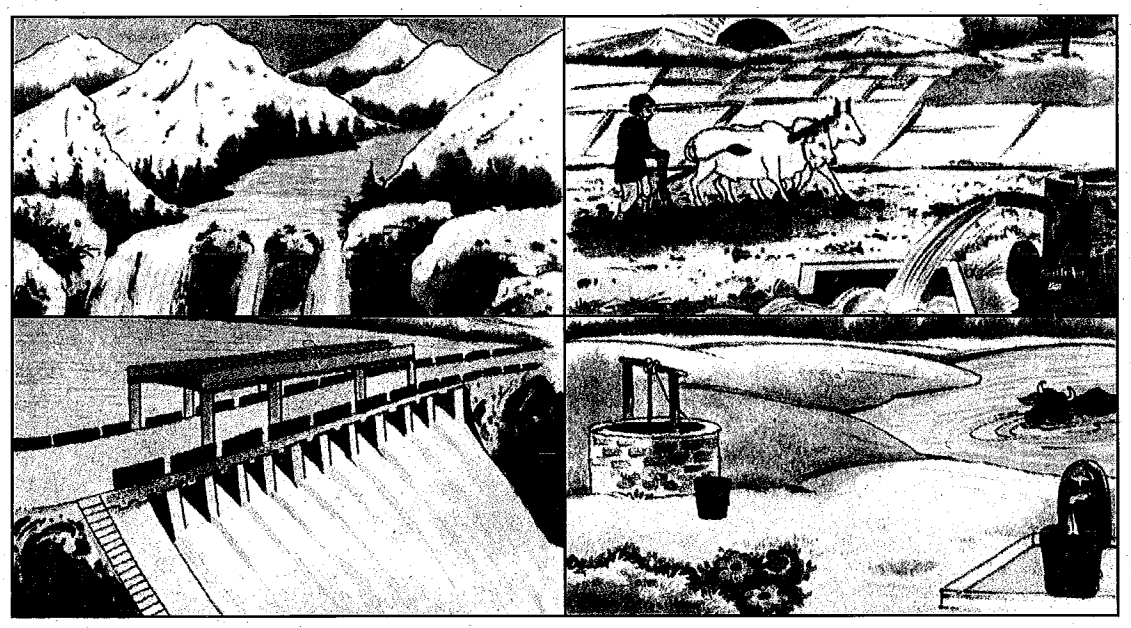
PDWR-02

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Need and Concept of Integrated Water Management

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Need and Concept of Integrated Water Management

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Need & Concept of Integrated Water Management

Unit No.	Unit Name	Page No.
Unit 1	Concept & Need of Participatory Approach in Watershed, Irrigation and Drainage Management	1-19
Unit 2	Water Conservation Strategies & Water Conservation Measures	20-34
Unit 3	Watershed Management & Catchment Area Treatment	35-42
Unit 4	Water logging & Salinity Problem	43-59
Unit 5	Reclamation of Waterlogged Saline Soils	60-78
Unit 6	Role of Farmer's Participation in Integrated Water and Agricultural Management	79-91
Unit 7	Rainwater Harvesting	92-130
Unit 8	Design of Water harvesting structure	104-117
Unit 9	Command Area Development Programme	118-134
Unit 10	Precision Land Levelling	135-153
Unit 11	Network Planning Below Outlet	154-166
Unit 12	Planning & Management of Integrated Water & Agricultural Management Approach for Sustainable Agricultral Production-A Case Study in Chambal Command, Rajasthan	167-178
Unit 13	Design of Surface Drainage System	179-195

UNIT-1

CONCEPT & NEED OF PARTICIPATORY APPROACH IN WATERSHED, IRRIGATION AND DRAINAGE MANAGEMENT

Structure:

1.0 Objectives

1.1 What People/ farmer participation is?

1.2 Why people participation

1.3 Why the Sense of Cooperation in people not developed?

1.4 What is to be done?

1.5 Global views on farmers participation

- 1.5.1 Experience of land and water management in rainfed areas
  - 1.5.1.1 Integrated Watershed Development Project (IWDP)
  - 1.5.1.2 National Watershed development project for Rained Areas (NWDPRA)
  - 1.5.1.3 People Awareness Watershed Development Initiative (PAWDI)
- 1.5.2 Other Development Schemes
  - 1.5.2.1 In Command Areas
  - 1.5.2.2 Chambal Command Area Experience

1.6 Participatory Drainage Management

- 1.6.1 Extent of the Problems
- 1.6.2 Technological Options

1.7 Socially supportive drainage

- 1.7.1 Participation of Beneficiaries
- 1.7.2 Need for farmers participation
- 1.7.3 Farmers Interest
- 1.7.4 Possible Organisation forms

1.8 Features of a Drainage organisation

- 1.8.1 Constraints in Implementing Drainage Projects
- 1.8.2 Economics of drainage
- 1.8.3 Factors affecting the cost of subsurface drainage system
- 1.8.4 Perceived constraints in adoption of SSD technology

1.9 Drainage and Environment

1.10 Benefits of Drainage

1.11 History of Drainage works in CCA

1.11.1 On-farm Development (OFD)

1.11.2 Subsurface Drainage

1.12 Why farmer's Involvement?

1.13 Strategy Adopted for PDM in CCA

1.13.1 Planning

1.13.2 Investigation

1.13.3 Extension

1.13.4 Installation

1.14 Future Strategy/Plan

1.14.1 Need for participatory rural appraisal

1.14.2 Establishment of working group for PDM

1.14.3 PIM VS PDM

1.15 Conclusion

1.16 Self Assesment questions

1.17 References

1.0 OBJECTIVES

Land is one of the most precious natural resource. It has varying uses to suffice the diverse needs of mankind. Intensive application of complex agricultural technologies and exploitation of land resulted in higher agricultural growth. Ironically, in the race for increasing agricultural production, the 'health' of the land was largely unattended.

Nowadays there is a great emphasis or global rush towards greening planet with taking care by various visions for " Sustainable Agriculture" and "Ecological Sustainable Development". For that there is a need to develop new technology based on more biologically and economically sustainable approaches to achieve success, there is a need to the willingness of the rural community to accept new technology and appropriate existing technology. The rate of changes towards more sustainable systems in our agricultural communities, will greatly rely on the research and extension approaches to put farmers/people participation in land and water management works(Lodha M.C.).

The another area for non-cooperation of people in development activities highlighted by Sharma D.K. in his paper on "Appropriate mass communication for transfer of technology in rural India". In this paper author stressed that though rural India holds the large industry(agriculture) as well as population in the country but still the citizens living in rural India(the majority) were never able to get their appropriate share, which could be attributed to lack of high rate literacy and inefficient communication of useful, educational, scientific and logical information. Though, there has been a large number of projects and programmes related to development in rural area but somehow these have not been able to achieve the expected impact. This may be due to many reasons but few of the major one are cited as follows :

- Lack of communication at grassroots level
- lack of peoples participation
- absolute absence of feedback and follow up of communicated material
- lack of women participation
- Lack of efficient use of vigour, talent, capacity and intellectuality of rural community.

Hence people participation is one of the major cause for project failure.

1.1 WHAT PEOPLE/FARMER PARTICIPATION IS ?

Participation, imperative for the development of developing countries denotes to the involvement and empowerment of people in solving their problems. Participation in a broader canvas, encompasses the rapport building, needs/problem identification, planning, designing, implementation and evaluation of development programmes with the inclusion of people in the process of decision making. It eventually activates people from passiveness to be decision makers, implementors and managers required for the self reliance and sustainable development.

Farmers participation can be defined as a continuous, two way communication process, which involves promoting fully informed farmers about the status and progress of studies and findings and implications of plan formulation and evaluation activities; and actively soliciting from all concerned citizens their opinions and perception of objectives and needs and their preferences regarding resource use and alternative development or management strategies and any other information and assistance relative to plan formulation and evaluation(Dadich, L.K., 1993).

1.2 WHY PEOPLE PARTICIPATION

In the developing countries, resources for development have all along been very scarce, but pressures for their allocation from various interest groups have progressively increased. The poor, since they have neither Socio-Economic nor political power, do not get admission or even gain access to the decision-making for resource allocation process and hence are unable to influence them. Therefore, the poor have not benefited from economic growth but in fact have become worse off. Thus, participation, power and well-being of farmers are critically interlinked (Garg & Srivastava, 1998).

Presently rural mass is rather confused about what to accept. They are suspicious about outside peoples role in their life and work. This situation needs immediate attention as well as efforts to improve the trust and harmony among villagers and village workers. Redesigning of communication and procedure may be necessity of modern India(Sharma, D.K., 1993).

Participation of people ignored so far has to be included in the pragmatic social approach of decision makers. An integrated, holistic, decentralised and co-ordinates efforts need to be made by the government, voluntary agencies/ N.G.Os., people's representative institution of panchyat-Raj and women's association(also women development programme) at the village level. The community leadership with an emphasis on small, marginal farmers, women and youth, should be developed by the community organisers(Swarankar, R.C., 1993).

There is an in built incentive in farmers/people participation in land and water management works that the sense of ownership.develops and they recognise that if system fails, it affects there progress.

The culture, product of interaction between human and natural resource (land, water, etc.) regulated the irrigation and agricultural practices for centuries. The social mechanisms of water utilisation evolved by people always had active participation among them. But the need based 'aqua-traditional culture' was replaced by 'aqua-technological culture' overwhelmed by techno-economic, bureaucratic-target oriented development of modern man. So to make any programme sustainable, these have to be synchronised in the socio-cultural milieu with the commitment of implementers to involve and empower people in decision making from the very initial stage of project. In any case, people should become self-reliant to have people's programme and government's participation rather than the existing government's programme and people's participation (Swarankar, R.C., 1993).

Concept of People's participation is recently introduced in all the important sectors of India. Participatory approach in watershed & Irrigation Management is a buzzword these days. This should also be replicated in Participatory Drainage Management (PDM). Therefore, inferences from outside experiences, intelligent guesses and limited experience in the country need to be pooled together to arrive at some successful paradigm for the PDM as stated by Gupta, 1998. The inadequate funds available with the governments for maintenance and operation of the irrigation system has made them rethink and turnover the system to the user's organisations. One can foresee a similar situation developing in the drainage projects. The poor performance of the surface drainage projects which have been implemented in several states since independence only underline the importance of PDM. Few attempts were made to involve the farming community only at project execution stage.

1.3 WHY THE SENSE OF COOPERATION IN PEOPLE NOT DEVELOPED?

In 1993, Swarankar, R.C., 1993 discussed the cause of non-cooperation of people in his paper on "Participation in people's World view-An Anthropological interpretation of Chambal Canal Irrigation". The culture, product of interaction between human and natural resources(land, water, etc.) regulated the irrigation and agricultural practices for centuries. The social mechanisms of water utilization evolved by people always had active participation among them. But the need based 'aqua-traditional culture' was replaced by 'aqua-technological culture' overwhelmed by techno-economic, bureaucratic-target oriented development of modern man. In the elitist-culture nihilism, ignorance and under estimation of the social surroundings, traditions, life style, language etc; resulted into the non-participation of people, adversely affecting the progress of the society. The existing situation calls for imbibing 'aqua traditional-technology culture' with an appropriate integration of traditions with technology in the process of development(Swarankar, R.C., 1993).

1.4 WHAT IS TO BE DONE?

It is possible only when any irrigation project, modernisation of agriculture and other

development programme are synchronised in the socio-cultural milieu with the commitment of implementors to involve and empower people in decision making from the very initial stage of project. In any case, people should become self-reliant to have people's programme and government's participation rather than the existing government's programme and people's participation(Swarankar, R.C., 1993).

Following objectives of farmers participation in relation to environment and project development have been considered suitable for land and water management projects(Dadich, L.K., 1993):

1. Information, education and liaison.
2. Identification of problems needs and important values.
3. Idea generation and problems solving.
4. Reaction and feedback on proposals.
5. Evaluation of alternatives.
6. Conflict resolution consensus.

In essence, public participation involves both information feedforward and feedback. Feedforward is the process where by information is communicated from public officials to citizens concerning public policy. Feedback information should be useful to decision makers in making timing and content decision(Dadich, L.K., 1993). As per feedback the people's participation and action plan can be decided.

One of the approach for land and water development is "delivery of services" approach to a target audience, is that technology transfer where we exchange our ideas and packages of practices to village communities. Here we are assumed to identify the problems and developing the solutions for people with land and water management problems with the linear extension model(Lodha M.C.).:

Research-->	Knowledge-->	Transfer-->	Adoption-->	Diffusion

The other approach is the client based technology development, where we encourage farmers to develop their own visions of sustainable agriculture and their own programmes of research and extension. As the group of farmers develop confidence, they develop more self reliance and create the environment that compels all government agencies to work in harmony with the land and water management programs(Lodha M.C.).

1.5 GLOBAL VIEWS ON FARMERS PARTICIPATION

1.5.1 EXPERIENCE OF LAND AND WATER MANAGEMENT IN RAINFED AREAS

There are so many development programmes were undertaken by the government namely as Desert Development Programme(DDP), Drought Prone Area Programme(DPAP), National Rural Employment Programme(NREP), Tribal Area Devlopment Agency Programme(TADA), Rural Landless Employment Generation Programme (RLEGP) from time to time. In all these programmes the employment generation was the prime objective

without thinking the sustainability of development programmes. Hence government launched the National Watershed Development Project for Rainfed Areas(NWDPRA), Integrated Watershed Development Project(IWDP) and Employment Assurance Scheme(EAS) land development programmes incorporating the sustainable-Economic-Ecological concept.

1.5.1.1 Integrated Watershed Development Project (IWDP):

The Integrated Watershed Development Project(IWDP) is an externally aided project sponsored by the world Bank for five years from 1991-92 to 1997-98 and aims at slowing down and reversing the ecological degradation in the districts of Ajmer, Bhilwara, Jodhpur and Udaipur. In IWDP priority has been given to achieve land conservation through organised groups of farmers, who share responsibility and combine their resources on community scale. The approach is based on the following principles of Community Action in Watershed area management. The overall impact was observed that farmers change more quickly for effective sustainable land use on IWDP principals voluntarily rather than waiting implementation by government agencies(Lodha M.C.). Because they (farmers) learn more and are influenced to change by others in the same community as they feel like working for their own benefit to solve the land and water management problems.

1.5.1.2 National Watershed development Project for Rained Areas (NWDPRA):

In the same manner National Watershed development Project for Rained Areas (NWDPRA) emphasises the government's policy resolution to stimulate and promote people's participation in project planning, project preparation and implementation and post project management of project assets as an integral part of the approach and strategy for watershed development. The basic objective behind people's participation is the ultimate goal, though a distant one at present i.e., to convert the watershed development project from a government scheme to a people's movement. The NWDPRA & IWDP are designed to be executed duly by elected people's organisations called "User Committees" involving 7 to 11 members with equal representation of women, weaker sections, schedule castes and schedule tribes. The function of the user committee shall include formulation of the watershed development plan, design and implementation of the plan by the beneficiaries.(Srinivas V.)

1.5.1.3 People Awareness Watershed Development Initiative(PAWDI):

The PAWDI project includes a slightly different approach of involving the Non Government Officials(NGO) at the commencement of the project implementation phase and having a pre-project preparatory phase to develop people's awareness. The probable role of NGO's as stressed by Bagda V.K. is as follows

1. Can act as a facilitators, mediators between government and the stakeholder.
2. Can create awareness among the community about the problem and their solutions.
3. Can prepare the ground for acceptance of technology.
4. Organise demonstration and exposure visits and capacity building through training
5. Can follow up, monitoring and supervision of the programme.
6. The NGO's with their vast experience and expertise in project formulation, evaluation,

monitoring, training an implementation have developed the capability to involve farmers in these works

7. Can assess the specific needs and roles of different target groups

1.5.2 OTHER DEVELOPMENT SCHEMES:

All other land and water development schemes taking into account the people/farmers/ beneficiary participation for the sustainable and replicable development include either physical contribution in terms of SHRAMDAAN or financial contribution to develop the sense of ownership.

1.5.2.1 In Command Areas

The farmers perception of irrigation management aspects like awareness of farmers about Water Distribution Committee, judicious methods of irrigation water application and scientific application of irrigation water are important aspect for any irrigation project.Flooding of field is common practice for pre-sowing irrigation and subsequent irrigation in almost all the command areas. Farmers training in method and time to stop and apply irrigation water is necessary to avoid the long run adverse effect of excess irrigation on soil and its quality. The farmers adopt only traditional method in taking decision on time of irrigation application like guess work, as and when water available etc. The tail enders are forced to prefer irrigation at night hours (Singh J., 1993)

1.5.2.2 Chambal Command Area Experience:

Chambal Irrigation project introduced in 1960 is one of the major river valley projects of India covering a culturable command area of 229,000 ha in Rajasthan and 2,20,000 ha in the state of Madhya Pradesh.The project area is spread over Kota, Bundi and Baran district of Rajasthan. The gross project area in Rajasthan is about 3,85,000 ha., with approximately 147218 farmers (Srivastava D. & Gaur A., 1996).

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. With the application of excess irrigation water and poor land and water management, the agricultural production did not rise to the desired extent as envisaged in the beginning of the project and the following problems started (Gaur A., Srivastava D., 1996):

- High seepage losses in canals.
- Inequitable distribution of water (head enders draw more water than tail 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 in the management of irrigation system and communication gap between farmers and the irrigation department.

In order to combat the above mentioned problems, a number of land development programmes were initiated in the Chambal Command Area (CCA) such as Land and Water Use and Management Project introduced during 1967 by the UNDP, and On-Farm Development (OFD) Programme for surface water management initiated in 1974. Most recent programme is the Rajasthan Agricultural Drainage Research Project (RAJAD) introduced in 1992 for the reclamation of waterlogging and soil salinity through surface and subsurface drainage(Srivastava D., & Gaur A., 1996). In all these command area development projects emphasis was given on farmers participation.

1.6 PARTICIPATORY DRAINAGE MANAGEMENT

Man's knowledge and desires are paradoxical. Few deny that drainage is essential, yet many wishfully hope to get along without it. Canal and distribution systems are essential too, but here the similarity ends. Without these latter features, irrigated agriculture cannot exist, but irrigated agriculture - of a sort and for a time - can exist without drainage. It would not be exaggerated to say that to sustain the irrigation drainage is inevitable and indispensable.

It has been reported that all over the world 4000 to 5000 M.ha. are degraded in some way or other, thus threatening the sustainable agriculture and India is no exception to this menace. The available estimates reveal that at global level about 1.5 M. ha area is lost annually as a result of soil salinity and waterlogging. Diverse statistics are available on the extent of these soils in India. They range from 5.5 to 13 M. ha. A recent (1991) assessment by the Ministry of Water Resources (MOWR) brings out that canal commands contain about 2.46 M. ha of waterlogged area, about 3.06 M.ha of salinity affected area, and about 2.46 M.ha of alkalinity affected area. Thus a little under 6 M.ha of farm area within Indian commands could be labelled as degrade lands. Ironically the health of the land and excessive human interference are responsible for the emergence of these soils.

Irrigation said to be the modern science, is the science of survival. The introduction of irrigation has yielded manifold increase in the agricultural production. The practice of the art of the drainage is as old as is the art of agriculture. Most agricultural lands have some natural and artificial drainage systems. Where man has practised irrigated agriculture successfully he has enlarged his territory, supported increasing populations, lived in better health and made great strides culturally. Where drainage has been overlooked or neglected, man's development and his civilizations have failed. Lack of adequate drainage has probably been the greatest single cause of failure on irrigation projects throughout the world.

1.6.1 EXTENT OF THE PROBLEMS

- Uneconomic returns - higher input cost. less value of output/production, lower profitability
- Loss of productive land
- Unhealthy eco system
- Labour migration
- Wider income disparities
- Affect the sustainability of secondary and tertiary sector

- Declined agricultural production
- Affect gross domestic Product
- Export reduction
- Higher imports

1.6.2 TECHNOLOGICAL OPTIONS

- Provision of appropriate land drainage, improved water management practices, selection of an efficient crop mix with low to moderate water requirement.
- Biological amelioration either by growing salt resistant crops or by growing salt resistant tree species.

1.7 SOCIALLY SUPPORTIVE DRAINAGE

1.7.1 PARTICIPATION OF BENEFICIARIES

It is widely accepted as the key to successful management of the drainage activity. The higher the degree of participation of the affected population, the greater will the success be. It has been realised that mere planning and executing the drainage systems to manage saline and waterlogged soils by Govt. agency may not yield desired results unless there is a positive attitude and strong will of the beneficiaries to participate in the program.

1.7.2 NEED FOR FARMERS PARTICIPATION

If the Govt. is able and willing to acquire such large amounts of money for drainage development, it might not be prepared to allocate large amounts for operating and maintaining the drainage systems. Farmers participation in the financing of these costs will be required. Besides, the concerned department does not seem to be prepared to take responsibility for O & M (Operation and maintenance) of the future drainage projects. Therefore. from the point of view of the Govt. and irrigation bureaucracy, farmers participation is a desirable goal.

1.7.3 FARMERS INTEREST

However, the farmers also have their interests. And they make their own cost-benefit analysis as well. For any farmer there are only two good reasons to join a drainage cooperative or any other suitable kind of farmer organisation for O & M of the drainage system, namely,

(a) drainage will serve his individual interest;

(b) this particular interest can only be served if he is a member of the farmer's organisation.

1.7.4 POSSIBLE ORGANISATION FORMS

Any chosen form of organisation should be embedded in an adequate legal framework. In that respect cooperatives and water board type organisations are on equal footing. However, drainage requires the cooperation of all farmers in the drainage area, without any exception. This is so because drainage technology is indivisible and cannot be executed in small parts. The success largely depends on a certain minimum area brought under subsurface drainage system. It is because salinity and watertable movement is a dynamic process in the subsoil zone. An individual farmer or a few of them with marginal or small holdings may not check the rise of watertable and the subsequent salt balance. Their

investment in isolation will not yield the desired results to conserve or to improve the soils.

Therefore, a compulsory form of organisation is needed, as for instance a water user association is. This will also solve the problem of free riders e.g. people who derive pleasure or benefit at the cost of investors.

1.8 FEATURES OF A DRAINAGE ORGANISATION

The farmers organisation to be formed should have some formalized relationship with the Command Area Development authorities, for disposal of the drainage effluent. The tasks of the organisation may or should include:

1. Operation and maintenance of the drainage system.
2. Realisation of adequate drainage charges to maintain the system.
3. Financial self supported.
4. Board from elected beneficiaries.
5. Demarcation of drainage area under organisation.
6. Own management to perform all activities.

1.8.1 CONSTRAINTS IN IMPLEMENTING DRAINAGE PROJECTS

Despite yielding high dividends by providing subsurface drainage the program is not attaining the popularity among the farmers.

- ❑ Indivisible nature of technology
- ❑ No attraction to an individual farm household on investment to prevent or cure the degraded lands
- ❑ Cost sharing
- ❑ Water sharing
- ❑ Problem of free riders
- ❑ Degree of participation of beneficiaries
- ❑ Perception of the program objectives
- ❑ Conflicting objectives

1.8.2 ECONOMICS OF DRAINAGE

It is the world's view that drainage is economically viable, though a costly proposition. It is therefore advised that economic feasibility and financial viability of the drainage project should be critically examined and thoroughly investigated. Also drainage should be resorted to as a last alternative when all other means of reclaiming the land have either failed or are not at all technically advisable. The drainage rate should be assessed minutely i.e. drainage for leaching the salt or drainage for watertable control or drainage for both, and the period of reclamation. Proper assessment of drainage rate will affect the cost of the system to a great extent. The cost of installation of subsurface drainage system include following components:

1. Drainage investigations

2. Topographical survey and subsurface drainage design
3. Selection of drainage material
4. Installation of SSD system
5. Maintenance charges
6. Establishment charges

1.8.3 FACTORS AFFECTING THE COST OF SUBSURFACE DRAINAGE SYSTEM

1. Drain depth and spacing
2. Selection of drainage material including envelope material
3. Installation method
4. Size of the project
5. Outlet conditions
6. Intensity of drainage investigations
7. Period of reclamation

1.8.4 PERCEIVED CONSTRAINTS IN ADOPTION OF SSD TECHNOLOGY

1. Huge initial investments
2. Laxity of Govt. staff in supporting the maintenance of drainage system
3. Beneficial to free riders as well
4. Non functional technology to manage drainage effluent

1.9 DRAINAGE AND ENVIRONMENT

Multipurpose projects require analysis of benefits and costs from a wide range of factors other than agriculture. Unfortunately, many gains and losses to certain aspects of the environment have not been quantified in any generally acceptable terms. Construction of dams, draining lands, deforestation, exploitation of land, intensive application of complex agricultural technologies have helped human beings satisfying their demands and made life more comfortable but these development activities have brought in some adverse effects too over the eco system. Agricultural drainage while sustaining the food production may land us in poor or degraded environment if the proper disposal of drainage effluent is not exercised. It may lead to deterioration of water quality, creation of insects, bacteria, viruses that may breed in the habitat, and diseases produced by them may find their way to neighbouring communities through carrier such as mosquitoes or domestic or wild animals.

Due consideration should be given while planning the drainage system taking into account all possible impacts on the environment. A environment friendly drainage system may or should include;

- ❑ treatment of drainage effluent, if required;
- ❑ regular monitoring of water quality;
- ❑ disposal of drainage effluent after ensuring that it is harmless;

- plan possible uses of drainage water i.e. fish farming, growing salt resistant crop varieties or tree species;
- health condition (Pre & Post) of the project population and the people downstream of the project.

