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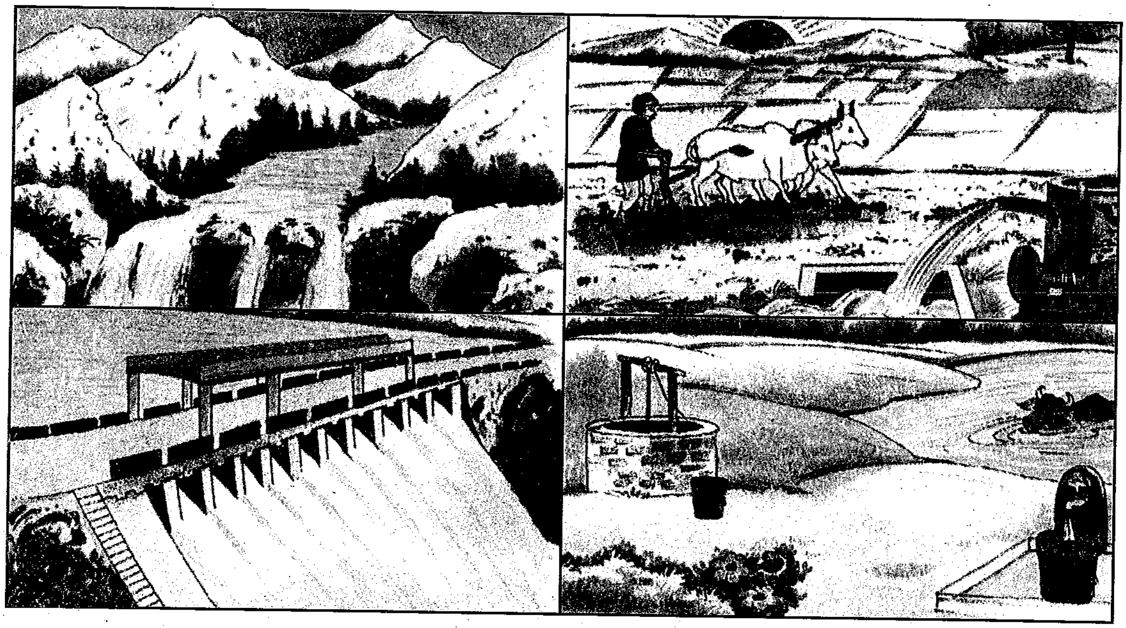
Vardhaman Mahaveer Open University, Kota



Need of Water Resource Planning and Management

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Vardhaman Mahaveer Open University, Kota

Need of Water Resource Planning and Management

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Production January 2008

Printed and published on behalf of the V.M. Open University, Kota by Director (Academic)

Printed by M/s. Harihar Printers, Jaipur Printed Copy 500 January-2008

PDWR-01

Vardhaman Mahaveer Open University, Kota

Need of Water Resource Planning and Management

Unit No.	Unit Name	Page No.
Unit 1	Status of Water Resources in India	1-18
Unit 2	Flow Measurement	19-48
Unit 3	On Farm Water Mangement and Water Budgeting	49-58
Unit 4	How to Apply Irrigation ?	59-72
Unit 5	How Much to Apply Irrigation ?	73-81
Unit 6	How do I know When to apply Trrigation ?	82-92
Unit 7	Sprinkler Irrigation System	93-110
Unit 8	Drip Irrigation System	111-128
Unit 9	Economics of Pressurised Irrigation	129-140
Unit 10	Introduction of Soils and Soils Classification	141-151
Unit 11	Soil Properties and Soil Water Plant Relationship	152-163
Unit 12	Irrigation Scheduling Based on Soil Characteristics	164-170

UNIT - 1

STATUS OF WATER RESOURCES IN INDIA

STRUCTURE

1.0 Objectives

1.1 Introduction

1.2 Irrigation World

1.3 Water in Indian Perspective

1.4 Stages of Irrigation Development

1.5 Water Resource Development

1.6 Surface Water Resources

1.7 Ground Water Resources

1.8 Utilisable Water Resources & Irrigation Performance

1.9 Irrigation Potential Created and Utilized

1.10 Future Need

1.11 Institutional set up for Water Resources

1.12 Self Assessment Test

1.13 References

1.0 Objectives

In the initial phase of water resources development during the plan period after independence, rapid harnessing of water resources was the prime objective. Accordingly, the State Governments were encouraged to expeditiously formulate and develop water resources projects for specific purposes like irrigation, flood control, hydropower generation, drinking water supply, industrial, and various miscellaneous uses. As a result, a large number of projects comprising dams, barrages, hydropower structures, canal network etc. have come up all over the country in successive Five Year Plans. A milestone in water resources development in India is creation of a huge storage capability. Because of these created storage works it has now become possible to provide assured irrigation in the command area, to ensure supply for hydropower and thermal power plants located at different places and to meet requirement for various other uses. Flood moderation could be effected in flood prone basins, where storage has been provided. Besides, supply of drinking water in remote places throughout the year has become possible in different parts of the country.

1.1 Introduction

1.1.1 Water

Water is often believed to have spiritual powers. In Celtic mythology, Sulis is the local goddess of thermal springs; in Hinduism, the Ganges is also personified as a goddess, while Saraswati has been referred to as goddess in Vedas. In addition, water is one of the "panch-tatvas" (basic 5 elements, others including fire, earth, space, air). Alternatively, gods can be patrons of particular springs, rivers, or lakes: for example in Greek and Roman mythology, Peneus was a river god, one of the three thousand Oceanids. In Islam, not only does water give life, but every life is itself made of water: "We made from water every living thing".

Water is a chemical substance that is essential to all known forms of life. It covers 71% of Earth's surface. There are 1.4 billion cubic kilometres (330 million mi^3) of it available on Earth. It appears mostly in the oceans (saltwater) and polar ice caps, but it is also present as clouds, rainwater, rivers, freshwater aquifers, lakes, airborne vapour, and sea ice. Water in these bodies perpetually moves through a cycle of evaporation, precipitation, and runoff to the sea. Water is a colourless, tasteless, and odourless liquid at ambient temperature and pressure. It is a very important solvent. Clean water is essential to human life. In many parts of the world, it is in short supply. Outside our planet, a significant quantity of water is thought to exist at the north and south poles of the planet Mars, and on the moons Europa and Enceladus.

1.1.2 General Facts

World oceans cover about three fourth of earth's surface. According to the UN estimates, the total amount of water on earth is about 1400 million cubic kilometre that is enough to cover the earth with a layer of 3000 metres depth. However, the fresh water constitutes a very small proportion of this enormous quantity. About 2.7 percent of the total water available on the earth is fresh water of which about 75.2 percent lies frozen in Polar Regions and another 22.6 percent is present as ground water. The rest is available in lakes, rivers, atmosphere, moisture, soil, and vegetation. What is effectively available for consumption and other uses is a small proportion of the quantity available in rivers, lakes, and ground water. The crisis about water resources development and management thus arises because most of the water is not available for use and secondly it is characterized by its highly uneven spatial distribution. Accordingly, the importance of water has been recognised and greater emphasis is being laid on its economic use and better management.

Water on the earth is in motion through the hydrological cycle. The utilisation of water for most of the users i.e. human, animal or plant involves movement of water. The dynamic and renewable nature of the water resources and the recurrent need for its utilisation requires that water resources are measured in terms of its flow rates. Thus, water resources have two facets. The dynamic resource, measured as flow is more relevant for most of developmental needs. The static or fixed nature of the reserve, involving the quantity of water, the length of area of the water bodies is also relevant for some activities like pisciculture, navigation etc.

1.2 Irrigation World

Analysing the country-wise geographical area, arable land and irrigated area in the

World, it is found that among the continents largest geographical area lies in Africa which is about 23 percent of the world geographic area. However, Asia (excluding erstwhile countries of USSR) with only 21 percent of world geographical area has about 32 percent of world's arable land followed by North Central America having about 20 percent of World's arable land. Africa has only 12 percent of world's arable land. It has been seen that irrigated area in the World was about 18.5 percent of the arable land in 1994. In 1989, 63 percent of world's irrigated area was in Asia, whereas in 1994 this percentage has gone up to 64 percent. Also, 37 percent of arable land of Asia was irrigated in 1994. Among Asian countries, India has the largest arable land, which is close to 39 percent of Asia's arable land. Only United States of America has more arable land than India.

