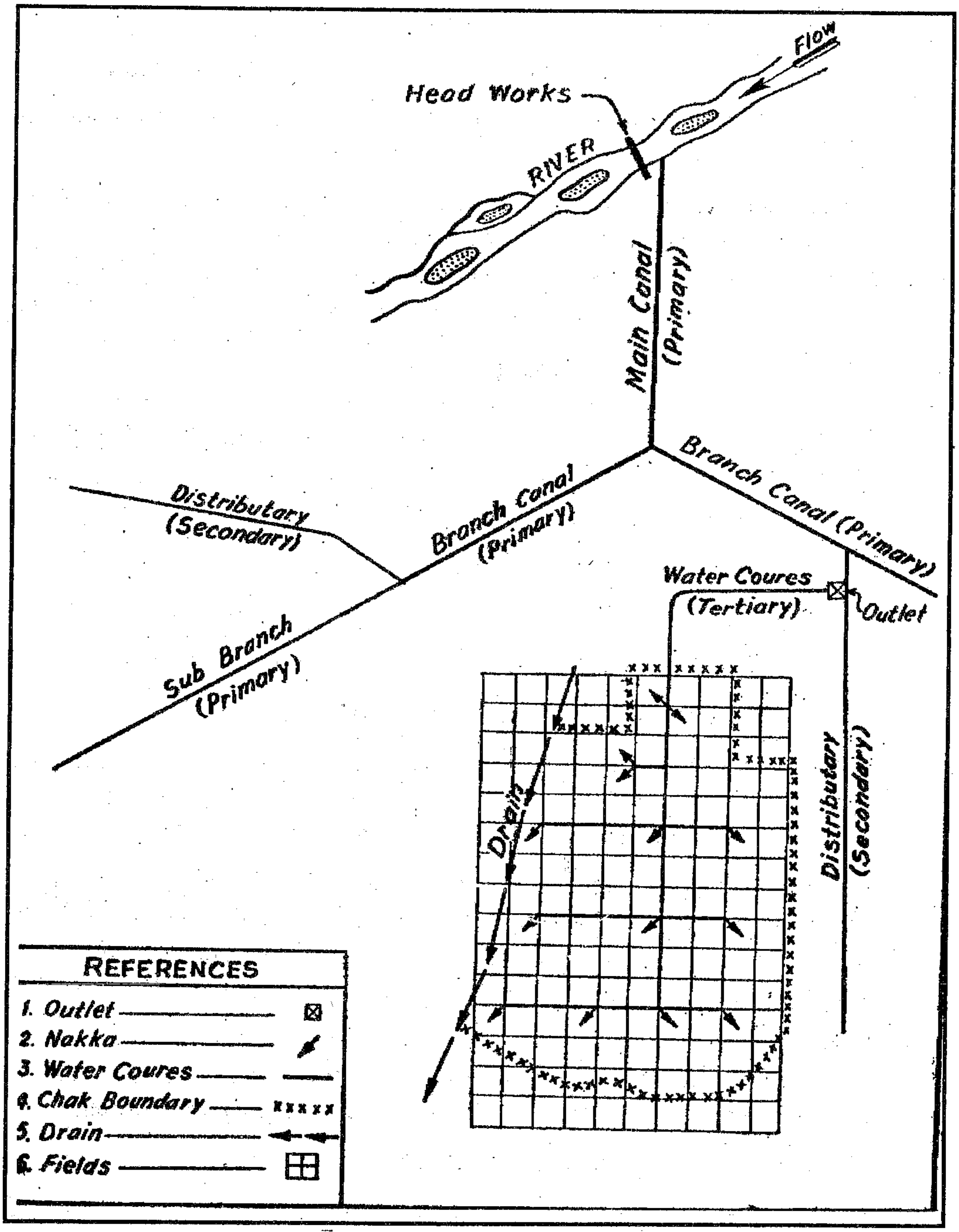

Figure 1. An Irrigation System.

Principal requirements of a good irrigated farming area are:

i) Controlled distribution of water from source to all the fields;

ii) Preparation of the field surface for efficient irrigation i.e. grading;

iii) Drainage of all unwanted water from rainfall, irrigation and drainage of water required for reclamation, if any;

iv) Access for vehicles and agricultural equipments to all farms;

v) Conservation of soil and water, protection from erosion;

vi) Possibility of the use of improved/modern cultivation and harvesting methods;

vii) Possibility of reclamation of saline or eroded lands;

viii) Ability to grow all types of crops suitable to respective agro-climatic zones;

ix) The water application/removal system to occupy the least amount of land in comparison to other alternative layouts.

Consideration of the requirements listed above shows that unless planning is done as an integrated whole, it is impractical or extremely expensive to provide one requirement at a time, i.e. if the water distribution network is first constructed, it will be difficult or at least very expensive, to superimpose a drainage network, and then a road network later.

11.2 METHODS OF LAYOUT

It is possible to systematise the main methods of irrinage layout. They can be divided as follows:

i) The traditional haphazard method;

ii) The rectangular or research farm method, and

iii) The contour method.

The distinguishing features of each of the three methods are as follows:

11.2.1 TRADITIONAL OR HAPHAZARD

Called traditional because it is the rule in practically every irrigation scheme, and haphazard because it grows and proliferates in haphazard fashion in accordance with local conditions, minor physical features, and the hour-to-hour needs of the farmers.

The distinguishing features of the Haphazard or Traditional systems of irrigation then are a long, diffused, poorly maintained, and uncontrolled distribution system which follows field boundaries, lack of a drainage network, impeded drainage, a poorly developed system of roads and small irregularly shaped plots and fragmented holdings (Figure 2).

Frequently after several years, the authorities realize that all is not going as it should. It is assumed that the cause of the trouble is that the fields are uneven, cannot be irrigated efficiently and that this accounts for the low yields and poor use of water.

11.2.2 Rectangular or Research Farm Type

This, in India, has been almost only used on university farms and government farms. It involves rectangular fields with a ditch running along the upper border and a drain along the lower end. Usually, the fields are irrigated by longish border strips (Figure 3).

When applied to general farming conditions, having small holdings, the system has the following further objections:

(i) Each cultivator owns, and must be allotted after development, a different size of holding. This type of layout would have to degenerate into a neater form of the haphazard system, with zigzag field channels, drains, and roads.

(ii) Vehicle access cannot be given to each plot without wasting an impossible amount of land.

(iii) Of all the layouts the Rectangular type conforms least to existing conditions. A rigidly right-angled layout is the exact opposite of nature, and will require the most change and therefore be the most expensive.

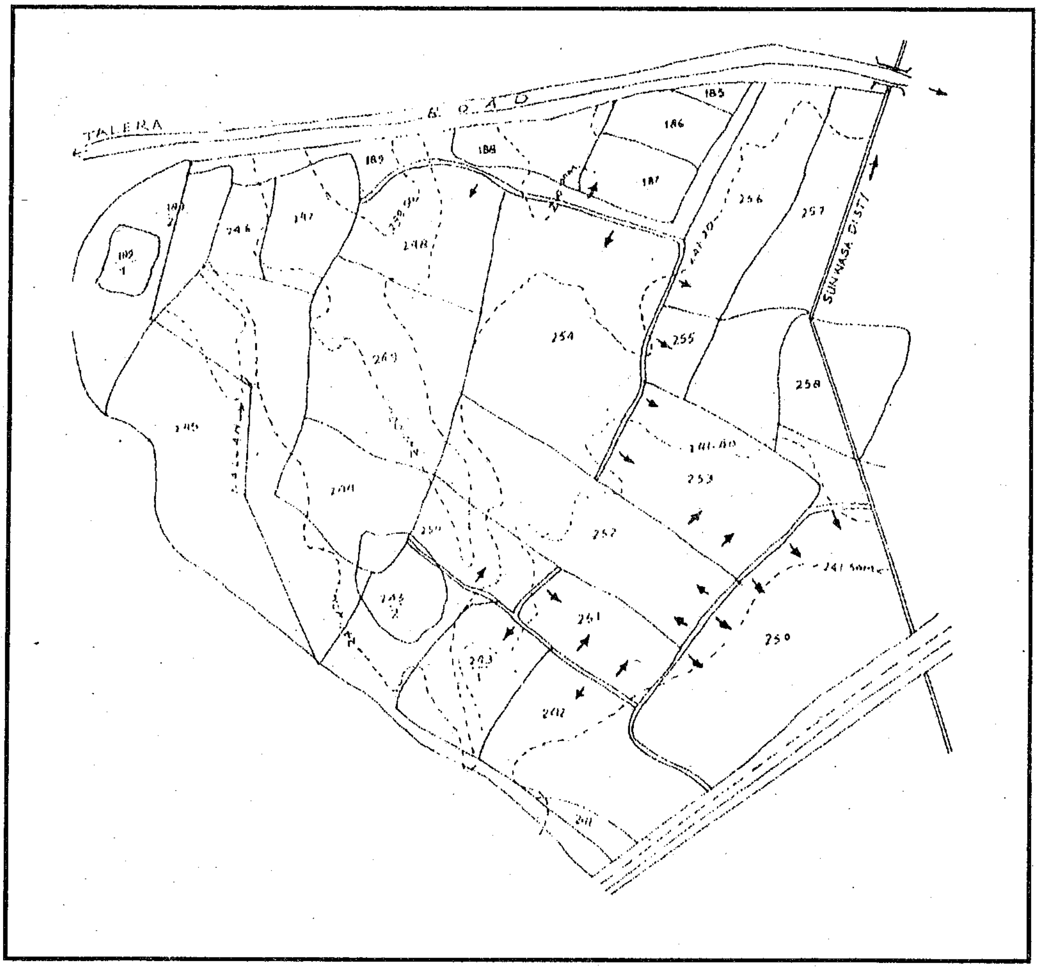

Figure 2. Traditional or Haphazard Method of Layout.

11.2.3 THE CONTOUR LAYOUT

The two main distinguishing features of this method (Figure 4) are:

(i) Field channels run down the top of natural ridges, with field drains in the intervening depressions;

(ii) Strip fields are laid out at such an angle to the existing contours that the slope of their long axis conforms to that required for most efficient irrigation. (It is, therefore, fundamental that the required long slope of the field is given at the time of designing the layout, depending on its "angle off" from the contour, and that the earth movement required for smoothing has little to do with the difference between required irrigation slope and pre-existing natural slope at right angle to the contour).