1.10 BENEFITS OF DRAINAGE

Judgements of the benefits of man's acts are always highly subjective. Consequently those having different value concepts hold some of the items listed as benefits of drainage in disdain. Conditions directly promoting the health and welfare of crops and of the people growing those crops are considered beneficial. Some of the benefits obviously could be construed as detrimental to other aspects of our ecology, a thought which drainage experts should constantly keep in mind.

Drainage is essential to maintain the supply of oxygen. Other factors associated with drainage and plant growth are soil temperature, traffic ability, resistance to disease and root growth, and chemical and biological conditions favourable to crop growth.

Proper control of salinity and high watertable can be accomplished only in well drained soils. Leaching water must be able to pass through the soil profile to move excess salts out of the root zone. This movement cannot occur unless free drainage exists. Conversely, a high water table creates a condition wherein capillarity moves salts into the root zone and deposits them there.

Subsurface drainage promotes conditions that maintain soil structure, trafficability and workability. Some of the less tangible benefits other than main benefits resulting from good drainage are as follows:

- Disease free eco system for mankind;
- Improvement of farmlands by elimination of boggy and weed-breeding areas;
- A firm dryland surface to support harvesting machinery;
- A longer growing season;
- Increased soil tilth;
- Early and more vigorous plant growth;
- Larger yields;
- A wider selection of crops;
- Decreased cost of production.

The inadequate drainage network due to ill maintained surface drains could all be traced to the non-participation of the people in drainage programme. It is now realised that people participation could have made a difference in the performance of the drainage. This paper tells about the drainage works in CCA, experiences of farmers involvement in drainage works, need of farmer's participatory drainage management and proper legislation requirements

1.11 HISTORY OF DRAINAGE WORKS IN CCA

Surface drainage was historically used as a flood control measure. When Chambal Command Area(CCA) ran into the problem of waterlogging and soil salinity, it was recognised that good on-farm surface drainage is essential in helping to control waterlogging conditions by removing excess precipitation and irrigation water through improvement of on-farm surface drainage and providing good outlet for drainage systems.

In 1967, a project of land and water use and management was undertaken with the help of government of India, United Nations development programme and the Food and Agriculture Organisation of the United Nation to develop proper water management principles; to find means to protect against salinity and waterlogging; and to make recommendations for proper land and water management. By the end of 1970, a land development system evolved which was subsequently supported by World Bank and known as On-Farm Development (OFD).

1.11.1 ON-FARM DEVELOPMENT (OFD)

The OFD programme is comprised of several components, including: the construction of irrigation and drainage ditches to serve each farm; realignment of farm boundaries to permit a more rational layout of irrigation, drainage and road system and land shaping to enable efficient irrigation of field crops. Therefore, one of the main objectives of the OFD programme was to construct surface drainage network at macro as well as micro level.

Macro Level Drainage: The tributary rivers of Chambal river and the network of meandering gullies (nallas) feeding them form the primary drainage system of the CCA. Accordingly 60 separate drainage zones have been identified within CCA. Under drainage master plan, main/sub main drains have been constructed in about 1,67,000 ha out of the total 2,29,000 ha area of CCA to provide drainage at macro level in most of the drainage zones.

Micro Level Drainage: The OFD programme constructed carrier drains and field drains located approximately 250-500 m apart to serve each farm. Field/carrier drains are given outlets into the sub main/main drains. About 72,000 ha area of CCA have been provided with micro level drainage.

Seepage drains: Seepage drains were also constructed adjacent to irrigation canals to drain the canal seepage water to control high water table and salinity problems in the adjacent fields.

1.11.2 SUBSURFACE DRAINAGE

In the early days, water table control was not considered a major issue and subsurface drainage was not appreciated. Only pilot subsurface drainage experiments have been carried out in small areas at Digod Farm by installing mole, plastic and asbestos drains.

The most recent and important programme 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 salinity is Rajasthan Agricultural Drainage (RAJAD) Research Project. It is a joint undertaking financed by the Government of India, the Government of Rajasthan and the Government of Canada.

Under RAJAD, subsurface drainage systems have been installed on experiment of test plots to establish design criteria as well as on large areas to demonstrate clearly the effectiveness of the technology for overcoming waterlogging and salinization of land. About 15000 ha of land have been provided with subsurface drainage systems outfalling into the main/submain drains. Therefore, under this program Main/Sub main drains of the area have been resectioned as per the requirement of SSD systems.

1.12 WHY FARMER'S INVOLVEMENT?

There are many good reasons for the involvement of farmers in developmental works like surface and subsurface drainage. Following are the few reasons:

- In view of liberalisation and privatisation, people are expected to assume a greater role and share the cost.
- It is no longer possible to burden the government for the works which are beneficial to the people and so people should be responsible for their execution and maintenance.
- Development of sense of ownership towards the drainage system.
- To keep construction process going smoothly, and to reduce conflict during construction.
- There are inadequate fund for operation and maintenance for drainage systems.
- Right Of Way(ROW): construction with drainage machines inevitably destroys crop, farmers contribution to provide ROW.
- Development of responsibility for drainage system execution and maintenance.

Many projects like HOPP in Haryana and Pilot participatory drainage research study in Pakistan have been started to explore the capacity of farmer to contribute to capital, operational and maintenance expenses with the involvement of farmers in all stages i.e. in planning, design, construction and operational phases of the project.

1.13 STRATEGY ADOPTED FOR PDM IN CCA

Irrigation and drainage works are by their virtue collective in nature and are not divisible. In other words the pipe drainage works affects all the farmers and are shared more or less equally in a drainage block. Even if one farmer objects to its installation then the whole process is jeopardised. Therefore, the co-operation and consensus of farmers is needed at the planning, designing and execution stage. A subsurface drainage system is largely an engineering exercise, but while designing, the social aspect is also required to be kept in mind for acceptable layout and this can come only when farmers are involved right from the beginning. During drainage project execution, farmers were involved right from the planning, designing and to the execution stage.

1.13.1 PLANNING:

Farmers were involved in selection of waterlogged and saline land. There opinion were taken and based on there information reconnaissance survey was done for further investigation regarding area selection.

1.13.2 INVESTIGATION:

During investigation to identify the actual problematic area, farmers were involved for many technical investigations like water table monitoring, hydraulic conductivity survey etc.

1.13.3 EXTENSION:

Subsurface drainage project unlike the irrigation project is very new for India. Neither the farmers nor opinion leaders had much of an idea about the concept, its necessity, the design criteria, and the type of machinery required. The nature of SSD project is such that it is to be executed throughout the year excluding monsoon season. So to avoid obstacles by farmers due to crop loss can only be achieved by efficient extension programme. To achieve these following steps were taken:

- ✓ Mass awareness campaigns were organised right from the beginning.
- ✓ Beneficiaries were given in-depth knowledge about the benefits of SSD, along with comparison of cost and the benefit.
- ✓ Farmers were not only contacted extensively but were taken to the Test plots and pre CON-1, so that they could not only themselves see the progress but may tell the peer group of farmers about the benefits of the SSD.
- ✓ Arrangement of field visits to farmers at the installation site.
- ✓ Organising the farmers meetings with the farmers where SSD is already executed. So that farmers may convince about benefits of SSD by looking as well as by discussing the benefited farmers (Brar, 1998).

1.13.4 INSTALLATION:

Farmer's participation was beneficial not only for construction activity but the education made them so co-operative and responsive that they started coming closer with great faith.

- ➢ During SSD installation, the designed lay out of the SSD system was accepted by the farmer's open heartily and made useful suggestions for further improvement. Looking to farmers perception, the perpendicular layout was finally accepted for in comparison to parallel layout of SSD was
- ➢ The farmers were so convinced that they have provided Right of Way(ROW) without claiming any crop compensation.
- ➢ During restoration they actively participated to restore their fields, watercourses and other utilities.
- ➢ Experience showed that in the Catchment blocks where the SSD was to begin and irrigation shut off was necessary, farmers have provided physical and human resources to the officials.
- ➢ They also came forward to close the drains moving into their fields so that SSD operation could take place.
- ➢ Use of heavy machine in SSD installation sometime requires electric shut down and for that they were very co-operating.

1.14 FUTURE STRATEGY/PLAN

To make sustainable the farmers, participation in PDM, it is necessary to know the farmer's expectation, requirement, need and vision. That is only be possible with the Participatory Rural Appraisal (PRA).

1.14.1 NEED OF PARTICIPATORY RURAL APPRAISAL

The importance of the local farming community's involvement for assessment and analysis of the needs has been named as Participatory Rural Appraisal (PRA). The PRA through farmers meeting, field visit interviews with the help of questionnaire should be tried to explore the perspective of the community on the waterlogging and salinity problem as caused by the irrigation system.

1.14.2 ESTABLISHMENT OF WORKING GROUP FOR PDM

After PRA assessment, the formation of a working group for PDM is very essential. Unlike to PIM working nature, PDM requires continuous support, active involvement of all the beneficiaries. Because the nature of drainage project is such that non-co-operation of a single members may fail the objectives of programme. The working group/farmer's organisation should have the following attributes as stated by Niazi & Knops et al, 1996:

1. **Felt Need:** The farmers must be convinced that there will be a definite and tangible gain for them by co-operating and taking responsibilities for irrigation and drainage activities and investments;
2. **Accountability:** The farmers' organisation should be solely and fully accountable and transparent to their farmers;
3. **Sustainability:** There must be a certain degree of social cohesion within the farmer's organisation to be able to survive the reliance on outsiders during the initial formation and establishment period; and
4. **Accessibility:** The farmers' organisation must have easy and ample access to the technical advice and expertise related to the tasks to be performed, either among its own members or by employing or hiring technical staff.

1.14.3 PIM VS PDM

There are only two options for successful implementation of PDM through formation of farmers' organisation. In first option, a new farmers organisation/working group is to be established. In anther option the PDM activities may be implemented with the already developed WUA's, working group for PIM. Think of a programme and end up in the formation of a society may only make numbers not the development. Can we imagine that farmers who are generally rated as poor in understanding the intricacies of the paper work, are made members of a number of societies? Will they be able to cope with the demand of time and energy required to run these societies?

Looking to above constraints and working behaviour of Water User's Association with several issues, that are directly related to drainage like repair and maintenance of field channels, drains and other structures of the physical system in its jurisdiction and control over water table fluctuations to avoid waterlogging, it is beneficial to have only single WUA to work for PIM as well as for PDM. This will avoid mushrooming of the farmer's organisation/societies and will create the following number of benefits

- It avoids multiplicity of societies.
- It adds a new dimension to the utility of the society. Additional membership would help the society to increase its strength to act as a pressure group.
- Expenditure on O & M could be collected easily with the collection of revenue for irrigation.
- Conflict resolution amongst the head and the tail end farmers is made easier.
- Managerial expertise is shared which otherwise may not be available to a society formed only for drainage.
- The increase in the cost of irrigation could be absorbed by the society.

1.15 CONCLUSION

Agriculture production has a vital importance for any society, for each country, no matter how large. Each society must have food security for its own needs. This century, particularly the latter half, has seen the greatest change in agriculture in history. Agricultural productivity has reached quite near to the stabilization of production. Today the world's agriculture is facing social, environmental, and economic crisis. We have entered a new era, very complicated phase, in which human food needs must harmonize with environmental, ecological, and sustainable principles. The above critical problem cannot be understood in isolation, these are all interconnected and interdependent. If the human community wants to assure food for its growing population and to maintain the quality of the environment, we must begin to interact with all factions of the community. We must make a new contract between Nature, society and agriculture. Leaving the nature alone is to pretend that we are not part of it. It is the humans who has intervened in the nature and degraded the environment, therefore once again the humans have to intervene to improve and restore it.

As first step, we must stop overpopulation ; then we must end the losses of valuable agricultural land; and, finally; we must intensify our use of the remaining land by better soil water management, including irrigation, drainage, and conservation.

A close interaction among agricultural, economic, social, environmental, and ecological scientists and with local farming community is an absolute necessity in the present context. If we are to have sustainable agriculture and sustainable society we must have positive acceptance of new values of sustainable development and holistically treat all related issues. Then and only then a new vision cosmic in nature and global in scope can rescue today's civilization.

1.16 SELF ASSESSMENT QUESTIONS

Now after studying this unit, now you can understand the basic principle behind farmers participation in Watershed, irrigation and drainage management. So to evaluate, answer the following questions?

1. Why people participation is necessary?
2. What is people participation?
3. What is the global scenario of people participation in land management works?

4. What strategy should we follow to fit the people in the project?

5. What is the Chambal Experience of Farmers participation in case of irrigation as well as in drainage management?

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UNIT-2

WATER CONSERVATION STRATEGIES & WATER CONSERVATION MEASURES

Structure :

2.1 Objectives

2.1. Introduction

2.2. Water Harvesting & Watershed Management

2.2.1. Selection Of Priority Areas

2.2.2. Soil Conservation Measures In Watershed Management

2.3. Drainage Line Treatment

2.3.1. Drainage line structures planning based on reach

2.3.2. Drainage line structures planning based on their purpose

2.3.3. Drainage line structures planning based on their life

2.3.3.1. Temporary Structures

2.3.3.1.1. Vegetative check DAM

2.3.3.1.2. Brush Wood check dam

2.3.3.1.3. Loose Stone check dams

2.3.3.2. Semi Permanent structure

2.3.3.2.1. Poly bag check dam

2.3.3.2.2. Log dams

2.3.3.3. Gabion Check dams

2.3.3.4. Permanent structure

2.3.3.4.1. Drop Inlet Spillway

2.3.3.4.2. Drop Spillway

2.3.3.4.3. Chute spillway

2.4 Summary

2.5 Self Assesment Test

2.6 References

2.0 OBJECTIVES

Water Conservation Strategies & Water Conservation Measures are the main in Watershed management, which implies the proper use of land and water resources of a watershed for optimum production with minimum hazard to natural resources.

The different objectives are as follows:

1. To control damaging runoff

2. To manage and use runoff for useful purposes
3. To control erosion and effect reduction in the sediment production
4. To moderate floods in the downstream areas
5. To enhance ground water storage
6. Appropriate use of land resources in the watershed-forest and fodder
7. Building and maintaining soil fertility

2.1 INTRODUCTION

The water resources of India are limited. About 75 percent of the total cultivated area in the country depends upon the rainfall to sustain production. The rainfall is rarely evenly distributed in accordance with the moisture requirement of the crops. Thus the crops under dry land conditions are exposed to periods of water excess or deficits. The inadequacy and uncertainty of rainfall often lead to either partial or complete failure of crops in large areas of India having arid and semi-arid climate. Therefore, the rainwater management, water harvesting and its recycling based on watershed approach gains utmost importance to get rid of problems in rainfed areas of the country.

2.2 WATER HARVESTING & WATERSHED MANAGEMENT

Water harvesting is the technique of collecting runoff rainwater from treated or untreated land surface and storing it in open water reservoir or in the soil itself the water harvesting technique are:

1. Micro plot water harvesting 2. Macro plot water harvesting

2.2.1. SELECTION OF PRIORITY AREAS

In a watershed management program, particularly in case of large watershed it may not be possible to treat the entire area of the watershed with land treatment measures. In such cases the watershed should be divided into subwatershed. The methods used for determining the priority of the subwatersheds for treatment from soil erosion and sediment yield point of view are:

1. Reconnaissance surveys
2. Soil and land use surveys
3. Interpretation of aerial photographs
4. Sediment observations

2.2.2. SOIL CONSERVATION MEASURES IN WATERSHED MANAGEMENT

Watershed management involve the various watershed management measures, which are effective in preventing or delaying the movement of soil and rock particles, from their point of origin in the drainage area. These are the following soil conservation measures:

Contour trenching on barren hill slopes

- Afforestation
- Diversion channel

- Bench terracing of steep slopes
- Contour or graded bunding of agricultural lands
- Gully protection
- Construction of small ponds
- Stream bank erosion control
- Road side stabilization
- Scientific method of agricultural practices like contour cultivation, strip cropping, crop rotation
- Pasture development
- Flood plain protection
- Water spreading for ground water recharge
- Shore line protection
- Control of land slides and land slips

2.3 DRAINAGE LINE TREATMENT

The formation of drainage line usually starts in hilly and non-arable areas where runoff is heavy with great velocity of water. The quantity of water further increases when the drainage line passes through the arable areas. The treatment of drainage line therefore should start from the upper reaches of, the watershed. The measures should be adopted after careful consideration of quantity of runoff, velocity of water and the cross sectional area of drains.

In the existing conditions only a small quantity of runoff is detained/conserved in non-arable as well as arable lands. Therefore considerable amount of runoff flows through drainage lines at high velocities. Due to this deep nalas/rivulets are formed which further leads to soil erosion in the adjoining fields. Thus finger gullies are developed in arable as well as non-arable areas. However due to soil and water conservation measures likely to be taken up in arable and non arable areas the rain water shall be conserved in the fields itself and the flow of runoff is likely to reduce in the nallas in future. Keeping this reduced amount of runoff and velocity of water In view, suitable structures shall have to be planned in drainage lines.

2.3.1. DRAINAGE LINE STRUCTURES PLANNING BASED ON REACH

A. Upper reaches:
   - Vegetative check dam
   - Brushwood cheek dam
   - Small loose stone structure.

B. Middle reaches
   - Brush wood check dam
   - Dry stone masonry
   - Polybag check dam

- ♦ Drop inlet structure

C. Lower reaches :

- ♦ Drop inlet spillway
- ♦ Drop spillway.
- ♦ Chute spillway
- ♦ Water Harvesting structure

2.3.2. DRAINAGE LINE STRUCTURES PLANNING BASED ON THEIR PURPOSE

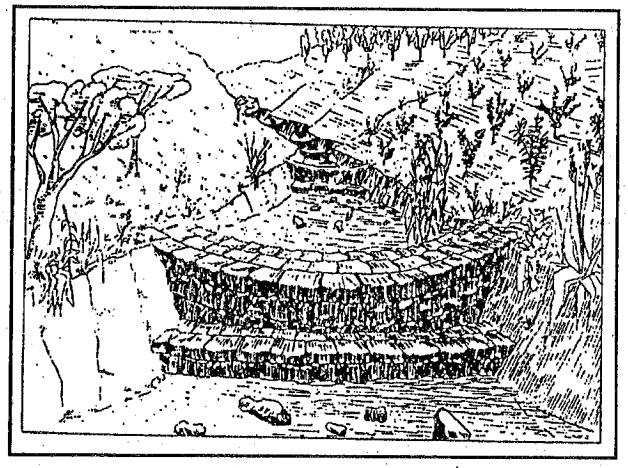


Fig. 1: Gully with check dam

The choice of structures shall depend upon the purpose for which these are to be constructed. Usually these are constructed for two distinct purposes.

♦ To reduce and control the runoff velocity so that it never attains erosive velocity.

♦ Impounding of water so that the precious water is used for increasing moisture regime, recharging of acquirers and bed cultivation.

2.3.3. DRAINAGE LINE STRUCTURES PLANNING BASED ON THEIR LIFE

The engineering structures could be classified based on their life

(i) Temporary (ii) Semi-permanent (iii) permanent.

3.3.1. TEMPORARY STRUCTURES

Temporary check dams constructed across the slope in the bed of a gully have two uses:

1. To collect sufficient soil; and water to enable the proper growth of vegetative cover
2. To check channel erosion until sufficient stabilising vegetation is stabilised

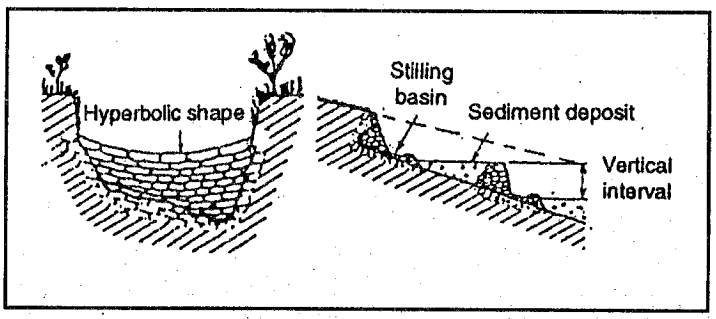


Fig. 2 Check Dam

The life of the temporary structure shall depend upon the material used but ordinarily they should last 3 to 5 years. However it is expected that silt deposition and vegetative growth shall further strengthen the structure

It has been found that several small check dams are more desirable than one large structure. The series of

check dams transform the longitudinal slope to a succession of steps with low risers and flat treads. Check dams depending on type of material used for construction are named as:

1. Vegetative Check Dam
2. Brush wood Check Dam
3. Loose Rock Dam

2.3.3.1.1. VEGETATIVE CHECK DAM:

The vegetative and low cost structures are usually preferred in rills/gullies with small watersheds. These should be extended sufficiently into the banks of Gullies to avoid washing out of structure around the ends. Proper foundation depth should also be given to avoid leakage underneath the structure. Ordinarily the height of structure should not be more than a metre. An effective height of about 60 to 75 cm is usually considered satisfactory.

As an integral part of most cheek dams an apron or platform of sufficient length and width must be provide to safely lead the water flowing over the top and conduct it away without scouring. A free board of minimum 15 cm is necessary. The notches should be made as wide as practically possible and in proportion to the, depth of structure in order to avoid concentration of water as it passes over the structure. Sufficient spillway capacity should be provided to handle, the peak runoff expected over a period of 10 years.

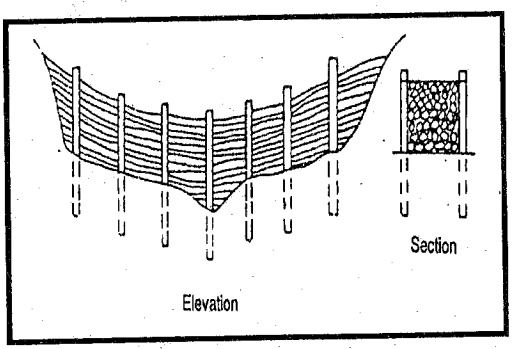


Fig. 3 Single Row Post Check Dam

Intensive Vegetative barriers

Intensive Vegetative barriers are constructed using rows of grasses, shrubs and trees across the drainage line. From upstream following arrangement is suggested in typical intensive vegetative barrier

- Ist 3 rows of grasses like vetiver, Panicum Antidotal at 20 Cm row to row spacing.
- Next 2 rows of shrubs and bushes like Agave (Americana Sisalane), Jarberi (ziziphus Spp) etc. at 30 Cm. row to row spacing.
- Last row of Aanwal, Ratanjot, lpomia. etc at 45 cm row row spacing.
- Bushes/trees are also to be planted in two or three rows on both side banks of the nallah.

A small bund or single row of loose stones is to be provided downstream of such barriers to facilitate initial establishment of vegetation. All the vegetation is to be transplanted after first shower of monsoon. The middle row of the vegetation is to be extended upto the top of the banks or even one metre beyond on both sides.

The construction of vegetative barriers shall depend on the quantity and velocity of runoff. The greater is the amount and velocity of runoff, more is the intensity of vegetation.

2.3.3.1.2. BRUSH WOOD CHECK DAM

Brush wood cheek dams are least permanent of all types of check dams. They are relatively cheaper and can be constructed with country wood stakes and bushes/ branches of trees and the vegetation available locally.

Brush wood check dams are suitable for rills and small gullies with small drainage areas. The anchoring stakes are driven in the ground to give strength to the structure. Wire is wound around the stakes to counteract uplift pressure of runoff water..

Brush wood check dams can be

1. Single Row Post or

2. Double Row Post type.

SINGLE ROW POST CHECK DAM: This Structure consists of a single row of wood stakes, to which are tied long branches of trees laid lengthwise to the gully with their bull-ends facing upstream. The longest branches are laid first and those of progressively shorter length on top till the require3d height is obtained.

Before the construction of dam, the sides of gully are slope to 1:1 and the gully bottom is lowered by about 15 cm to 20 cm for whole of the length of dam. 25 cm excavation is done in side the banks to give stability to structure. Treatment with aldrine 30% E.C. is done to safeguard dead wood against termites. Country wood stakes of about 7.5 cm diameter are dipped in Coaltar and driven 60 cm apart along the dam line. The stakes should go about 90 cm into gully bed and their tops are kept at such heights as to form a distinct water way to enable the maximum runoff being discharged without undermining the dam at the ends. First a layer of straw is placed at the bottom and over it, longest branches specially selected are laid along the length of the gully and well pressed. Over this another layer of straw is spread and shorter branches are laid. This process is repeated till a dam of required height in the gully bed is obtained. The brush is anchored on to the stakes by means of galvanised iron 10 gauge wire so that the bushes are not carried away by water. Intermediate states of shorter lengths are also used and the brush wood is anchored on to them to prevent its being lifted from the bed by water. The longer branches act as apron for the dam and prevent overfall erosion scour. As the green leaves rot, tile branches set loosened and the dam cannot be kept rigid. This is overcome by use of additional rows of stakes. These stakes can be driven down to tie the stakes wherever it is necessary. Heavy stones are laid on the top of bushes to give strength to the structure and counter act uplift pressure of water.

DOUBLE ROW POST BRUSH CHECK DAM : This method is used in the control of medium gully. The construction is Similar to single row post excepting that in the case of two row post type, the straw and brushes wood is laid across the Gully between two rows of country wood posts. The distance between the rows should not more than 90 cm. The stakes are 10-13 cm in diameter and are driven 90 cm apart to go at least 90 to 120 cm into the hard bed of the gully.