1.3 Water in Indian Perspective

General

India is a land of many rivers and mountains. Its geographical area of about 329 million hectare is criss-crossed by a large number of small and big rivers, some of them figuring amongst the mighty rivers of the world. The rivers and mountains have a greater significance in the history of Indian cultural development, religious and spiritual life. It will not be an exaggeration to say that the rivers are the heart and soul of Indian life.

India is a union of States with a federal set up. Politically, the country is divided into 28 States and 7 Union Territories. A major part of India's population of 1,027,015,247 (2001 census) is rural and agriculturally oriented for whom the rivers are the source of their prosperity.

Physiographically, India may be divided into seven well defined regions. These are:

1 The Northern Mountains, comprising the mighty Himalayan ranges;

2 The Great Plains traversed by the Indus and Ganga Brahmaputra river systems. As much as one third of this lies in the arid zone of western Rajasthan. The remaining area is mostly fertile plains;

3 The Central Highlands, consisting of a wide belt of hills running east west starting from Aravalli ranges in the west and terminating in a steep escarpment in the east. The area lies between the Great Plains and the Deccan Plateau;

4 The Peninsular Plateaus comprising the Western Ghats, Eastern Ghats, North Deccan Plateau, South Deccan Plateau and Eastern Plateau;

5 The East Coast, a belt of land of about 100-130 km wide, bordering the Bay of Bengal land lying to the east of the Eastern Ghats;

6 The West Coast, a narrow belt of land of about 10-25 km wide, bordering the Arabian Sea and lying to the west of the Western Ghats, and;

7 The islands, comprising the coral islands of Lakshadeep in Arabian Sea and Andaman and Nicobar Islands of the Bay of Bengal.

1.3.1 Climate

The presence of the great mountain mass formed by the Himalayas and its spurs on the North and of the ocean on the South are the two major influences operating on the climate of India. The first poses an impenetrable barrier to the influence of cold winds from central Asia, and gives the sub-continent the elements of tropical type of climate. The second, which is the source of cool moisture-laden winds reaching India, gives it the elements of the oceanic type of climate.

India has a very great diversity and variety of climate and an even greater variety of weather conditions. The climate ranges from continental to oceanic, from extremes of heat to extremes of cold, from extreme aridity and negligible rainfall to excessive humidity and torrential rainfall. It is, therefore, necessary to avoid any generalisation as to the prevalence of any particular kind of climate, not only over the country as a whole but also over major areas in it. The climatic condition influences largely the water resources utilisation of the country

1.3.2 Rainfall

Rainfall in India is dependent in differing degrees on the South-West and North-East monsoons, on shallow cyclonic depressions and disturbances and on violent local storms which form regions where cool humid winds the sea meet hot dry winds from the land and occasionally reach cyclonic dimension. Most of the rainfall in India takes place under the influence of South West monsoon between June and September except in Tamil Nadu where it is under the influence of Northeast monsoon during October and November. The rainfall in India shows great variations, unequal seasonal distribution, still more unequal geographical distribution, and the frequent departures from the normal. It generally exceeds 1000 mm in areas to the East of Longitude 78 degree. It extends to 2500 mm along almost the entire West Coast and Western Ghats and over most of Assam and Sub-Himalayan West Bengal. On the West of the line joining Porbandar to Delhi and thence to Ferozpur the rainfall diminishes rapidly from 500 mm to less than 150 mm in the extreme west. The Peninsula has large areas of rainfall less than 600 mm with pockets of even 500 mm. The estimate of aerial average rainfall is subjective depending on the method adopted. Therefore, estimates of local rainfall over the country obtained by employing other techniques may differ, especially in a vast country like India.

1.3.3 Temperature

The variations in temperature are also marked over the Indian sub-continent. During the winter seasons from November to February, due to the effect of continental winds over most of the country, the temperature decreases from South to North. The mean maximum temperature during the coldest months of December and January varies from 29 degree centigrade in some part of the peninsula to about 18 degree centigrade in the North, whereas the mean minimum varies from about 24 degree centigrade in the extreme South to below 5 degree centigrade in the North. From March to May is usually a period of continuous and rapid rise of temperature. The highest temperature occurs in North India, particularly in the desert regions of the Northwest where the maximum may exceed 48 degree centigrade. With the advent of South West Monsoon in June, there is a rapid fall in the maximum temperature in the central portions of the country. The temperature is almost uniform over the area covering two thirds of the country that gets good rain. In August, there is a marked fall in temperature when the monsoon retreat from North India in September. In Northwest India, in the month of November, the mean maximum temperature is below 38 degree centigrade and the mean minimum below 10 degree centigrade. In the extreme North, temperature drops below freezing point

1.3.4 Evaporation

Evaporation rates closely follow the climatic seasons, and reach their peak in the summer months of April and May and the central areas of the country display the highest evaporation rates during this period. With the onset of monsoon, there is a marked fall in the rate of evaporation. The annual potential evaporation ranges between 150 and 250 cm over most parts of the country. Monthly potential evaporation over the Peninsula increases from 15 cm in December to 40 cm in May. In the Northeast, it varies from 6 cm in December to 20 cm in May. It rises to 40 cm in June in West Rajasthan. After the onset of monsoon, potential evaporation decreases generally all over the country.

1.3.5 Agro climatic Zones

The Planning Commission after examining the earlier studies on the regionalisation of the agricultural economy has recommended that agricultural planning be done based on agro climatic regions. For resource development, the country has been broadly divided into fifteen agricultural regions based on agro climatic features, particularly soil type, climate including temperature and rainfall and its variation and water resources availability as under:

- Western Himalayan division
- Eastern Himalayan division
- Lower Gangetic plain region
- Middle Gangetic plain region
- Upper Gangetic plain region
- Trans-Gangetic plain region
- Eastern plateau and hill region
- Central plateau and hill region
- Western plateau and hill region
- Southern plateau and hill region
- East coast plain and hill region
- West coast plain and hill region
- Gujarat plain and hill region
- Western plain and hill region
- Island region

1.3.6 Rivers

India is blessed with many rivers. Twelve of them are classified as major rivers whose total catchment area is 252.8 million hectare (Mha). Of the major rivers, the Ganga - Brahmaputra Meghana system is the biggest with catchment area of about 110 MHa that is more than 43 percent of the catchment area of all the major rivers in the country. The other major rivers with catchment area more than 10 MHa are Indus (32.1 MHa), Godavari (31.3 MHa), Krishna, (25.9 MHa) and Mahanadi (14.2 MHa). The catchment area of medium rivers is about 25 MHa and Subernarekha with 1.9 Mha catchment areas is the largest river among the medium rivers in the country.

1.3.7 Water Bodies

Inland Water resources of the country are classified as rivers and canals; reservoirs; tanks & ponds; lakes, derelict water; and brackish water. Other than rivers and canals, total water bodies cover all area of about 7 MHa. Of the rivers and canals, Uttar Pradesh occupies the First place with the total length of rivers and canals as 31.2 thousand km, which is about 17 percent of the total length of rivers and canals in the country. Other states following Uttar Pradesh are Jammu & Kashmir and Madhya Pradesh. Among the remaining forms of the inland water resources, tanks and ponds have maximum area (2.9 MHa) followed by reservoirs (2.1 MHa).

Most of the area under tanks and ponds lies in Southern States of Andhra Pradesh, Karnataka and Tamil Nadu. These states along with West Bengal, Rajasthan and Uttar Pradesh, account for 62 percent of total area under tanks and ponds in the country. As far as reservoirs are concerned, major states like Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, and Uttar Pradesh account for larger portion of area under reservoirs. More than 77 percent of area under beels, oxbow, lakes, and derelict water lies in the states of Orissa, Uttar Pradesh, and Assam. Orissa ranks first as regards the total area of brackish water and is followed by Gujarat, Kerala, and West Bengal. The total area of inland water resources is, thus, unevenly distributed over the country with five states namely Orissa, Andhra Pradesh, Gujarat, Karnataka, and West Bengal accounting for more than half of the country's inland water bodies.