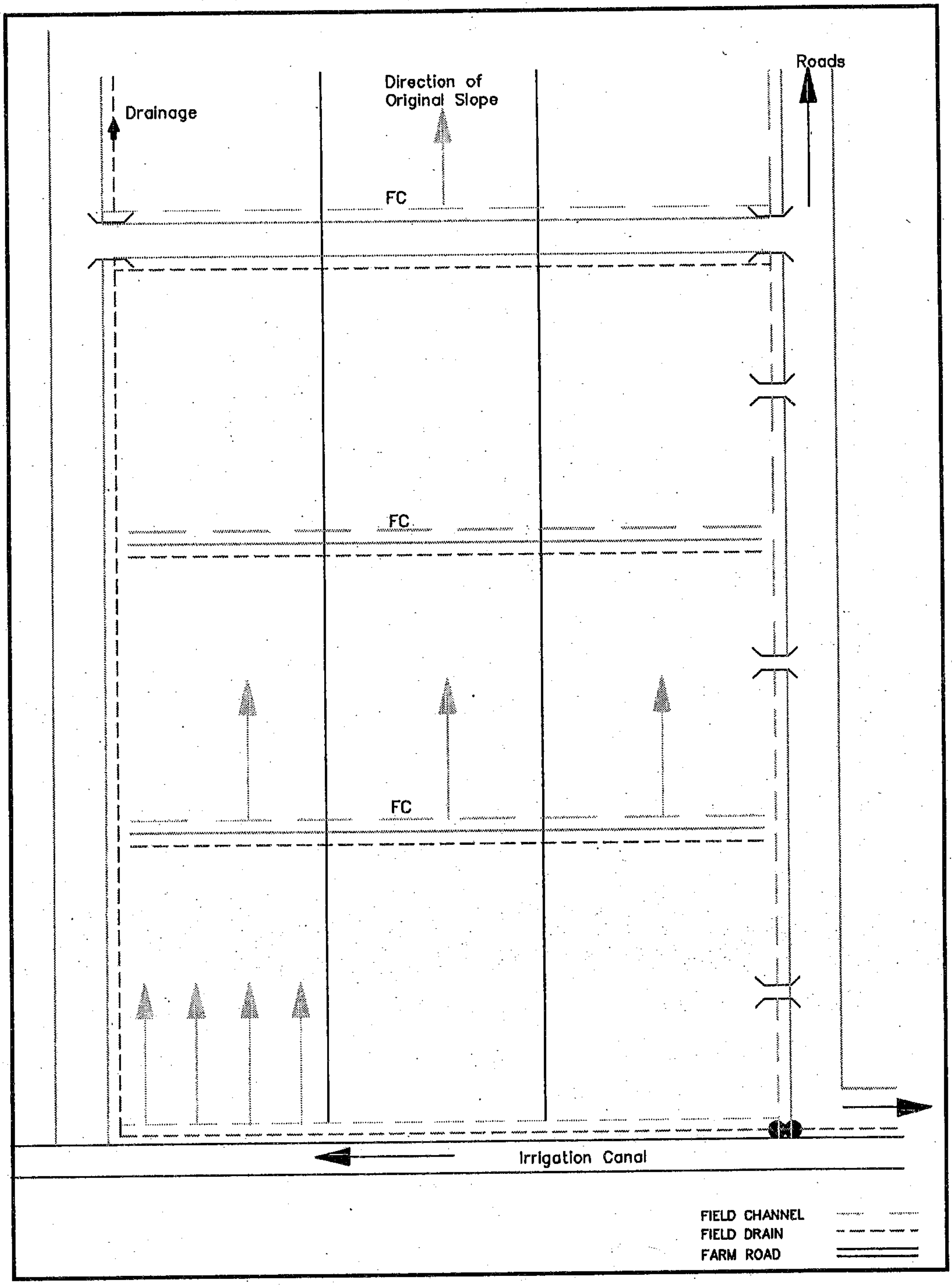

Figure 3. Rectangular Farm Layout.

In the contour type layout (Figure 4), watercourses are laid out down the highest points of the secondary ridges with field drains placed to the intervening secondary drainage depressions. Spoil from the excavation of the drains forms drain-side inspection, maintenance, and access tracks passing the tail of every strip. Where necessary, subsurface reclamation drains below the fields can run out at right angles to the field drains.

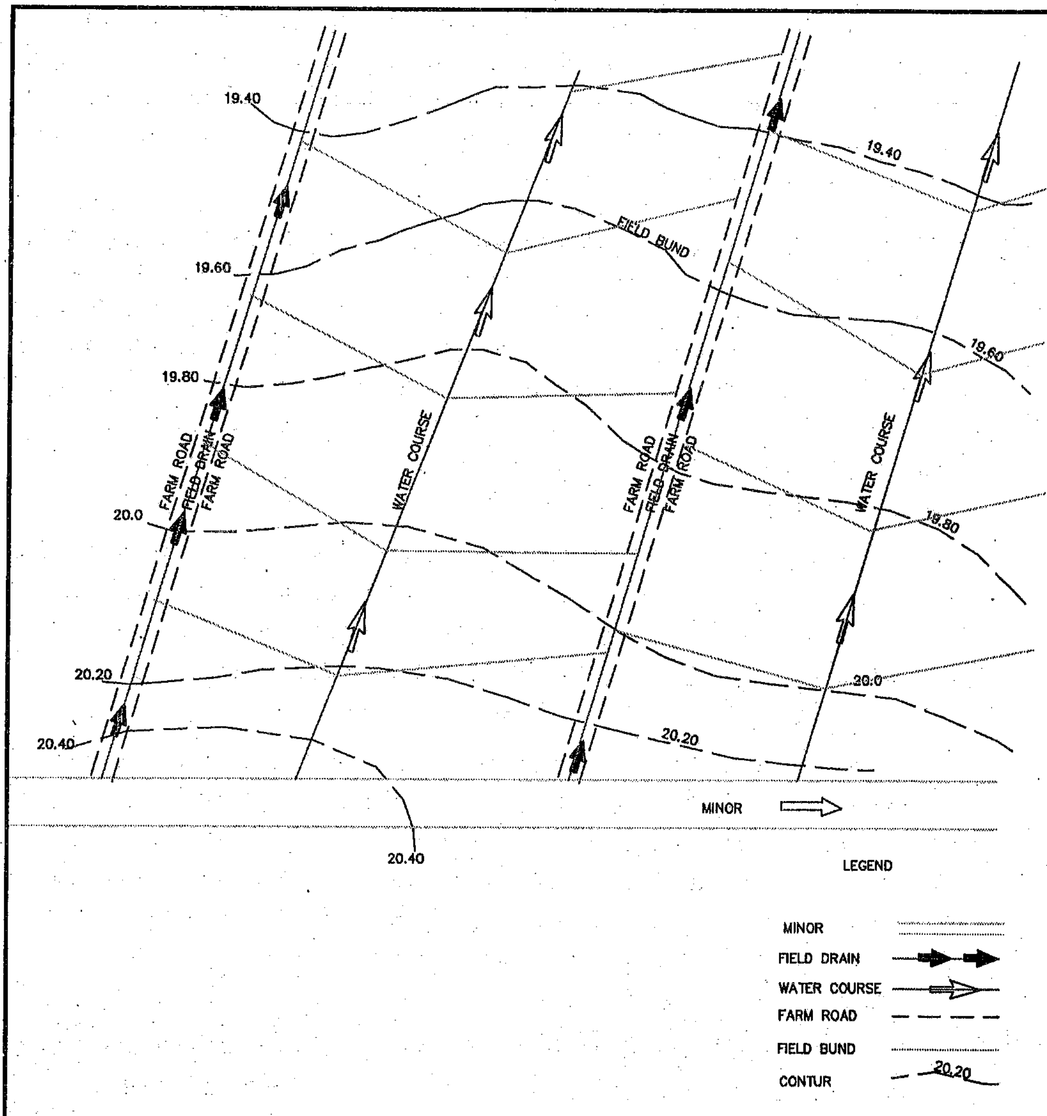

Figure 4. The Contour Method of Layout.

Strip fields run from channel to drain at such an angle to the existing contour as to provide the required longitudinal slope for irrigation. Length of field depends to some extent on topography, on the infiltration capacity of the soil, and on the standard of technology of the farmer. It is felt, for example, that farmers cannot handle a flow much longer than 200 meters. Width of field depends on the pre-existing slope of the land acres the field (narrow strips on steeper land to save earthwork) subject to a minimum of 15 meters, which is just over double the turning circle of a tractor, and therefore the minimum width of mechanical cultivation, which is inevitable in the next decade. There are five factors which interrelate to affect irrigation efficiencies apart from the skill of the cultivator - infiltration rate, slope, length of run, width of run, and size of stream. All are governed by practical limits but, using the contour method, there is sufficient flexibility to obtain required physical conditions at the time of layout design without the necessity of moving earth.

In the contour type layout every farmer has access to a watercourse at the head of his fields and discharges excess water into a drain at the foot of his strips. No one depends on those above him to allow him to have his share of water through their land, and none receives drainage water on his land from those above. All have access to their plots at all times for cultivation and to carry off the harvest. The contour layout, with its graded bunds and automatic disposal of excess water through the built-in complementary drainage network is an ideal soil and water conservation protection, fields are of such a shape and size as to allow modern agricultural machinery to work. Experience has shown that there is invariably a net gain in cultivable land after development.

11.3 DESIGNING AND PLANNING OF IRRINAGE SYSTEM

Before planning a irrinage system L-sections of canals irrigating the area to be planned, the Sajra map of the area, planned outlet positions and their CCA and the drainage plan of the area (if available) should be collected along with the L-sections of seepage, carrier, sub-main and main drains of the area. Cultivator list along with the revenue map of the area should also be collected. After collection of the record, survey work is taken up for planning and designing of irrinage system.

Good planning calls for maximum coverage of the irrigable lands at minimum construction cost, operation and maintenance expenses. Desirable location should therefore be determined principally on topographic consideration and therefore adequate information on topographic conditions, soil characteristics, intended irrigation methods and water delivery arrangements, etc. be collected.

A well designed irrigation system delivers the required amount of water to all parts of the area to be irrigated at the required rate without damage to the soil or excessive loss of water. It should be easily accessible and easy to operate without obstructing other farming operations. Laying out fields of workable size and shape is important to successful irrigation farming. The fields should be laid out as nearly rectangular as possible (Figure 4). Sharp turns in field boundaries should be avoided as far as possible in order to facilitate the use of modern farm equipment.

Before planning an irrigation system, reconnaissance survey the area to find out any variation between survey and planning such as excavation of drain, canal capacity works, construction of structures, power line, etc. If any variation is found then it should be marked on the grid map.

Detailed guidelines for the planning & designing of Irrinage system is available at the Unit No. 12 of Course 4.

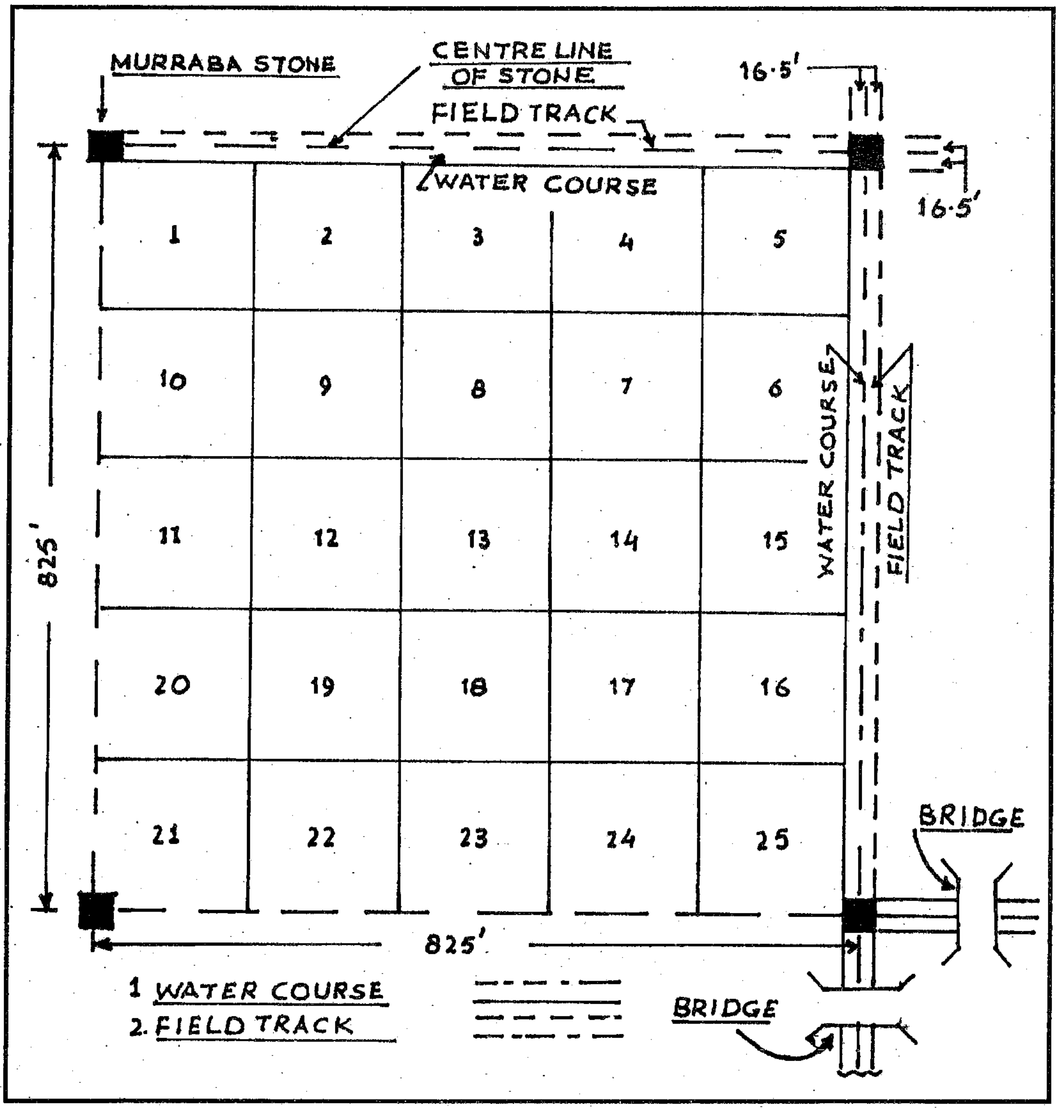

Figure 5. Sample Layout of Chak Plan of I.G.N.P. Area.