A brush wood apron held by galvanised iron wire is necessary to prevent scour. The double post type is more sturdy and stable. Larger stones are placed on top of the brush to keep it compressed and in close contact with the gully. The centre of the dam should be low enough to provide the necessary spillway capacity. Depending on the site conditions the selection of the type of the brushwood cheek dam differs. If a large volume of runoff

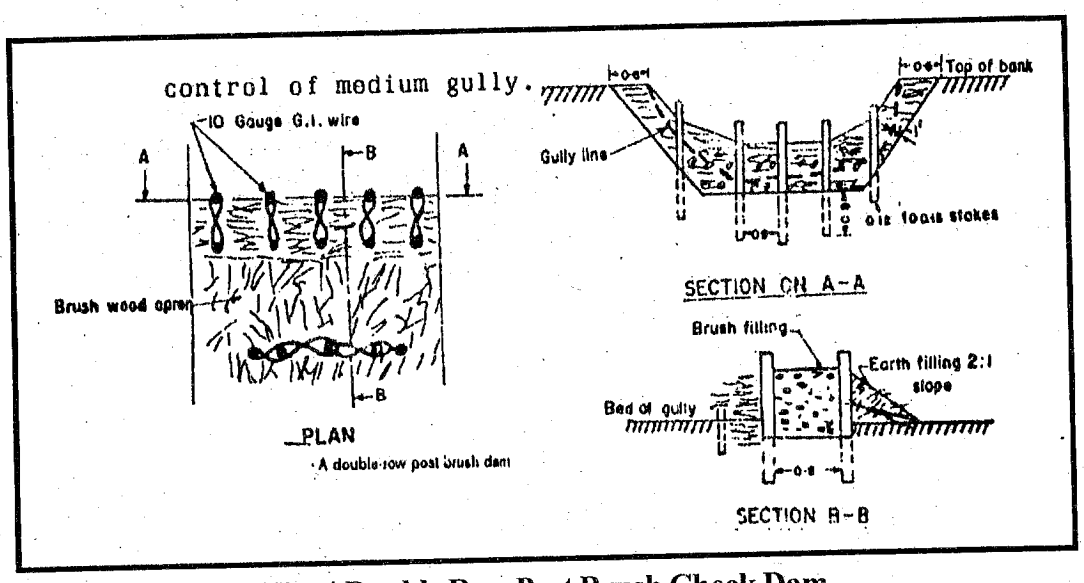


Fig. 4 Double Row Post Brush Check Dam

is to be handled than double or multiple row of brushwood check dam can be constructed.

2.3.3.1.3. LOOSE STONE CHECK DAMS

If stones of fairly good size are available in large quantities, they can be used for constructing check darns. These have a relatively longer life and usually require lesser maintenance. These structures are effective for checking velocity of run off water in step and broad gullies.

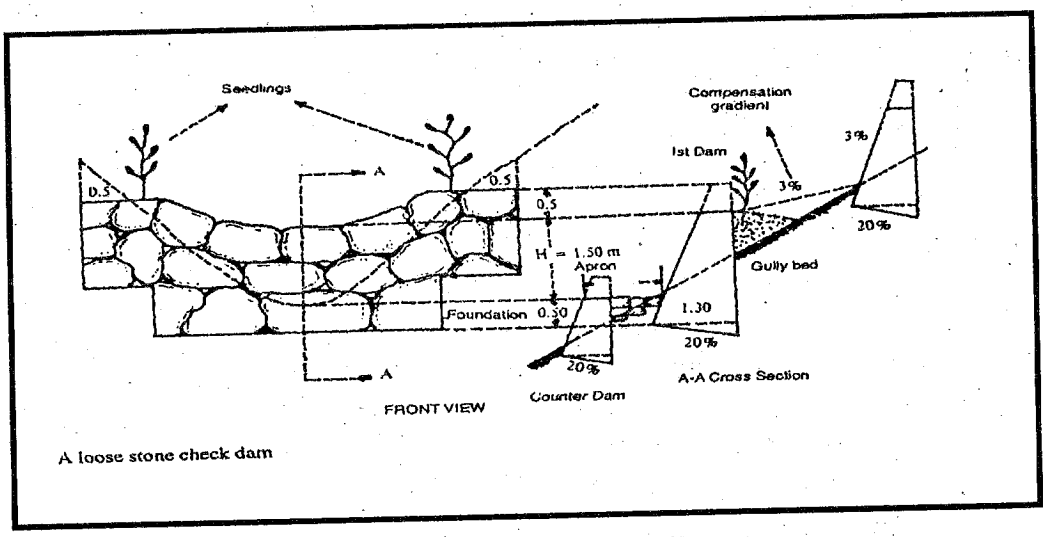


Fig. 5 Loose Stone Check Dam

Construction: The site where the dam is to be constructed is cleared and banks are sloped to 1:1. The bed of gully is excavated to a uniform depth of about 30 cm and dry stones are laid from that level as shown in figure. The top of the structure is given crescent shape for safe disposal of the maximum runoff from the catchment area. The stone filling should go upto 30 cm to 60 cm into the stable portion of the gully banks to prevent endcutting. In the down stream side, sufficient length and width of apron has to be provided to prevent scouring. The thickness of the apron packing should not be less than 45 cm and gully side above the apron have to be protected with stone pitching to a height at least 30 cm above the anticipated maximum water level t o side scouring, due to

falling water. The stability of structure is secured by using stones of as large size as can he procured and careful packing, bedding and wedging. Flat stones are the best for dam construction and can be laid in such a way that all the stones are keyed together.

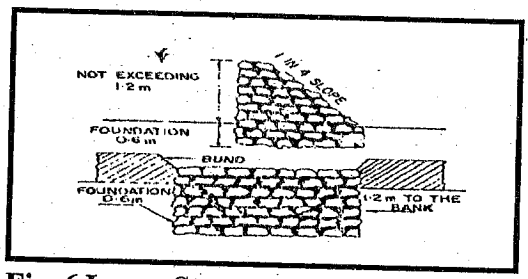


Fig. 6 Loose Stone Check Dam Section

If irregularly shaped stones have to be used, the structure is usually encased in woven wire so as to prevent the stones from being washed away. Such a structure is called GABION.

Whatever may the shape of structure, following, design criteria of dry stone cheek dam is in practice and has been found to be suitable for adoption:

The maximum height of structure should not be more than a metre. Once the height (H) is fixed the other perameters can be found out as given.

- Base width =1.4 H
- Top width =0.4 H (minimum 40 cm).
- Down stream slope = 1:1
- Depth of foundation = 0.4 H

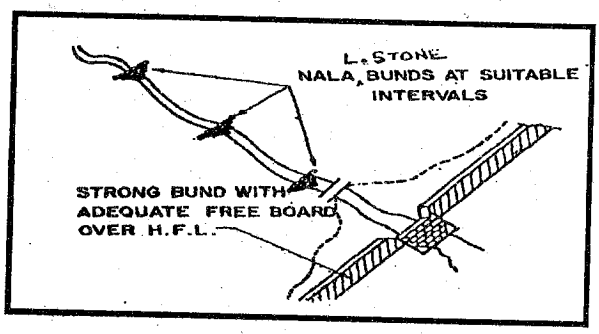


Fig. 7 Nala Bunding Structure

Earth fill on the upstream side of the wall is provided upto 0.4 H height at slope of 1.5:1 or 2:1 depending on the soil type.

2.3.3.2. SEMI PERMANENT STRUCTURE

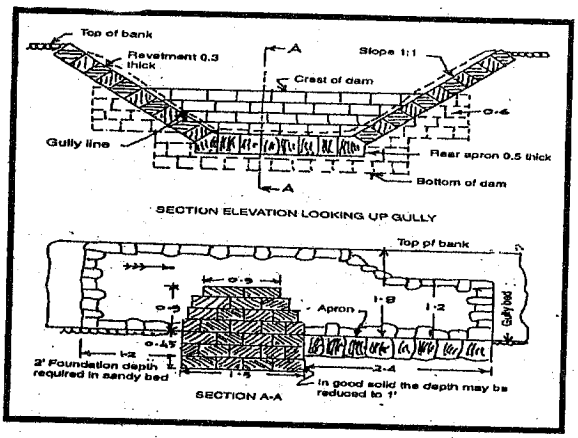


Fig. 8 Dry Stone Check Dam

These have a longer life and usually do not require any maintenance as well as the assistance of vegetative growth for controlling the gully. They can be constructed in places where materials are available in large quantity. These dams are effective in step gullies traversing hilly and mountainous regions. They are also useful in ravines where passage for live stocks have to be provided for.

2.3.3.2.1. POLY BAG CHECK DAM

Empty cement poly bags filled with unscreened nallah sand are used for construction of barrier across the drainage line when relatively high volume is to be handled at moderate velocities.

These structures are cheaper than dry stone masonry structures if the stones are to be procured and transported from long distance. In the nallah bed, about 20 cm soil is excavated for foundation purpose. Polybags are filled with unscreened nallah sand upto 80% capacity are than stacked in layers to attain requisite height. Only polythene thread should be used for sewing the bags.

The bags are then tied with each other on the up-stream side by polythene thread so as to make them as one unit. The cutting of joints (as in masonry pattern) should be adopted while stacking the bags. In the middle or lower reaches of drainage lines, poly bags can be encased in woven wire to give additional strength to the structure. Permanent structures for drainage line treatment.

2.3.3.2.2. LOG DAMS

When timber is plentiful and semi-skilled labour is available, log dams mat be erected. Figure of log dam gives the details of construction. In regions where attack of termites is anticipated, necessary care should taken.

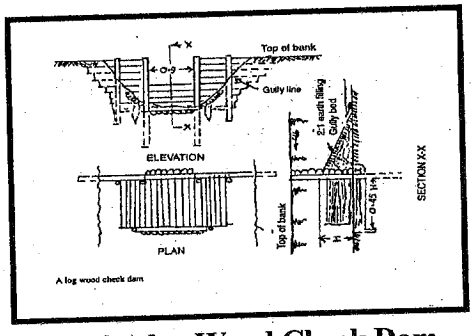


Fig. 9 A log Wood Check Dam

2.3.3.3. GABION CHECK DAMS

If abundant stones are valuable, but their shape makes them unsuitable for loose stone construction, or if expected water velocity is very high, gabions are used.

A gabion is rectangular shaped cage made of galvanised wire, which is filled with locally

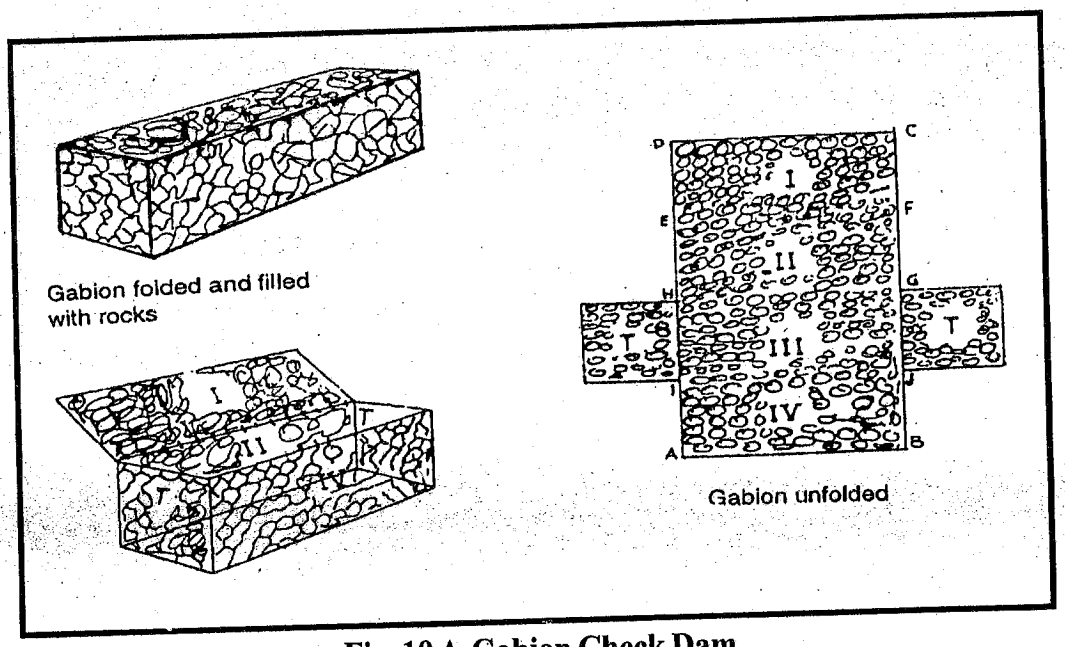


Fig. 10 A Gabion Check Dam

found rocks or stones. To facilitate the transport, gabions are conveyed flat and are folded to shape at the construction site (Fig.)

The gabion check dam is made by connecting several gabions in both horizontal and vertical direction (Fig.). Usually, gabions are 1 m wide and 1 or 0.5 m high; their length can very between 2 and 6 m.

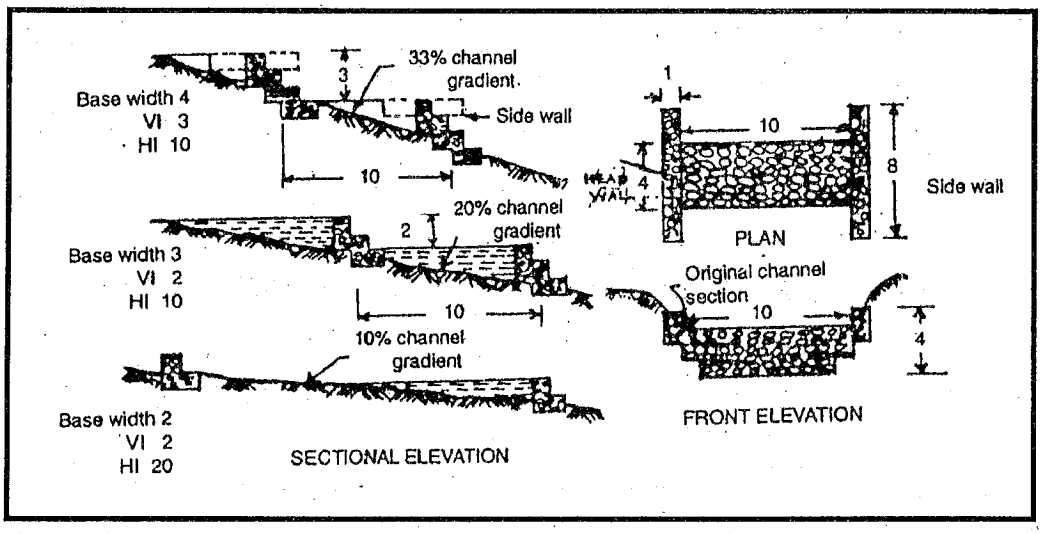


Fig. 11 Structural Design of Gabion Cross Barrier on different Channel Gradients

An important advantage of a gabion structure is its flexibility; it will shape itself according to the stream bed even when this changes due to, for example, erosion, without losing its stability (Fig.)

Just after construction, gabions are permeable, but they will slow down the water velocity considerably, causing sedimentation and finally complete filling up behind the gabion check dam is achieved.

2.3.3.4. PERMANENT STRUCTURE

Permanent structures for drainage line treatment are suggested in the lower reaches of the drainage line where quantity and velocity of runoff to be handled is more or these are

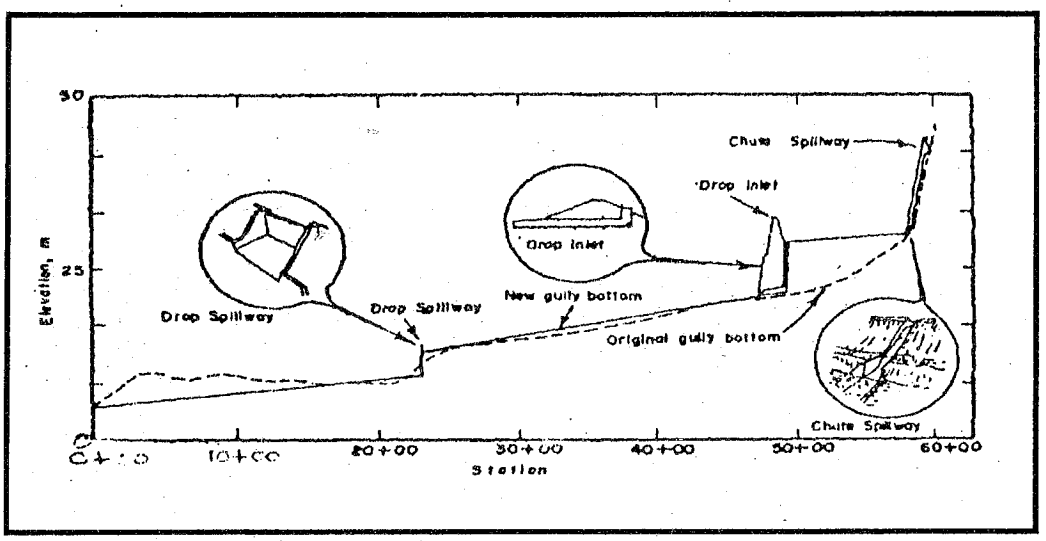


Fig. 12 Profile of a Gully Showing the Application of Different Types of Permanent Structures

to be constructed for harvesting of the runoff. These structures (small in size) can also be constructed after every 4th semi permanent structures in the drainage lines.

These are adopted only when the benefits from such structures are justified as compared to the cost of construction.

Main Function

- To halt the advancement of vertical over falls at Gully head.
- To stabilize grade in the bed of gully and
- Storage of runoff water.

General Requirements.

1. Should be constructed with permanent material.
2. Should have adequate capacity to handle the runoff.
3. Should help in stablIz!n8 the gully and store water wherever necessary.
4. The choice and design of the structure shall depend upon the drop to be negotiated and runoff to be handled.

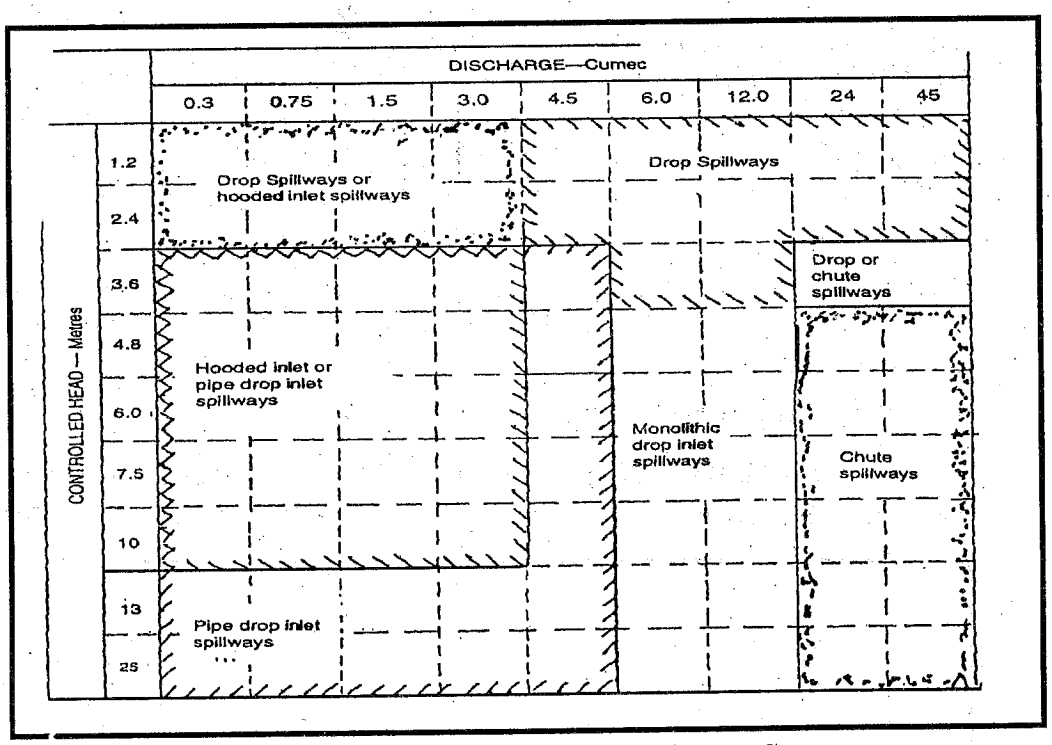


Fig. 13 General Guide to Selection of Permanent Structure

Type of Permanent Structures

- Drop inlet spillway
- Drop spillway
- Chute spillway
- Water harvesting structures

2.3.3.4.1. DROP INLET SPILLWAY

A drop inlet spillway is a closed conduit generally designed to carry water under pressure from above an embankment to a lower elevation. An earthen embankment is required to direct the discharge through the spillway. Thus, the usual function of a drop inlet is to convey a portion of the runoff through or under an embankment without erosion. Vegetated or earth spillways around one or both ends of the embankment should always be used in conjunction with drop inlet spillways. Nomenclature for various parts of drop inlet spillways are shown in Fig. ().

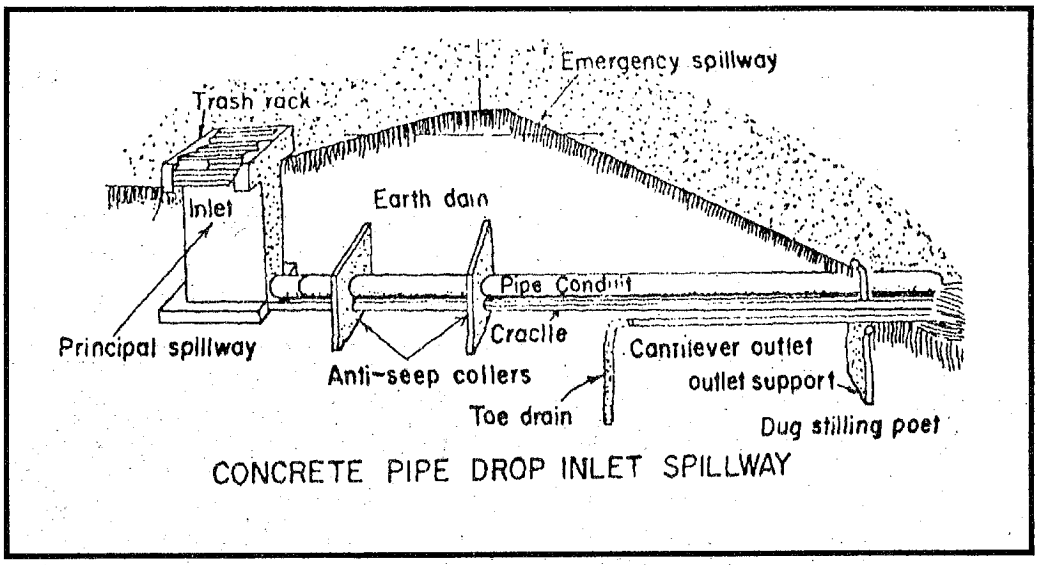


Fig. 14 Drop Inlet Spillway

Materials :

The riser of a drop inlet spillway may be of plain concrete, reinforced concrete blocks, masonry or pipe. The barrel may be of reinforced concrete, concrete or clay tile, or corrugated or smooth metal pipe having watertight joints. In India RCC pipes are generally used.

Functional Uses

- Principal spillways for farm ponds or reservoirs
- Grade stabilization
- Disposal system at lower end
- Principal spillways for debris basins
- Roadway structure
- Flood prevention structure
- Surface water inlet for drainage or irrigation

Adaptability :

It is a very efficient structure for controlling relatively high gully heads, usually above 3 m. It is well adapted to sites providing an appreciable amount of temporary storage above the inlet. It may also be used in connection with relatively low heads, as in the case of a

drop inlet on a road culvert, or in passing surface water through a spoil bank along a drainage ditch.

Advantage :

For high heads, it requires less material than a drop spillway. Where an appreciable amount of temporary storage is available, the capacity of the spillway can be materially reduced. Besides effecting a reduction in cost, this reduction of discharge results in a lower peak channel flow below, and can be a favourable factor in downstream channel grade stabilisation and flood prevention.

Limitation :

Small drop inlets are subject to blockage by debris. They are limited to locations where satisfactory earth embankments can be constructed.

2.3.3.4.2. DROP SPILLWAY

It is a weir structure in which flow passes through the weir opening drops down to the level of apron or stilling basin and than passes into the downstream channel. When used for water harvesting the height is to be designed after drawing depth-capacity curve.

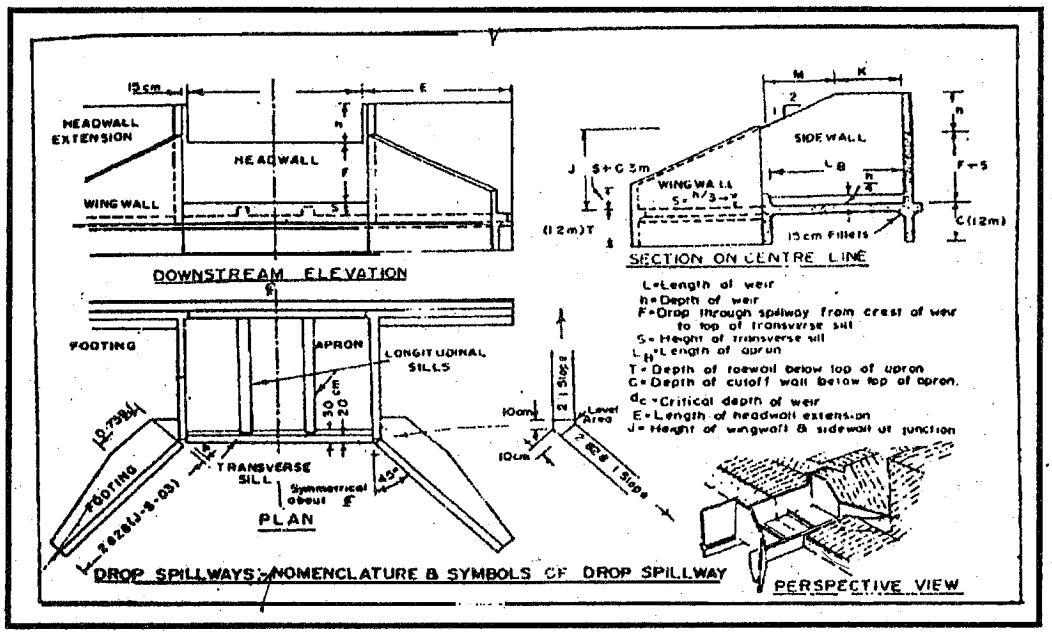


Fig. 15 Drop Spillway

Material :

Reinforced concrete, Plain concrete, R.R. stone masonry in lime or cement mortar.