1.4 Stages of Irrigation Development

Ancient Time

The history of irrigation development in India can be traced back to prehistoric times. Vedas and ancient Indian scriptures made references to wells, canals, tanks and dams which were beneficial to the community and their efficient operation and maintenance was the responsibility of the State. Civilization flourished on the banks of the rivers and harnessed the water for sustenance of life. According to the ancient Indian writers, the digging of a tank or well was amongst the greatest of the meritorious acts of a man. Brihaspathi, an ancient writer on law and politics, states that the construction and the repair of dams is a pious work and its burden should fall on the shoulders of rich men of the land. Vishnu Purana enjoins merit to a person who affects repairs to wells, gardens, and dams.

In a monsoon climate and an agrarian economy like India, irrigation has played a major role in the production process. There is evidence of the practice of irrigation since the establishment of settled agriculture during the Indus Valley Civilization (2500 BC). These irrigation technologies were in the form of small and minor works, which could be operated by small households to irrigate small patches of land and did not require co-operative effort. Nearly all these irrigation technologies still exist in India with little technological change, and continue to be used by independent households for small holdings. The lack of evidence of large irrigation works at this time signifies the absence of large surplus that could be invested in bigger schemes or, in other words, the absence of rigid and unequal property rights. While village communities and co-operation in agriculture did exist as seen in well developed townships and economy, such co-operation in the large irrigation works was not needed, as these settlements were on the fertile and well irrigated Indus basin. The spread of agricultural settlements to less fertile and irrigated area led to co-operation in irrigation development and the emergence of larger irrigation works in the form of reservoirs and small canals. While the construction of small schemes was well within the capability of village communities, large irrigation works were to emerge only with the growth of states, empires and the intervention of the rulers. There used to emerge a close link between irrigation and the state. The king had at his disposal the power to mobilize labour, which could be used for irrigation works.

In the south, perennial irrigation might have begun with construction of the Grand Anicut by the Cholas as early as second century to provide irrigation from the Cauvery river. Wherever the topography and terrain permitted, it was an old practice in the region to impound the surface drainage water in tanks or reservoirs by throwing across an earthen dam with a surplus weir, where necessary, to take off excess water, and a sluice at a suitable level to irrigate the land below. Some of the tanks got supplemental supply from stream and river channels. The entire landscape in the central and southern India is studded with numerous irrigation tanks that have been traced back to many centuries before the beginning of the Christian era. In northern India also, there are a number of small canals in the upper valleys of rivers, which are very old.

Irrigation during Medieval India

In the medieval India, rapid advances also took place in the construction of inundation canals. Constructing bunds across streams blocked water. This raised the water level and canals were constructed to take water to the fields. These bunds were built by both the state and private sources. Ghiyasuddin Tughluq (1220-1250 is credited to be the first ruler who encouraged digging canals. However, it is Fruz Tughlug (1351-86) who, inspired by central Asian experience, is considered the greatest canal builder before the nineteenth century. Irrigation is said to be one of the major reasons for the growth and expansion of the Vijayanagar Empire in southern India in the fifteenth century. It may be noted that, but for exceptional cases, most of the canal irrigation before the arrival of the British was of the diversionary nature. The state, through the promotion of irrigation, had sought to enhance revenue and provide patronage through rewards of fertile land and other rights to different classes. Irrigation had also increased employment opportunities and helped in the generation of surplus for the maintenance of the army and the bureaucracy. As agricultural development was the pillar of the economy, irrigation systems were paid special attention. This is demonstrated by the fact that all the large, powerful, and stable empires paid attention to irrigation development.

Irrigation development during British

Irrigation development under British rule began with the renovation, improvement, and extension of existing works, like the ones mentioned above. When enough experience and confidence had been gained, the Government ventured on new major works, like the Upper Ganga Canal, the Upper Bari Doab Canal and Krishna and Godavari Delta Systems, which were all river-diversion works of considerable size. The period from 1836 to 1866 marked the investigation, development, and completion of these four major works. In 1867, the Government adopted the practice of taking up works, which promised a minimum net return. Thereafter, a number of projects were taken up. These included major canal works like the Sirhind, the Lower Ganga, the Agra and the Mutha Canals, and the Periyar Dam and canals. Some other major canal projects were also completed on the Indus system during this period. These included the Lower Swat, the Lower Sohag and Para, the Lower Chenab and the Sidhnai Canals, all of which went to Pakistan in 1947.

The recurrence of drought and famines during the second half of the nineteenth century necessitated the development of irrigation to give protection against the failure of crops and to reduce large scale expenditure on famine relief. As irrigation works in low rainfall tracts were not considered likely to meet the productivity test, they had to be financed from current revenues. Significant protective works constructed during the period were the Betwa Canal, the Nira Left Bank Canal, the Gokak Canal, the Khaswad Tank, and the Rushikulya Canal. Between the two types of works, namely productive and protective, the former received greater attention from the Government. The gross area irrigated in British India by public works at the close of the nineteenth century was about 7.5 Mha out of which 4.5 MHa came from minor works, like tanks, inundation canals etc. for which no separate capital accounts were maintained. The area irrigated by protective works was only a little more than 0.12 MHa.

1.5 Water Resource Development

At the time of commencement of the First Five Year Plan in 1951, population of India was about 361 million and annual food grain production was 51 million tonnes (MT), which was not adequate. Import of food grains was then inevitable to cover up the shortage. Attaining self sufficiently in food was therefore given paramount importance in the plan period and in order to achieve the objective, various major, medium and minor irrigation and multi-purpose projects were formulated and implemented through successive Five Year Plans to create additional irrigation potential throughout the country. This drive compounded with green revolution in the agricultural sector, has enabled India to become marginally surplus country from a deficit one in food grains.

Thus, the net irrigated area is 39 percent of net sown area and 30 percent of total cultivable area. As stated earlier, the ultimate potential due to major and medium projects has been assessed as 58 MHa of which 64 percent is estimated to be developed.

1.5.1 Hydro-Electric power

India has a vast potential for hydro-power generation, particularly in the northern and north-eastern region. As per an estimate of Central Electricity Authority, the potential in the country is assessed as 84,000 MW at 60 percent load factor, which is equivalent to about 450 billion units of annual energy generation. The basin wise distribution is as given below:

S.No.	Basin	Potential at 60 percent load factor (MW)
1.	Indus Basin	20,000
2.	Brahmaputra Basin	35,000
3.	Ganga Basin	11,000
4.	Central India Basin	3,000
5.	West Flowing River System	6,000
6.	East Flowing River System	9,000
	Total	84,000

At the time of independence, out of total installed capacity of 1362 MW, hydro-power generation capacity stood at 508 MW. The capacity has since been raised to about 13,000 MW. In addition, 6,000 MW is available from projects under construction. A potential of about 3,000 MW is contemplated from projects already cleared. The total potential harnessed/under harnessing would thus be about 22,000 MW, which is nearly one-fourth of the estimated potential.

1.5.2 Domestic water supply

The National Water Policy has assigned the highest priority to drinking water supply needs followed by irrigation, hydro-power, navigation and industrial and other uses. In the successive five-year plans and the intervening annual plans, efforts have been made to rapidly develop water supply and sanitation systems. In the context of the "International Drinking Water Supply and Sanitation Decade", the Government of India launched the decade program in April, 1981 with a view to achieving population coverage of 100 percent water supply facilities in urban and rural areas, 80 percent sanitation facilities in urban areas and 25 percent sanitation facilities in rural areas respectively by the end of the decade i.e. March, 1991. However, due to financial and other constraints the targets originally set for the decade were scaled down to 90 percent in the case of urban water supply and 85 percent in the case of rural water supply, 50 percent in the case of urban sanitation and 5 percent in the case of rural sanitation respectively. As per policy adopted, provision for drinking water is to be made in all water resources projects. The drinking water requirements of most of the mega cities/cities in India are met from reservoirs of irrigation/multi-purpose schemes existing in near by areas and even by long distance transfer. Delhi getting drinking water from Tehri Dam and Chennai city from Krishna Water through Telugu Ganga Project are typical examples.