11.4 DESIGN OF CHAK

It is a piece of command area of a canal which receives irrigation from a single outlet in the canal. It may generally comprise of few hectares to about 40 ha. The main factor for deciding the layout of the chaks are the topographical features like ridges, natural drains and the prescribed size of chak. The natural ridge and valleys are marked on the block contour map to divide the command under the minor in to different chaks. The area between two valleys will normally be the topographic limits or boundaries of a chak. If any of the chaks exceed the prescribed size of the chak, it should be further subdivided. The size of the chak should be such that the irrigation in the chak must be completed in the specified flow period with the design flow rate. The size of the chak is mainly governed by cropping pattern and peak water requirement of crops.

The objective of planning and design of a chak is to divide the command area of a distributory or minor into suitable sizes (known as chaks) and to find a suitable alignment of water course in that area so that the cost of water course per unit of culturable command area is minimum and convey water to the farms in the shortest possible time, or in best efficient manner. Objectives of good chak design are :

(i) Equitable distribution of water to individual fields in the command.

(ii) Improved water management.

(iii) Improved irrigation efficiency, by minimising operational losses.

(iv) Increased potential and agriculture production.

To achieve the above objectives, the planning and design of chaks involves mainly the following items of work:

(1) Location and fixing the outlet level of the water course.

(2) Marking of chak boundaries.

(3) Selection of alignment and section of watercourse as well as field drains.

(4) Fixing of location of structures.

As per letter no.:6(1), 79-1 & 8 CAD dated 10th October 1979 from Shri. S. S. Puri, Secretary to the Government of India, Planning Commission addressed to Secretaries, Irrigation Department of all State Governments relating to utilisation of Irrigation Potential Construction and Maintenance of Watercourses and Field Channels, the chak command should be sub-divided into suitable number of sub-chaks of size varying between 5 to 8 ha unless topography permits otherwise. While planning the minor distribution system upto sub-chak command, the layout of field channel/farm channel may also be done within a sub-chak to carry water to each farm gate. The design and layout consideration of field channel/ farm channel will be similar to that of a watercourse the only difference being that the field channel/farm channel may be lined or unlined. Moreover, these field channels/farm channels will have the same capacity as that of the off-taking watercourse.

- **Fixing Outlet Level of the Watercourse**

An outlet is a connecting link between the watercourse and the canal system i.e. main canal, branch, distributary or minor. The outlet may be regulated or unregulated. The outlet on minor should be located considering following points:

- Outlet structure should be preferably in cutting and not in filling. If it is in filling then good compaction should be done.
- Outlet should be located in its own command. It should not be away from its own command as far as possible.
- It should be at least 5 m upstream of drop or fall structure on a minor. The outlet is fixed upstream of fall structure rather than downstream to have maximum command.
- The sill level of the outlet should be taken at or near the bed of minor, so that the outlet can draw its discharge of 30 lps even when the minor is flowing half of its capacity.
- An outlet must not be taken directly from main canal and branch canals. Even if it is necessary, parallel minors may be planned for serving areas adjacent to the canals.

Fixing the level of an outlet in a channel depends upon the flow characteristics, i.e. the fluctuations in the water level in the parent channel and the topography of the chak. Outlets may run free flow or submerged depending upon the full supply level of the water course at the downstream of the outlet. The level of the outlet is so fixed that it always draws its share of water, inspite of the fluctuations of the water level in the parent channel. The water level in the parent channel generally varies from half to full supply depth according to the water demand.

Generally a minimum working head of 0.3 m (or 1 feet) at the head of outlet is considered adequate.

Where there are chances of loosing any command, a highest possible level of the water course is desirable. But in low lying areas, a lower level of the water course may be preferred. The advantage of a lower level is that the water course can draw more silt at this level then that at higher level but it should not loose any command. The disadvantage is that because of the lower level of the outlet, the gradient available in water course will be less.

- **Marking of Chak Boundaries**

The chak boundary of a water course of an outlet, taking off from a canal is marked in such a way that maximum area can be irrigated. The size and shape of chak is fixed in such a way that the cost per ha is minimum. This can only be achieved when the length of water course per ha. of culturable command area is minimum. The size and shape of the chak are important factors in keeping the length to be minimum . The chaks should also have manageable size. The size of the chak is generally kept for a discharge varying from 1 to 3 cusecs. Chaks of less than 0.5 cusecs and greater than 3 cusecs may not be generally economical. Also chaks for greater than 3 cusecs discharge are too big for reasonable management. For discharge greater than 3 cusecs a minor may be considered and chaks may be further subdivided.

Generally chaks may be square or rectangular in shape, but strip chaks (narrow width and very long) should be avoided as these chaks are generally not economical and length of water course per hectare of CCA is more in such chaks. In such chaks the maximum length of water course becomes the limiting criteria. The slope of water course should be fixed in such a way that there is maximum command with smallest section. Water courses with steeper bed slopes are economical as they require smaller section due to higher velocities. But it may loose command. For flat slopes a higher section of the water course is required for the same discharge or CCA.

11.5 WATER CONTROL AND DIVERSION STRUCTURES

Water control and diversion structures are necessary to give easy and effective control of irrigation water on the farm. Good control will reduce the labour required to irrigate and check erosion and water loss. Following structures are necessary on the field channels:

(1) Measuring device
(2) Drops or fall structures
(3) Diversion boxes
(4) Turnouts
(5) Checks
(6) Nakkas
(7) Crossings
(8) Tailescapes

11.5.1 MEASURING DEVICE

It is essential to have at least one measuring device in each chak. It may be installed in a fairly straight reach between outlet and the first diversion box or the turnout. The purpose of this measuring device is for measuring the water flow in the channel. It helps in scheduling the water supply in the chak and also controlling the flow so as to control the irrigation within the chak. Such a control is necessary to create confidence in irrigators that assured one cusecs flow is being given to them and also to ensure proper distribution of water.

11.5.2 DROP OR FALL STRUCTURE

Field channels are generally aligned on ridges and run across falling contour. In steep topography, this involves steep bed gradients, which may generate erosive velocities. The bed gradient has to be flattened to get non-erosive velocities by provision of drops at suitable locations.

At the locations of drops, the water falls through a certain height, changing the potential energy into kinetic energy. No strata can withstand the high velocity and erosion is inevitable in such a situation, if proper arrangement to dissipate this energy is not made. Therefore fall structures are provided on watercourses so that safe dissipation of surplus energy can be made.

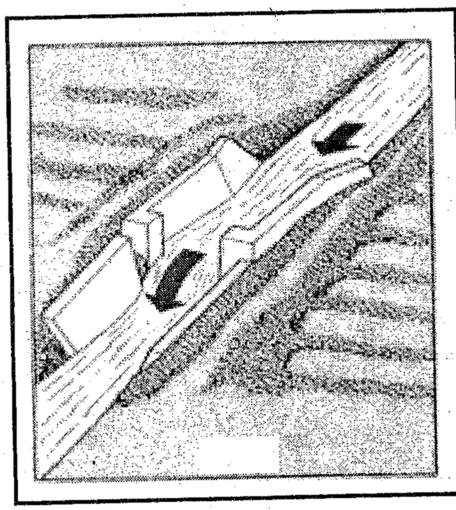

Figure 6. Drop Structure.

11.5.3 DIVISION BOXES

The purpose of a division box is to divert the flow from the watercourse into one branch where watercourse is branching, either into one or more branches. It is mostly used for diverting the full stream flow. This structure is more or less the same as a turnout. These are generally precast structures but can be constructed also in U.C.R. or B.B. Masonry. Proper foundation should be provided if precast structure is used.

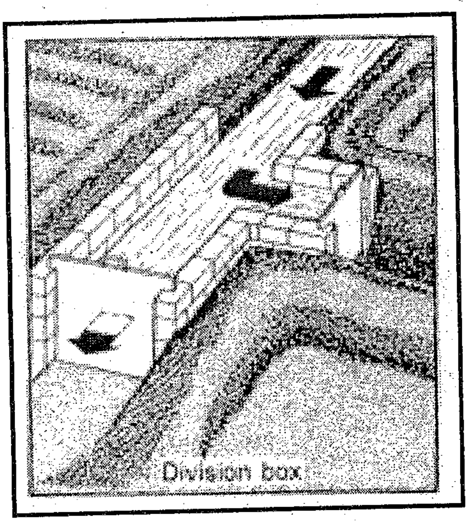

Figure 7. Division Box.

11.5.4 TURNOUTS

A turnout is a structure at the property head (Farm gate) for taking the water from the watercourse/field channel to the field channel/farm channel or in the farm. It also functions as a controlling structure for diverting the flow of water in one, two or three directions. Water from the watercourse should be taken from only one point which would be fixed. It is not good to cut the watercourse bank as this increases the operational losses. Hence turnouts, either pipe turnouts or diversion box type turnouts, may be provided at the suitable location for each field. The turnout should be located at such a point so that there is maximum command, minimum cost of land shaping, minimum chances of damage to turnout, watercourse, least dispute among cultivators, less chances of choking and least interruption in supply. The most desirable position of locating a turnout is at the highest possible point on the ground along the watercourse for covering the maximum command.

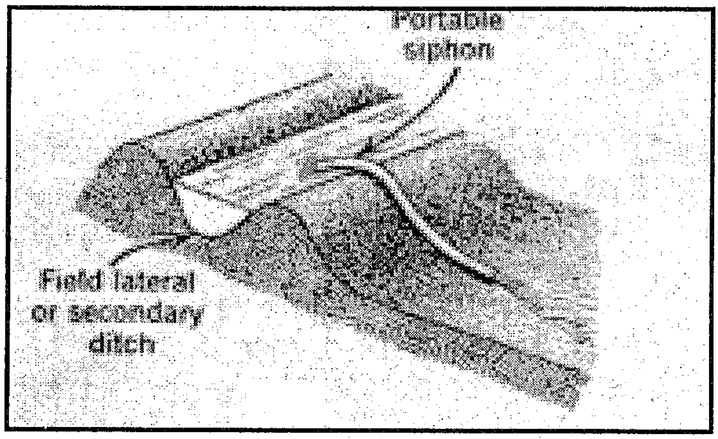

Figure 8. Use of Syphon to divert water in the field.

Turnouts structures can be provided with grooves so that farmer can insert a plank in it to head up water.

11.5.5 CHECKS

Checks are nothing but the cross regulators in the watercourse to divert the required flow into field channel through turnouts. They are placed across watercourse/field channel to raise the water level. Alternatively, canvas dams can also be used for regulation.

11.5.6 NAKKAS

For the proper regulation and control of irrigation water, in the watercourse conveyance system, suitable control structures are required in it at suitable locations. These structures are known as farm irrigation control structures or locally as Nakka. It may be defined as a feeding point directing the supply from the watercourse to the field channel in a particular farm. These are also used for diverting the flow from one branch to other branch of watercourse.

11.5.7 CROSSINGS

Where the channel crosses an existing road, cart track or a natural drainage line, a satisfactory crossing arrangement has to be provided. As far as possible, the bed gradient of the field channel at the crossing should be avoided.

A simple arrangement with a hume pipe supported by head walls at both ends would be suitable. Construction of this type of crossing is quick and the cost is also low. Minimum 30 cm diameter RCC spun pipe, type NP3, is suitable for taking the traffic load.