Functional Use :

- Grade stabilization in lower reaches of water ways and outlets.
- Erosion control for protection of fields, roads, building and other improvement from gullies.
- Grade control and stabilizing channels.
- Outlets for surface water, the upper and along drainage ditches.
- Reservoir spillway where total drop is relatively low.

- Control of tail water at the outlet of a spillway or conduit.
- Protection of outlet and grassed water ways.

Adaptability :

It is an efficient structure for controlling runoff at relatively low heads, normally upto 3m.

Advantage:

- The chances of failure or damage to structure is less than other type of structures.
- Rectangular weir is less likely to be clogged by debris.
- Relatively easy to construct.

Limitations:

1. It is costlier than other type of structures where the discharge capacity is less than 3 cumecs and total head or drop is not more than 3 m.
2. It is not recommended where temporary storage is needed to obtain a large reduction in discharge.
3. A stable grade below the structure is essential.

Site Selection

Proper side selection is dependent upon the adequate field surveys and foundation data. Site should be selected so that the spillway can be located on a reasonably straight section of channel perpendicular to the flow direction, with no upstream or down stream or curves within at least 30 m of the structure.

The site selected should provide an adequate foundation for the spillway. The foundation material must have the required supporting strength, resistance to sliding and piping and be reasonably homogenous so as to prevent settlement of the structure.

2.3.3.4.3. CHUTE SPILLWAY

It is an open channel with steep slope in which is carried at super critical velocities. It consists of an inlet, vertical curve section, steep sloped channel and an outlet.

Material

Reinforced concrete is the most widely used and safest material for large chutes. Plain concrete and masonry, though not as suitable as reinforced concrete, can also be used.

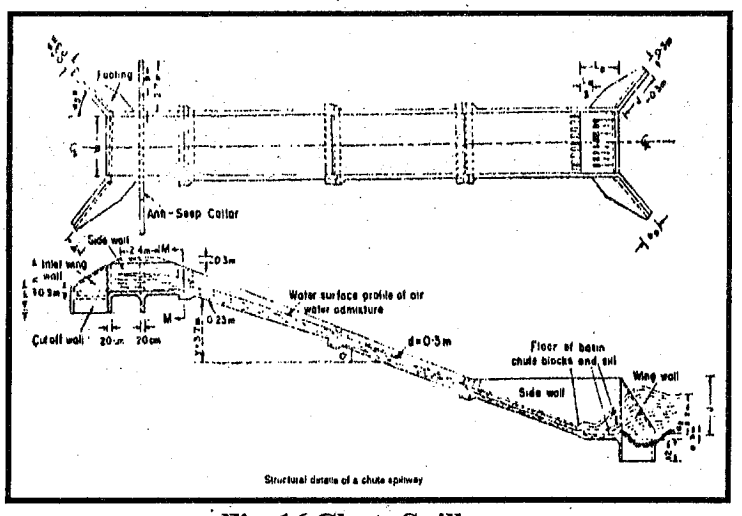


Fig. 16 Chute Spillway

Functional Use

- To control gradient in either natural or constructed channels.

- To serve as a spillway for flood prevention, water conservation and sediment collecting structure.

Adaptability :

Concrete chute is particularly recommended for high overfall, where side conditions do not permit the use of detention type structure. It can also be used with detention dams, taking advantage of the temporary storage to reduce the required capacity and the cost of the chute.

Advantages :

It is usually more economical than a drop-inter-structure, when large capacities are required.

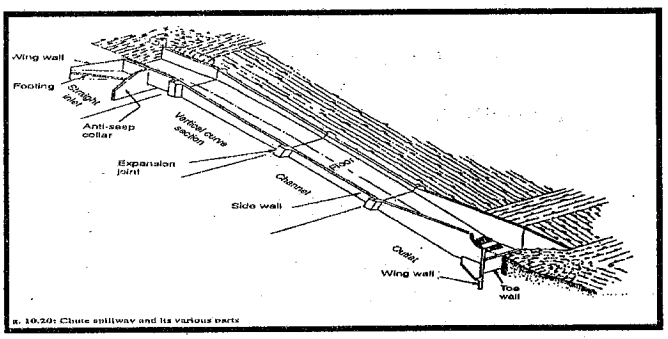


Fig. 17 Nomenclature of Chute Spillway

Limitations :

There is a considerable danger of undermining of the structure by rodents. In poor drainage locations, seepage may weaken the foundation. It must be placed on compacted fill or on undisturbed soil in an abutment.

2.4 Summary

The Proper use of Land and water resources for optimum production with minimum hazard to natural resources is water & land conservation.

2.5 Self Assessment Test

1. What are the soil conservation measures in water shed management?
2. What is the log Dams ?

2.6 References

Watershed Management: Guide lines for Indian Conditions by E.M. Tideman

Design Manual on Watershed Development and Soil Conservation, A report by Directorate of Watershed Development and Soil Conservation, Rajasthan, Jaipur

Technical Manual for Watershed Development. A report by Directorate of Watershed Development and Soil Conservation, Rajasthan, Jaipur

UNIT-3

WATERSHED MANAGEMENT & CATCHMENT AREA TREATMENT

Structure :

3.0 Objectives

3.1 Introduction

3.2 Factors Affecting Watershed Management

3.3 Kind And Amount Of Data Necessary

3.4 Rain Water Management

- 3.4.1 Increasing Soil Moisture Storage
- 3.4.2 Reducing Soil Moisture Losses
- 3.4.3 Increasing Depth Of Soil Moisture Zone
- 3.4.4 Tailoring The Crop To The Available Moisture

3.5 Selection Of Priority Areas

- 3.5.1 Reconnaissance Survey
- 3.5.2 Soil And Land Use Surveys
- 3.5.3 Interpretation Of Aerial Photographs
- 3.5.4 Sediment Observations

3.6 Conservation Measures In Watershed Management

3.7 Watershed Planning

- 3.7.1 Description Of The Watershed
- 3.7.2 Watershed Problems
- 3.7.3 Proposed Management Programme
  - 3.7.3.1 Agricultural Lands
  - 3.7.3.2 Conservation Irrigation
  - 3.7.3.3 Protection Against Floods
  - 3.7.3.4 Forest Lands
  - 3.7.3.5 Grazing Lands Management

3.8 Effects Of Works Of Improvement

3.9 Comparison Of Benefits And Costs

3.10 Self Assessment Questionnaire

3.11 Suggested Readings

3.0 OBJECTIVES

Soil and water are of crucial importance for mankind. The continuing and ever accelerating depletion of the available soil and water resources in India and elsewhere in the world is a matter of grave concern. The technical knowledge as to how to arrest this degradation and how to conserve soil and water exists, but this knowledge has been applied on a limited scale. One of the reasons is that the existing knowledge is not easily available who should apply it. This unit is basically prepared to propagate the knowledge available for successfully implementing watershed management.

Watershed management/catchment area treatment implies the proper use of land and water resources for optimum production with minimum hazard to natural resources. The different objectives are as follows:

1. To control damaging runoff
2. To manage and use runoff for useful purposes
3. To control erosion and effect reduction in the sediment production
4. To moderate floods in the downstream areas
5. To enhance ground water storage
6. Appropriate use of land resources in the watershed-forest and fodder
7. Building and maintaining soil fertility

3.1 INTRODUCTION

Agriculture production in India in view of its poor endowment of water resources is critically dependent on the vagaries of monsoon, uncertainty of rainfall as well as its unequal distribution. This is the primary reason for the low productivity of un-irrigated land. Watershed approach for development of rainfed areas will certainly help in increasing the productivity and making the rural areas more prosperous. The watershed development project endeavor to achieve the twin objective of restoration of ecological balance and enhancing productivity through sustainable soil and water conservation practices in the rainfed areas of the state.

Watershed management or the catchment area treatments are the same except they are used in different places. When we talk about the water contributing to a dam, than we say about the catchment area and there we talk about the different land treatment, which helps in soil and water conservation along with reducing erosion. Thus leads to less silt load to the dam. Which is the main factor affecting the storage capacity of the dam.

So now what is the meaning of watershed and its management? Dear friend, Watershed is natural unit draining runoff water to a common point. So area contributing to a common point is called the watershed of that area. It can be demarcated based on ridge and gully lines. The size of the watershed can be selected depending upon possibilities of developing it completely within a reasonable period of 3-5 years. A watershed may be only a few hectare as in case of small ponds or hundreds or square kilometers as in case of rivers.

3.2 FACTORS AFFECTING WATERSHED MANAGEMENT

The important factors which are to be studied for developing management program:

1. Size & shape
2. Topography
3. Soil characteristics
4. Precipitation
5. Land use
6. Land use
7. Vegetative cover

3.3 KIND AND AMOUNT OF DATA NECESSARY

The kind and amount of data necessary for planning watershed improvement project will depend in part upon the nature of the purpose of the project. The data necessary for planning can be grouped under the following broad categories:

1. Hydrological information (precipitation, crop water requirement, stream flow data, sediment flow)
2. Soil and land use data (land use informations, soil data, topographic, types of vegetation)
3. Economical & social data (cost benefit ratio of the project)

3.4 RAIN WATER MANAGEMENT

The fundamental principles of managing the rain water in drylands ire (1) to catch rain water in such a way that minimum or no loss takes place, (11) to store the rain water so that better water potential is build up, and (iii) to preserve it so that most efficient use is made of the available water potential.

3 These objectives can be achieved by

4 Taking steps which are conducive to the maximum absorption into the ground of the rainfall reaching a given area,

5 Reducing the losses of the stored water by evaporation and consumption by weeds,

6 Increasing the depth of the soil moisture zone,

7 Adopting a suitable cropping pattern and

8 Using water-harvesting methods.

3.4.1 INCREASING SOIL MOISTURE STORAGE

To increase soil moisture storage infiltration rate of the soil, infiltration opportunity time, and moisture holding capacity of the should be increased by improving soil structure through organic amendments and chemicals, by providing ridge and furrow system of cultivation, and by mechanical shattering of the hard pan if any. In general

all cultural practices, which reduce runoff and erosion, result in increased storage of soil moisture.

3.4.2 REDUCING SOIL MOISTURE LOSSES

Substantial amount of the stored water may get by evaporation from soil surface and weed growth. The evaporation from soil surface may be reduced by (I) decreasing turbulence transfer of water vapour to the atmosphere, (II) decreasing capillary conductivity of the soil, and decreasing moisture hold rig capacity of the surface soil. Weeds may be controlled by the use of primary and secondary tillage, and herbicides and weedicides.

INCREASING DEPTH OF SOIL MOISTURE ZONE

Deep ploughing through subsoilers can increase the depth of the soil moisture zone or chiesel ploughs which will shatter the hard or compacted layer if present in the effective crop root zone. The selection of deep-rooted crop varieties can further enhance the soil moisture zone for the crops.

3.4.3 TAILORING THE CROP TO THE AVAILABLE MOISTURE

In drylands the crop production is to be carried out under a wide range of soil moisture regime, which vary from season to season. The increase yield and. stabilize crop production, the crop plan should be so determined that maximum utilisation of the rains is made in good year and some threshold yield is obtained even in a subnormal year.

The common practice in most of the low rainfall (< 500 mm) areas is to grow a single crop at a piece of land during a year. The possibilities of double cropping exists only in area of medium or higher rainfall (> 500 mm)

The moisture reserves are known in advance for seeding of rabi crops as the rabi crops are grown on the area left fallow during rainy season for moisture conservation. Therefore rabi crops may be tailored to the moisture present in the soil profile at the time of seeding.

3.5 SELECTION OF PRIORITY AREAS

In a watershed management program, particularly in case of large watershed it may not be possible to treat the entire area of the watershed with land treatment measures. In such cases the watershed should be divided into subwatershed. The methods used for determining the priority of the subwatersheds for treatment from soil erosion and sediment yield point of view are:

1. Reconnaissance surveys
2. Soil and land use surveys
3. Interpretation of aerial photographs
4. Sediment observations

3.5.1 Reconnaissance survey

Reconnaissance survey of the entire watershed gives an idea of the relative erosion status of the subwatersheds. This method should be only used when other methods are not available.

3.5.2 Soil and land use surveys

Soil and land use surveys interpretation provides the information on the relative erosion status of the various subwatersheds, which are very helpful for prioritizing the watershed developmental activity. The main disadvantage with this method is that it requires lot of time and personnel.

3.5.3 Interpretation of aerial photographs

Scientific interpretation of aerial photographs provide qualitative information regarding land, including location, general texture of various soil, general evaluation of sand, gravel and boulder deposits, drainage characteristics, spread of vegetation etc. The information on erosion conditions of the area can be gathered with aerial photographs, which is further used in deciding up the priority work.

3.5.4 Sediment observations

Sediment observations from the specific area give the actual picture of the extent of the erosion. Actual measurement of the silt load contributed by each of the Subwatersheds will give a clear picture of the erosion in the subwatersheds. Observations in respect of silt loads recorded over a period of three to five years will indicate the subwatersheds which are contributing higher silt loads. The main difficulty with this procedure is that the data has to be collected over a period of years so that reliable conclusions from the data can be drawn.

3.6 CONSERVATION MEASURES IN WATERSHED MANAGEMENT

Watershed management involve the various watershed management measures which are effective in preventing or delaying the movement of soil and rock particles, from their point of origin in the drainage area. These are the following soil conservation measures:

1. Contour trenching on barren hill slopes
2. Afforestation
3. Diversion channel
4. Bench terracing of steep slopes
5. Contour or graded bunding of agricultural lands
6. Gully protection
7. Construction of small ponds
8. Stream bank erosion control
9. Road side stabilization
10. Scientific method of agricultural practices like contour cultivation, strip cropping, crop rotation
11. Pasture development
12. Flood plain protection

13. Water spreading for ground water recharge
14. Shore line protection
15. Control of land slides and land slips

3.7 WATERSHED PLANNING

3.7.1 Description of the watershed

i) Location
ii) Size and shape
iii) Climate
iv) Geology
v) Slopes
vi) Surface drainage
vii) Soils
viii) Physiography
ix) Water uses and needs
x) Land use and cover conditions
xi) Economic data

3.7.2 Watershed Problems

Problems resulting from flood water, erosion and sediment damage and these associated with conservation development utilization and disposal of water are to be discussed.

i) Flood water damage
ii) Sediment damage
iii) Erosion damage
iv) Problems related to water management
v) Special problems
vi) Socio economic problems

3.7.3 Proposed Management Programme

Details of the proposed treatment measures are given different factors to be described under each item are as follows.

3.7.3.1 AGRICULTURAL LANDS

Recommendations should be given for each capability class.

- Agronomic Practices - Crops proposal, rotations, cultural operations, introduction of improved seeds, Use of manures and fertilizers, green manuring, use of improved implements, plant protection measures, expected cost and yields.

- Engineering Measures in Agricultural Lands (Classwise): Proposed measures, justification, specifications of in individual measures with plans and designs, calculations and cost estimates.

3.7.3.2 CONSERVATION IRRIGATION

Selection and design of suitable method of irrigation for each part of land, duration of irrigation, conveyance system, location and specifications, land levelling, plan for disposal of excess water and agronomic measures.

3.7.3.3 PROTECTION AGAINST FLOODS

Channel improvements; flood retarding structures, their location, design and cost estimate.

3.7.3.4 FOREST LANDS

Management practices for existing forests, degraded forests, and farm forestry Engineering measures to be adopted on forest rangelands.

3.7.3.5 GRAZING LANDS MANAGEMENT

a) Pastures - Species selected, method of raising mechanical practices like contour furrowing and water spreading, management practices, yields and costs.

b) Grazing Lands - Improvement practices recommended grazing systems to be prescribed.

c) Special Problems- Control measures recommended for special problems like landslides, stream bank erosion along highways.

3.8 EFFECTS OF WORKS OF IMPROVEMENT

Likely benefits viz. increased agricultural production, flood control; reduction of sediment loads, increased forest produce etc. is outlined.

3.9 COMPARISON OF BENEFITS AND COSTS

The discussion should show the ratio of the average annual benefit to average annual costs of the project. Only primary benefit are to be used for benefit cost comparison.

3.10 SELF ASSESSMENT QUESTIONS

Now you can understand the basic principle of watershed management and catchment area treatment. So now you have to make a short note on the following:

1) What are the factors, which influences the watershed management?
2) What is the meaning of rainwater management?
3) What kind of data is necessary in watershed management?
4) How you prioritize the area in the watershed management?
5) Name the watershed management/catchment area treatment measures?
6) How you plan the watershed management measures?

3.11 SUGGESTED READINGS

Watershed Management: Guide lines for Indian Conditions by E.M. Tideman

Design Manual on Watershed Development and Soil Conservation, A report by Directorate of Watershed Development and Soil Conservation, Rajasthan, Jaipur

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UNIT-4

WATERLOGGING & SALINITY PROBLEM

Structure

4.0 Objectives

4.1 Introduction

4.2 Waterlogging

4.3 Development of waterlogging conditions

4.4 Rising watertable problems

4.5 Extent of the problem

4.6 Impact of waterlogging problem

4.7 Saline soil condition

4.8 Criteria for saline soils

4.9 Summary

4.10 Self Assessment Test

4.11 Key Words

4.12 Suggested Readings

4.0 OBJECTIVES

The primary objective of irrigation and drainage for successful crop production is the development and maintenance of an environment in the plant root zone in which soil moisture - oxygen-salt balance is favourable for plant growth. The application of excess irrigation and/or recharge from irrigation distribution network causes gradual rise of water table and creates waterlogging conditions in the root zone. The excess soil moisture (waterlogging conditions) affects crop growth because of deficient aeration. The poor quality irrigation water adds salts to the soil. The presence of excess salts in the soil profile affects the physical and chemical properties of the soil adversely affecting the crop production. The article describes the diagnosis & impact of waterlogging & salinity problem.

4.1 INTRODUCTION

India has made rapid strides in creating irrigation potential since independence. The pre-plan irrigation potential was 22.6 million hectares. By the end of 1990-91, 80.8 million hectare irrigation potential had been created in the country (Central Water Commission, 1995). This tremendous increase in irrigation potential along with improved agricultural practices has been effective in stabilizing agricultural production even in the draught years. However in the zeal to create more and more irrigation potential, due attention was not given to the water management & drainage aspects. This resulted in waterlogging and salinity problems in many irrigation commands in the country. Thus, irrigation water which greatly helped farmers also caused waterlogging and soil salinity in most of the Canal Command Areas. This has resulted in millions of hectares of land gradually going out of cultivation.

Waterlogging and poor quality irrigation water and their impact on the environment are the most important concerns from ecological development point of view in irrigation projects. The primary objective of irrigation and drainage for successful crop production is the development and maintenance of an environment in the plant root zone in which soil moisture - oxygen-salt balance is favourable for plant growth. The application of excess irrigation and/or recharge from irrigation distribution network causes gradual rise of water table and creates waterlogging conditions in the root zone. The excess soil moisture (waterlogging conditions) affects crop growth because of deficient aeration. The poor quality irrigation water adds salts to the soil. The presence of excess salts in the soil profile affects the physical and chemical properties of the soil adversely affecting the crop production (Sewa Ram, 1997).

It has been reported that most crop groups will grow and respire normally if the oxygen diffusion rates exceed 4x10-7 gm/cm2/minute. This diffusion rate cannot be maintained for a distance of even a few centimetres through a soil medium unless interconnected air passages are present. But if the soil contains as much as 4 percent by volume of air passages, this rate could be supplied to a depth of 1 m or more (Woolley, 1965). The excess moisture also creates hindrance in the inter-culture operation and delays trafficability of farm equipments for timely farm operations specially for Rabi crops. Delayed plantation of Rabi crops reduces their yield resulting in overall reduction in the yield potential creating socio- economic problems.

The waterlogging may be in the form of:

Surface ponding : Water standing on the land surface during prolonged periods due to inadequate surface drainage; and

High watertable : groundwater levels rising and remaining in the root zone during prolonged periods due to inadequate ground water drainage.

Both forms of waterlogging can be harmful to the agricultural use of the land as they restricts the aeration of the roots and the timeliness of the farm operation.

India experiences a wide range of climatic and physiographic conditions and a corresponding wide range of waterlogging and salinity conditions. India's waterlogging conditions can be broadly classified into the following groups:

Rainfed induced waterlogging found naturally in imperfectly drained land throughout the country during the monsoon rainy period. It occurs both in the form of surface waterlogging (a prolonged period of surface ponding), as well as in the form of subsurface waterlogging (a prolonged period with high watertable). The occurrence is more widespread and more severe in the higher rainfall areas as compared to lower rainfall areas. These types of waterlogging situation can be found during the monsoon throughout the country.

Irrigation induced waterlogging and salinity is a relatively recent feature, developed mostly since the late 19th century when large scale canal irrigation was introduced. It is found in different command areas throughout the country either in the form of waterlogging only, mostly in the higher rainfall, eastern part of the country or as the twin problem of waterlogging and salinity, mostly in the drier north-western part of the country.

4.2 WATERLOGGING

Till 1996, there was no uniformity in the definition of waterlogged areas and thereby the measurement of watertable level, to provide reliable data for the total area affected by waterlogging in the country, was lacking the standardization, although these variations are due to many variables like type of crop tolerance, type of soil, quality of water etc. Due to such lack of uniformity of the norms of categorization of waterlogged area in the agro-climatic conditions, statistics available in this regard were of questionable nature with respect to magnitude and relevance. The available statistics is for the entire land area suffering from waterlogging and salinity, without any separation of the affected area due to canals and due to other causes like inundation of low lying area, encroachment or choking up of the natural drains etc.

An area may be waterlogged when the watertable rises to an extent that the soil pores in the root zone of a crop became saturated resulting in restriction of the normal circulation of air, decline in level of oxygen and increase in the level of carbon dioxide. In humid areas, waterlogging problems are due to excessive precipitation. In irrigated regions in addition to excess rainfall waterlogging is also due to excess seepage from irrigation network and over irrigation.

According to the Report of the Working Group (1991), a special committee of the Central Board of Irrigation and Power has defined waterlogging as follows:-

> ***An area is said to be waterlogged when the watertable rises to an extent that the soil pores in the root zone of a crop become saturated resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide. The watertable, which is considered harmful, would depend upon the type of the crop, type of soil and quality of water. The actual depth of watertable when it starts affecting the yield of crops adversely, may range over a wide range from zero for rice to about 1.5m for other crops. Wheat and sugarcane are affected when watertable is within 0.6 m, maize, bajra and cotton are sensitive to watertable within 1.2m, and gram and barley within 0.9m.***

As per Ministry of Water Resources (MOWR, 1996), the classification of waterlogged areas may be made on the basis of the measurements of water table between October and December (Post monsoon) for Indian conditions as per the following norms:

- **Fully waterlogged:** Water table within 1 m below ground surface.
- **Waterlogged:** Water table within 2 m below ground surface.
- **Potentially Waterlogged:** Water table between 2 to 3 m below ground surface.
- **Safe areas:** Water table deeper than 3 m below ground surface.

4.3 DEVELOPMENT OF WATERLOGGING CONDITIONS

In every irrigated command prior to the introduction of irrigation, there exists a natural water balance between rainfall on the one hand and stream flow, groundwater evaporation and evapo-transpiration on the other hand. This balance is disturbed when additional

quantity of water is spread on the land for irrigation. A sizable contribution to groundwater is introduced in the form of seepage from unlined irrigation channels net work. The irrigation water let on to the field over and above the quantity actually utilised for sustaining plant growth also adds to the ground water storage. This new accretion of groundwater may be withdrawn from the sub-soil, under good sub-soil drainage conditions. When natural drainage conditions are not good, it will rise the sub soil water levels or form perched watertable and may cause waterlogging and soil salinity. The ideal condition for permanent irrigated agriculture in arid and semi-arid regions is to have watertable sufficiently deep so that there is unrestricted downward movement of water and salts from the root zone (O.P. Singh, 1997).