1.5.3 Navigation

Total navigable length of inland water-ways in the country is 15,783 km of which maximum stretch lies in the state of Uttar Pradesh followed by West Bengal, Andhra Pradesh, Assam, Kerala, and Bihar successively. Amongst the river system, the Ganga has the largest navigable length followed by the Godavari, the Brahmaputra, and the rivers of West Bengal. Waterways have the unique advantage of accessibility to interior places. Besides, they provide cheaper means of transport with far less pollution and communicational obstacles. The waterways traffic movement has gone up progressively from 0.11 MT in 1980-81 to 0.33 MT in 1994-95. The development of inland water transport is of crucial importance from the point of energy conservation as well. The ten waterways identified for consideration for being declared as national waterways are namely:

- The Ganga-Bhagirath-Hoogli
- The Brahmaputra
- The Mandavi, Zuari river and the Cumbarjua Canal in Goa
- The Mahanadi
- The Godavari
- The Narmada
- The Sunderbans Area
- The Krishna
- The Tapi
- The West Coast Canal

The Ganga-Bhagirath-Hoogli and Brahmaputra have already been declared National Waterways. Farakka Navigation Lock has been opened for transport, thus allowing transport for upstream reaches of Ganga with Calcutta. With network of national waterways the carriage and cargo in this sector in the 10 river systems is expected to increase by 35 MT per year.

1.5.4 Industrial Use

A basic necessity of industrial development is adequate availability of water. The Second Irrigation Commission in its report of 1972 recommended a provision of 50 billion cubic metres (BCM) for industrial purpose for the country as a whole. However, a recent assessment indicates that requirement for industrial use during 2000 AD will be about 30 BCM. While it will rise to 120 BCM by 2025 AD.

1.5.5 Inland Pisciculture

Because of water resources development works, apart from the major objectives there has been development in various other sectors as well. Among them, development in inland fish production occupies a prominent place. During 1950-51, total inland fish production stood at 0.22 MT which by 1994-95 had gone up to 2.08 MT India has now the distinction of being the seventh largest producer of fish in the world and second largest producer of inland fish after China. Amongst the states, West Bengal is the highest producer followed by Andhra Pradesh and Bihar. These three states put together produce about 50 percent of total inland fish production in the country, while West Bengal alone accounts for about one third of the production.

1.5.6 Water development & health

While water is essential for sustenance of human life, it can as well create problems concerning human health being a carrier of vectors for diseases such as typhoid, cholera, diarrhoea, malaria, filariasis, shistosomiasis etc. if mismanaged. Water development projects have, however, contributed positively to the human health in the country. Among the human health benefits, the important one is improved diets resulting from an increased production of staple foods, new opportunity of growing fruits and vegetables and increased purchasing power for foods not produced by those on farm. Other nutrition improvement is due to development of pisciculture and better facilities for feeding and watering the domestic livestock, which can also improve diet and income considerably. The development of water development projects not only enabled the country to overcome floods and drought but also have provided enough food and fibre for the ever increasing population. Water development projects have facilities in providing safe water for human consumption, considering scarcity of water now faced in most parts of the country.

Almost all the projects implemented in the country provide water for domestic purpose although primarily some of the projects were not meant for this purpose. With 80-90 percent precipitation accruing during monsoon only, it has become imperative to store water for domestic use. Water supply also has helped to keep populated areas clean and hygienic through better drainage and improved sanitation. Water supply has thus contributed in improvement of health.

1.6 Surface Water Resources

Surface water available from different basins in India is 1869.35 cubic Kilometre per year. The basin wise detail is as follows:

Cubic Km/Year

S.No.	Name of the River Basin	Average annual availability
1	Indus (up to Border)	73.31
2	a) Ganga	525.02
	b) Brahmaputra ,Barak & Others	585.6
3	Godavari	110.54
4	Krishna	78.12
5	Cauvery	21.36
6	Pennar	6.32
7	East Flowing Rivers between Mahanadi & Pennar	22.52
8	East Flowing Rivers between Pennar and Kanyakumari	16.46
9	Mahanadi	66.88
10	Brahmani & Baitarni	28.48
11	Subernarekha	12.37
12	Sabarmati	3.81
13	Mahi	11.02
14	West Flowing Rivers of Kutch, Sabarmati including Luni	15.1
15	Narmada	45.64
16	Tapi	14.88
17	West Flowing Rivers from Tapi to Tadri	87.41
18	West Flowing Rivers from Tadri to Kanyakumari	113.53
19	Area of Inland drainage in Rajasthan desert	NEG.
20	Minor River Basins Draining into Bangladesh & Burma	31
	Total	1869.35

1.7 Ground water resources

The total replenishable ground water resources of the country have been estimated as 434 billion cubic meter (BCM) presuming some quantities of states & UT's under estimation. Keeping a provision of about 71 BCM/yr out of 434 BCM, 361 BCM/yr of resources is estimated to be available for irrigation. The Net Draft for irrigation is around 150 BCM/yr and the level of ground water development is 42%. Ground water resources of the country are given below.

S. No.	States	Total replenishable ground water resource	Provision for domestic, industrial & other uses	Available ground water resources for irrigation	Net draft	Balance ground water resource for future use	Level of ground water development
		BMC/yr	BMC/yr	BMC/yr	BMC/yr	BMC/yr	%
1	Andhra Pradesh	35.29	5.29	30.00	8.57	21.43	28.56
2	Arunachal Pradesh	1.44	0.22	1.22	-	1.22	Neg.
3	Assam	24.72	3.71	21.01	1.84	19.17	8.75
4	Bihar	26.99	4.05	22.94	10.63	12.31	46.33
5	Chattisgarh	16.07	2.41	13.66	0.81	12.85	5.93
6	Delhi	0.29	0.18		0.12		
7	Goa	0.22	0.03	0.19	0.02	0.17	8.30
8	Gujarat	20.38	3.06	17.32	9.55	7.77	55.16
9	Haryana	8.53	1.28	7.25	8.13	0.00	112.18
10	Himachal Pradesh	0.37	0.08	0.29	0.03	0.26	10.72
11	Jammu & Kashmir	4.43	0.66	3.76	0.03	3.73	0.81
12	Jharkhand	6.53	0.98	5.55	1.84	3.71	33.13
13	Karnataka	16.19	2.43	13.76	4.76	9.00	34.60
14	Kerala	7.90	1.31	6.59	1.46	5.13	22.17
15	Madhya Pradesh	34.82	5.22	29.60	8.02	21.58	27.09
16	Maharashtra	37.87	12.40	25.47	9.44	16.04	37.04
17	Manipur	3.15	0.47	2.68	Neg.	2.68	Neg.
18	Meghalaya	0.54	0.08	0.46	0.02	0.44	3.97
19	Mizoram	Under estimation					
20	Nagaland	0.72	0.11	0.62	Neg.	0.62	Neg.
21	Orissa	20.00	3.00	17.00	3.61	13.39	21.23
22	Punjab	18.66	1.87	16.79	16.40	0.00	97.66
23	Rajasthan	12.71	1.99	10.71	9.26	1.45	86.42
24	Sikkim	Under estimation					
25	Tamil Nadu	26.39	3.96	22.43	14.45	7.98	64.43
26	Tripura	0.66	0.10	0.56	0.19	0.38	33.43
27	Uttar Pradesh	81.12	12.17	68.95	32.33	36.62	46.89
28	Uttaranchal	2.70	0.41	2.29	0.82	1.47	35.78
29	West Bengal	23.09	3.46	19.63	7.50	12.13	38.19
	TOTAL STATES	**431.77**	**70.92**	**360.73**	**149.82**	**211.53**	**41.53**

	Union Territories						
1	Andamand & Nicobar	Under estimation					
2	Chandigarh	0.030			0.025		
3	Dadar & Nagar Haveli	0.042	0.006	0.040	0.005	0.031	12.81
4	Daman & Diu	0.013	0.002	0.010	0.008	0.003	70.00
5	Lakshdweep	0.002			0.007		
6	Pondicherry	0.029	0.004	0.020	0.116	0.000	
	Total U. Territories	0.116	0.013	0.071	0.160	0.035	
	Grand Total	431.88	70.93	360.80	149.97	211.56	41.57

State-wise Details of Net Irrigated Area (NIA), Net Sown Area (NSA) and percentage of NIA to NSA is stated below:

(000, hectares)