Following two precautions are necessary in case of hume pipe drain crossings:

(1) Waterway should be adequate to avoid heading up on upstream side.

(2) Minimum solid cover (cushion) over the pipe top may be kept as 40 cm to avoid breakage of pipes.

11.5.8 TAILESCAPES

Tailescapes are provided at the tail of watercourse where it is outleting in a drain or nallaha. The function of tailescape is to prevent the erosion of the soil at the tail of watercourse and to discharge the flow safely.

11.6 SUMMARY

Good planning calls for maximum coverage of the irrigable lands at minimum construction cost, operation and maintenance expenses. Desirable location should therefore be determined principally on topographic consideration and therefore adequate information on topographic conditions, soil characteristics, intended irrigation methods and water delivery arrangements, etc. be collected. A well-designed irrigation system delivers the required amount of water to all parts of the area to be irrigated at the required rate without damage to the soil or excessive loss of water. It should be easily accessible and easy to operate without obstructing other farming operations. Laying out fields of workable size and shape is important to successful irrigation farming. The fields should be laid out as nearly rectangular as possible. Sharp turns in field boundaries should be avoided as far as possible in order to facilitate the use of modern farm equipment.

11.7 SELF-ASSESSMENT

1. Define Irrinage.
2. What are the principal requirements of a good irrigated farming area?
3. What are the main methods of Irrinage layout?
4. What are the main features of contour layout method?
5. What are the different water control & diversion structures?

11.8 KEY WORDS

- ***Irrinage:*** Planning and execution of irrigation & drainage system simultaneously.
- ***Contour lay out method:*** Watercourses are laid out down the highest points of the secondary ridges with field drains placed to the intervening secondary drainage depressions.
- ***Watercourse:*** Watercourse is a network of small irrigation channels from canal outlet to the individual farm, which carries water to the fields in a chak.
- ***Chak:*** Chak is a piece of command area of a canal, which receives irrigation from a single outlet in the canal. It may generally comprise of few hectares to about 40 ha.

11.9 SUGGESTED READINGS

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UNIT-12

PLANNING & MANAGEMENT OF INTEGRATED WATER & AGRICULTURAL MANAGEMENT APPROACH FOR SUSTAINABLE AGRICULTURAL PRODUCTION- A CASE STUDY IN CHAMBAL COMMAND, RAJASTHAN

Structure

12.0 Objectives

The economic development of the country is highly dependent upon judicious use of the natural resources. Land and water two most natural resources, are very limited in our country. The ever increasing demand for agricultural products and the requirements of other sectors emphasizes the need of conservation of these resources and agricultural production on sustainable basis. In the recent years, priority to consolidate the already developed irrigation potential is gaining through participatory irrigation management.

The Chambal Irrigation project introduced in the early sixties is one of the major river valley projects of India covenng a culturable command area of about 229,000 ha in Rajasthan and a similar area in the downstream of Madhya Pradesh. Following the development in irrigation potential, a combination of problems such as: inequitable distribution of water, inefficient irrigation delivery system, excess water application, lack of maintenance of irrigation systems and poor drainage system started building up watertable and consequently resulted in waterlogging and soil salinity and reduced crop yields even with improved agronomic practices.

In order to. combat these problems, a number of land development programs were initiated in the Chambal Command Area(CCA). The most recent and important program is the Rajasthan Agricultural Drainage Research Project (RAIAD). RAJAD introduced subsurface drainage to eliminate the physical constraint of soil salinity for crop production as a part of overall water management.

The IWAM pilot program was introduced under RAJAD project in June, 1994 with a view to develop, demonstrate and evaluate Improved and integrated water and agricultural management procedures In three blocks selected as a model for optimum crop production and for sustainable agriculture development. IWAM is a system approach to irrigation management involving scientific irrigation network planning, on?farm application and management of water including appropriate drainage, keeping in view the agricultural management through suitable cropping pattern, ecological and socio-economic aspects.

Following the system identification with respect to various inputs such as social, soil bench mark survey and land and water use practices, a series of measures were introduced and the attained results were reduction in irrigation water losses, productivity improvement measures and opprtunities for the regulation of the watercourse at the head end consequent increase in the watercourse command irrigation efficiency. It was observed that combined adoption of the border strip surface irrigation method and land levelling resulted in a measurable saving of irrigation water and increased water use efficiency over the prevailing irrigation application of flooding the land.

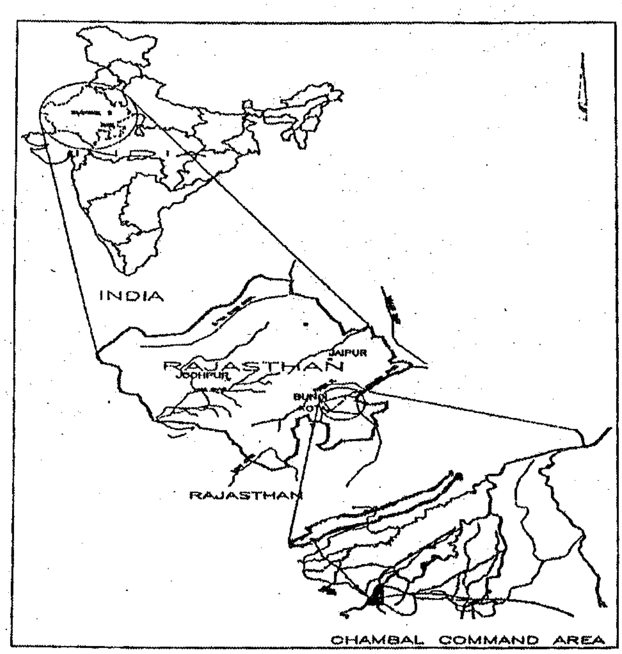
A comparison of applied depth in border experiments with the depth applied under conventional water application following wild flooding, (with surface runoff checked) showed that an average 40 to 64 percent more water has been applied in conventional irrigation over the border irrigation. The analysis of wheat yield and water applied show that the water use efficiency was 284 kg per ha per cm of irrigation water in 6 in border, 265 kg per ha per cm in 9 m border, 202 kg per ha per cm in 12 m border much higher compared to conventional irrigation i.e. 130 kg per ha per cm of irrigation.

Advantages of measures such as proper operation and maintenance of watercourse and drains through farmers participation and recommended packages of practices for crop production were demonstrated through field trials on different IWAM sites. The tested IWAM programme was then extended to several outlets in Chambal Command by CADA. Irrigation system Improvement program has been taken up in Chitawa Distributory by RAJAD. The results of IWAM programme were encouraging and has given replicable models for sustainable agricultural production in Command Areas. Still there is strong need to develop site specific IWAM practices and a related technological developmental model suitable to the end users.

Experience of IWAM In Chambal command Area reveals that farmers if provided with sufficient knowledge, opportunities and support can manage the agriculture and Irrigation system by their own in. a very effective manner. To make it more effective there is a need for proper commitment at all levels, proper legislation, proper awareness on benefits of Integrated Water & Agricultural Management. The Rajasthan government is now planning to introduce these measures through a World Bank aided Water Resources Consolidation Project (WRCP).

12.1 Introduction

The Chambal Irrigation project introduced In the early sixties, is one of the major river valley projects of India covering a culturable command area of about 2,29,000 ha in Rajasthan and a similar area in the state of Madhya Pradesh (fig-1). Water utilization during the Initial phase was low, as in initial phase farmers of the area were not accustomed to irrigation. To bridge the wide gap between the potential created and the potential utilized, incentives like additional and/or bigger size outlets were allowed. Following



the introduction of irrigation, the Irrigation and crop related problems emerged out such as (Gaur A., Srivastava D., 1996):

- High seepage losses In canals.
- Inequitable distribution of water (head enders draw more water than tall enders)
- Inefficient water delivery (unreliable and unpredicted water supply).
- Improper canal roster.
- Improper method of irrigation application such as wild flooding
- Poor drainage system resulting in waterlogging and salinity.
- Poor management of fertilizers in crop production.
- Weed and pest problem in the crops.
- Lack of participation of farmers and communication gap between farmers and the irrigation department.

12.2 Irrigation

Chambal Irrigation project construction began in 1953 and continued until 1971 with irrigation available since 1960. It is located in semi and clime zone in Rajasthan. This system was designed mainly for protective irrigation and did not include any on farm management works or any training to the farmers about the method of irrigation which resulted in inequitable distribution of water and low irrigation efficiency. Due to lack of water control and low irrigation efficiencies, water do not reach to the lower ends of the distributary system. For these reasons agricultural development in the Chambal Project Area has not fulfilled expectation at the time the irrigation project was constructed.

Although irrigation intensity has been increased to the value expected by the project at the time of construction to 130% (90% in Rabi and 40% in Khanf) from 76% (55% in Rabi and 21% in Kharif) but not necessarily that all beneficiaries are getting required amount and frequency of water. The overall Irrigation efficiency of the irrigation system was estimated by UNDP in 1968 to be only 34 per cent excluding losses from Kota barrage. In order to increase overall irrigation efficiency a number of land development programmes were initiated in the Chambal Command Area (CCA). The details are as follows:

12.2.1 LAND AND WATER USE AND MANAGEMENT PROJECT

This program was introduced during 1967 by the UNDP with FAD of the United Nations as the executing agency, embarked with the aims:

- ☐ To find the means to protect salinity and waterlogging;
- ☐ To study the problem of weed control in existing irrigation canals and drains;
- ☐ To design and execute irrigation improvement;
- ☐ Landscaping and drainage on pilot areas;
- ☐ To develop proper water management principals for existing water resources and make recommendation on their development and

- To develop proper land use patterns and farm practices for the intensification of agriculture.

Conclusion reached as a result of study were lack of water control and waterlogging. The major thrusts were the development of a system onfarm development suited to the area.

12.2.2 ON-FARM DEVELOPMENT (OFD) PROGRAM

A program of On?Farm Development was initiated in 1970's in order to increase irrigation efficiency and thereby mitigating the impacts of waterlogging. This program included land levelling, realignment of watercourses, surface drains and farm boundaries. Approximately 58,000 ha had completed by 1993-94.

Although on?farm irrigation efficiencies and surface drainage improved through the OFD program, salinity and waterlogging problems continued to exist. Since the drainage and OFD Improvement, little or no maintenance of drains has been provided and as result of which the drains are choked with typha or weed Infestation, Now cleaning or desilting the seepage drain Is very tedious jub.

12.2.3 RAMSTHAN AGRICULTURAL DRAINAGE RESEARCH PROIECT (RAJAD)

The project was introduced in 1992 to demonstrate the benefits of horizontal subsurface drainage and associated water management techniques as means of arresting the deterioration of land from waterlogging/salinity. It is a joint undertaking financed by the Government of India, the Government of Rajasthan and the Government of Canada). The project's specific goal is **"to improve agricultural productivity of the farmers of the command area while enhancing the welfare of the State's inhabitants by ensuring a reliable output of basic food commodities through applied research and development".**

The long term good impact of various land development programmes was not fully realized as the farmers did not adopt the concept of " Integrated on farm water and agriculture management". One of the reason is over irrigation, which is mainly due to field geometry, field topography. The farmers don't have the confidence of proper irrigation water supply even after 30 years of irrigation in Chambal Command Area, which is also one of the prime factors of over irrigating their fields. The equitable distribution of water has not received it's due importance. In the same command of a minor, some fields at the head reach receive excessive water whereas others in tail reach suffer from lack of irrigation water.

The poor drainage conditions are being addressed by improving surface drainage through on-farm development works and SSD Installation in waterlogged and saline lands under RAJAD. The emphasis on land and water management however lacks. So to meet out the RAIAD goal (sustainable crop production for the welfare of the farmers of CCA), It is imperative that crop production per unit area per unit of irrigation application depth should be maximised with the incorporation of Integrated water and agricultural management (IWAM). Therefore the concept of Integrated water and agricultural management has become necessary In Chambal Command for sustained crop production.