Waterlogging is caused both by natural as well as man-made factors. Some of these are (Gupta et. al., 1995):

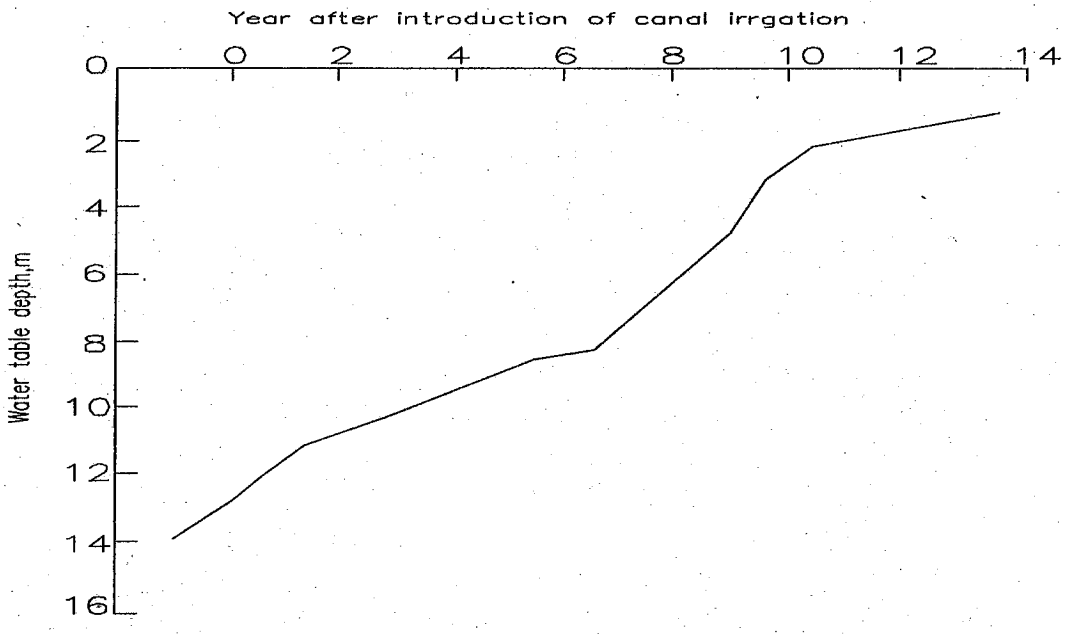
- Deforestation and poor upkeep of watersheds.
- Development activities such as construction of roads, bridges, railway lines and buildings resulting in choking of natural drainage.
- Poor natural drainage as a consequence of unfavourable topography or unfavourable sub soil geology like existence of hard pan at shallow depths.
- Spilling of rivers resulting in submergence of agricultural lands.
- Heavy storm rainfall coupled with poor natural drainage.
- Hydraulic pressure of water from upper irrigated areas resulting in seepage in low lying areas.
- Introduction of irrigation without taking into account characteristics of soils and subsoil's for their irrigability.
- Heavy losses of water due to seepage from canals, distributaries and watercourses.
- Excess application of water particularly in the initial years when the command is not fully developed.
- Poor on farm management resulting in poor application efficiencies.
- Unrealistic cropping patterns tilted in favour of water loving crops.
- Lack of night irrigation in some commands.
- Inadequate drainage and poor maintenance of existing drainage system and outlets.
- Lack of conjunctive use of surface and ground waters.

4.4 RISING WATERTABLE PROBLEMS

In most canal irrigated areas, due to rise of water table, (Example Figure 1), problem of soil deterioration through salt accumulation has assumed serious proportions. According to one estimate, nearly 50 percent of the canal-irrigated area is affected by salt problems in varying degrees due to inadequate or lack of artificial/restricted natural drainage. Salt problems have also increased where saline ground water has been used for irrigation. In

any coastal areas excessive exploitation of ground water has caused seawater intrusion resulting in worsening of the salinity problem.

Under irrigation, the recharge to the groundwater will almost always increase due to (partly inevitable and beneficial) deep percolation of irrigation water and higher percentage of deep percolation of the rainwater as compared to rain fed land use. As a result, watertable will rise until the level at which a new equilibrium between recharge and discharge is reached. This level may be so close to the soil surface that the root zone becomes waterlogged. The observations of chronological watertable data have shown



that in almost all the irrigation commands after the introduction of canal irrigation, the watertable has a rising trend (Table 1). The root zone may also become salinised when there is insufficient leaching or when the ground water is saline.

Figure 1 Trend of groundwater table rise at Haryana Agricultural University Farm at Hisar, India, after the introduction of canal irrigation.

Table 1. Rising trend of watertable in irrigation commands

Name of the irrigation command	Rise of watertable (m/year)
Mahi Right bank canal command (MRBC), Gujarat	0.28
Rajasthan Canal Command (IGNP), Rajasthan	0.29 - 0.88
Western Jamuna & Bhakra Canal Command, Haryana	0.30 - 1.00
Sirhand Canal Command Punjab	0.10 - 1.00
Sharda Sahayak Canal Command Uttar Pradesh	0.68
Malprabha Canal Command, Karnataka	0.60 - 1.2
Nagarujan Sagar Irrigation Project, Andhra Pradesh	0.32
Sriram Sagar Irrigation Project, Andhra Pradesh	0.26

(Source:- Dr. O.P. Singh, 1997).

4.5 EXTENT OF THE PROBLEM

National Commission on Agriculture (1976) in its report, estimated that about 6.0 million ha of land suffers from the waterlogging problem. The problematic area with high water table covers an area of 2.6 million ha while remaining 3.4 million ha suffers from surface water stagnation (Gupta et al., 1995).

In various major and medium irrigation commands, throughout the country, the Ministry of Water Resources, India estimated the waterlogged and saline areas in 1987 as 2.44 million ha and 3.30 million ha respectively (Table 2) (World Bank/UNDP/IPTRID, 1993). The waterlogging conditions refer to high water table during the pre-monsoon period (within 2 m below soil surface).

Table 2 Waterlogging and Salinity in Major and Medium Commands, 1987 (Thousand hectares).

State	Waterlogging	Salinity
Andhra Pradesh	266	28
Bihar	620	223
Gujarat	173	911
Haryana	249	197
Karnataka	26	51
Madhya Pradesh	73	36
Maharashtra	15	5
Orissa	196	-
Punjab	200	490
Rajasthan	180	70
Tamil Nadu	16	140
Uttar Pradesh	430	1150
Total	2440	3302

(Source: Ministry of Water Resources, India (World Bank/ UNDP/ IPTRID, 1993).

4.6 IMPACT OF WATERLOGGING PROBLEM

Ill effects of waterlogging problem can be summarised as follows:

1 Poor soil aeration results from waterlogging problem. This restricts root development and doesn't provide a more favourable environment for beneficial soil micro-organisms and earthworms. When soil aeration is reduced, the severity of soil-borne root diseases is increased.

2 Excess soil moisture with waterlogging problem provides difficulty in efficient operation of tillage, planting and harvesting equipment.

3 Poor soil structure is found with waterlogging problem since there is more chance of destroying soil tilth due to compaction when working soil is too wet.

4 Soils doesn't warm up more quickly when abundant water is present in the soil system. This results in poor seed germination and a reduced rate of plant growth.

5 Decreased supply of nitrogen can be obtained from the soil when the watertable is in the root zone. De-nitrification often occurs in soils with excess soil moisture.

6 Smaller growing season is available as the planting dates are delayed due to waterlogging problem.

7 Certain toxic substance and disease organisms are accumulated in the soil strata due to waterlogging problem. In wet soil, roots can be injured by toxic substances produced in the reduction of iron and manganese salts and the reduction of nitrates to nitrites.

8 Winds are more liable to uproot plants growing in soils that are waterlogged, since root systems are shallower, and soil strength is poor.

9 Soil erosion and sediment loss is increased due to waterlogging problem, since these soils doesn't have a greater capacity to absorb rainfall and the suspended sediments are carried to downstream area.

10 Fuel consumption is more in working around wet areas in fields, that are waterlogged. Also, waterlogged land is difficult to work, their is more need for dual wheels or four-wheel drive tractors, besides decreasing the life of machinery and equipment.

11 A good variety of crops can not be grown successfully on a waterlogged farm land. Only selected crops can be grown in these areas.

12 Weed problem is maximum and its control is difficult since shallow rooted weeds and undesirable grasses often thrive in wet soil, crowding about the planted crop.

13 Waterlogged grazing land doesn't supports more livestock, with more compaction damage to vegetation and soil from animal traffic.

14 Waterlogging problem increases the diseases that thrive on wet land. These include foot rot and liver fluke that infect livestock, and diseases carried by mosquitoes to both livestock and human beings. The plant diseases such as root rot, stem rot etc. are also found in waterlogged area.

15 Salinity and alkalinity problems are mostly found in arid/semi-arid regions along with waterlogging problem.

4.6.1 WATERLOGGING AND CROP YIELD

The growth of most crops is affected by continued saturation or by ponded water on the soil surface. Saturation of the root zone results in an oxygen deficiency which can reduce water uptake, nutrient uptake and root respiration and build up toxic gases which leads to the death of cells and roots. Field experience and research shows that crop yield for most crops will drop drastically if waterlogging duration is longer than 2 to 3 days. The relationship between crop yield and watertable depth is shown in Figure 2.

The impact of waterlogging varies, depending upon the stage of crop growth and the duration of saturation. High water table conditions, even for relatively short periods, can negatively impact both crop yields and quality. Sustained high water table conditions will result in total failure for nearly all crops (Semedma and Rycroft, 1983).

Waterlogging of the entire root zone for a period of 2 or 3 days can cause complete crop

failure for some crops if it occurs during the seedling stage. A mature crop would suffer less damage. A healthy crop is able to withstand waterlogging better than a poor one. Most crops have a large proportion of their roots in the topsoil and so early restoration of topsoil is important.

World Bank (Barber, 1985), based on the field surveys on the rising watertable and development of waterlogging in North West India, reported that direct yield reductions attribute to watertable at various depths for a range of crops (Table 3). Table 3 reveals that most of the crops give a good to excellent yield when a watertable is maintained at 1.2-1.5 m depth below ground surface.

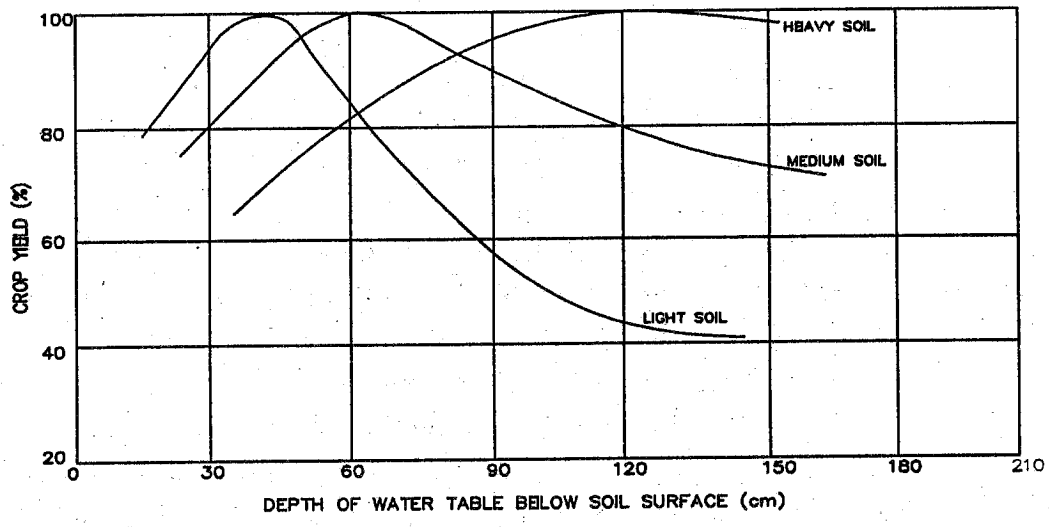


Figure 2 **Relationship between crop yield and water table depth.**

Table 3 Percentage yield reduction of crops due to variation of water table.

Depth of watertable below ground level (m)	Yield Reduction Percent						
						Fodder	
	Mango	Cotton	Oil	Sugarcane	Wheat	Rabi	Kharif
< 0.30	100	94	85	85	77	74	71
0.30-0.45	100	71	66	66	49	45	27
0.45-0.60	100	55	54	54	35	30	0
0.60-0.75	100	46	42	42	24	19	0
0.75-0.90	91	37	32	32	15	11	0
0.90-1.00	76	29	22	28	9	5	0
1.0-1.20	61	22	13	13	4	2	0
1.2-1.50	38	15	5	5	1	0	0
1.5-1.80	7	6	1	1	0	0	0
1.8-2.10	0	3	0	0	0	0	0
> 2.10	0	0	0	0	0	0	0

(Source: Barber, 1985).

Table 4 shows crop yields of some selected crops obtained at ground water levels ranging between 40 and 150 cm below soil surface (Ochs and Bishey, 1992).

Table 4 Relative Crop Yields Obtained at Ground Water Levels ranging between 40 and 150 cm below Soil Surface.

Crop	Grain, root, tuber yield (%) for various water table depths					Actual yield at 100% (kg/ha)
	40 cm	60 cm	90 cm	120 cm	150 cm	
Cereal						
Wheat	58	77	89	95	100	4,600
Barley	58	80	89	95	100	4,100
Oats	49	74	85	99	100	5,000
Pulses						
Peas	50	100	100	100	100	2,750
Beans	79	84	94	94	100	3,100
Other						
Rapeseed	79	95	98	98	100	2,500
Sugar beet	71	84	97	97	100	40,500
Potatoes	90	100	92	92	96	26,000

(Source: Ochs & Bishey, 1992 after Van de Goor, 1972).

As shown in Table 4 the shallower the water table the lower the crop yield.

4.6.2 FLOODED SOIL CONDITION

Excess irrigation results into flooded condition and repeated excess irrigation for longer period may lead to saline conditions in soil. These two conditions impose certain constraints for plant growth.

On excessive irrigation or following inundation, water fills the pores in the soil, air is expelled from them and gas diffusion is markedly impaired. Since oxygen diffusion in air is about 103 to 104 time more rapid than in water or in water saturated soils, oxygen is depleted more rapidly. It is also depleted but less by the respiration of soil micro organisms and plant roots. Availability of oxygen in water is much lower than in soil. Therefore, plant may suffer by stress from insufficient supply (hypoxia) or complete lack (anoxia) of oxygen. On excessive irrigation, hypoxia occur however on waterlogging or flooded condition for longer period anoxia occur. An unfavourable soil structure and occurrence of micro-organisms with their activities may contribute to hypoxia. If water stagnates for a longer period of time may lead to submerged condition and to the anoxia.

As a result of disturbed soil aeration lowering of 02 concentration leads to an increase in C02 concentration which may reach up to 50 percent of the gas phase in the soil. Lack of 02 and a high C02 content in the soil cause characteristic alternations in appearance and metabolism of plants growing in such environment.

In poorly aerated or waterlogged soils during decomposition of organic matter, phenolics and short chain fatty acids often accumulate and inhibit the root growth. Organic substances

with high lignin content (straw) gives rise to phenolic acids that severely inhabit root elongation in sensitive species (rye and wheat) even at concentrations between 1 to 10 mg/L and tolerant species (sugarcane) at 100 mg/L. Acetic acid and other volatile (short chain) fatty acids accumulation under waterlogging are detrimental to root elongation and inhibit root and shoot growth even in plant species adapted to waterlogging.

Poor aeration as result of excessive irrigation for longer period to soils with high organic matter and at high temperatures, an abnormally large amount of ethylene may accumulate in the rhizosphere. At low concentrations, ethvlene stimulate root growth but at high concentrations (1-10 microlitre/ha) of gaseous, phase of soil, in most plant species inhibit root extension although it stimulate initiation of lateral roots and formation of aerenchyma in root cortex.

Most plant species not adapted to waterlogging, develop injury symptoms sequentially over a period of several days if waterlogging continues. Wilting and in herbaceous sps, epinasty (downward bending of leaves) are likely the first symptoms. A decrease in water permeability of the roots and an accumulation of ethylene in the shoots are responsible for wilting and epinasty, respectively.

A decline in or cessation of shoot extension is another typical symptom, followed after several days of waterlogging by enhanced senescence of lower leaves, indicating N - deficiency. Waterlogging can impair the N-nutrition of legumes by interfering with nodulation.

Cessation of root growth and root respiration leads to drastic drop in the uptake and transport of mineral nutrients to shoot within few days of waterlogging.

In soils, high in organic matter and nitrate, sudden waterlogging might lead to an accumulation of NO2 in the soil solution to concentrations which are toxic to roots of sensitive plant species e.g. tobacco is injured by NO2 concentration as low as 5 mg/L. Waterlogging injury caused primarily by Mn toxicity occurs in plant species with low inherent Mn tolerance e.g. Alfalfa. Short term responses of plants to anaerobic soil conditions can readily be demonstrated by waterlogging of a previously well aerated soil. The growth of existing roots ceases immediately. Waterlogging inhibit synthesis and shoot export of cytokinin and gibberellin and cause inhibition of leaf extension and enhanced leaf senescence.

Anaerobic root respiration leads to the formation of acetaldehydes and particularly ethanol. In tomato a 24 hr period of waterlogging was sufficient to increase ethanol concentration in the xylem exudates to 5 to 7 ppm which is toxic to tomato. Similarly, after 3 to 4 days flooding the ethanol concentration shoots increased sharply in the roots of pea plants to 2.1 mm compared with 0.07 mm in un-flooded control. It was concluded by many workers that the accumulation of ethanol is mostly responsible for flooding injury to nonwet land species.

4.6.3 STRUCTURAL CHANGES

0_2 stress causes segregation of fibrillar and granular components and extrusion of the fibrillar component of the nucleolus in the form of the so called accessory bodies. In long lasting anerobiosis (72 hr), the nuclear membrane is interrupted and lipid bodies appear in the nucleoplasm, which is taken for irreversible damage.

Less anoxia resistant plants show increase in size and shape, become irregular, density of matrix decreases etc. in mitochondria of meristematic cells. Prolonged lack of 02 (e.g. 35 hr in wheat, 26-72 hr in maize or 72 hr in pea) leads to enormous increase in size of the mitochondria, dilation of cristae and decrease of the matrix density upto disintegration of the whole organelle.

4.6.4 METABOLIC CHANGES

Lack Of 0_2 markedly affects membrane system of cell. Changes occur in the permeability of the plasmalemma, manifested by increase leakage of electrolytes (especially K) and organic metabolises.

Hypoxia markedly affects protein synthesis. Lack of 02 induces the synthesis of specific so called stress proteins within 90 minutes of stress. Hypoxia also affects the rate of photosynthesis. This drop is connected with lowering of chlorophyll and carotenoid content, closure of stomata.

4.7 SALINE SOIL CONDITION

SOIL SALINITY

Soil salinity problem in irrigation commands develop whenever soil and hydrological conditions favour the accumulation of soluble salts in the root zone. The rise of water table in semi-arid and arid areas mobilises the salts present in the soil profile and ground water. Once the ground water table rises within 2-3 m of the soil surface, it contributes substantially to evaporation from the soil surface and water uptake by plants. The upward flux of water due to evaporation and water uptake by plants, results in gradual concentration of salts in the root zone. In the initial years, there may be reduction in crop yield due to salinity but as the severity of the problem increases, the land may become completely unproductive.

EXTENT OF THE SALINITY/ALKALINITY PROBLEM

The estimates of the extent of salt affected soils in the country vary widely (Gupta et. al., 1995). According to a recent report (Singh, 1992) the salt affected soils are estimated to occupy about 6.4 million ha of lands in irrigation commands located mostly in arid and semi-arid regions. On the other hand, working group of MOWR (1991) assessed that an area of 3.30 million ha is affected by the problem of soil salinity/alkalinity.

Natural salinity developed at various locations in the semiarid parts of north-west and central India under the naturally prevailing hydrological and geochemical conditions of the land. A particular form of this type of salinity is the usar land, sodicity found in many depression areas in the western part of the Gangetic plain. Natural salinity is also found in the plains and deltaic areas along the coast.

Irrigation induced waterlogging and salinity is a relatively recent feature, developed mostly since the late 19th century when large scale canal irrigation was introduced. It is found in different command areas throughout the country either in the form of waterlogging only, mostly in the higher rainfall, eastern part of the country or as the twin problem of waterlogging and salinity, mostly in the drier north-western part of the country.

Even water of good quality may contain from 100 to 1000g of salt per cubit meter. With an annual application of 10,000 m3/ha, between 1 and 10 tons of salts are added to the

soil. As a result of transpiration and evaporation of water, soluble salts further accumulate in the soil (Figure 3) and must be removed periodically by leaching and drainage.

Plants growing in saline soils face two problems:

(1) High salt concentrations in the soil solution (i.e. high osmotic potential give off water pressure and correspondingly low soil water potential).

(2) High concentration of potentially toxic ions such as Cl and Na or unfavourable combinations of salt ions (e.g. a high Na/Ca ratio).

Salt exclusion minimize ion toxicity but accelerates water deficit in plant, whereas salt absorption facilitates osmotic adjustment but can lead to ion toxicity and nutritional imbalance. In most instances, growth inhibition in salt-sensitive species even at low salinity levels is caused primarily by ion toxicity.

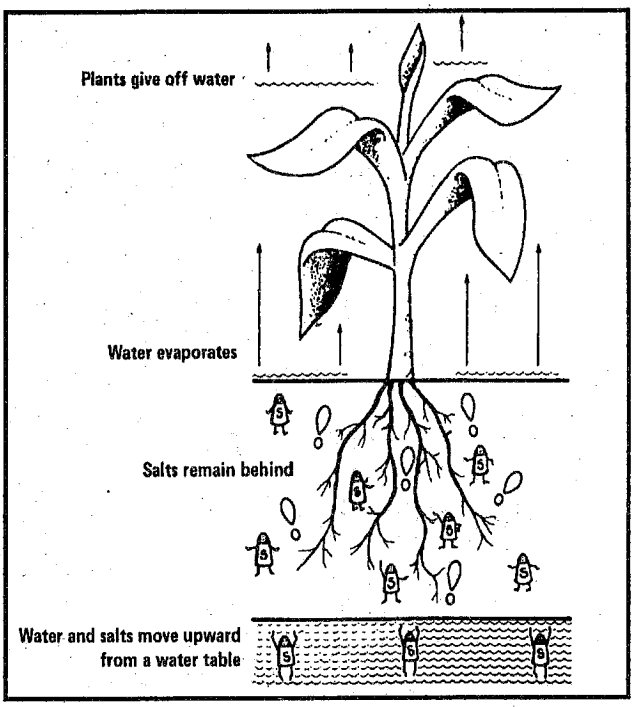


Figure 3 : Salt accumulation.

Plant injury under saline conditions is due to osmotic and toxic affect of salts. In sulphate salinity, halophytes are presumably exposed mainly to an osmotic action. In chloride salinity the adverse effects on physiological processes in cells are presumably due mainly to toxic and less so to osmotic action of salts.

Whether a water deficit or ion toxicity is the main constraint, plant growth also depends on the type of salinity (e.g. whether the predominant anion is Cl- or S04 -2,) and the size of the cation ratio (Ca2+/Na+), the duration of exposure and the salinity level. In plants exposed to high salinity levels for short periods, water deficit is the principal constraint. In plants exposed for long periods, which is more typical of field-grown plants, in addition to water deficit, specially in expending leaves, ion toxicity and imbalance are increasingly important.

Salinity level and leaf area are inversely related. The C02 fixation per unit leaf area may decline. Lower rates of net C02 fixation during the light period are not necessarily caused by water deficit and partial stomat a closure but can also be the result of direct adverse affects of Chlorides.

After long-term exposure to high salinity levels, lower rates of net photosynthesis may also be caused by a drop in chlorophyll content per unit leaf area, not per unit weight of chlorophyll indicating that the remaining chlorophyll is fully photosynthetic active.

Salinity may also increase the respiration rate of the roots which have higher carbohydrate requirement for maintenance of respiration in the saline substrate. This accounts for 25

percent of total growth reduction caused by salinity.

Protein synthesis in leaves of plants growing in saline substrates may decline in response either to water deficit or to a specific ion excess. Effect of Na, Cl salinity on protein synthesis might be due to Cl toxicity in sensitive species (e.g. soybean), whereas in the more salt tolerance barely, Na+ , K+ imbalance in the leaves is probably the responsible factor.

The adverse effects of NaCl concentrations on both potassium content and protein synthesis in barley can be a counter balanced by KCC despite further decrease in the osmotic potential and increase in Cl concentration of the substrate.

In many herbaceous plant species (fruit trees) growth inhibition occurs even at very low levels of Cl salinization where water deficit is not a constraint. In these species Cl toxicity is responsible for growth inhibition. At isosmotic concentrations NaCl is much more inhibitory than NaSO4 on growth of peanut.

Soil salinity increases incidence of calcium related physiological disorders such as tipburn of lettuce and blossom and rot in tomato either by competition between Na+ and Ca_2+ during uptake or by decreasing the soil water potential and thus the root pressure. When salinity is correlated with alkalinization, decrease in calcium solubility by precipitation of $CaCO_3$ can be an additional factor.

Although high levels of Cl may inhibit $N0_3$- uptake induced N deficiency is not likely to be important factor in the growth depression caused by soil salinity. In construct under field condition salt tolerance is apparently reduced in various crop species when large amount of N fertilizer is applied. This is related to a change in water balance imposed by N viz, change in rooting pattern and in phytohormone level (decrease in the abscisic/ cytol in ratio).

In legumes relying on N_2 fixation the situation might be different because salinity impairs modulation either directly by interfering Rhizobium colonization or indirectly by inhibiting root hair development.

In soils with high P availability, salinity imposed by Cl salts stimulates P uptake and can lead to P toxicity levels in the leaves.

Change in phytohormone levels are involved in the response of plants to salinity. Elevated levels of abscisic (ABA) are a typical response to water deficit induced by drought or salinity. Elevated levels of ABA in the leaves are important for rapid osmatic adjustment via stomatal closure. Then also favour the accumulation of amino acids in general and proline in particular and improve adaptation to salinity. Salinity may enhance senescence, indicated by inhabitation of protein synthesis and more rapid chlorophyll degradation.

Climatic factors such as relative humidity, temperature and radiation and soil aeration affect crop growth which explain that for crop production in saline soil salt tolerance of plants, agronomic parameters such as irrigation cycling, water management are as important as selection of plant species and cultivators. In this regards, pressurised irrigation systems are important as we can keep balance between soil, air and water, particularly drip irrigation system where required amount of water is applied as per need of crops. Therefore, use of pressurised irrigation systems do not cause excess irrigation, so there is less danger of hypoxia conditions and development of salinity.

4.8 CRITERIA FOR SALINE SOILS

In general, a saline soil is considered to be one which has an ECe greater than 4 dS/m. This definition is supported by a review of several major subsurface drainage projects (Framji et al, 1987; Amer and Abdel Dayem, 1987; Amer and Ridder, 1989). This same criterion appears in most publications.