S.No.	States	Net sown area (NSA)	Net Irrg area (NIA)	% of NIA to NSA
1	Andhra Pradesh	11115	4528	40.74%
2	Arunachal Pradesh	164	42	25.61%
3	Assam	2734	170	6.22%
4	Bihar	7437	3625	48.74%
5	Chattisgarh	4763	984	20.66%
6	Goa	141	23	16.31%
7	Gujarat	9443	2979	31.55%
8	Haryana	3526	2958	83.89%
9	Himachal Pradesh	555	126	22.70%
10	Jammu & Kashmir	748	311	41.58%
11	Karnataka	10410	2643	25.39%
12	Kerala	2206	381	17.27%
13	Madhya Pradesh	14664	4135	28.20%
14	Maharashtra	17636	2959	16.78%
15	Manipur	140	65	46.43%
16	Meghalaya	230	54	23.48%
17	Mizoram	94	9	9.57%
18	Nagaland	300	72	24.00%
19	Orissa	5829	1933	33.16%
20	Punjab	4264	3602	84.47%
21	Rajasthan	15865	4907	30.93%

22	Sikkim	95	17	17.89%
23	Tamil Nadu	5303	2888	54.46%
24	Tripura	280	37	13.21%
25	Uttar Pradesh	17612	12814	72.76%
26	West Bengal	5417	2354	43.46%
	Total States	140971	54616	38.74%
	Total UT's	130	66	50.77%
	Grand Total	141101	54682	38.75%

1.8 Utilizable Water Resources & Irrigation Performance

From above illustrations, it is clear that in India about 1869 cubic kilometre per year i.e. 1869 BCM per year of surface water and 434 BCM per year of ground water are available for utilization. Until 1997-98, total 629 BCM per year was being used for different purposes out of which 524 BCM per year was used for irrigation. It is clear that there is a huge gap between utilizable water resources and actually utilised. However, due to poor irrigation techniques and unawareness among the end users, lot of potential created is resulting in wastage of resources. Many efforts are being made at the government level to train farmers, to demonstrate new techniques and to educate them for better irrigation performance.

1.9 Irrigation Potential Created and Utilized

Until year 2002, irrigation potential was created for 93.95 million hectares out of which 80.06 million hectare is utilized from surface & ground water resources. It includes major, medium & minor irrigation projects (surface & ground water both). Plan wise position of irrigation potential created and utilised is given below.

(In million hectares)

Plan		Potential created					Potential utilised				
		Major & Medium	Minor			Total	Major & Medium	Minor			Total
			S.W.	G.W.	Total			S.W.	G.W.	Total	
1	2	3	4	5	6	7	8	9	10	11	12
Up to 1951 (pre-plan)	Cumm.	9.70	6.40	6.50	12.90	22.60	9.70	6.40	6.50	12.90	22.60
I Plan	During	2.50	0.03	1.13	1.16	3.66	1.28	0.03	1.13	1.16	2.44
(1951-56)	Cumm.	12.20	6.43	7.63	14.06	26.26	10.98	6.43	7.63	14.06	25.04
II Plan	During	2.13	0.02	0.67	0.69	2.82	2.07	0.02	0.67	0.69	2.76
(1956-61)	Cumm.	14.33	6.45	8.30	14.75	29.08	13.05	6.45	8.30	14.75	27.80
III Plan	During	2.24	0.03	2.22	2.25	4.49	2.12	0.03	2.22	2.25	4.37
(1961-66)	Cumm.	16.57	6.48	10.52	17.00	33.57	15.17	6.48	10.52	17.00	32.17
Annual	During	1.53	0.02	1.98	2.00	3.53	1.58	0.02	1.98	2.00	3.58
Plans (1966-69)	Cumm.	18.10	6.50	12.50	19.00	37.10	16.75	6.50	12.50	19.00	35.75
IV Plan	During	2.60	0.50	4.00	4.50	7.10	1.64	0.50	4.00	4.50	6.14
(1969-74)	Cumm.	20.70	7.00	16.50	23.50	44.20	18.39	7.00	16.50	23.50	41.89
V Plan	During	4.02	0.50	3.30	3.80	7.82	2.77	0.50	3.30	3.80	6.57
(1974-78)	Cumm.	24.72	7.50	19.80	27.30	52.02	21.16	7.50	19.80	27.30	48.46

Annual Plans (1978-80)	During	1.89	0.50	2.20	2.70	4.59	1.48	0.50	2.20	2.70	4.18
	Cumm.	26.61	8.00	22.00	30.00	56.61	22.64	8.00	22.00	30.00	52.64
VI Plan (1980-85)	During	1.09	1.70	5.82	7.52	8.61	0.93	1.01	4.24	5.25	6.18
	Cumm.	27.70	9.70	27.82	37.52	65.22	23.57	9.01	26.24	35.25	58.82
VII Plan (1985-90)	During	2.22	1.29	7.80	9.09	11.31	1.90	0.96	6.91	7.87	9.77
	Cumm.	29.92	10.99	35.62	46.61	76.53	25.47	9.97	33.15	43.12	68.59
Annual Plans (1990-92)	During	0.82	0.47	3.27	3.74	4.56	0.85	0.32	3.10	3.42	4.27
	Cumm.	30.74	11.46	38.89	50.35	81.09	26.32	10.29	36.25	46.54	72.86
VIII Plan (1992-97)	During	2.21	1.05	1.91	2.96	5.17	2.13	0.78	1.45	2.23	4.36
	Cumm.	32.95	12.51	40.80	53.31	86.26	28.45	11.07	37.70	48.77	77.22
IX Plan (1997-02)	During	4.10	3.59		3.59	7.69	2.57	1.22		1.22	3.79
	Cumm.	37.05	16.10	40.80	56.90	93.95	31.02	12.29	37.70	49.99	81.06

Till IX plan Ultimate Irrigation Potential (UIP) was 139.89 million hectares. State wise UIP, Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU) is given below:

(million hectares)

S.No.	Name of the State	UIP			IPC			IPU		
		Major & Medium	Minor	Total	Major & Medium	Minor	Total	Major & Medium	Minor	Total
1	2	3	4	5	6	7	8	9	10	11
1	Andhra Pradesh	5.00	6.26	11.26	3.30	3.02	6.32	3.05	2.78	5.83
2	Arunachal Pradesh	0.00	0.17	0.17	0.00	0.10	0.10	0.00	0.08	0.08
3	Assam	0.97	1.90	2.87	0.24	0.60	0.85	0.17	0.49	0.67
4	Bihar	5.22	5.66	10.89	2.68	4.72	7.40	1.71	3.76	5.47
5	Chattisgarh	1.15	0.57	1.72	0.92	0.49	1.41	0.76	0.32	1.08
6	Goa	0.06	0.05	0.12	0.02	0.02	0.04	0.02	0.02	0.04
7	Gujarat	3.00	3.10	6.10	1.43	2.00	3.43	1.30	1.88	3.18
8	Haryana	3.00	1.51	4.51	2.10	1.63	3.73	1.85	1.58	3.43
9	Himachal Pradesh	0.05	0.30	0.35	0.01	0.16	0.17	0.01	0.14	0.15
10	Jammu & Kashmir	0.25	1.11	1.36	0.18	0.38	0.56	0.17	0.37	0.54
11	Jharkhand	1.28	1.18	2.46	0.35	0.59	0.94	0.23	0.47	0.70
12	Karnataka	2.50	3.47	5.97	2.12	1.59	3.71	1.84	1.54	3.39
13	Kerala	1.00	1.68	2.68	0.61	0.64	1.25	0.56	0.60	1.16
14	Madhya Pradesh	4.85	11.36	16.21	1.39	2.26	3.64	0.88	2.15	3.03
15	Maharashtra	4.10	4.85	8.95	3.24	2.94	6.18	2.15	2.56	4.70
16	Manipur	0.14	0.47	0.60	0.16	0.08	0.23	0.11	0.06	0.17
17	Meghalaya	0.02	0.15	0.17	0.00	0.05	0.05	0.00	0.05	0.05
18	Mizoram	0.00	0.07	0.07	0.00	0.02	0.02	0.00	0.01	0.01
19	Nagaland	0.01	0.08	0.09	0.00	0.08	0.08	0.00	0.07	0.07
20	Orissa	3.60	5.20	8.80	1.83	1.47	3.30	1.79	1.34	3.13
21	Punjab	3.00	2.97	5.97	2.54	3.43	5.97	2.49	3.37	5.85
22	Rajasthan	2.75	2.38	5.13	2.48	2.45	4.93	2.31	2.36	4.68
23	Sikkim	0.02	0.05	0.07	0.00	0.03	0.03	0.00	0.02	0.02
24	Tamil Nadu	1.50	4.03	5.53	1.55	2.12	3.67	1.55	2.12	3.67
25	Tripura	0.10	0.18	0.28	0.00	0.11	0.11	0.00	0.10	0.10
26	Uttar Pradesh	12.15	17.48	29.64	7.91	21.60	29.51	6.33	17.28	23.61
27	Uttaranchal	0.35	0.52	0.86	0.28	0.50	0.78	0.19	0.40	0.59
28	West Bengal	2.30	4.62	6.92	1.68	3.79	5.48	1.53	3.10	4.63
	Total States	58.37	81.38	139.75	37.04	56.86	93.90	31.01	49.01	80.02
	Total UT's	0.10	0.05	0.14	0.01	0.04	0.05	0.00	0.04	0.04
	Grand Total	**58.47**	**81.43**	**139.89**	**37.05**	**56.90**	**93.95**	**31.01**	**49.05**	**80.06**

There is a huge difference between Ultimate irrigation potential, IPC and IPU. Therefore, IPU may be increased to IPC for optimum utilization of resource.