Though Chambal Command Area Development strategy initially aimed at Protective Irrigation but later on efficient administrative and management measures enabled the productive irrigation. Still there Is a strong need of physical improvements, integration of efficient planning and best use of land and water for optimum sustainable agriculture production. So the combination of agricultural practices with proper onfarm water management has become the basis of IWAM.

12.3 IWAM CONCEPT

In terms of optimum agriculture productivity of irrigated lands, drainage is an element of overall land and water management. In the absence of a multidisciplinary approach for tackling the waterlogging and salinity problems, full potential may never be achieved. Shady etal state that concept of overall water management should be considered seriously to increase the efficiency of the use of water resources and to decrease the necessity for investment in land and water development. The program aims were to:

- Adopt an integrated multi?disciplinary approach,
- Increase the effectiveness of water deliveries and of water applications,
- Install pilot scale demonstrations of effective water delivery and control system,
- Provide structured and non?structured interventions in supply and distribution systems to restore confidence of the farmers in the irrigation system,
- Assist in the introduction of warabandi in the selected blocks,
- Assist in the formation of Water Users' Association.

The criteria of selection was to have the three representative models (fig-2): one non-saline and without subsurface drainage (IWAM-1 of 26 ha), another with SSD already installed (IWAM-2 having 40 ha area) and third with SSD partially uncultivable land due to high salinity (IWAM-3 having 19 ha area). IWAM-4 (deep water table and no SSD) was later on selected for making comparison with IWAM-2.

The program has brought together various disciplines (fig-3) under one umbrella to study and combat the existing problems using an Integrated approach. Under this programme, along with the formation of water users group, various physical Improvements were done In the pilot areas and improved water management technology and agricultural practices were demonstrated to the farmers by conducting the experiments on their fields.

12.3.1 IMPROVEMENT IN IRRIGATION SYSTEM

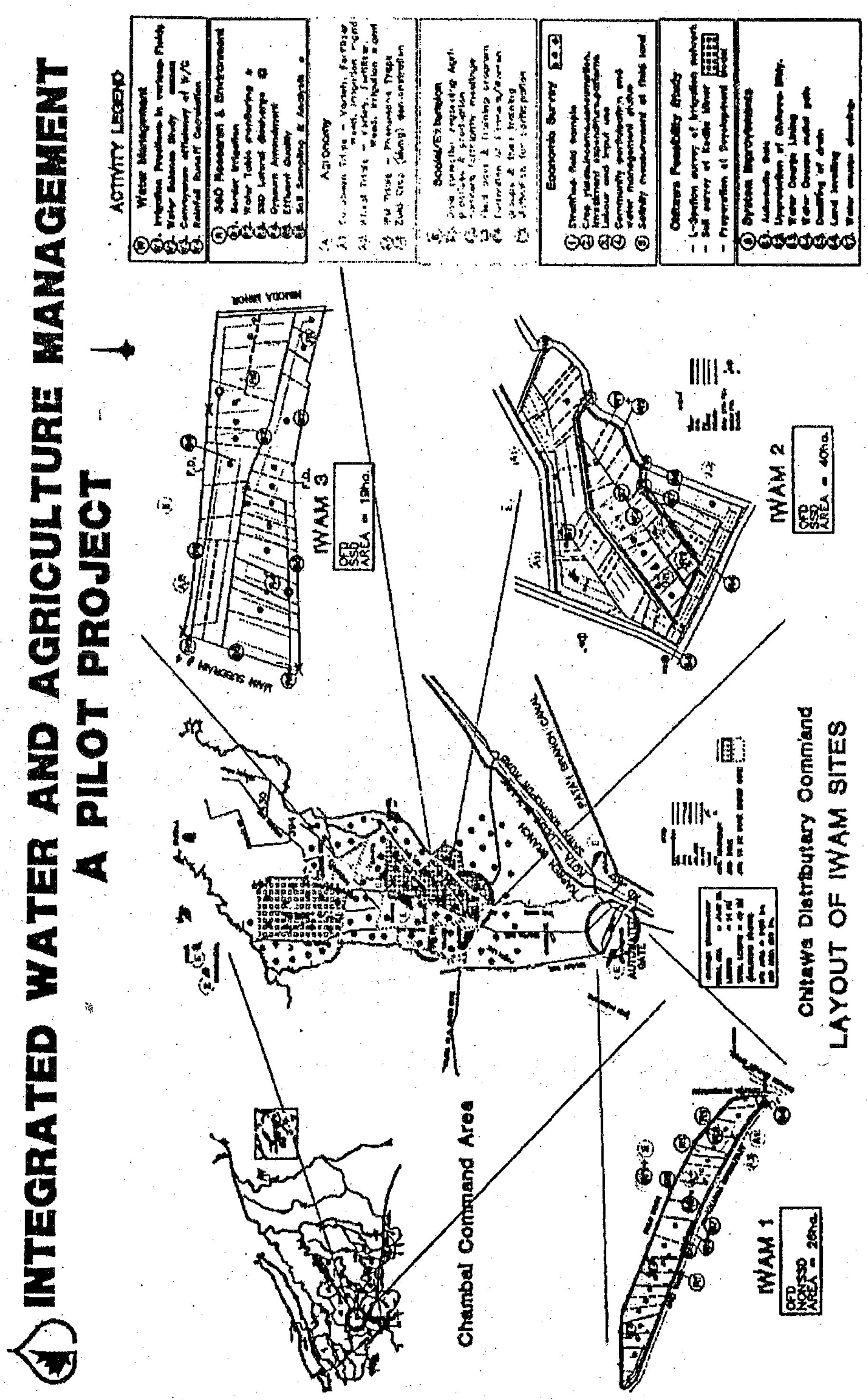
12.3-1.1 *Maintenance of Irrigation field channellwatercourse*

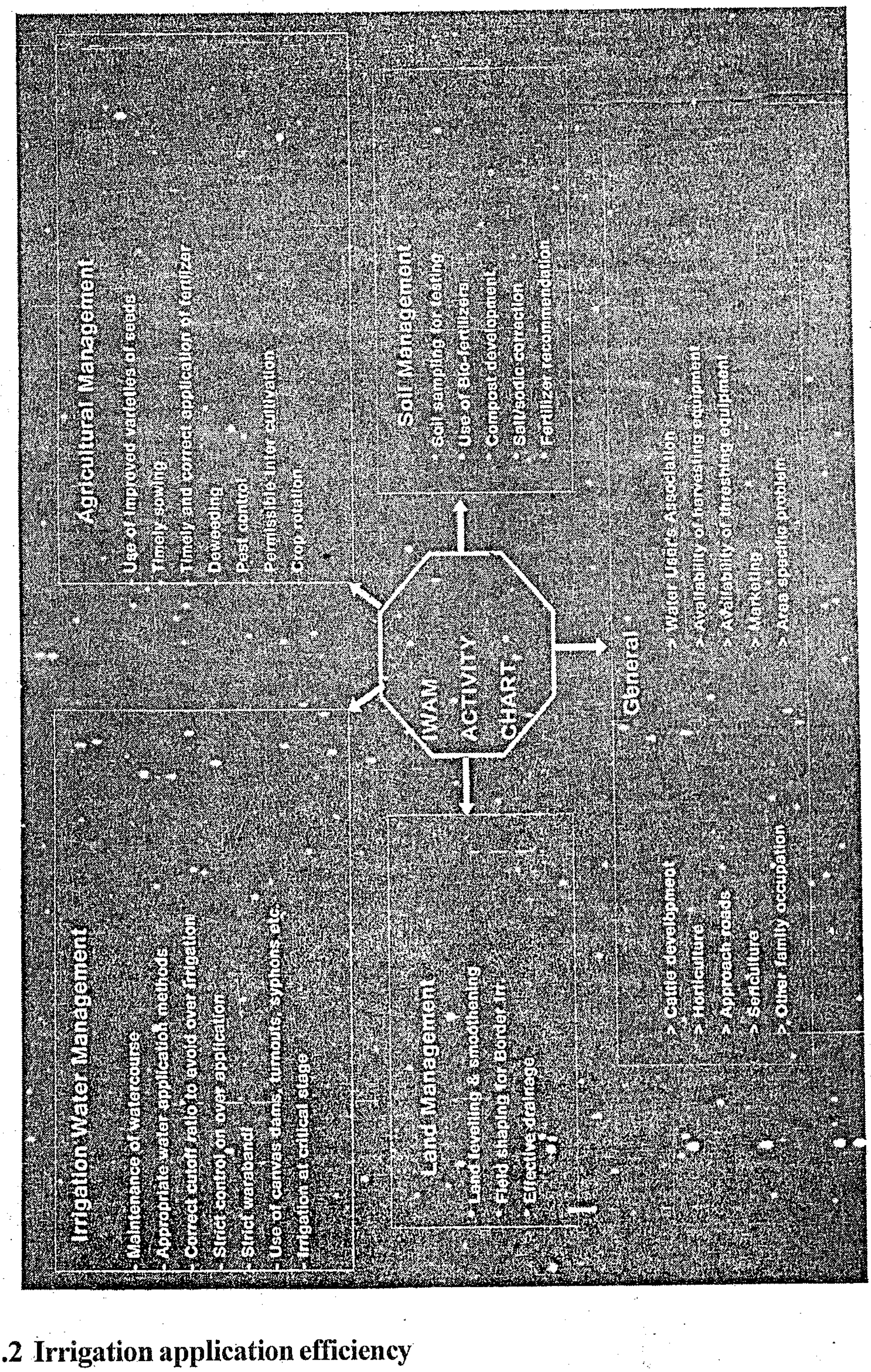
It has been observed that a significant amount of water is lost through the watercourses, either due to poor conveyance efficiency or due to improper control.

- **Lining upper reaches of the watercourse :** It was experienced from the IWAM sites that the lining of upper reaches saves a considerable amount of water. It was observed that the maximum seepage was from the upper reaches and generally the upper reaches being government land, it was not attended by the farmers.
- **Reducing wastage through gated outlet :** The farmers used to drain excess water in to the drains when they do not need. Providing gates on the watercourse saved about 60% of water available at head of water course in IWAM- I and 50% in IWAM-2 outlet. So in this manner if all the watercourses are provided

with gated outlet, it will save a considerable amount of water loss, and ultimately the irrigation intensity can be improved.

- **Improving watercourse converyance efficiency :** The unequitable distribution and excessive seepage losses from the watercourse causes the low watercourse discharge, which Is not sufficient to meet the crop water requirement. All the IWAM watercourses were cleaned with farmers participation. From IWAM experience, the efficiency of the water courses has been improved from 40% to 60%.





12.3.1.2 Irrigation application efficiency

Under IWAM programme, the farmers were demonstrated various sizes of border strips along with minor land levelling. An appropriate size of border and inflow rates to suit various border lengths were arrived. As a result of which the farmers have started making the borders in their field.

A comparison of applied depth in border experiments with the depth applied under conventional water application following wild flooding (with surface runoff checked) showed that on an average 40 percent in first irrigation and 64 percent in second irrigation, more water has been applied in conventional irrigation over the border irrigation, The analysis of crop yield and total water applied to all IWAM sites show that the water use efficiency was 284 kg per ha per cm of irrigation water in 6 m border, 265 kg per ha per cm in 9 m border, 202 kg per ha per cm in 14 m border and 130 kg per ha per cm of irrigation in conventional irrigation.

The study indicates that border width of 6 m with cutoff ratio of 75 percent may be adopted for border lengths of 50 m to 150 m for the available discharge of 2 to 4 lps per meter border width following the guideline that more the border lengthier be the discharge.

12.3.1.3 Irrigation scheduling

It was observed that the farmers of Chambal Command Area over irrigate the field without considering the crop water requirement, so the irrigation induced salinity and waterlogging problem arised. So the effect of irrigation on critical stages of crop growth was studied: first at the CRI (crown root initiation), second at tillering and third at the milk stage in wheat and compared with the conventional system.