Data supplied by Bresler et. al (1982) identify crop threshold values and expected yield reductions as soil salinity values increases. Using these tables, the threshold salinity values (the maximum soil salinity value before yield reduction begin) and yield reductions for ECe values of 2 and 4 dS/m can be identified for a number of crops **(Table 5).**

The yield reductions indicated in Table 5, show that crop yields decline rapidly for increasing salinity above ECe values of 4 dS/m.

Table 5: Threshold Ece and Yield Reductions

Crop	Threshold ECe (dS/m)	Yield Reductions (%) at various ECe values			
		ECe = 2	ECe = 4	ECe = 6	ECe = 8
Sorghum	4.8	0	0	5	14
Paddy Rice	3.0	0	12	37	60
Wheat	6.0	0	0	7	21
Sugarcane	1.7	0	12	24	34
Maize	1.7	0	24	48	72
Soyabean	5.0	0	0	20	60
Mustard	5.0 approx	0	0	13	39

In reviewing the literature, there does not appear to be wide support for using an ECe value of 2 dS/m to define the lower limit of a saline soil requiring reclamation. Nevertheless, it is possible and even probable that soils with ECe values between 2 and 4 dS/m will become more saline in the future. Although ECe values at 2 to 4 dS/m do not represent a criterion for requiring immediate reclamation, such salinity levels are often indicators of high water table conditions.

ECe as a measure of soil salinity

The soluble salt concentration of the soil is generally expressed in terms of electrical conductance of the saturation paste extract (ECe). The deleterious effect of high soluble salts on crop growth is mostly related to the increasing difficulty of extracting water from more concentrated solution. This is due to the increased osmotic pressure (OP), which is quantitatively related to the ECe of the soil.

The soil samples brought from the field are air dried, grinded and passed through 2-mm sieve. Make a saturated paste by adding water to the soil while stirring, until the saturation point is reached i.e. the point at which the soil surface glisten although there is still no free water. Extract soil solution samples from the paste using suction equipment. Measure the

electrical conductivity value of the saturation extract using a conductivity meter.

Sodicity status

(i) Exchangeable Sodium Percentage:

The amount of sodium adsorbed on the soil, expressed in milliequivalent per 100 gm soil, as percentage of soil CEC is called exchangeable sodium percentage (ESP).

$$ESP = \frac{\text{Exchangeable } Na+}{CEC} \times 100$$

(ii) Sodium Adsorption Ratio:

To overcome the difficulties, efforts have been made to estimate ESP from the analysis of the saturation extract. Sodium Adsorption Ratio (SAR) of the saturation extract adequately defines the exchangeable sodium ratio and ESP of the soil.

$$SAR = \frac{Na+}{\sqrt{\frac{Ca+^2 + Mg+^2}{2}}}$$

(iii) PH as a measure of ESP:

There is an intimate relationship between ESP and pH of the saturation paste. As the pH increases, ESP also increases.

Types of salt-affected soils

Three types of salt affected soils are saline, alkali (sodium) and saline-alkali (saline-sodium) soils. These soils may be summarized as under:

Criteria	Alkali Soil	Saline soil	Saline-alkali soil
ECe (dS/m)	< 4	> 4	> 4
ESP	> 15	< 15	> 15
pH	> 8.5	< 8.5	Nearly 8.5
Dominant ions	Carbonates Bicarbonates	Chlorides sulphate	Mixed

4.9 SUMMARY

India has made rapid strides in creating irrigation potential since independence. This tremendous increase in irrigation potential along with improved agricultural practices has been effective in stabilizing agricultural production even in the draught years. However in the zeal to create more and more irrigation potential, due attention was not given to the water management & drainage aspects. This resulted in waterlogging and salinity problems

in many irrigation commands in the country. Thus, irrigation water, which greatly helped farmers, also caused waterlogging and soil salinity in most of the Canal Command Areas. This has resulted in millions of hectares of land gradually going out of cultivation.

An area may be waterlogged when the watertable rises to an extent that the soil pores in the root zone of a crop became saturated resulting in restriction of the normal circulation of air, decline in level of oxygen and increase in the level of carbon dioxide. In humid areas, waterlogging problems are due to excessive precipitation. In irrigated regions in addition to excess rainfall waterlogging is also due to excess seepage from irrigation network and over irrigation.

Soil salinity problem in irrigation commands develop whenever soil and hydrological conditions favour the accumulation of soluble salts in the root zone. The rise of water table in semi-arid and arid areas mobilises the salts present in the soil profile and ground water. Once the ground water table rises within 2-3 m of the soil surface, it contributes substantially to evaporation from the soil surface and water uptake by plants. The upward flux of water due to evaporation and water uptake by plants, results in gradual concentration of salts in the root zone. In the initial years, there may be reduction in crop yield due to salinity but as the severity of the problem increases, the land may become completely unproductive.

4.10 SELF-ASSESSMENT TEST

1. Define waterlogging conditions.
2. What are the criteria for classification of waterlogged area as per Ministry of Water Resources?
3. What are the reasons for waterlogging conditions?
4. What are the impacts of waterlogging problem?
5. How soil salinity develops in irrigation commands?
6. How salt affected soils are classified?

4.11 KEY WORDS

Waterlogged Area : when the watertable rises to an extent that the soil pores in the root zone of a crop become saturated resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide.

Surface ponding : Water standing on the land surface during prolonged periods due to inadequate surface drainage; and

High watertable : groundwater levels rising and remaining in the root zone during prolonged periods due to inadequate ground water drainage.

Saline Soils : Soils having Ece greater than 4 dS/m.

Sodic Soils : Soils having ESP greater than 15.

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UNIT-5

RECLAMATION OF WATERLOGGED SALINE SOILS

Structure

5.0 Objectives

5.1 Introduction

5.2 Drainage Methods

5.3 Factors Influencing Drainage

5.4 Design of Horizontal Subsurface Drainage System

5.5 Drainage Design Criteria

5.6 Construction Technique

5.7 Summary

5.8 Self-Assessment Test

5.9 Key Words

5.10 Suggested Readings

5.0 OBJECTIVES

Reclamation of waterlogged saline soils requires adequate drainage. Adequate drainage could be defined as the removal of excess water and salt from the soil at a rate, which will permit normal plant growth. Adequate drainage may also be defined as the amount of drainage necessary for agriculture to be maintained successfully and perpetually. The drainage planner for a drainage system in an irrigated area must be constantly aware of land and water resources as well as the agricultural aspects. In drainage planning, environmental aspects should also be considered carefully. Selection of a drainage system is arrived at after careful examination of various alternative methods. This article deals with the various alternatives of drainage, their selection, planning etc.

5.1 INTRODUCTION

Drainage can be either natural or artificial. Most lands have some natural surface and subsurface drainage. When natural drainage is inadequate to handle the water reaching the land by either natural or artificial means, manmade or artificial drainage is required. Artificial drainage thus fills the gap between that provided by nature and the established need. This is usually done by supplementing existing natural systems. For example, natural streams and watercourses can be re-sectioned, or where no suitable ones exist, new drainage channels can be constructed. Almost every physical aspect and conditions of lands, as well as man's potential agricultural use of them will affect the ultimate drainage requirement.

When the total quantity of water introduced into the soils from various sources exceeds the total quantity disposed-of through natural drainage process and the quantity used by crops to meet their physiological needs, the watertable will rise. Thus a simple but comprehensive definition of adequate drainage could be the removal of excess water and salt from the soil at a rate which will permit normal plant growth. Adequate drainage

may also be defined as the amount of drainage necessary for agriculture to be maintained successfully and perpetually. The maintenance of satisfactory salt balance is necessary. The aspect of economic justification must then be reconciled. The prime objective should be to design and construct a drainage system which as optimum integration of soils, crop and irrigation.

Drainage benefits are given below:

1. Better soil aeration results from good drainage. This permits more extensive root development and a more favorable environment for beneficial soil microorganisms and earthworms. When soil aeration is reduced, the severity of soil-borne root diseases is increased.
2. Better soil moisture with good drainage permits more efficient operation of tillage, planting and harvesting equipment.
3. Better soil structure can be developed and maintained with good drainage since there is less chance of destroying soil tilth due to compaction when working soil is too wet.
4. Soils warm up more quickly when free water is removed by a drainage system. This results in better seed germination and an increased rate of plant growth.
5. An increased supply of nitrogen can be obtained from the soil when drainage lowers the watertable in the root zone. Denitrification often occurs in soils with poor drainage.
6. Larger growing season can be achieved with good drainage due to earlier possible planting dates.
7. Certain toxic substance and disease organisms are removed from the soil due to better drainage and soil aeration. In wet soil, roots can be injured by toxic substances produced in the reduction of iron and manganese salts and the reduction of nitrates to nitrites.
8. Winds are less liable to uproot plants growing in soils that have been properly drained, since root systems are deeper, and soil strength is greater.
9. Soil erosion and sediment loss can be reduced by subsurface drainage, since drained soils have a greater capacity to absorb rainfall and the soil filters out suspended sediment.
10. Good drainage saves fuel that would be used in working around wet areas in fields, that are not properly drained. Also, since drained land is easier to work, their is less need for dual wheels or four-wheel drive tractors, besides increasing the life of machinery and equipment.
11. A good variety of crops can be grown successfully on a well drained farm land.
12. Weed problem is minimized and its control is easier with good drainage since shallow rooted weeds and undesirable grasses often thrive in wet soil, crowding about the planted crop.
13. Well drained grazing land supports more livestock, with less compaction damage to vegetation and soil from animal traffic.

14. Good drainage reduces diseases that thrive on wet land. These include foot rot and liver fluke that infect livestock, and diseases carried by mosquitoes to both livestock and human beings. The plant diseases such as root rot, stem rot etc. are also reasonably controlled.

15. Drainage is essential for salinity-alkalinity control in arid/semiarid regions.

The drainage planner for a drainage system in an irrigated area must be constantly aware of land and water resources as well as the agricultural aspects. In drainage planning, environmental aspects should also be considered carefully. Selection of a drainage system is arrived at after careful examination of various alternative methods. Important drainage methods are mentioned below:

1 Surface drainage, including land grading and smoothing,

2 Subsurface drainage or pipe drainage,

3 Tubewell drainage, and

4 Bio drainage,

5 Preventive measures like

(a) Lining of water distribution system,

(b) On-farm water management, and

(c) Maintenance of surface drainage system.

Factors which are of prime importance in drainage are enumerated below:

i) Topographic factors.

ii) Soil factors.

iii) Water and climatic factors.

iv) Crop factors.

5.2 DRAINAGE METHODS

5.2.1 SURFACE DRAINAGE

Surface drainage (**Figure 1**) is the removal of water from the surface of the land. The water may be from excess precipitation, water applied in irrigation, losses from conveyance channels and storage systems, or water, which has seeped from ground water at a higher elevation. Flat or level land having impermeable sub soils with shallow top-soil frequently requires surface drainage because pipe drains are not practical or economical. Wherever mechanized farming operations are done surface drainage system should meet its requirement. Open drains are advantageous for removing large volumes of either surface or subsurface water, including storm water from land where the watertable is near the ground surface. Open drains are essential for disposing of storm water also. However they have a few disadvantages: i) take land out of production, ii) cause soil erosion, iii) require frequent cleaning, and iv) harbor and distribute obnoxious weeds. Surface drainage broadly comprises five categories.

1 On-farm field drainage system - It consists of graded channels that collect excess water from fields.

2 Intermediate drains (Collector or Carrier drains) - These are link drains between the various field drains and sub-main drains or main drains.

3 Main drains - Main/sub-main drains are principally excavated or natural drains, collecting water from link drains or directly from field drains.

4 Seepage drains- Seepage drains are located along earthen/lined canals and intercept surface/subsurface flow. These drains help in management of excess discharge from fill reaches of canals to the adjacent fields.

5 Land grading and smoothing- Most natural soil surfaces including many cultivated fields are more or less irregular consisting of randomly distributed elevated areas and depressions. It results in poundage of water, inefficient irrigation, interrupted surface drainage, difficulties in mechanized field operations and consequently non-uniformity of crop field and poor quality grain. In many cases, the areas can be relieved of these problems by reforming the land surface so as to provide continuous gentle slope to result in regulated water flow and adequate drainage. Land grading and smoothing is probably the simplest yet the most important type of surface drainage.

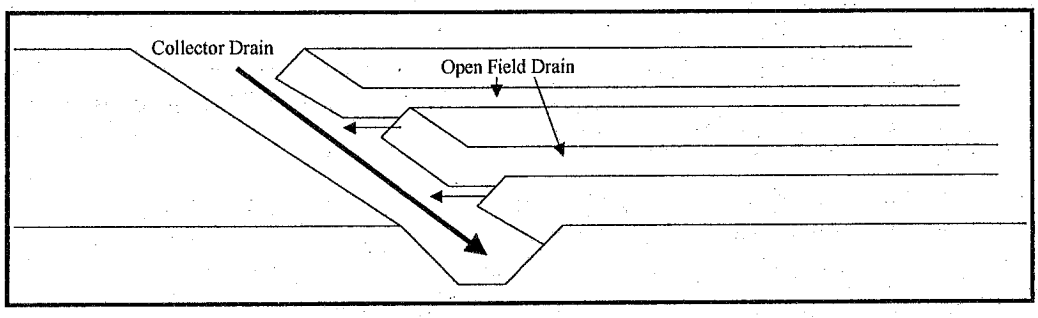


Figure 1 : Surface Drainage.

5.2.2 SUBSURFACE DRAINAGE

Subsurface drainage is accomplished by buried pipes or pipeless (moles) drains and also by deep open drains (ditch). Open drains have already been mentioned in para 2.1. Pipe and mole drains are described below :

1. Pipe drains - Pipe drainage consists of a system of pipes made of baked clay tiles, concrete, plastic tubing, or any other perforated conduit suitable for this propose. The excess soil water enters in lateral lines through butt joints, slots or other perforations and flows towards the collector and the main drains. Pipe drains are used to:

   - Intercept the lateral flow of ground water coming from a known source of seepage upslope, to keep it from reaching the area to be protected, and
   - Lower the ground water table and remove excessive soil moisture in the plant's root zone over the drainage areas.

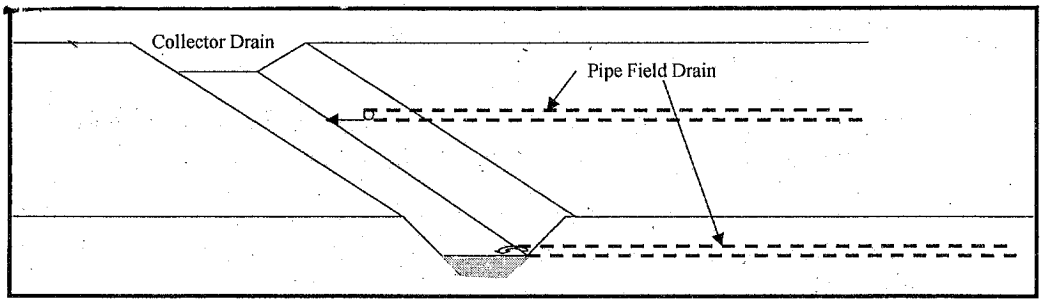


Figure 2 : Sub Surface Drainage.

2 Mole drains - Mole drains or pipeless drains are cylindrical channels artificially produced in the subsoil by means of a mole plough. Principally and hydraulically mole drains are similar to pipe drains except that they are not lined with tiles or other stabilizing materials. Moling is often considered to be a temporary method of drainage as the moles function efficiently for a few years and then gradually deteriorate.

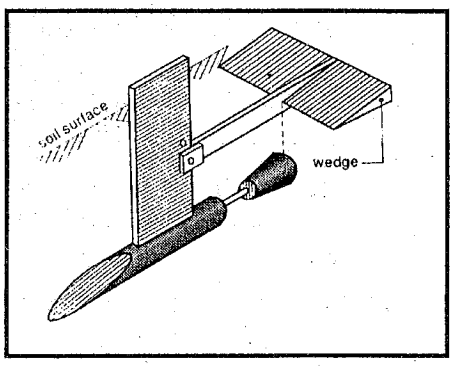


Figure 3 : Mole Drainage.

5.2.3 TUBEWELL DRAINAGE

Under some conditions, pumping ground water to provide land drainage is an effective method of lowering a high watertable and reducing salt hazards in irrigated area., Tubewell with pumping equipment is one of the drainage system which extracts ground water directly. The system as a whole consists of a number of such tubewells spread over the area to be drained. In many cases the drained water augments the supply of irrigation water. Irrigation or a drainage tubewell functions in a similar manner and is constructed in the same way. They, however, differ from each other on the following accounts.

- An irrigation well can be located at any place with a good aquifer underneath. A drainage well requires that the pumped aquifer should be interconnected to the watertable. In case of wells in a confined aquifer, if the confining layer is impermeable (no leaky), the wells may little utility as a drainage method.
- Interference between wells is often avoided in case of irrigation wells, where as for drainage wells some interference is desirable.

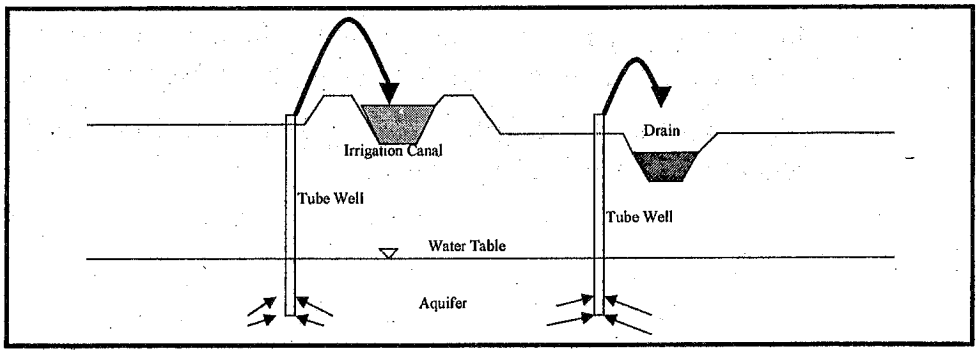


Figure 3 : Tube Well Drainage

- Irrigation wells are necessarily located on the highest portion of the farm to allow water to flow through gravity. For drainage wells, no such condition is necessary unless drainage water is to be used for irrigation.

5.2.4 BIO DRAINAGE

Use of quick growing plants (exotic trees) has been utilized to improve marshy and waterlogged lands. It is because such plants draw water at a fast rate. This system of drainage requires thorough investigations on plant species to suit specific areas particularity is saline soils.

5.2.5 PREVENTIVE MEASURES

Prevention is better than cure is an old adage that has a direct relevance to waterlogging and soil salinity. In areas where waterlogging and salinity have not developed as yet, it is possible to take preventive measure to save the soil health degradation. Basically the preventive measures could be classified into three groups:

1. Lining of water distribution system,
2. On-Farm water management, and
3. Maintenance of surface drainage system

- **Lining of water distribution system**

Loss of water through seepage in an irrigation canal system constitutes one of the most serious from of water loss, **Table 1**. It is due to this reason that waterlogging problem appears much early and spreads much faster. It is recognized that a substantial saving in the loss of water can be achieved by lining of canals.

Table 1 : Seepage losses in unlined and lined canals

S. No.	Type of Canal	Average seepage losses through wetted perimeter	
		Cusec/million Sq ft	Cumec / million Sq m
1.	Unlined Canal		
a.	Silt clay loam soil	8	2.27
b.	Sandy loam / lose sandy soil	15 to 20	4.25 to 5.67
c.	Porous gravelly soil	35	10.00
2.	Lined canal with pucca lining	2	0.567
3.	Lined canal with LDPE film	0.5	0.142

(Source - WAPCOS, 1988)

- **On-Farm Water Management**

Efficient utilization of the irrigation water on the farm reduces the ground water recharge. It is estimated that as much as 50 per cent of the water delivered at the field goes waste due to application losses. To save this water, on - farm water management should include efficient land grading and shaping, efficient design and layout of irrigation methods,

scientific scheduling of irrigation water supplies, and crop planning for optimal water use. An efficient design of surface irrigation method can improve the water application efficiency to 70 percent or higher. The water management must aim at optimum yield per unit of water applied with minimum loss of soil and plant nutrients.

- **Maintenance of Surface Drainage System**

Storm water stagnation makes a sizeable contribution to ground water. Surface drainage system plays an important role in quickly removing the storm water from the area. A common observation in many areas is that the drains are poorly maintained. Perhaps this has been solely attributed as the reason for rising watertable. Though, efficient functioning of drains alone cannot solve the problem of rising watertable, yet it should reduce its rate of rise. The maintenance should include restoring bed level, repairing side slopes, maintaining the ancillary workes and to control the vegetative growth in the drains. Typha and bulrush are a few water loving plants which grow in irrigation as well as drainage channels. Typha has a highly restrictive effect on the drainage system.

5.3 FACTORS INFLUENCING DRAINAGE

5.3.1 TOPOGRAPHIC FACTOR

Topography, which is of prime importance in drainage, influences the general plan and, the location of the outlet, sub outlet, and collector drains. Even before reaching the planning and design stage of drainage, the importance of topographic features can be recognized. Where surface slopes are sufficiency, excess precipitation, irrigation water, and canal water will flow rapidly from the area. Such rapid removal of excess surface water diminishes percolation to the watertable. Favorable topography may provide adequate surface drainage and reduce the need for artificial subsurface drainage. Investigation of the topography may reveal the lack of natural outlets for drainage water. Irrigation schemes are usually developed in areas characterized by broad and flat lands that can be easily irrigated. Often these areas are ancient depressions without any drainage outlet. Hence in arid areas, there are hardly any natural channel and stream ways. Thus, any drainage plan in such irrigated areas must often include the construction of a drainage outlet system. The objective is to key the drainage system to the topography.

Table 2 shows how various topographic factor will influence the type of drainage needed.

Table 2: Various topographic factors influencing the type of drain needed.

Topographic factor	Implied drainage considerations
1. Steep, hilly	a) No outlet problem; surface drainage adequate. b) Single line interception in swale bottoms. c) Look for seepage at toe of slope, or at outcrops, or along waterways.
2. Rolling	a) Probably no outlet problem; surface drainage adequate b) Single line or herringbone pattern of drain system. c) Single line along wet waterways.

3. Benches	a) Probably no outlet problem b) Grid system on bench and probably an interceptor line at toe of bench.
4. Gently sloping	a) May have outlet problem; surface drainage generally adequate b) Grid system or open drains on grid parallel to canal system c) Single line along wet waterways.
5. Flat lake bed or flood plain	a) Probably needs outlet drain. b) Grid system or open drains on grid parallel to canal system in direction of greatest slope. c) Drainage pump occasionally needed.
6. Closed basin	A) Would need outlet facility Drainage well or sump with pump might solve drainage and outlet problems.

(Source – Donnan and Schwab, 1974)

5.3.2 SOIL FACTORS

Soils are the results of complicated geological processes. Wide varieties of geologic situations have important bearing on drainage investigations and determinations of drainage needs. Therefore, in the interest of accuracy, time, and the design of an effective drainage system, an evaluation of the geologic situation by a qualified geologist is desirable. Another important factor is the knowledge of the presence of soil barriers or hard pans in the soil profile. These pans restrict the movement of water, thus causing waterlogging conditions. Some soils drain easily, others are extremely difficult to drain. Generally the coarse-textured soils drain better than the fine textured soils, although texture is not necessarily related to permeability.

In most irrigated areas the soils are formed into complex profile patterns. Stratified sands, silts, and clays are commonly found. Finetextured clay layers are often underlain or overlain by coarse-textured sands. Thus, it is important to bore holes to find out where the coarse, drainable layers are located. The sequence of permeable and impermeable soils and their ability to transit water determines both the type of system that should be installed and their design criteria. **Table 3** has been developed to help assess soil factors and their influence on drain choice.

Table 3: Assessment of soil factors and their influence on drain choice

S. No.	Soil Factors	Implied drainage considerations
1.	Deep (2m or more) permeable sands, sandy loams or clay loams.	Open drains or tube drain suitably spaced.
2.	Deep (2m or more) impermeable silty clays and clays.	Careful management of irrigation water plus mole drains suitably spaced; surface drains and/or tube drains.

3.	Shallow (1 m or less) permeable sands, sandy loams and clay loams underlain by impermeable soils.	Consider deep plowing to 120 cm depth and then installation of drains at 120 cm depths with careful irrigation water management; tube drains at 1 m depth in humid areas.
4.	Shallow (1 m or less) clay or silty underlain by permeable soils.	Tube drains suitable space with periodic clays subsoiling of upper soil strata; surface drains in humid areas
5.	Soils that gradually change to more permeable strata with depth	Tube or open drains will have greatest effect if placed as deep as possible.
6.	Soils that gradually change to less permeable strata with depth	Tube drains will have greatest effect if placed as shallow as possible below the root zone and surface drains
7.	Deep (3 to 4 m thick) impermeable clays and silty clays underlain by water–bearing coarse sands or gravels	Sump or drainage well; surface drains in humid areas

(Source - Donnan and Schwab, 1974)

5.3.3 WATER AND CLIMATIC FACTORS

The source of all waters coming into the irrigation areas must be determined. The common sources of water of major importance in drainage problem areas are precipitation, irrigation, and seepage with hydrostatic pressure manifested in various form. The water source survey provides a key to the measures needed to remedy undesirable drainage conditions. More specifically, the water source often governs the type of drainage to be installed. Thus, if excess water is due to precipitation, the remedial measure would probably be better surface drainage; if due to canal seepage, a seepage or an interception drain may be indicated; and if due to artisan pressure, pumped wells may provide the most practicable remedy. Consideration of all the pertinent information on geology, topography, soil strata and watertable is needed to determine the source of water.