1.10 Future Needs

Estimates of total annual requirement of water are given below.

Use	Year									
		2010			2025			2050		
	1997-98	Low	High	%	Low	High	%	Low	High	%
Surface Water										
Irrigation	318	330	339	48	325	366	43	375	463	39
Domestic	17	23	24	3	30	36	5	48	65	6
Industries	21	26	26	4	47	47	6	57	57	5
Power	7	14	15	2	25	26	3	50	56	5
Navigation		7	7	1	10	10	1	15	15	1
Ecology		5	5	1	10	10	1	20	20	2
Evaporation	36	42	42	6	50	50	6	76	76	6
Total	399	447	458	65	497	545	65	641	752	64
Groundwater										
Irrigation	206	213	218	31	236	245	29	253	344	29
Domestic	13	19	19	2	25	26	3	42	46	4
Industries	9	11	11	1	20	20	2	24	24	2
Power	2	4	4	1	6	7	1	13	14	1
Total	230	247	252	35	287	298	35	332	428	36
Total Water Use										
Irrigation	524	543	557	79	561	611	72	628	807	68
Domestic	30	42	43	5	55	62	8	90	111	10
Industries	30	37	37	5	67	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Navigation	0	7	7	1	10	10	1	15	15	1
Ecology	0	5	5	1	10	10	1	20	20	2
Evaporation	36	42	42	6	50	50	6	76	76	6
Grand Total	629	694	710	100	784	843	100	973	1180	100

From the table it is evident that there is a need for proper water management in all the sectors. Wastage should be minimized and better technologies should be adopted to get better efficiency. Maximum demand shall always be in the irrigated agriculture therefore, it is the right area where efforts should be to minimise wastage. Where ever possible recycling of water should be done. Secondly monitoring at individual river basin is desired for optimum utilization of water.

1.11 Institutional Set up for Water Resources

At the central level, the Union Ministry of Water Resources is responsible for development, conservation and management of water as a national resource i.e. for the general policy on water resources development and for technical assistance to the states on irrigation, multipurpose projects, ground water exploration and exploitation, command area development, drainage, flood control, water logging, soil erosion problems, dam safety and hydraulic structures for navigation and hydropower. It also oversees the regulation and development of inter-State rivers. These functions are carried out through various Central Organisations. The Ministry of Urban Development handles urban water supply and sewage disposal while Rural Water Supply comes in the purview of Department of Drinking Water under Ministry of Rural Development. The subject of Hydroelectric power and thermal power is the responsibility of the

Ministry of Power. Pollution and environment control comes under the purview of the Ministry of Environment and Forests. Water being a State subject, the State Governments have primary responsibility for use and control of this resource. The administrative control and responsibility for development of water rests with the various State Departments and Corporations. The irrigation/ water resources departments handle major and medium irrigation. Minor irrigation is looked after partly by water resources departments, minor irrigation corporations, Zila Parishads/ Panchayats and by the other departments such as agriculture. Urban water supply is generally the responsibility of public health departments and panchayats take care of rural water supply. Government tube wells are constructed and managed by the irrigation/ water resources department or by tube well corporations set up for the purpose. Hydro-power is the responsibility of the State Electricity Boards..

1.12 Self Assessment Test

1. What are the well defined Regions in India Physiographically?
2. How many water ways are fit for Navigation in India?

1.13 References

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UNIT-2

FLOW MEASUREMENT

STRUCTURE

2.0 Objectives

2.1 Introduction

2.2 Choice of Flow Measuring Structures

2.3 Principal Methods For Measurement Of Discharges

2.4 Main Requirement For Flow Measurement

2.5 Area Velocity Method

2.6 Area Slope Method

2.7 Use Of Hydraulic Structures

2.8 Measurement By Stage Discharge Curve

2.9 Designing Of Standing Wave Flume For Discharge Measurement

2.10 Self Assessment Test

2.11 Key words

2.12 Suggested Readings

2.0 Objectives

The aim of this unit is to acquaint the students/users to know

- Basic concept of flow measurement
- Choice of flow measurement method
- Techniques of flow measurement
- Basic concept of various hydraulic structures

2.1 Introduction

Water is a limited resource. With ever increasing population and industrialization its demand is also on the rise. Knowledge of quantity of water available and that being utilised is therefore first stage in efficient management of this vital resource. In any irrigation system, therefore, to make the distribution and utilisation of water more effective, it is necessary to know and also adjust the discharges in conveyance systems. Flow measurements are therefore essential for efficient irrigation management.

Water measurement is important for :

- Water conservation.
- Equitable distribution of water
- Determining the amount of water available
- Meeting legal obligations.
- Successful management of available supply.

Since most of the irrigation channels are not provided with metering devices at head regulators or at each diversion, it is necessary to fix a stage-discharge relationship and for that, too, measurement of actual flow is necessary.

2.2 Choice of Flow Measuring Structures

Factors effecting choices are :

(A) Water quality Criteria.

(i) No restrictions for pure (ordinary) and clean water.

(ii) Presence of chemical may affect choice of material.

(iii) Presence of silt & debris may affect selection of device.

(B) Water Quantity Criteria.

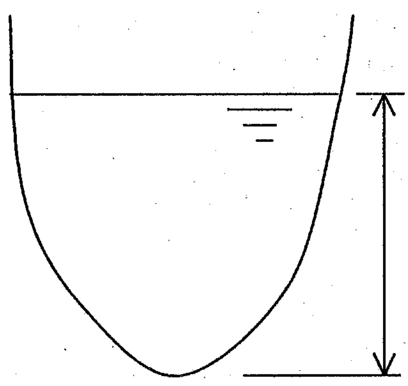
(i) Thin plate devices for very small to small discharges eg. laboratories, drain age gallery etc.

(ii) Flumes for medium discharges eg. minors, distributories etc.

(iii) Long base structures for high discharges eg. main canals, river streams etc.

2.3 Principal methods for measurement of discharge in open channels

The principal aim of flow measurement by any method is to establish a relationship between discharge & depth of flowing water.



h = ## m ➔ Q = ??

Practical Limitation

All methods of flow measurement are subject to errors

How to minimize errors

- Follow the recommendations of relevant National and International standards
- The accuracy of measurement depends upon the evaluation of coefficients in the discharge equation
- Must be done precisely

Basically, the water flow measuring methods are of two types:

(i) Indirect Method

In this average velocity of flow is obtained and the discharge is computed by multiplying cross-sectional area of the water body in the system with velocity.

This method is also called Area Velocity method.

(ii) Direct Method

Discharge is directly obtained by measuring depth of flow, through standard structures like; Notches, Weirs, Flumes, Orifices, etc.

For the measurement of water flow, a number of standard structures have been developed which are calibrated to indicate discharge at different water levels. Already some structures are available in each system. These structures can be used for flow measurements. However, these structures need to be re-calibrated in-situ wherever needed.

The flow measurement methods can be compiled as :

(1) Area Velocity Method.

(2) Area Slope Method.

(3) Stage Discharge Curve Method.

(4) Use of Hydraulic Structure.

(5) Chemical Method.

(6) Tracer Technique.