12.3.2 SURFACE & SUBSURFACE DRAINAGE SYSTEM IMPROVEMENT

12.3.2.1 Installation of SSD :

To reclaim the waterlogging and soil salinity, SSD is an effective solution. Installation of subsurface drains in IWAM-2 & 3 showed that the waterlogging and

12.3.2.2 Maintenance of surface drainage systems :

The performance of the effective surface drainage system lies in continuous maintenance. In this regard the farmers were motivated to clean their field drains. In some areas response came with a 30% contribution to work with DRDA scheme " APNA GAON APNA KAM". Field days were organised to clean the surface drains with farmers participation. Surface drainage systems are maintained by the following improvements:

- Desilting/cleaning of MD, CD & SD.
- Replacement of missing inlets to drains
- Minor land smoothing in all IWAM areas.

12.3.2.3 Water table monitoring :

The effect of water table on crop growth should be correlated to assess the crop water requirement and for that water table monitoring is must. For SLIstainability, the training of farmers were organised for water table monitoring.

12.3.2.4 Water Quality Measurement :

The effluent quality test is to assess the environmental impact. Water quality samples are collected from surface runoff and subsurface drainage water. From these samples, water quality and its environmental impacts are studied. Therefore, nitrogen, phosphorous and potassium, trace elements dissolved in the water samples are analyzed.

12.3.3 IMPROVEMENT IN AGRONOMICAL PRACTICES

12.3.3.1 Weed and fertilizer (Nitrogen) Management in various crops

Different weed management techniques such as hand weeding and herbicide applications were demonstrated and the recommendation was made for the application rate along with the required dose of fertilizer.

Use of improved and correct qunatity of seed

Based on the soil fertility/capability status, the agriculture research wing should propose the improved varieties of seed along with the correct seed application rate to farmers of chambal command area.

Development of Compost pit and use of FYM

The agricultural waste should be degraded to produce the compost fertilizer.

12.4 IMPROVEMENT IN FARMER PARTICIPATION

12.4.1 MOTIVATION OF THE FARMERS:

The farmer are generally not aware of the use of improved technology in irrigation practices. The farmers consider that the maintenance of in inigation and drainage systems is not their responsibility. Furthermore, being a common structure no individual takes it as his responsibility. So the farmers are motivated to adopt the improved irrigation practices and to recognize their responsibilities.

12.4.2 GROUP FORMATION:

To develop an active participation of farmers in the IWAM sites, farmers formed homogeneous groups and chose two leaders in each group. The leaders are trained in motivation, communication skills and group dynamics as well as training for qualities of leadership.

12.4.3 FARMERS' MEETINGS:

The groups hold weekly meeting in the villages and work on an action plan pooling resources from everywhere. The groups are motivated to follow the Warabandi irrigation system and consequently they form a water users association.

12.4.4 ORGANIZE FIELD DAYS.

Field days were organized at the IWAM sites where about 50 farmers participated each time. Demonstrations included field trials on suitable methods of irrigation, water management and fertilizer management. The farmers were advised to improve and maintain their watercourses and field drains. The field days were supported by various communication aids like charts, posters and banners. Experts from various disciplines were involved.

12.4.5 MOTIVATION TO FORM WATER USERS ASSOCIATIONS:

There is a lack of collective. effort to improve the water distribution and management system. So, the farmers are encouraged to form water users associations. On all outlets warabandi was started, consequently WUA could have saved 32 days of canal run in year 1994-95 rabi season. With improved irrigation management and On-Farm Development work, farmers could have irrigated 60 ha. additional area which was earlier not possible.

The results of IWAM can only be achieved with whole hearted participation of the farmers. The practice of IWAM necessarily requires Participatory Irrigation Management(PIM) practices to be adopted. Introduction of IWAM would be an incentive for PIM. The rotational water supply (Warabandi) can be addressed easily with the help of Water Users Association (WUA).

12.5 BENEFITS

More incremental returns to farmer over time would encourage him to retain WUA. CAD extension and irrigation department shall continue to help WUA by maintaining water availability and control leading to higher production or income.

12.5.1 DEVELOPMENT OF OWNERSHIP

CAD is considering to recognize the role of WUAs in irrigation management by transferring some of the rights which can bring ownership among the users thereby attracting long term investments in the upkeep of infrastructure. Some of these rights are :

- Right to take/maintain design discharge at the head of minor;
- Right to recover the irrigation charges from farmers and keeping 50% for maintaining minor or for WUA.
- Management control over water, to allocate and distribute according to WUAs and outlet committees decision etc.

12.5.2 WUA PARTICIPATION IN CANAL UPGRADATION

Normally, the practice in other part of the country is that the canal systems are upgraded before they a re given to the WUAs. But in Chambal Command WUA is formed first and they are involved them actively in civil works required for upgrading the minor. This has the advantage of assessing and prioritizing the local needs in a better fashions. Also work through this approach is more economical and qualitatively of superior nature. The WUA also gets better exposure in carrying civil works, apart from developing a sense of ownership.

12.5.3 CONTINUOUS SUPPORT

CAD has agre providing continuous support tc all WUAs by involving local NGOs and providing of organizational, technical, financial support. Continuous training to WUAs executive members in above mentioned topics is also provided from time to time.

12.6 REPLICABILITY OF IWAM ON LARGE SCALE

12.6.1 IWAM PROGRAMME BY EXTENSION DEPARTMENT

The results of farmers response toward IWAM was so encouraging that extension wing of Command Area Development started the IWAM activity on outlet basis and for that they have selected 105 outlet during 1995-96 with the objective to transfer the improved water and agricultural management technologies as recommended by RAIAD IWAM programme. This was very fast response for the field replication in a larger area from three outlet. In future there is a programme to apply the IWAM programme on 673 outlet. The objective of IWAM programme introduced by CAD Extension department is "To transfer the improved integrated water management technology recommended by IWAM pilot programme (RAJAD) to the farmers in 100 outlets of Chambal Command Area."

12.6.2 RAJAD IWAM ON CHITAWA DISTRIBUTARY COMMAND

In addition to that, RAJAD has selected entire command of Chitawa distributary for IWAM which will include the formation of empowered water users assbciation, upgradation of Chitawa distributary and its minors and land and soil improvement by providing the proper surface and subsurface drainage in problematic areas. The main aim of the programme is to provide a package of improved water management practices to be adopted in entire Chambal Command area.

It was also felt that the integrated approach of IWAM and PIM should be introduced over the entire Command Area to get the optimum agricultural production per unit of land per unit of water along with augmentation of agriculture production with demographic growth. Experience gained from PIM and IWAM in Chambal Command reveals that the some budget provision is necessary to Initiate the motivational activities in prelimi. ry stage of WUAs; formation.

12.7 CONCLUSION

Experience *of IWAM* and PIM in Chambal command Area reveals that farmers if provided with sufficient *knowledge,* opportunities and support can manage the agriculture and irrigation system by their *own* in a very effective manner. To make it more effective there is a need for proper commitment at all level, proper legislation, proper awareness on benefits of participatory irrigation management.

12.8 SELF ASSESSMENT QUESTIONS

Now after studying this unit, now you can understand the basic principle behind integrated water and agricultural management. So to evaluate, answer the following questions?

1. After the introduction of irrigation, name the problems related to irrigation and crop?
2. How different development program came in CCA and for what purpose?
3. What is the concept of IWAM and what are the main components of IWAM?
4. How the farmers participation helped in achieving the goals of IWAM?
5. How such program can be replicated and sustained?

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UNIT-13

DESIGN OF SURFACE DRAINAGE SYSTEM

Structure

13.0 OBJECTIVES

Surface drainage is the removal of excess water from the land surface. Open drains refer to open channels used for agricultural drainage. On farm field drains or surface drains collect excess water from individual holdings and dispose of excess water to the open drains. They are generally shallow, as they carry excess water from a small area. Shallow open drainage ditches are often used in conjunction with land grading and levelling to provide a complete practical solution to a drainage problem. Shallow open ditches can be used to remove surface water or to intercept overland flow while deep open ditches can be used to provide subsurface drainage (i.e. lower the water table).

13.1 INTRODUCTION

Surface drainage is the removal of excess water from the land surface. Open drains refer to open channels used for agricultural drainage. On farm field drains or surface drains collect excess water from individual holdings and dispose of excess water to the open drains. They are generally shallow, as they carry excess water from a small area. Thus, open drains cater to a much larger area and involve several land holdings. These are also known as intermediate drains, since these are the links between on-farm field drains and main/natural drains. A typical drainage system is shown in Figure 1.

The selection of a surface drainage system for a field or area depends largely on soil characteristics, topography, climate, type of crop, value of land and the availability of a suitable outlet. The three main types of surface drainage system are open ditches, grassed channels and land grading.

Shallow open drainage ditches are often used in conjunction with land grading and levelling to provide a complete practical solution to a drainage problem. Shallow open ditches can be used to remove surface water or to intercept overland flow while deep open ditches can be used to provide subsurface drainage (i.e. lower the water table). The spacing and depth required for deep open ditches is similar to subsurface drains. Because of this, subsurface drains are usually the most feasible solution for subsurface drainage and are often used in conjunction with surface ditches.

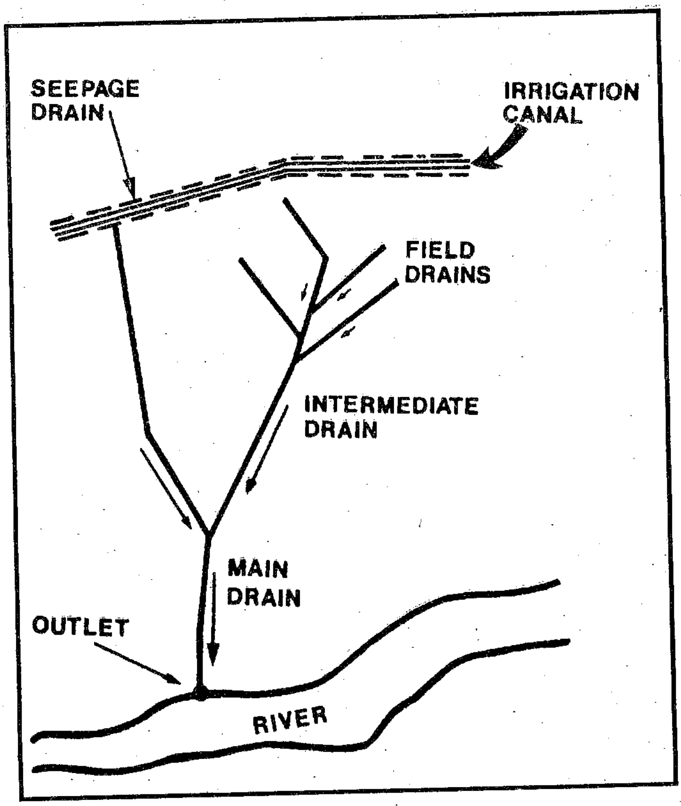

Figure 1 Typical surface drainage system for canal irrigated areas.

13.2 DESIGN OF OPEN DRAINS

The main drains usually form the backbone of a farm drainage system. These open drains can be used to intercept surface runoff from higher ground and hillsides, to drain surface water and/or act as an outlet for subsurface drainage. The main advantages of this system are:

- Low initial cost.
- Capacity for large volume of water.
- Rapid removal of surface water, and
- Easy to construct.

The main disadvantages are:

- Loss of farmable area.
- High maintenance requirements, and
- Impediment to efficient fieldwork.

The design of surface drainage system largely dependent upon topography. Accurate survey information is therefore necessary.

13.3 DESIGN FLOW RATE

The first step in surface drainage system design is to calculate the watershed area and the peak runoff that might occur. It is often desirable to predict the total volume of runoff, which may come from a watershed. Along with time of flooding allowed for a particular land use in the watershed, it can be used to calculate the design flow rate.

The objective of peak runoff estimation is to provide necessary data for the design of agricultural surface drainage systems. It should focus on the amount of water that can be expected and its frequency.

The determination of the capacity of drainage channels for the safe removal of excess water from the surface of the land is an important and at the same time difficult task in planning a drainage scheme. The volume of water that must be removed by surface drainage channels is dependent upon a number of variable conditions. The most important of these variables are:

- Intensity of rainfall.
- Soil characteristics in the watershed.
- Size and surface topography of the watershed area.
- Vegetative cover and land use in the watershed.
- Tolerance of crops to flooding in the area to be protected.