Precipitation

Rainfall causes flow on land and, thereafter to the drainage channels with some infiltration into the soil. This water must be carried away from agriculture lands within a period, which does not create harmful conditions of waterlogging. Since water moves towards the topographic low points, both surface and subsurface waters normally flow in the same disposal channel. Design consideration must include the total capacity of both types. Precipitation records seldom have to be collected or compiled primarily for drainage investigation. Usually, they will be available with the design or investigation wing of irrigation department and with government of India offices, like India Meteorology Department, Central Water Commission, Ganga Flood Control Commission etc. The project hydrologist shall analize the data and provide values of flood volumes, frequently and the period of floods. Storm flow depends on topography, soils, vegetative cover, land use, and the climatic characteristics of the area. Temporary flooding of waterlogging occurs during crop growth in irrigated areas or account of heavy rain storms especially if

they occur after irrigation application, and cause considerable reduction in crop yield. Waterways in the canals, road, railway embankment impede the natural drainage capability of the land and flood waters remains on lands for greater time. To compute the drainage requirement for irrigated areas, it is necessary to know the reduction in crop yields with depth and duration of flooding at different crop growth stages. Alkali and other sons with low infiltration rates would require higher drainage rates to save crops from temporary flooding. As such, data on drainage rates and yield reduction due to flooding need to be collected for different irrigated areas to formulate drainage strategy.

Design standards for storm frequencies and allowable period of crop submergence have some variations in different organizations. As per U.S.B.R., surface drains should be designed to handel flow from 5-15 year storm frequencies. Where relatively expensive structures are involved or where structures may dictate the need for a more conservative design, the 25 year storm frequency should be used. Cross structures for major highways, railroads, and canals should be designed for flows from a 25-year storm, for less major crossings, flows from 10 year storm can be used, and flows from a 5 year storm can be used for structure within a field or a farm. pounding for strom flow in the field should be considered for surface drain capacity estimates, but pounding on arable land should not be permitted, for periods exceeding 48 hours. Most crops submerged over 48 hours suffer reduced productions, and many crops are destroyed completely.

Irrigation

Many drainage problems in irrigated areas are traceable to faulty irrigation practices, particularly the application of too much irrigation water. To Determine the extent to which irrigation practices contribute to such problems, studies should be made of i) the effect on the watertable for each irrigation, ii) watertable fluctuations through out the irrigation season, and iii) long term changes in watertable elevation after irrigation was introduced in the area. Inefficient application and use of irrigation water are likely to result in the loss of large amounts of water by deep percolation and surface runoff. Methods of applying water very widely, depending on such factors as soil, slope, crops, size of field, delivery schedule of water, and available flow.

The main factors which have created waterlogging and high ground water levels are:

i) Supply and application of full irrigation supplies to the command area even though the commands are only partially developed.

ij) Farmers have still to adjust to irrigated agriculture.

iii) Drainage network only partly completed in the command area where irrigation is introduced.

iv) Structures such as tubewells, dugwells etc. using groundwater in pre-irrigation period get disregarded by farmers because of cheaper rates of canal water. The irrigation projects are now designed for supplies, both from canal and ground water sources. Hence, use of earlier ground water facilities and extremely slow pace or neglect to add new ground water structures viciates the project design assumption. Provision of adequate water supply to the fields for irrigation keeping in view the status of development of command area, farmers readyness to use irrigation water efficiently, extend of drainage construction and the use of ground water facilities are the most important measures against waterlogging conditions.

Seepage

The amount of seepage generally depends on the following factors

i) Height of canal embankment and soil type.

ii) Distance of nearest drain from the canal and difference of water levels of canal and the drain.

iii) Location of barrier or hard pan below soils.

iv) Hydraulic conductivity of soils through which seepage flow takes place.

v) Even if a canal is in cutting in rocky reaches and previous strata like murum is encountered in the bed of the channel, seepage occurs and sub soil water movement below rocky strata continues till the drainage channel relieves water pressures through its pervious bed. Otherwise artisan pressure builds up and are relieved through fissures in rocky strata or by tubewell pumping.

Table 4 has been developed to help asses water source factors and their influence on drain type.

Table 4 : Assessment of water source factors and their influence on drain type.

S.No.	Watertable factor	Implied drainage considerations
1.	Water table fluctuates with irrigation	• Improved water management may preclude drain system. • Pipe drain grid system will handle excess irrigation water.
2.	Water table fluctuates with rainfall	• Better surface drainage is needed • Tube drain system should be considered.
3.	Artesian pressure from deep water bearing aquifers	• Drainage relief well or deep pipe systems are needed
4.	Seepage from canal or reservoir	• Lining of canal or reservoir to prevent seepage may eliminate the drainage problem • Interceptor drain pipe or open drain near canal or reservoir.
5.	Seepage from outcrops or along toe of bench	• Interceptor drain pipe or open drain
6.	Seepage from leaking artisan wells	• Seal or cap well to prevent uncontrolled flow. • Isolate artisian flow and carry away in deep open drain
7.	Pounded water at lower ends of fields	• Proper leveling will eliminate pond areas • Pump- back drain systems • Proper tail water waste ditches
8.	Pounded water in fields	• Proper grading for even distribution • Surface field drains

9.	Drainage water of poor quality	• Drainage waste water must be disposed off so as to eliminate contamination downstream (irrigated areas only).
10.	Drainage water of good quality	• Drainage waste water can be reused or mixed with fresh water for reuse downstream.

(Source - Donnan and Schwab, 1974)

5.3.4 CROP FACTORS

Some crops require large amounts of irrigation water as compared to others. As the application losses are directly proportional to the amount of water applied, addition to ground water will be more in crops which require larger quantities of water. The high water requirements of sugarcane have been responsible for waterlogging in many areas. Area under lowland rice generally increases beyond expectation in irrigation commands. As lowland rice needs more water for its optimum growth, irrigation losses are also high.

While selecting crops, distinction should be made between the areas where waterlogging is developing and where it has already developed. Proper selection of crop rotation can help reduce the ill effects of water logging.

Crops susceptibility and stage of growth-There are wide differences in susceptibility to damage amongst various crops and amongst varieties of a crops. Stage of growth at which submergence occurs also influences the extent of damage. In general, crops are more tolerant at later stages of growth than at the beginning. Though no exhaustive studies have been conducted on crop damage vis-a-vis soil submergence and stage of growth data pertaining to many crops on specific locations is available. The results of these studies should be fairly good indicator of the performance of these crops at other locations under conditions similar to that of the experiments. The information, therefore, should be useful in calculating the design flow rates.

5.4 DESIGN OF HORIZONTAL SUBSURFACE DRAINAGE SYSTEM

Design of subsurface drainage (SSD) system includes following elements to be determined:

- Soil hydrological parameters
- Spacing and depth of laterals
- Diameters and gradients of lateral and collector pipes
- Envelope Design
- Layout of laterals and collectors

5.4.1 Soil hydrological parameters

The proper identification of a drainage problem and selection of a technically and economically viable solution requires detail investigations of soil condition and other related factors. It is well known that the two soil properties required for many of the depth and spacing equations are the saturated hydraulic conductivity (Ksat) and the drainable porosity f.

5.4.2 Saturated hydraulic conductivity

The hydraulic conductivity, K is the constant of proportionality in Darcy's law and is defined as the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. Hydraulic conductivity can have any units of length/time (m/day). Its order of magnitude depends on the texture of the soil and is affected by the density and viscosity of the ground water. Number of techniques for measurements of hydraulic conductivity like auger hole method, piezometer, two well, four well techniques etc. Most effective way to measure hydraulic conductivity (Ksat) is to install a drain and calculate the value of Ksat from drain discharge and water table position.

5.4.3 Drainable porosity

It is treated as a constant in drain spacing equation for failing water table condition. In, reality, however, the rate of pore space drainage varies with time and it also depends upon rate ratio of fall of water table.

5.4.4 Transmissivity

The transmissivity, KH is the product of average hydraulic conductivity, K and the saturated thickness of the aquifer, H. Consequently, the transmissivity is the rate of flow under a hydraulic gradient equal to unity through a cross section of unit through a cross section of unit width and over the whole saturated thickness of the water bearing layer. It has the dimensions of length^2/time and can, for example, be expressed in m^2/day. It's order of magnitude can be derived from those of K and H.

5.4.5 Impermeable layer

The influence of the impermeable layer depends on its depth below the drains and also on spacing. The impermeable layer may be taken as that having a hydraulic conductivity of one fifth, one tenth, or less than that of the overlaying layers.

5.5 DRAINAGE DESIGN CRITERIA

The drainage design criteria expresses the agriculture function (the drainage requirement of the widely grown crop in the area) of the drainage system in terms that can be used as input in the drainage equations. For steady state equation,' it required in the form of hydraulic head-discharge (h-q) relationship. Hydraulic head is taken as depth of drain minus depth of watertable congenial for most of the crops which is about 1.0 m. The q is taken as drainage coefficient. In unsteady state equations, input information is required in the form of watertable draw down in a given time. This may be taken as the watertable drop below active root zone from the ground surface within tolerable time for a widely grown crop in the project area.

5.5.1 Drainage Coefficient

Capacity of drainage system depends upon drainage coefficient. It is the rate of removal of water from the soil surface or soil profile necessary to provide certain degree of crop protection from excess surface and sub surface water within a specified time of 24 hours. For surface drainage design it is generally expressed as flow rate per unit of area which varies with size of area and for subsurface drainage design it is expressed in terms of depth of water in mm to be removed in a specific time of 24 hours. The coefficient varies

with the geographical location, land use and size of area to be drained. In humid areas this is closely related to the rainfall and soil permeability. Therefore, within areas of similar climate and soil characteristics, there is similarity in drainage coefficient. For this reason, it is possible to establish ranges of drainage coefficient that are applicable to large areas. In arid and semi-arid irrigated areas, the irrigation system and field application losses determine the drainage coefficient. Drainage coefficient can be computed from various approaches depending upon the objectives and cost effective scenarios of draining lands. Some of them are:

(a) SCS/USDA methodology for arid regions

(b) Duty of irrigation water and cropping intensity

(c) Yearly water balance

(d) Average water balance for monsoon period

(e) Leaching requirement

(f) Yearly salt balance

(a) SCS/USDA methodology for arid regions

$$Q = \frac{(P + C)^* I}{100\ F} \quad \ldots\ldots (1)$$

Where Q is the drainage coefficient in cm/day, P and C are percolation and seepage losses expressed in percentage depth of irrigation, I is the depth of irrigation water in cm and F is irrigation interval in days.

From the information and data currently available, the drainage coefficient applicable to irrigated land generally range from 1 mm/day to 7 mm/day.

(b) Leaching requirement

The leaching requirement can be calculated with the following formula:

LR ECw/(S*ECe-EQw) ..... (2)

Where

Ecw EC of irrigation water (dS/m).

ECe EC of saturation extract or salt concentration in the root zone.

The depth of irrigation water required to meet this leaching requirement:

Di (ET-Dr) / (1-LR) ..... (3)

The depth of drainage water required to meet LR

dw (ECi/ECd) * Di ..... (4)

Where ECi and ECd are irrigation and drainage water quality respectively.

c) Yearly Salt Balance

Drainage water requirement to maintain the salt balance can be computed by:

ECiw * Diw = ECdw * Ddw ..... (5)

Where

ECiw and ECdw are EC of irrigation and drainage water and, Diw and Ddw are the depth of irrigation and drainage water, respectively.

5.5.2 SPACING AND DEPTH OF LATERALS

- **Depth**

Depth of the lateral drains can be predetermined based on the following factors and spacing can be calculated from the above equations. The factors are:

- The water level that can be maintained in the main drain or outlet depth.
- Minimum soil cover should not be less than 60 cm.
- Depths of water table that permit optimum growth of crops. Water table depth of 1.0 m would be optimum for most crops.
- The critical water table depths that check the re-salinisation.
- Where subsoil is relatively impermeable, place pipe on or above the impermeable layer. If pipe must be placed below the impermeable layer, the trench should be backfilled with permeable soil or gravel.
- The depth that can be reached by available machinery.

In general, the depth of drains may be limited between 1.0 and 2.0 m. The length of lateral drains varies from 200 to 600 m depending on the natural slope available and layout of the areas.

- **Spacing**

The water table between two parallel drains is curved, its elevation being highest midway between the drains. The factors which influence the height of water table are: precipitation and other sources of recharge, evaporation and other discharge, soil properties, depth and spacing of the drains, cross sectional area of the pipes, and water level in the drains. A definite relationship exits between depth and spacing of drains. For soils of uniform permeability, the deeper the drains, the wider the spacing, hence fewer drains are required and the pipe cost is lower. Several equations relating the above factors are available in literature. The most common equations used are given below.

Steady state conditions are mostly applicable in flat areas of humid regions, where drainage need is determined by, long duration. intensity rainfall. Hooghoudt (1940) gave a steady state drain spacing formula (known as ellipse equation) for pipe drainage. He judiciously combined the solution for radial flow and horizontal flow to drains to develop an equivalent depth de. The ellipse equation can be used to any reasonable depth to an impervious layer.

$$q = \frac{4 K h (2d_e + h)}{L^2} \qquad \text{..... (6)}$$

Where,

- q Drainage rate in volume per unit area drained per unit time, m/day.
- K Hydraulic conductivity of the soil, m/day.
- L Spacing between the drain, m.

h Watertable above the drain centre axis, m.

d_e Effective depth of impervious layer below drains, m.

If the hydraulic conductivity of the layer of the soil below drain depth is different than the hydraulic conductivity of the soil above drain depth, above equation can be written in the following form:

$$q = \frac{8\ Kb\ de\ h + 4\ Ka\ h^2}{L^2} \quad \ldots\ldots (7)$$

Where,

Ka Hydraulic conductivity above the drain

Kb Hydraulic conductivity below the drain

The term $4Kah^2/q$ is taken by Luthin (1966) to represent the flow to the drains primarily through the saturated soil above the drains and the term $8Kbdeh/q$ to represent the flow through the saturated soil below drain depth.

Above equation may be written as:

$$q = A\,h + B\,h \quad (8)$$

Or this equation can also be written as:

$$\frac{q}{h} = A + B\,h \quad (9)$$

where

$$A = \frac{8\ Kb\ de}{L^2} \quad (10)$$

and

$$B = \frac{4\ Ka}{L^2} \quad (11)$$

Ka and Kb are the hydraulic conductivity above and below the drain respectively. Above equation shows that q-h relation will approach a straight line when the value of Bh^2 is small, compared to the value of Ah. Such a straight line indicates a better transmissivity below the drain level than above the drain level. When flow above the drain level is not low, the q-h line will be curved and its shape will depend on the relative contribution made by each of the two layers. The stronger the curvature the larger the contribution made by the layer above the drains. A plot of q/h versus h helps one to interpret the measured q - h relationship. The q/h versus h relation is presented by a straight line making an angle with the horizontal axis. If the value of Bh ($\tan a = 4K/L^2$) is relatively small, the q/h line will be horizontal.

5.5.3 Envelope Design

Envelope materials are used to protect the drain pipes from clogging. Gravel, woven and non-woven geotextiles are used as envelopes. Gravel envelopes are, however, now becoming obsolete due to the problem of the gravel transport from distant places and laying difficulties around the drain pipe in the trench. Geotextiles are light and convenient to use. The main purpose of placing envelopes around pipes are to prevent the entry of

soil particles which reduce pipe flow capacity, improve permeability in the immediate vicinity of the drain openings, and provide suitable bedding for pipes by stabilizing the soil around the pipes. Drain sedimentation is affected by soil factors and drainage installation procedures. The soil factors which have most significant effects are: texture, structure, particle shape, density and soil mineralogy. Broughton (1993) suggests that in humid and sub-humid climatic zones, soils without dispersion problem do not require envelopes when the clay content is greater than 30%. Where the soil has an SAR > 8 at the time of installation an envelope is recommended for soils with less than 40% clay in any layer above pipe. Design of envelope is a function of soil particle diameter. Fabric envelope selection criteria:

Dierickx et al. (1992) discussed envelope requirements as a function of soil particle size and geotextile type. They identified two main types of envelope: one less than 5 mm thick, the other being greater than 5 mm.

For envelopes less than Smm thick: $O_{90}/D_{90} < 2.50$

For envelopes greater than 5 mm thick: $O_{90}/D_{90} < 5.00$

where

O_{90} The pore size of the geotextile for which 90% of the pores have a smaller diameter.

D_{90} The particle size of the soil for which 90% of the pores have a smaller diameter.

For both types of the envelopes

$O_{90} > 0.1$ mm

To prevent fabric Clogging

Koerner (1990) recommends Caroll's criterion

$$\frac{O_{95} \text{ in mm of geotextile}}{D_{85} \text{ in mm of soil}} < 2.5 \quad \text{..... (12)}$$

5.6 CONSTRUCTION TECHNIQUE

The construction of SSD normally involves:

(a) Setting out of alignment and levels

(b) Excavating the trenches at required grade

(c) Placing the drain pipe and envelope material

(d) Backfilling the trenches

Pipes may be installed in a trench, excavated by hand or by machine, or these may be installed directly in the soil without first excavating a trench. The principle types of machines used for installation are backhoe, trenchers and trenchiess plow. Trench installation involves: the excavation of a trench, the laying of the pipe with or without an envelope, and the backfilling of the trench.

These three activities can be done in a series of continuous operations by machines.

However, manual installation may still be justified where either only a very small area needs to be drained and there is no machine locally available ' or in general where there is a preference for labour intensive work. Normally a team of 20 labour can install 50 m/ day.

The combination of machine trenching using a backhoe and hand laying is frequently employed on small areas particularly within stony soils, and for the installation of larger collector drains. Installation speed of 150 m/day per backhoe can be assumed.

The trenchers generally excavate and finish a continuous trench to the required depth and grade with laser control and have attachments for pipe installation and backfilling of the trench. These machines operate continuously and are either wheel or chain type. The speed of these machines can be up to 1000 m/hr although 600 m/hr is more typical. The speed depends on installation depth, soil type, field size and conditions. The trenchers can install larger diameter pipes and up to depth of 3.5 m.

Trenchless machines have the potential to work faster and ideally suited to the installation of corrugated plastic pipe up to 200 mm diameter and usually they can place pipe up to 2.2 m depth. Installation speed of these machines can be 5000-6000 m/day.

Drainage Materials

These are consider in two groups pipes and envelope material. The pipes used for laterals are with open joints or perforations, which collect and convey drainage water into collectors. Clay and concrete pipes used for laterals are usually made in lengths of 30 cm with 10 cm internal diameter. The essential feature of such drains is that water enters the pipe through the gaps between the tiles. However, now a days with the availability of faster installation speed these have become obsolete. The perforated plastic tubing Of PVC are now used. For lateral pipes perforation are provided in 2 to 3% of the surface area of the rectangular perforation of 2 mm width in the valley of the corrugations. Envelope materials can be gravel, straw, geofabric woven or non-woven type. Now a day, geofabric materials are preferred due to their longer life and easy to install over pipes.

Drainage Structures

The installation of SSD includes the construction of structures like junction boxes, manholes or inspection chambers, outlet structures, drain and road crossings, etc.

5.7 SUMMARY

Drainage can be either natural or artificial. Most lands have some natural surface and subsurface drainage. When natural drainage is inadequate to handle the water reaching the land by either natural or artificial means, manmade or artificial drainage is required. Artificial drainage thus fills the gap between that provided by nature and the established need. This is usually done by supplementing existing natural systems. For example, natural streams and watercourses can be re-sectioned, or where no suitable ones exist, new drainage channels can be constructed. Almost every physical aspect and conditions of lands, as well as man's potential agricultural use of them will affect the ultimate drainage requirement.

5.8 SELF –ASSESSMENT TEST

- Define Agriculture Drainage?
- What are the benefits of drainage?
- What are different methods of drainage?
- What are the preventive measures for waterlogging & salinity?
- Which factors influence the selection of drainage?
- What is the Hooghoudt's equation to determine drain spacing?

5.9 KEY WORDS

- ***Agricultural Drainage*** means removal of excess water and salt from the soil.
- ***Hydraulic conductivity*** means as the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.
- ***Impermeable layer*** means layer having a hydraulic conductivity of one fifth, one tenth, or less than that of the overlaying layers.
- ***Drainage Rate*** means rate of removal of water from the soil surface or soil profile necessary to provide certain degree of crop protection from excess surface and sub surface water within a specified time of 24 hours.

5.10 SUGGESTED READINGS

- Analysis of subsurface drainage design criteria 1995 ed. RAJAD (Rajasthan Agriculture Drainage Research Project) Publication.
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UNIT-6

ROLE OF FARMER'S PARTICIPATION IN INTEGRATED WATER AND AGRICULTURAL MANAGEMENT

Structure:

6.0 Objectives

6.1 Introduction

6.2 Sustainability

6.3 Fitting Projects to People

6.4 What People/farmer Participation is

6.5 Why it is needed

6.5.1 Productivity

6.5.2 Power realities

6.6 What is to be done for effective farmer's participation

6.7 Global scenario of farmers participation

6.8 National Scenario of Farmers participation

6.9 State Scenerio of Farmers participation

6.9.1 Experience of Farmer's Participation in Chambal Command Area(CCA)

6.9.1.1 In Drainage Management

6.9.1.2 In Irrigation Management

6.10 Conclusion

6.11 Self Assessment Questions

6.12 Suggested Readings

6.0 Objectives

It is estimated by the year 2025, 66% of the world's population will face water shortages unless water is used more wisely. Rajasthan state with low & erratic rainfall and with the deeper strata of saline is in very critical situation. The availability of water resources for agriculture purposes is likely to be curtailed in future due to increased demand in other uses i.e. drinking, live stock, industries, power generation etc. On the contrary, need for more water for producing food and fiber to meet the demand of increasing population cannot be ignored.

The growing demand of water for irrigated agriculture makes it imperative that irrigation system management strategy gives the optimum agricultural production. Low efficiency of water utilization is prevalent in the agricultural as well as the domestic and industrial water consumption sectors also. Therefore, there is a need of the hour that highest priority is given to the water saving practices and devices.

Agriculture sector is the largest water user sector using about 90% of the water and it is assessed that the present efficiency of utilization in medium and minor surface water

irrigation project commands is less than 40%. With modern irritation techniques like sprinkler and drip, the over all efficiency can be improved to a great extent. The efficiency of irrigation system also depends to a large extent on operation and maintenance of the water delivery system. The involvement of the beneficiaries in water management at the field level is one field, where improvement in irrigation efficiencies can be achieved.

It should be endeavor of every Agriculture Engineer to ensure optimal utilization of every drop of water, through people participation with the aim of increased water-use efficiency and use of water saving devices and practices leading to an efficient, scientific, innovative and responsive irrigation management.

6.1 Introduction

Agriculture is the mainstay of Indian economy. It sustains over 70 percent of the population; contributes 35.6 percent to gross national products and adds 39 percent in export income. Of the total geographical area 328.73 million hectares (Mha), 304.21 Mha is reported for land utilisation. Out of the latter, area under cultivation is 142.74 Mha of which 37.63 Mha is double cropped. Thus the gross area under cultivation is 180.36 Mha. The per capita availability of land comes to only 0.60 hectares, one of the lowest in the world. The average size of farm holding is 1.82 hectares but is fragmented in 5-6 parcels reducing the operating unit to 0.3 to 0.4 hectares only.

There are 89.39 million farm holdings in the country of which 50.98 million are marginal (one hectares and below) and 16.10 million small (holding up to 2 hectares). Thus a total of 74.6 percent farm holding farm holding belongs to marginal and small categories, which operates only 26 percent of the cultivated land. Population in India is increasing at the rate of 2.22 percent per annum and out of this 80 percent population live in villages. Thus the country represents a very complex socio-economic milieu and therefore a challenging task is to sustain the agricultural production with the population growth (Prasad C., 1992).

After independence, a huge investment & tremendous efforts was made on creating irrigation potential to have self-sufficiency in food production through irrigated agriculture. All these efforts have resulted in raising created irrigation potential from pre-independence figure of 22.6 Mha To 91 Mha. Merely creating Irrigation potential by construction irrigation system is no guarantee about its full utilisation to get envisaged benefits. With the application of excess irrigation water and poor land and water management, the agricultural productivity did not rise to the desired extent as projected in the beginning of irrigation projects. Results of failure are:

- ❑ Inequity, in-adequacy and unreliability of supply of water
- ❑ Gap between irrigation potential created and utilised
- ❑ Low irrigation efficiencies
- ❑ Lack of interdisciplinary approach in system operation
- ❑ Low level of farmer's participation

The basic causes of failure are:

- ✓ Insufficient budget causes least stress on operation and maintenance (O&M)
- ✓ Preference to construction over O & M

- ✓ Indifferent & unconcerned farmers attitude
- ✓ Lack of administrative & political will towards betterment of irrigation system
- ✓ Lack of farmers participation

So to overcome the above deficiency, participation at every stage of irrigation projects was realised by the Government. As they are the real stakeholders and are deeply concerned for the socio-economic development and sustainable development.

6.2 Sustainability

Sustainability, sustainable development and sustainable agriculture have become buzzwords in the World's scientific and political circles during the last two decades. Sustainability has become a global movement, a global ideology, a new paradigm launched by scientists and politicians toward the common people in an attempt to change their attitudes toward the acceleration of consumption of non-renewable natural resources and also to deliver a very serious warning for the survival of today's humanity and civilization.

Unfortunately agreement on a definition of sustainable agriculture has not yet been reached, what does it mean, what is the main target of sustainability? The answers are unclear, according to John Luna (1993), who told a Callaway Gardens Workshop: "I don't think there's a person in this room who can come up here and say what "What sustainable agriculture is". But there is great number of views, different definitions derived from the many different objectives sustainability is seen as serving.

The word sustainability means " the ability to keep in existence, maintain or prolong". It represents a state of holding, lasting, continuing. But is there such a state existing in nature. Perhaps nature itself is very often not sustainable at all.