2.4 MAIN REQUIREMENTS FOR FLOW MEASUREMENT

a. The depth of the flow of water in a specified reach

b. The cross-sectional area of the channel, at the depth through which water is flowing; and

c. The velocity of the flow.

2.5 Indirect Methods for Measuring Water Flows

2.5.1 Pre requirements

I. A measuring rod, with clear markings is installed to measure the depth of the flow. Either a vertical staff gauge is fixed in the centre of the system or a gauge is marked along the side of the channel. The zero of the gauge is fixed at the bed level of the canal.

II. The cross-section of the channel at the gauge site is plotted on a graph paper and the areas are worked out at different depths. A table is prepared with depths and corresponding areas.

III The velocity of water is assessed using the float method. Any material which floats on water may be used for assessment of velocity in the canal, like a dry twig, a leaf, etc.

IV. For farmers to understand three distinct marks of identification with different colors, like red, green, and black, can be made on the gauge corresponding to expected full supply, three-fourth supply and half supply against promised quota. This will help WUAs to understand the supplies of irrigation water.

2.5.2 AREA VELOCITY METHOD:

In this method discharge is computed as

Q = A x V, where Q is the discharge,

A is the cross sectional flow area & V is the mean velocity of flow

In this method, two stages are required

(i) Measurement of Area

(ii) Measurement of mean velocity

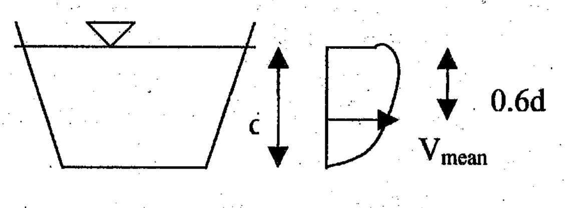


Fig:1 Variation of velocity across depth

(i) Measurement of cross sectional area is done using chain, tape, scale etc. Total cross sectional flow area is determined

(ii) Measurement of mean velocity

The Velocity of flow in an open channel is not uniformly distributed in any X-section. It varies across the depth of flow. The velocity is zero at the bottom of the canal while at the surface it is nearly maximum. The mean velocity is computed by determining the flow velocity at different depths & thereafter plotting the variation. The mean velocity is the total area divided by the depth of flow. This is a quite cumbersome process & hence practically, mean velocity can be computed as one of the following:

1 $V_{mean} = (V\ 0.2d + V\ 0.8d)/2$

2. $V_{mean} = V\ 0.6d$

Where V_{mean} = mean velocity of flow

$V_{0.2d}$ = Velocity at 0.2 depth from top

$V_{0.8d}$ = Velocity at 0.8 depth from top

$V_{0.6d}$ = Velocity at 0.6depth from top

The average velocity (Vmean) at any X-section lies at about 0.6 times the depth of flow from top surface.

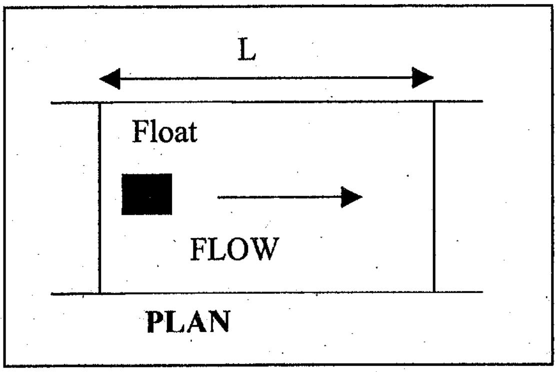
Discharge (Q) = V_{mean} x A

All that is needed now is to measure V_{mean} and X-section area (A).

2.5.3 Velocity Measurements :

Either of the following methods can be used to measure mean velocity of the flow:

2.5.3.1 Surface Float Method.



Surface float is nothing but matter which floats on water surface. By applying simple principle of physics, surface velocity is determined. A float is made to flow on water surface & thereafter time is computed in traveling a known distance. Thus velocity is determined.

Surface Velocity = Distance (L) /Time Taken (T)

Surface float method gives surface velocity of flow while for calculation of discharge, mean flow velocity is required. The mean flow velocity is determined by multiplying surface velocity with correction factor given in table -1 .

Table : 1 Correction factor (Velocity coefficient)

Hydraulic mean depth		Corrector factor		
		Mannings coefficient		
Feet	**Meter**	**0.02**	**0.0225**	**0.025**
.5	.15	.695	.67	.646
1.0	0.3	.734	.710	.688
2.0	.6	.764	.742	.721
4.0	1.2	.786	.766	.746
6	1.80	.796	.777	.788

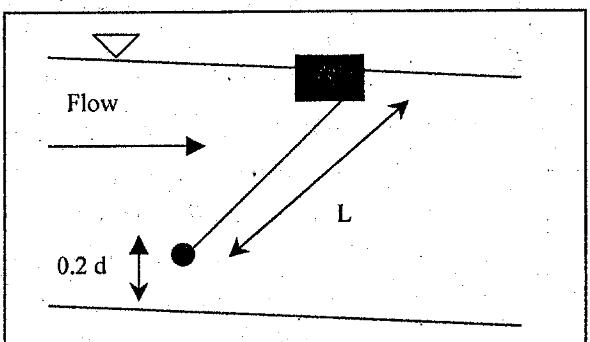
Precautions :

(i) L < 30 M. (Distance should be less than 30 M)

(ii) Avoid Curved reach.

(iii) Avoid observation when strong wind in blowing.

2.5.3.2 Sub-Surface (Double Float) Method



Double float method

Surface float method gives the surface velocity & is a very rough method for determining of velocity. Double float method is an improved method over surface float & gives mean velocity directly. The procedure for its measurement is similar to that of surface float method.

Double (Sub - Surface) float consists of:

(i) Surface float of light material.

(ii) A heavy metallic ball.

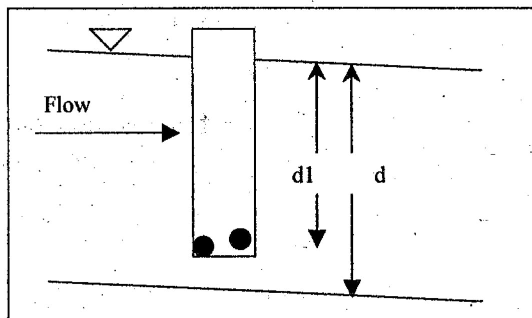
(iii) A string or chain of variable or adjustable length (L)

The Length "L" of the string is so adjusted that C.G. of the ball remains at about 0.2 times depth of flow above the channel bed.

This float directly measures mean velocity (V_{mean}) of flow.

2.5.3.3 Velocity Rod

They also give V_{mean} directly and consist of two telescopic tubes. The rod is made to float almost vertically by putting heavy beads at bottom.

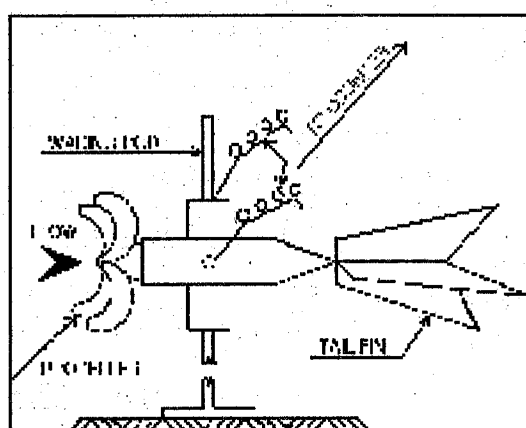


Velocitv Rod

$V_{mean} = V \{(1.012 - 0.116(d - d_1)^{1/2}/d\}\backslash$

2.5.3.4 Current Meters

Current meter is a mechanical device that measures directly the velocity of flow of filament of water in which it is suspended. It consists of:



(i) Propeller blades or cups, which rotate by force of flowing water.

(ii) A tail fin to keep instrument aligned along the direction of flow.

(iii) Automatic counter to record revolution of the propeller.

R.P.M. of propeller depends upon velocity of streamline, it is kept along and is recorded with the help of a counter and a stop watch. Using a calibrated chart prepared in a laboratory, velocity is directly noted with respect to R.P.M of current meter propeller.

Specifications of current meters (cup-type) to be used must conform to I.S. 3910-1966, where as I.S. 3918-1966 be referred to for their use. Some important instructions however are given below.