Mainly following techniques are followed in India to estimate the volume of runoff:

i) Rational Method.

ii) US Soil Conservation Service Method (1972) as modified to conditions in India is used for estimating design runoff volume.

iii) Empirical formulae are used to determine water yield or annual runoff.

13.3.1 Rational Method

The rational method is used to predict design flows from small urban and rural watersheds. For rural watershed areas, the upper limit for which the Rational Method is valid is 500 ha. Two significant limitations to the Rational Methods are estimating the time of concentration and selecting an appropriate runoff coefficient. The following considerations should be taken into account when using the Rational Method:

- ♦ The rainfall intensity used should be uniform over the entire watershed.
- ♦ The peak runoff rate occurs when the entire watershed is contributing.

This method is used extensively in many parts of the world. This method is expressed as:

$$Q = 0.0028\, C\, i\, A \qquad (1)$$

where

Q = peak runoff rate, cum/sec,

C = runoff coefficient (as given in Table 1),

i = rainfall intensity, mm/hr, for the design period and for a duration equal to the time of concentration of the watershed area,

A = watershed area, ha.

Table 1 Runoff Coefficient (C)

Topography and vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat (0-5% slope)	0.10	0.30	0.40
Rolling (5-10% slope)	0.25	0.35	0.50
Hilly (10-30% slope)	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.66
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82
Urban Areas	30% of Area impervious	50% of Area impervious	70% of Area impervious
Flat	0.40	0.55	0.65
Rolling	0.50	0.65	0.80

For watershed with more than one type of topography or vegetation, the following equation should be used to provide coefficient with weighted averages.

$$C = \frac{\Sigma C_1 A_1 + C_2 A_2 + \ldots\ldots}{\Sigma A_1 + A_2 + \ldots\ldots} \qquad (2)$$

Where

C_1, C_2 .... = Runoff coefficient for area 1, 2

A_1, A_2 .... = Area of type 1, 2

Rainfall intensity is obtained using the storm duration and a selected rainfall frequency. The storm duration for this method is equal to the time of concentration (Tc). Time of concentration (Tc) of a watershed is the time required for water to flow from the most remote (in time of flow) point of the area to the outlet once the soil has become saturated and minor depressions filled. Tc can be estimated from Table 2 or from the following equation:

$$Tc = 0.0195\, L^{0.77}\, S^{-0.385} \qquad (3)$$

Where

L = maximum length of flow (m)

S = grade of drainage area (m/m)

Tc = time of concentration (min)

Table 2 Time of Concentration for Small Drainage Areas, Tc (Minutes).

Maximum length of flow (m)	Gradient of Drainage Area (percent)					
	0.05	**0.1**	**0.5**	**1.0**	**2.0**	**5.0**
100	13	10	5	4	2	2
200	21	16	9	7	5	4
300	29	23	12	9	7	5
400	37	28	15	12	9	6
500	44	33	18	14	11	7
1000	74	57	31	23	18	13
1500	102	78	42	32	25	17
2000	127	97	52	40	31	22
2500	150	115	62	47	36	26
5000	256	196	106	81	62	44

From the estimated storm duration (Tc) and a selected rainfall frequency, the design rainfall intensity (i) is obtained. Agricultural drainage systems are normally designed for a rainfall frequency of 5 to 10 years return period.

13.3.2 Soil Conservation Service Method

This method was developed in the United State from many years of storm flow records of agricultural watersheds. The Ministry of Agriculture, Govt. of India utilized this technique for conditions in India (IMTP, 1986), The method is commonly referred to as curve number method of estimating runoff.

In this method, the rainfall is converted to runoff by the following mathematical relation,

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \qquad (4)$$

where

Q = Depth of runoff over the catchment, mm,

P = The depth of rainfall over the catchment, mm,

Ia = The initial abstraction in equivalent depth over the catchment, mm,

S = The potential maximum retention of water by the soil and cover in an equivalent depth over the watershed, mm, Initial abstraction, Ia essentially consists of losses from interception, surface storage and water, which infiltrates prior to runoff. It is usually incorporated as a fraction of potential maximum precipitation, S. Value of Ia for Indian conditions are reported in Table 3. As an example let us incorporate Ia = 0.3S in Equation 4, such that

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \qquad (5)$$

Table 3 Initial abstractions commonly used in Indian conditions (Ia)

Region	Initial Abstractions (Ia)
All regions including black regions with AMC I	0.3S
Black Soil region with AMC II and III	0.1S

AMC - Antecedent moisture conditions is described below:

Antecedent moisture condition - The index of watershed wetness used with runoff estimation method is antecedent moisture condition (AMC). Three levels of AMC are used :

AMC - I Lowest runoff potential. The watershed soils are dry enough for satisfactory cultivation to take place.

AMC - II The average condition.

AMC - III Highest runoff potential. The watershed is practically saturated from antecedent rains.

The AMC is estimated from the 5-day antecedent rainfall by the use of Table 8, which gives the rainfall limits by season categories. The rainfall limits are plotted as boundary points for the AMC groups. No upper limit is intended for AMC - III.

If S is known, Q can be calculated with the help of Equation 5 for a given value of P. Curve numbers are evaluated from appropriate tables to calculate S and hence the runoff. The value of S is given by the relation,

$$S = \frac{25400}{CN} - 254 \qquad (6)$$

Where, CN = Curve number, (Table 7)

Once the value of Q is known in mm, the volume of runoff can be calculated simply by the relation,

Volume of runoff = Runoff X Drainage Area

= Q X Area

Volume of runoff (cum) =10 X Q X Area............. (7)

Here area is in ha and Q is in mm.

The exact procedure of calculating the curve numbers consists of the following steps.

Step I

Determine the size of the drainage watershed and the extent of different types of soils and land use. Evaluate the area as percent of the total area under various hydrological soil groups.

Step II

The rainfall data for the return period and duration considered safe for various crops in the protected region is estimated. In general 24 hrs rainfall of 5-10 years return period is taken for design. In agriculture 5-year return period values are more common. The point rainfall values are then converted to area wise rainfall using reduction factors listed in Table 5.

Step III

Based on hydrologic properties, Table 6, land use, soil conservation treatment or practices and hydrologic conditions and antecedent moisture conditions, hydrologic soil cover complex numbers are obtained from Table 7. The antecedent moisture index can be selected from Table 8. For cultivated crops soil conservation treatment or practices are evidently clear in Table 7 itself; the effect of these practices on pastures, forest and tree crops, Table 9, is converted to area wise rainfall described in Table 5. The hydrologic soil cover complex numbers in Table 7 are for antecedent moisture index II. Corrected curve numbers for antecedent moisture condition I and III can be obtained from Table 10.

Step IV

Calculate the weighted curve numbers for different soil groups and land use patterns. A typical example for such calculations is given below (IMTP, 1988).

Step V

With the weighted curve number, S is calculated with the help of Equation 5. Once S is known, the depth of runoff to be removed is worked out with Equation 1 using Ia = 0.15S or 0.35S depending upon the soil described in Table 4.

Table 4 : Weighted curve number

Area description	Percent area	Hydrological soil group	Curve number	Curve number times percent area
Roads (dirt)	2	B	83	166
Wasteland	10	B	80	800
Pasture (poor)	20	B	79	1580
Forest (dense)	4	B	40	160
Cultivated (Straight row)	64	C & D	92	5888
			Total	8594

Step VI

The depth of runoff is converted into volume of runoff using Equation 7.

Example:

$$\text{Weight curve number} = \frac{\text{number times percent area}}{100}$$

$$= \frac{8594}{100} = 85.94 = 86 \text{ (say)}$$

Table 5 Areawise correction factors for rainfall

Drainage Area(ha)	Correction Factor
Upto 50	1.000
Upto 100	0.999
Upto 200	0.998
Upto 500	0.994
Upto 1000	0.997
Upto 2000	0.994
Upto 5000	0.936
Upto 10000	0.871

Table 6. Hydrologic soil groups for determining runoff potential

Group	Runoff potential	Characteristics
A	Low	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessive drained sands or gravel. Soils have a high rate of water transmission.
B	Moderately Low	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textured soils. These soils have moderate rate of water transmission.
C	Moderately High	Soils having below average infiltration rate after pre-saturation. Comprises of shallow soils containing considerable clay and colloids though less than those of group D.
D	High	Soil having very slow infiltration rates when thoroughly wetted. It consists of clay soils with a high swelling potential, waterlogged soils, soils with a clay pan or clay layers at or near the surface and shallow soils cover nearly impervious material.

Table 7 Runoff curve numbers for hydrologic soil cover complexes.

Land use	Cover treatment or practice	Antecedent Moisture Conditions II				
		Hydrologic conditions	Ia = 0.3S			Ia=0.1S
			A	B	C	D
Agriculture, Forest and Pastures						
Cultivated	Straight row		76	86	90	93
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
		Poor	66	74	80	82
Terraced	Contoured	Good	62	73	77	81
		Poor	67	75	81	83
	Bunded	Good	59	69	76	79
	Paddy*		95	95	95	95
Orchards	-	With understorey Cover	39	53	67	71
	-	Withoutun derstorey cover	41	55	69	73
Forest	-	Dense	26	40	58	61
	-	Open	28	44	60	64
	-	Shrub	33	47	64	67
Pasture	-	Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Non - Agricultural						
Wasteland			71	80	85	85
Roads (dirt)			73	83	88	90
Hard Surface areas			77	86	91	93
Supplementary for Sugarcane Crop						
Limited cover, Straight row			67	78	85	89
Partial cover, straight row			49	69	79	84
Complete cover, straight row			39	61	74	80
Limited cover, Contoured			65	75	82	86
Partial cover, contoured			25	59	45	83
Complete cover, contoured			6	35	70	79

* 100 mm rainfall is assumed as storage. Remaining rainfall is used to calculate the runoff with CN=95 which is independent of the soil type.

Table 8 Antecedent rainfall conditions to evaluate antecedent moisture conditions

General description	5 day antecedent Rainfall (mm)		Condition
	Dormant season	Growing season	
Optimum soil condition from about plastic limit to wilting point	12	36	I
Average value for annual floods	12-28	36-53	II
Heavy rainfall or light rainfall and low temperatures within 5 days prior to the given storm	28	53	III

(Source - Handbook of Hydrology, Min. of April, 1972)

Table 9 : Hydrological conditions for pastures, forest and tree crops

Vegetative condition	Hydrologic conditions
PASTURE	
Heavily grazed. Has no mulch or has plant cover on no less than 50 percent of the area.	Poor
Not heavily grazed. Has plant cover on 50-75 per cent of the area.	Fair
Lightly grazed. Has plant cover on more than 75 per cent of the area.	Good
FOREST AND TREE CROPS	
Heavily grazed or regularly burned. Litter, small trees, and brush are destroyed.	Poor
Grazed but not burned. There may be some litter but woods are not protected.	Fair
Protected from grazing. Litter and shrub cover the soil.	Good

Table 10. Corrected to curve numbers for antecedent moisture conditions of the watershed.

CN for Condition II	Ia=0.3S		Ia=0.1S
	CN for Condition I	CN for Condition III	CN for Condition III
100	100	100	100
95	87	98	98
90	78	96	96
85	70	94	94
80	63	92	92
75	57	88	88
70	51	85	85
65	45	82	82
60	40	78	78
55	35	74	74
50	31	70	70
45	26	65	65
40	22	60	60

- **Design curve**

To reduce calculation work, curves are available for directly evaluating runoff for a given storm.

- **Drainage rate**

A simple procedure to find out drainage discharge has been developed which mainly uses curves which are available in "Design Curves for Agricultural Drainage Channels", Technical Series No.7, Ministry of Agriculture.