Throughout the world a number of scientists, working groups have defined it, some of them are reproduced below.

"The successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources. (CGIAR)

John Ikerd (1993) asserts that sustainable system must be environmentally sound, economically viable, and socially supportive if they are to remain productive and useful over time.

Pearce and Turner (1990) argue that a sustainable system must follow four basic rules:

I. Use renewable resources at a rate less than natural rate of regeneration;

II. Maintain wastes from production below the assimilative capacity of the environment;

III. Ensure that the reduction of the non-renewable resources is compensated by increases in renewable resources;

IV. Guarantee that depletion of non-renewable resources occurs only if accomplished by an increased standard of living.

From the above definitions it can be derived that sustainability must account for the

regeneration of natural resources at a rate faster than the rate of their use, while maintaining environment and sufficing the needs of society.

6.3 Fitting Projects to People

Putting people first in development project comes down to tailoring the design and implementation of projects to the needs and capabilities of people who are supposed to benefit from them. No longer should people be identified as " target groups". Rather, abstractly speaking, we should consider them as "intended beneficiaries". They are to be benefitted, rather than "impacted." In design and implementation we have only intentions, since our knowledge of how to improve the productivity and well being of the poor majority is limited. We can and should be clear about whom we expect to benefit, and how, but we cannot be certain our efforts will bear the desired fruits until the processes of economic and social change have been put in motion. Fortunately, some of the unanticipated outcomes can be favourable. The probabilities of gaining momentum, rather than losing it, in the course of carrying out projects should be greater to the extent that the mode of design and implementation reflects a "learning process" approach. This should enlist the participation of intended beneficiaries as much as feasible in all aspects of project operations.

Often a question arises whether the participatory approach advocated here can get and keep the support it needs. This is a stereotyped view, but one finds it applied in many if not most developing countries. Certainly there are situations in some countries where a participatory approach is unlikely to gain acceptance or become effective. But the stereotyped view should not obscure all possibilities for working in this desirable mode.

- The expectation that strictly technocratic non-participatory approach can "deliver the goods" has lost credibility in recent years. Both poverty and population continue to grow is likely to open opportunities for more participation than now because of favourable ideological orientations, fear of present disorder, or apprehension over when an increasingly unjust future otherwise holds for the next generation.
- Governments are facing overwhelming fiscal problems, with a triple burden of budget deficits, foreign exchange shortages, and mounting external debts. There is more need than before to mobilize local resources both for capital and recurrent costs and to put all resources to their best possible uses. Meeting these needs requires greater local participation.
- The capabilities of the poor majority have been upgraded over the last 30 years by education, health, communication, and other investments. Self management of development task is now more feasible. The poor are more confident as well as more competent to handle responsibilities of decision making and implementation.

6.4 What People/farmer Participation is

Participation, imperative for the development of developing countries denotes to the involvement and empowerment of people in solving their problems. Participation in a broader canvas encompasses the rapport building, needs/problem identification, planning, designing, implementation and evaluation of development programmes with the inclusion

of people in the process of decision making. It eventually activates people from passiveness to be decision-makers, implementers and managers required for the self-reliance and sustainable development (Dadich, L.K., 1993).

Involving farmers and getting their participation in canal operation and on-farm water management is now generally accepted at all planning levels to improve the irrigation efficiency. However, the perception of participation varies from individual to individual depending upon their background. According to Brewer(1986), farmers participation refers two things:

1. Farmers should contribute to system operations and maintenance
2. Farmers should have some influence over system decision

The National water Policy of 1987 considers the farmers' participation in water distribution and collection water rates as an integral part of irrigation systems.

6.5 Why it is needed

According to Brewer (1986), there are two reasons for the need of farmer's participation:

6.5.1 Productivity

Farmers produce crops; government officers do not. Farmers bear all the risk of farming; if a crop falls, it is the farmers who suffer; not the irrigation engineer or extension officer. Another way to look at the situation is that farmers are the customers of the irrigation system manager. So it is a duty of system manager to please the farmers as best. Therefore, it is best to have farmers into decision-making.

6.5.2 Power realities

Farmers actually have most of the power in an irrigation system anyway, if they choose to exercise it. At any time they may disrupt the government plan and break the irrigation network if they want. Furthermore, the government recognises that it lacks the manpower and other resources to fully control water and perform all of the maintenance on any system.

Also, farmers now influence canal operation plan, even when they have no direct voice. The most common way is to appeal to politician, who than put pressure to government servant to change their decision. Sometime through corruption-more direct method, they influence the system decision.

But there are also some other reasons for the need of farmer's participation

- In view of liberalisation and privatisation, people are expected to assume a greater role and share the cost.
- No longer possible to burden the government for the works, which are beneficial to the people, and so people, should be responsible for O&M.
- Development of sense of ownership towards the irrigation system.
- Reduce conflict.
- Inadequate fund for operation and maintenance for irrigation systems.

6.6 What is to be done for effective farmer's participation

Effective farmer's participation is only possible when there is a proper commitment of implementers to involve and empower people in decision making from the very initial stage of project. In any case, people should become self-reliant to have people's programme and government's participation rather than the existing government's programme and people's participation (Swarankar, R.C., 1993). So to have effective participation two basic principles are required:

Communication-	between farmers and other farmers
	Between farmers and officers
Discipline-	among farmers
	among officer

6.7 Global scenario of farmers participation

All over the world, the countries that once promoted more government involvement in irrigation management are adopting new policies of involving farmers to take over the system. Farmer's involvement encouraged in operation and maintenance, allowing the government or public water irrigation agencies to focus on the main irrigation network, that is, rationalization of the respective roles of government and water users. The Participatory Irrigation Management (PIM) in becoming a global trend now (Tanwar 2001).

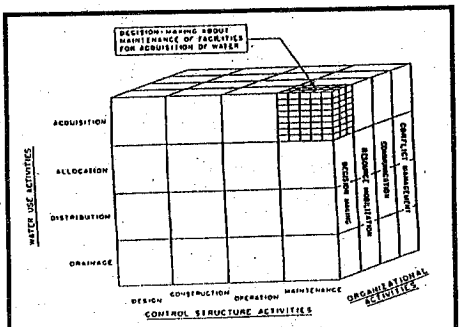


Figure 1- Matrix of Irrigation Management Activities

Uphoff (1997) has represented the multiplicity of irrigation management tasks and their interrelationship in a matrix diagram as indicated by figure-1. Irrigated agriculture management activities mainly focus on:

1. Water use activities
2. Control of water structures
3. Organizational functions

Canal irrigation sector has three phases.

Phase I- Main challenge to get water from its source of acquisition to farmers' fields considered as the domain of the civil engineering.

Phase II- Next challenge to maximize the land returns as the domain of agricultural engineering cum agronomist domain.

Phase III- Final challenge to the water users (farmers) to optimize the agricultural production with precise management and application of irrigation waters.

Management approaches in irrigation generally fall into three categories:

1. Government / public sector management,

2. Private sector management, and
3. Users organizations.

The last approach is now widely practiced as public sector management is inefficient and burdensome to the government, and private sector management does not fit irrigation management, which involves a large number of small farmers. The government can better handle the regulatory aspects, while the management aspects shall be rests with the irrigation users. In the advanced countries, the USA, France and Japan, the irrigation users dominate up to project/sector level, while in developing countries the users could hardly touch the quaternary or tertiary level of the irrigation management Figure-2).

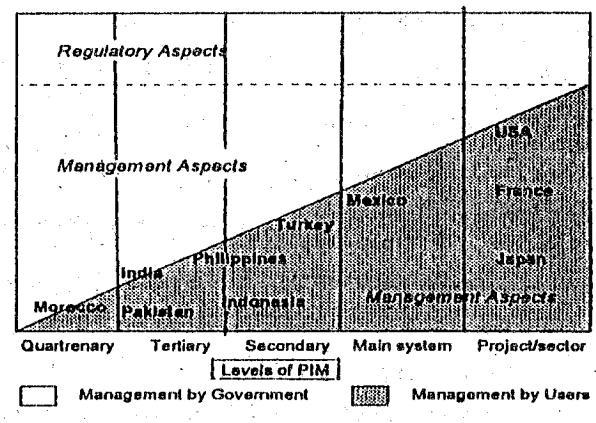


Figure 2 Level of Farmers Participation in Irrigation Management

Table 1 - World Countries with WUA managed Irrigation System

High level (Project/Sector)	Medium Level (Secondary)	Low Level (Tertiary/Quaternary)
USA	Mexico	China, Nepal, Sri Lanka
France	Philippines	India, Argentina, Pakistan
Japan	Turkey	Egypt, Colombia, Chile
Italy	Indonesia	Brazil, Bulgaria, New Zealand
		Vietnam, Albania, Jordan
		Morocco, Madagascar, Fizi
		Moldova, Romania, Tanzania
		Senegal, Macedonia

Countries over the world, which have adopted high or low level irrigation reforms towards partnership of farmers in irrigation management are listed in Table 1.

6.8 National Scenerio of Farmers participation

Irrigation system in India comprises canal irrigation based mainly on large irrigation system, tank irrigation, tubewell and well irrigation, and other sources of surface lift irrigation and microstructures. The canal and tank irrigation constitutes about 40% irrigation (canal 34% and tank 6%), that is almost completely managed by the state government irrigation departments. So canal irrigation is a government-dominated sector, and governments have assumed primary responsibility for developing and managing canal irrigation systems.

India have a very rich experience of farmers participation both in traditional & in large scale projects. These are the traditional people participated program

- ***"PHAD system"*** (group of contiguous farms growing same crop) was prevalent in Maharashtra for over 200 years.
- ***"Khuls system"*** in the foothills of Himachal Pradesh.
- ***"Tanks system"*** in the south India.
- ***"Ahar-Pyne system"*** was prevalent in South Bihar.

Conventional government managed irrigation system in India include:

- ***"Warabandi System"*** in the North India based on the Northern India Irrigation and Drainage Act of 1873 in states of Punjab, Haryana, Rajasthan and Uttar Pradesh,
- ***"Shejpali System"*** in the Western India based on the Bombay Irrigation Act of 1879 in states of Maharashtra and Gujarat,
- ***"Satta System"*** in the Eastern India based on Bengal Irrigation Act of 1876 in states of West Bengal, Bihar and Orissa, and
- ***"Land Class System"*** in the South India with water rights assigned to land and the collected as land tax in states of Tamil Nadu and Kerala.

To have financial viabilty and sustainabilty of the water users associations, the following developmental steps were observed:

In 1974- CAD agency was created to implement on-farm water management activities, under financial assistance from the central government.

In 1985- CAD promoted the farmers participation in operation and maintenance of irrigation systems.

"Action Research Programme" was launched with Rs 0.28 million per programme.

In 1987- Guidelines for Outlet Committees " at outlet level and " Managing Committees" at minor level were issued with provision of management subsidy of Rs 100/- per ha for first two years and Rs 75 for 3rd year.

In 1993- Emphasis with the revision of cost norms on Action Research Programme.

In 1996- After first national level conference on PIM at New Delhi the Ministry of Water Resources are now providing Rs 250/- per ha, the state share is Rs 200/- per ha and Rs 50/- per ha to be contributed by WUA.

In India the irrigation management transfer to farmers is being tried at tertiary level as a means to reduce pressures on government finances, improve performance of irrigated agriculture, and ensure sustainability of irrigation systems (MOWR 1995, Navalawala 1995, India NPIM 1998, Joshi et al. 2001).

There are mostly pilot or partly full scale PIM programs in 16 states: Andhra Pradesh, Assam, Bihar, Gujarat, Goa, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal (Navalawala 1995, Brewer 1997, INCID 1996, MOWR 1997, Tanwar 1997/ 2001, Joshi et al. 2000).

6.9 State Scenerio of Farmers participation

The government of Rajasthan has adopted the PIM policy in all the three major irrigation commands of Chambal, IGNP and Mahi. More them 335 WUAs are registered in CAD commands. More than 3843 outlet committees are formed during the implementation of on-farm development works or after their completion in IGNP.

The lack of focus, powers and functions led to the demise of WUA on Gudha Irrigation Project, which had been formed under USAID project. The department of irrigation under World Bank funded agriculture development programme has taken up pilot projects in 6 minors. In Chambal Command also three WUAs, other than outlet committees, have been formed and have started joint action for regulation and rotation of water.

Awareness campaign have been taken up by organizing state level and project level state/project levels with active participation of farmers. Training programme for officials and farmers have been taken up and education tours to other state to see the model projects. A high level working group and a steering committee are functioning in the state to monitor the progress and provide impetus to PIM. The state contemplates one WUA for each minor canal. A distributary level federation will be formed. These societies will take over management in distributary command. WUA will be responsible practically for all activities in its area of jurisdiction. IMTI Kota is providing training facilities of agency staff, farmer's organization and farmers. A PIM manual has been prepared and circulated. The Rajasthan Farmers Participation in Management of Irrigation Systems(RFPMIS) Act 2000 has been already enacted since July 2000 and RFPMIS Rules enacted since November 2002.

6.9.1 Experience of Farmer's Participation in Chambal Command Area(CCA)

6.9.1.1 In Drainage Management

On Farm Development (1974) : The government made a decision to involve farmers in On Farm Development(OFD) by forming working groups named as Chak and Catchment Committees for efficient implementation of OFD works. These committees are involved since time of area selection to construction and finally to re-allotment. The cultivator problems are disposed off at site itself by concerned site in-charge so that the farmers are not required to approach higher officials. This has established a new relationship between engineers and farmers.

Since OFD programme changes orientation and size of farm holdings because of more rational layout of irrigation, drainage and road systems; and about 5 to 9% land goes under permanent ROW with the consent, co-operation, involvement and participation of farmers through these Committees.

Integrated Water & Agricultural Management Programme (1994): An Integrated Water and Agricultural Management Programme (IWAM), was developed in 1994 in the Rajasthan Agricultural Drainage Research Project (RAJAD), with an objective "to develop, demonstrate and evaluate improved and integrated water management procedures for optimum production and sustainable agriculture with active involvement and participation of farmers" (Gaur & Srivastava, 1996). Because of active farmers participation the encouraging results were observed just after one year of IWAM implementation (Table-2):

Table 2- IWAM Pilot Plot Preliminary Results

Canal rehabilitation	Canal section improvement and better flow characteristics
Flow regulation	Early closure of water courses resulting in water saving (50%)
Cleaning of Water courses (1 Km length)	· Improved conveyance efficiency from 40% to 60%. · Reuse potential of drainage water
Cleaning of surface drains	Lowering water table in IWM-1
Irrigation Improvements (Border strip Irrigation and land leveling)	6 m wide border strip irrigation in appropriate; increased yield; reduced surface runoff; 1800 sqm of irrigated area resulted in 40-50% water saving over flood irrigation.
Agronomic Improvements	Reduced fertilizer use and Weed management in 300 sqm of cropped area improved wheat yield by 20%.

SSD Installation through RAJAD project: Farmer's were so motivated through mass awareness campaign the following encouraging results were found

- Lay out of the SSD system was accepted by the farmer's open heartily and made useful suggestions for further improvement
- Provided Right of Way (ROW) without claiming any crop compensation.
- During restoration they actively participated to restore their fields, watercourses and other utilities.
- Farmers actively participated in closing of irrigation system.
- came forward to close the drains
- Helps in electric shut down and for that they were very co-operating.

6.9.1.2 In Irrigation Management

CAD Model of WUA(1995): Devised and developed by CAD Chambal project organisation, this model is being, in general used by the states' Irrigation department for implementation of PIM. Project authorities prepare the project report, get them administratively approved and financial allocation managed through NABARD or other such financing agency. 10% contribution of the cost of rehabilitation works is, however borne by the concerned WUA, generally in the form of labour component. Meanwhile agriculture extension unit of CAD organisation mobilizes farmers to constitute WUAs and get them registered as co-operative societies.

The farmers of CCA were encouraged to form water users associations to optimise agricultural production per unit of water application. The result of the motivation for forming the water users association was so encouraging that within a year 30 WUAs

were formed in 1995-96. This water user's association through active involvement of the user members have successfully managed, maintained and distributed the water to their respective minor commands. The following achievements of 32 WUA's, in it self tells the story of active participation of the farmers (Garg and Pareek, 1998):

- 245 km stretch of water courses were cleaned
- Developed 215 Compost pits
- Appreciable saving of irrigation water ranging from 30 to 90 days. Overall saving of 507 irrigation days
- Increase in CCA of the respective minors by about 20%. Total additional irrigated area of 700 ha due to adoption of improved irrigation management measures.
- Satisfactory supplies of water to tail ends and 8 to 15 days earlier the water reaches the tail end.

IMTI-Gudha Model(1997): In this model, the minor is first handed over to the respective WUA for O & M, then minimum works pertaining to deferred maintenance of the system are carried out by government funding through respective WUA s only, of course under technical control / guidance of the ID officials. The major advantages are that WUA members understand the system, involve themselves in their operation & maintenance and gain experience, to later on work independently to carry out all O & M works.

Right from the formation of Water Users Association, the farmers were involved in walk through Survey, planing to the execution of the system improvement works. Nature and type of works to be done were discussed with respective WUA, reviewed on technical and 'actual needs'. Farmers were actively involved in revision of chakbandi, change in outlet size & its position re-designing the operation plan, prioritize the works.

Farmers gave helping hand in verification of khasara number, marking of Nakka & W/C alignments, marking of outlet points and Chak boundaries. In the execution of rehabilitation works WUAs worked better than any normal civil contractor so everybody was satisfied with the nature and quality of works executed. Weekly meeting on every Wednesday, between concerned faculty of IMTI, staff of Irrigation division, Bundi and member of WUAs executive chaired by Director, IMTI were held in the project area to review progress and sort out problems, if any. This minimized traditional paper work for obtaining necessary approvals on issues related to administrative, technical and financial matters.

The productivity improvement of important crop due to better water management after USAID(1997-98) was 67% , and that was improved to 105% because of active farmers participation in PIM works(2000-01). They have followed the canal operation plan and removed the unauthorized cuts. So presently the number of outlet reduce to 50% from the previous situation. Appreciable saving of water was observed ranging from 40 to 60% in different minor, was also the impact of active farmers participation.

6.10 Conclusion

Problems in irrigation water management are the product of processes of generating and transferring technology, and much of the solution lies in farmers' capacities and participation. This follows and fits recent shifts in perception and priority. Development

activities should have an equal emphasis on sustainability by taking care on social issue (people participation and adoption of programme by heart). Now, the time has come, where government will have to involve the farmers/beneficiaries right from the planning, designing to the execution of any development project.

Farmer's participation in Irrigation Water Management sector is very much essential because without this the desired objectives of maximising the agricultural production on sustainable basis can not be achieved. Further, the problem related with waterlogging, soil salinity, socio-economic, environmental will also grow immensely resulting in adverse effect on attaining the potential benefit from the irrigation project. The strong need for implementation of PIM has been very well realized by most of the states in India and they have initiated the action. The encouraging success of active farmer's participation in canal operation is yet a difficult task as there is resistance from both sides, unless the benefits to both are clear.

Experience of farmers participation in irrigation and drainage management 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 and proper policies to work with farmers to improve irrigation systems efficiency, equity, accountability, economy and the environmental management. On the other hand financial viability and sustainability of the farmers organizations (water users associations) are also the challenging tasks.

6.11 Self assessment questions

Now you can understand the basic principle of farmer's participation in integrated water and agricultural management. So now you have to make a short note on the following:

1. Why people participation is necessary?
2. What is people participation?
3. How can we make people participation sustainable?
4. What strategy should we follow to fit the people in the project?
5. What is the Global, national & state scenario of people participation particularly in water management?
6. What is the Chambal Experience of Farmers participation in case of irrigation as well as in drainage management?

6.12 Suggested readings

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UNIT-7

RAIN WATER HARVESTING

Structure

7.0 Objectives

7.1 Introduction

7.2 Rain Water Harvesting

7.3 Traditional In-Situ Water Harvesting Structures

7.4 Water Harvesting Structures

7.5 Utilization of Harvested Water

7.6 Action Needed

7.7 Summary

7.8 Self-Assessment Test

7.9 Key Words

7.10 Suggested Readings

7.0 OBJECTIVES

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. Rainwater harvesting is not a new concept in our state. Khadins, Nadis, Kunds, Bawaris were constructed in ancient times for storing rainwater for drinking purposes and diverting it to the fields for irrigation. However, the development of major & medium irrigation projects in recent decades and the neglect of traditional systems have pushed them to a position of insignificance.

7.1 INTRODUCTION

Water is most essential for survival of the organic life. It occurs in nature as fresh water in ice caps, glacier's, rivers, lakes, tanks and ground water reservoirs. The total quantity of water on earth is almost constant and is kept circulating through what is known as hydrological cycle. Available water on earth is not suitable for human being. 97% of this is saline and is in oceans. Out of the rest, 2.3% is in ice caps, 0.6% is as ground water and rest 0.1 % is in lakes, rivers, etc.

Our country has over 16% of population of world but has only 4% of utilizable world water resources. Total geographical area of Rajasthan is 34.20 m ha which is 10.42% of the country, out of which 27.46 m ha is culturable. Total overall water resources of Rajasthan are only 1.18% of the country's water resource. Due to scanty and uneven distribution of rainfall state is severely and regularly suffering from drought problem. In case of area where rainfall is quite good, dry spells even within the monsoon period

results in fluctuation of crop production. In such areas, occurrence of high intensity rainfall event may result in floods. The main problem of rainfall in the state is the large-scale variation in rainfall over different parts (from as low as 100 mm to 1200 mm), its short duration and high variability. The shortage of ground and surface water resources and quality deterioration is due to increasing demand for agriculture, industrial use, domestic use and quality deterioration in quality of usable water due to pollution and salinity ingress.

Frequent droughts in the state have resulted in serious consideration to water harvesting & improve ground water recharge so as to have assured supply even during prolonged droughts. 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 and improve ground water recharge so as to have assured supply even during droughts besides maintaining the ecological balance of the state.

Harvesting of rainwater and re-using it for drinking and life saving irrigation is not a new concept in our country. Water harvesting has been practiced in India for centuries. It has been also mentioned in Vedas (Atharva Ved 19.2.1), one should take proper managerial action to use and conserve the water from mountains, wells, rivers and also rain water for giving piece and prosperity to mankind for a long time.

In semi-arid areas of our country & in central & south India in ancient times, large scale inundation schemes have been used for storing rain water and diverting it to the fields below for irrigating the crops like paddy and sugarcane. Structures have been constructed with sophisticated forms of water control and land management. In Bihar and U.P. there are thousands of 'ahars' covering a total of more than 800,000 ha (Tidewan, 1996).

Rainwater harvesting is not a new concept in our state also. Similar structure were also constructed in western Rajasthan with prevailing unfavorable hydro-meteorological conditions, and inadequate ground water resources, rainwater collection was the only solution. The traditional water harvesting systems were '**Tankas**' (covered underground tanks), '**Khadins**' (earthen embankment in plain area) and '**Nadis**' (excavated or embankment village ponds), which utilized collection of surface runoff from micro catchments. Similar systems of inundation farming in Pakistan are known as 'sailabas' and 'kuskabas'.

However, the development of major & medium irrigation projects in recent decades and the neglect of traditional systems have pushed them to a position of insignificance.

7.2 RAIN WATER HARVESTING

Water harvesting connects collection and storage of rainwater and also other activities aimed at harvesting surface water and ground water, prevention of losses through evaporation and seepage. Rainwater harvesting and runoff recycling has four district components viz. collection (harvesting) of excess rainfall, efficient storage of harvested water, water application (including lifting and conveyance) and optimum utilization of applied water for maximum benefits.

7.2.1 Objectives of Water Harvesting Structures

Water harvesting structures combine multiple objectives, some of them are direct and immediate, therefore, easily understandable. Other benefits are indirect and long term

ones. The advantages of such structures are as follows:

- They intercept runoff and moderate peak flow and volume.
- They increase large absorption of available rainwater leading to all round improvement of moisture conditions.
- They enhance groundwater recharge and improve dry weather flow in bigger streams while ensuring perenniality of many nallahs and medium streams.
- They provide irrigation potential to mini-commands both in rabi and kharif.
- They intercept and reduce silt and thus reduce sediment production in the stream flows and finally in the reservoir.
- They help in levelling up undulation or eroded (gullied) area.
- They help in reclaiming additional productive land.
- They provide a remunerative single or double crop and regular jobs to the people.
- They provide additional employment through tree plantation due to improved soil and moisture conditions; and
- They increase total production as well as total resource for the entire area.

7.2.2 Methods of Rain Water Harvesting

The water harvesting can be achieved by:

- **In-Situ Harvesting**: Nadi, Tanka, Sand Filled Reservoirs, Ponds, Roof Top Collections/Hill Top Collections, etc.
- **Storage of water in aquifers** (natural underground reservoirs): Percolation Tanks, Khadins, Anicut, Check Dams, Sub-surface Dams/Barriers, Injection Wells.
- **Soil Conservation Methods** which helps in increased ground water recharge also: Gully Plugging, Contour Bunding, Afforestation, Contour Trenching, Land Levelling, Terracing, and Bunding of Fields.
- **Enhancement of surface run-off collection**: Catchment Treatment.
- **Evaporation Control**: Chemical films, Coating material, etc.

7.3 TRADITIONAL IN-SITU WATER HARVESTING STRUCTURES

Traditional water harvesting systems are based on sound principles. However, their improvement incorporating modern technology and scientific inputs would make them even more efficient as contribution to solving the problem of drinking water in rural areas along with life saving irrigation.

Tanka

It is a local name given to a covered underground tank, generally constructed of masonry or concrete for collection and storage of surface runoff. This tanka collects the runoff water from artificial catchment constructed all around the tanka. These structures have