13.4 CHANNEL DISCHARGE CAPACITY, VELOCITY AND DIMENSIONS

- Velocity

For open channels with uniform fallow, Manning's formula is used for calculating the velocity in the channel.

$$V = \frac{R^{2/3} S^{1/2}}{n} \text{ (in metric units)} \quad 8$$

Discharge Q can be calculated by the formula

$$Q = A \times V \quad 9$$

Where

V = Average velocity of flow in m/sec

n = roughness coefficient

R = A/P, the cross sectional area divided by the wetted perimeter,

S = hydraulic gradient, generally taken as bed slope in open channels, m/m

A = Cross sectional area of flow sq m, and

P = wetted perimeter, m

Permissible values to avoid scouring may be adopted from Table 11.

Table 11: Maximum allowable velocities in channels for different soil textures

Soil texture	**Maximum allowable velocity(m/sec)**
Very light silty sand	0.30
Light loose sand	0.50
Coarse sand	0.75
Sandy and sandy loam	0.75
Silty loam	0.90
Firm clay loam	1.00
Stiff clay or stiff gravelly soil	1.50
Coarse gravel	1.50
Shale, hardpan, soft rock etc.	1.80
Hard cemented conglomerates	2.50

(Source: IMTP, 1986).

Slightly higher velocities are allowed if water contains colloidal silt.

If the land slopes are steeper to create scouring velocity, the same has to be reduced by a gentle slope of the drain through provision of suitable drops/falls in the channels.

- Side slopes

The side slopes of the drains in general are recommended as given below:-

Firm soil	**1.0:1 (horizontal: vertical)**
Loam soil	**1.5:1**
Sandy soil	**2.5:1**

However, it is desirable to design the side slope of a channel from consideration of angle of repose of the soil.

- **Roughness Coefficient**

Values of roughness coefficient 'n' in the Manning equation for earthen channels can be selected from Table 11.

Table 11 : Values of 'n' for earthen channels

S.No.	Type of Channels	n-values		
		Min.	Design.	Max.
1.	Earth bottom, rubble sides drainage ditches, large, no vegetation	0.028	0.032	0.035
2.	(a) 0.8m, hydraulic radius	0.040		0.045
	(b) 0.8-1.2m, hydraulic radius	0.035		0.040
	(c) 1.2-1.5m, hydraulic radius	0.030		0.035
	(d) 1.5 m, hydraulic radius	0.025		0.030
3.	Small drainage ditches	0.035	0.040	0.040
4.	Stony bed, weeds on bank	0.025	0.035	0.040
5.	Straight and uniform	0.017	0.0225	0.025
6.	Winding and sluggish	0.0225	0.025	0.030

(Source - Schwab et al, 1981)

These values increase with poor maintenance of drains and weeds growth. In newly dug channels, the value of 'n' is lower and velocities higher than design values.

- **Channel Grade**

The grade of a channel should be as uniform as possible. Generally, the selection of grade is restricted due to fixed land slope and outlet elevation. The grade should be as steep as possible provided that the maximum allowable flow velocities are not exceeded. Design grades should be from 1% to 0.3% and should never be less than 0.05%.

- **Channel depth and width**

The depth should be sufficient for the design discharge. However if these are to be used for controlling watertable, the depth of main and subdrains should be kept between 2m to 3m. Effective bed levels of the channel depend on the outfall available in the natural stream in which the main drain joins. Borings along the drain alignment indicate the location of murrum or pervious layer in the bed portion. In case, the drain depth does not puncture the pervious strata, short vertical hole filled with filter material can help in releasing the ground water flow into the drain, such holes at intervals are made in the bed of the drain. The bed width also depends on the peak design discharge at different points.

- **Channel Bottom width**

After the channel grade, depth and side slopes are selected. The bottom width can be computed for a given discharge. The bottom width for the most efficient cross section and minimum volume of excavation is determined by the formula:

$$b = 2d \tan \theta \qquad 10$$

where

b = bottom width,

d = design depth,

θ = Side slope angle

For any side slope it can be shown mathematically that, for a bottom width computed form Equation 10, the hydraulic radius is equal to one half the depth. The minimum bottom width should be 1.2 m except in small laterals. It is not always possible to design for the most efficient cross section because of construction equipment limitations, allowable velocities, and increased maintenance.

- **Cross-section of drain**

The cross section of a channel is designed to meet the combined requirements of capacity, velocity, depth, side slope and bottom width. The most efficient ditch will be the one with the most capacity for a given slope and cross section. The slope will be determined by the lay of the land and the depth of the outlet. The most efficient cross section will be the one with the smallest wetted perimeter. The parabola has the smallest wetted perimeter and it is well suited for concrete channels. For earth channels, a trapezoidal cross section should be used. Generally a trapezoidal cross section as shown in Figure 2 is used and a minimum bottom width of 0.6 m is recommended.

The following factors should be considered by the designer in adjusting depth, bottom width and side slopes to obtain the required cross sectional area of a drainage channel.

i) A deeper ditch gives a higher velocity than a shallow one.

ii) A deeper ditch may provide a better opportunity for future pipe drainage on farms.

iii) A deeper ditch probably will remain effective for a longer period as sediment bars may cause less obstruction.

iv) A deeper ditch requires less waterway than a shallow drain.

v) A deeper section may uncover unstable layers of soil.

vi) A shallow drain may be more practical to maintain by pasturing or by mowing flat side slopes.

vii) The depth should be related to a good outlet condition.

viii) Design velocity should be selected so as to maintain the ditch cross section with time. In channels that flow intermittently, some scouring may be desirable at high flows to counteract sediment deposition that occurs at low flows.

- **Berms and Spoil Banks** - Adequate beams are required to:

i) Provide for work areas and facilitate spoil bank spreading.

ii) Prevent excavated material falling/rolling back into the ditch.

iii) Lessen sloughing of drain banks caused by heavy bank loads too near the edge of the bank.

Drains normally involve excavation of earth, which is used in making roadway on one side or both sides as required in the area. Provision of roadway on one bank leaves the other bank for depositing the balance excavation as spoil bank should have side slopes of minimum 1.5:1, Figure 2. However, Provision of 2:1 slope shall have greater advantage of stability and greater scope for plantation of trees but has the drawback of more land requirement.

The berm width for drains should not be less than the depth of cutting. Minimum width of berms are given in Table 13.

Table 13 Minimum berm widths

Depth of drain, m	Minimum berm width, m
0.6 - 1.2	1.2
1.2 - 1.8	1.8
1.8 - 2.4	3.0
More than 2.4	4.5

(Source: IMTP, 1986)

The berm width should be increased in unstable soil where it is feared that the drain will enlarge the section. Such locations should be shown in the longitudinal section and other drawings of the drain. The best use of the spoil and how far it can be spread are determined by the type of excavated soil, the adjacent land use, the need for roads, and the maintenance measures. In some locations, spoil banks can be spread and used to good advantage for farm and local roads. Sometimes, the depth of farm drains is slightly greater than required for considerations of storm water flow in order to make available sufficient earth from excavation for farm roads along the drain. The spoil is spread until the height is reduced to an economical figure, usually not more than 1m.

When unproductive soils occur at lower depths in large drains, the good soil should be segregated during construction if practicable and spread to better advantage. Fertile spoil may be used for land grading, shaping in the adjacent fields, or as topsoil on the spoil banks. Safe entry of surface water through the spoils into the ditch should be provided. In placing and spreading the spoil, points of entry and type of inlet structure to be used need to be determined.

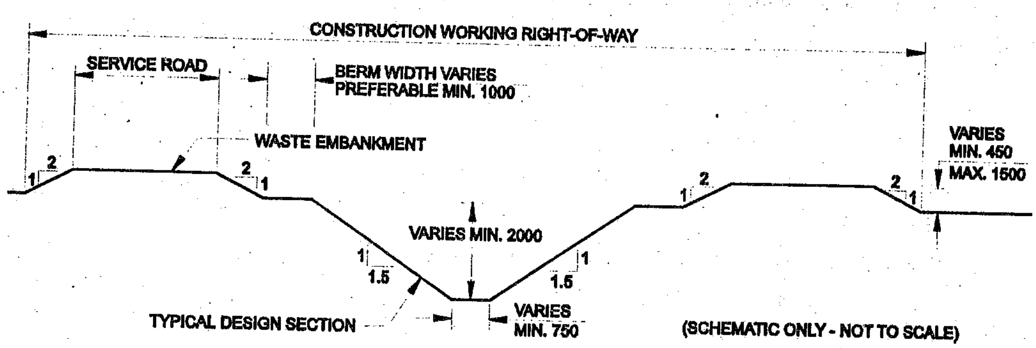

Figure 2: Cross Section of a Drain.

- **Freeboard**

Freeboard is the additional depth above the design water level used to provide a safety factor for the design storm. Generally a freeboard of 25% of designed depth is kept. Normally, the drains are in digging but in certain location, have to negotiate depressions as part of design of the drainage system.

- **Seepage drains**

Wherever the design water surface of a canal is above the ground level, the banks of the canal are made up of filled earth. Depending upon the height of water level, above the ground, volume of seepage through the canal embankments varies. Part of this seepage goes into the subsoil and part comes out on the land surface, creating wetness. Excessive seepage from unlined canals having banks made up of sandy/sandy loam material results in waterlogging conditions near the toe of the canal banks if some drainage channels do not exist to intercept the seepage water. Hence, drains are constructed along the embanked canal banks to dispose off the seepage in about top one meter of the land surface. Seepage drains should be constructed along constant running irrigation channels, ie. main branch canals and in some cases, the distributaries. In heavy embankment reaches of canal and with non-cohesive soils in the banks, the seepage at the toe of canal bank on one side maybe about 0.1 to 0.5 cumecs in a length of about 1 to 2 km of the branch/ main canal. The bed width of the seepage drain to cater to this seepage volume may be a small value but form practical considerations, a minimum bed width of 0.6 m has to be dug out. It may also be mentioned that volume of canal seepage water going into the seepage drain depends son the depth of barrier layer below the ground surface.

13.5 LOCATION, SPACING AND ALIGNMENT

Ditches should be located so as to provide the most effective drainage and to cause the least interference with irrigation system and farm operations. Drainage ditches serve as outlets for surface runoff from rainfall, as outlets for excess irrigation water, or as disposal ditches for pipe drains. They may be located parallel to canal embankments to collect seepage water. For controlling the watertable they may be installed parallel and at regular intervals with the same depth and spacing as pipe drains. Pipe drains are normally installed for subsurface drainage because land is not taken out of crop production. Ditches should normally be located in existing natural channels or placed in or close to the low points in depressions or swales. To improve alignment ditches may cut through minor rises in topography. Crossings with irrigation watercourses should be avoided. Grade control and crossing structures should be minimized.

13.6 SUMMARY

Surface drainage is the removal of excess water from the land surface. Open drains refer to open channels used for agricultural drainage. On farm field drains or surface drains collect excess water from individual holdings and dispose of excess water to the open drains. They are generally shallow, as they carry excess water from a small area. Thus, open drains cater to a much larger area and involve several land holdings. These are also known as intermediate drains, since these are the links between on-farm field drains and main/natural drains. Shallow open drainage ditches are often used in conjunction with land grading and levelling to provide a complete practical solution to a drainage problem. Shallow open ditches can be used to remove surface water or to intercept overland flow while deep open ditches can be used to provide subsurface drainage (i.e. lower the water table). The spacing and depth required for deep open ditches is similar to subsurface drains. Because of this, subsurface drains are usually the most feasible solution for subsurface drainage and are often used in conjunction with surface ditches.

13.7 SELF ASSESSMENT TEST

- What are the main advantages & disadvantages of open drains?
- What are the important variable on which volume of water that must be removed by surface drains depends?
- Explain in detail the Rational Method.
- Explain the procedure of calculating the curve number under Soil Conservation Service Method.

13.6 KEY WORDS

- Surface Drainage: Removal of excess water from the land surface.
- Open Drains: Open channels used for agricultural drainage.
- Channel Grade: Slope of the channel bottom.
- Freeboard: Additional depth above the design water level used to provide a safety factor.

13.7 SUGGESTED READINGS

- Design Curves for Agricultural Drainage Channels, 1972. Technical Series No. 7, Water Management Division, Ministry of Agriculture New Delhi.
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