(i) For measurements made at one point current meter should be exposed for 120 seconds or 150 revolutions whichever occurs later.

(ii) When measurements are taken at more than one point in a vertical direction, it should be exposed for at least 30 seconds at each point.

(iii) If velocity is subjected to periodic pulsation current meter should be exposed for at least two consequent periods of 50 seconds each.

(iv) Minimum interval of each reading should be one minute.

(vi) Curved reach should be avoided.

(vii) Avoid observation during strong wind and turbulent flow.

(viii) If it is essential to take reading during strong wind, avoid readings at 0.2d.

(ix) Get the instrument re-calibrated after 6 months or 300 working hours which ever occurs earlier.

Limitations :

- Cup-type current meter may give great errors for Velocity less than 0.3 m/sec.
- Proximity of boundary, if less than 0.3 m may give errors more than 6%.

Tests before use

(i) Spin test: Resting on horizontal flat surface, if a hard spin is given to propeller it should not stop before 90 Sec. (without spring contact) and 75 sec. (with spring).

(ii) Response to velocity test: When lowered from 0.6d to 0.8d, the change in R.P.M. shall be significant within 30 seconds.

(iii) Slow motion test: It must be capable of recording velocity up to 0.15 m/sec. within 95% accuracy.

2.6 AREA SLOPE METHOD

The method only gives a rough estimate and is used when other methods are not feasible due to

(i) Non-availability of equipment or

(ii) Frequent change in depth of flow.

Two variants to be measured are water surface slope and X sectional are of flow. If Manning's formula is used, selection of Manning's roughness coefficient 'n' is done by experience.

Mean value of x-sectional area and wetted perimeter are obtained by actual measurement.

Water energy line slope is obtained by the formula :

$$S = (Z_1 - Z_2) + \{(V_1^2 / 2g) - (V_2^2 / 2g)\} / L$$

Where Z_1 & Z_2 are water surface elevations with respect to a common fixed datum, V_1 & V_2 are mean velocities of flow at two X-sections, distance L apart.

Mean Velocity of flow is obtained by

$V_{mean} = (1/n) \times R^{2/3} \times S^{1/2}$ (in metric units ; n, R & S have usual connotations)

2.7 USE OF HYDRAULIC STRUCTURES

This method differs from other methods as a standard type hydraulic structure is erected across the flow and used. Certain rules of hydraulic are followed and once standardised, no field calibration or measurements other than regular recording of water levels are needed to obtain a continuous or instantaneous discharge.

Three main categories of such structures are.

(A) Thin plate devices usually made from metal, set vertically and perpendicular to the direction of flow.

(B) Long base weirs made of concrete or masonry or any such material.

(C) Flumes made up of any material e.g. concrete, metal, timber or fibreglass of standard shape and size depending upon their location and performance required.

2.7.1 Thin Plate Structures

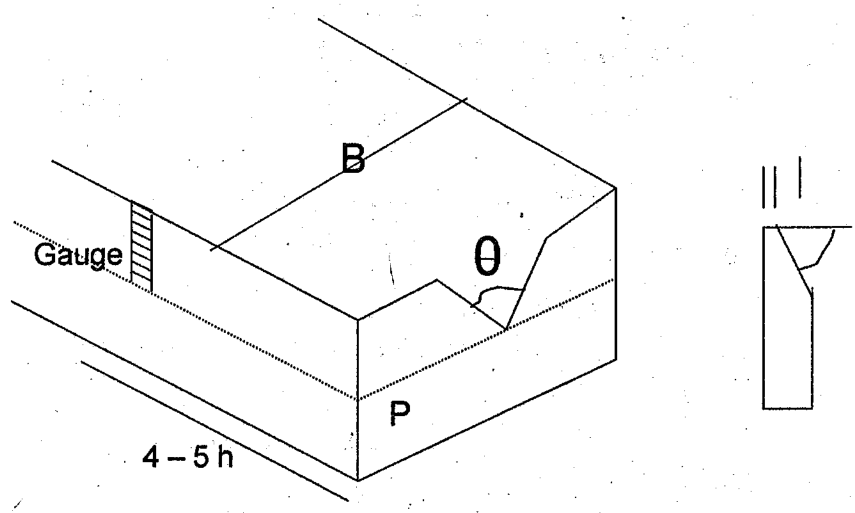
(A) Notches: These are standard thin plate weirs and have thin crest profile and are installed where sufficient fall is available.

(i) V notch :

(i) Should be installed absolutely vertical and perpendicular to direction of flow.

(ii) Vertical bisector of the notch shall be equidistant from both banks.

(iii) Crest of rectangular notch must be perfect by horizontal and sides truly vertical.



(iv) Crest thickness should not exceed 2mm.

(v) Chamber face must be on d/s side.

(vi) Crest of notch must be at least 10 cm. above d/s water level to have free fall conditions.

The discharge formula is

$Q = C_e\ (8/15)\ (\tan\alpha/2)\ (2g)^{1/2} h_e^{5/2}$

Where $C_e = (h/B\ ,\ b/B,\ \alpha)$

$H_e = h + h^k$.   also $h_k = (h/p\ ,\ p/B)$

For $\alpha = 90°$, for irrigation channels

$h_k = 0.0085$ M is negligible and for $\alpha = 90°$, C_e is function of angle α only and can be adopted from the table-1below.

Table -1

Values of C_e for V/S h (rounded off to 3rd place)

Head (h) (Cms.)	Crest Angle (α) 90°	53°8'	28°4'	Head (h) (Cms.)	Crest Angle (α) 90⁰	53° 8'	28°4'
6	0.603	0.661	0.642	25	0.585	0.590	0.600
8	0.596	0.606	0.632	30	0.585	0.588	0.598
10	0.592	0.602	0.622	35	0.585	0.588	0.596
15	0.586	0.596	0.610	38	0.585	0.587	0/595
20	0.585	0.591	0.604				

Limitations:

(i) Water must be free from sediments to prevent damage to crest.

(ii) Adequate fall must be available.

(iii) Higher discharges may cause energy dissipation problems d/s of fall.

(ii) Rectangular Notch.

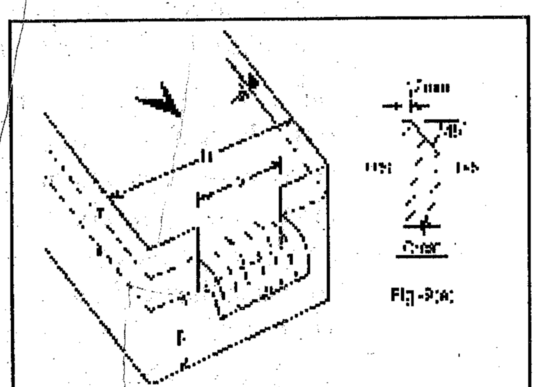
General formula for Rectangular notch is

$Q = Ce \times (2/3) \times (2g)^{1/2} \times b_e \times H_e^{3/2}$

Where $b_e = b + K_b$

$H_e = h + K_h$

and $C_e = (b/B,\ h/p)$



For channels

$K_h = 0.001$ is negligible.

Therefore $h_e = h$.

and $C_e = a + a'\ (h/p)$

Values of a, a' and K_b as worked out experimentally are given in tables 2 & 3 below

Table-2. a and a' values w.r.t b/B ratio.

b/B	1.0	0.4	0.2	0
a	0.602	0.591	0.589	0.587
a'	0.075	0.006	0.002	(-)0.002

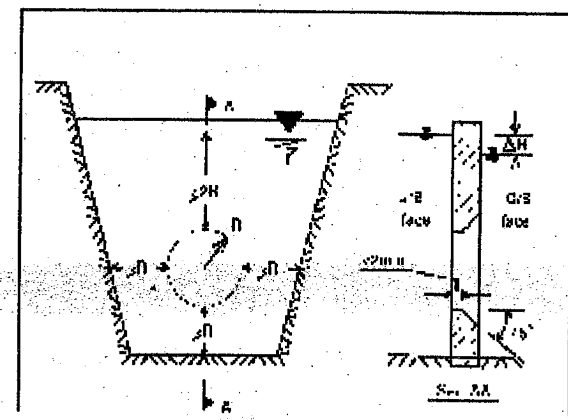
Table - 3: K_b Values w.r.t. b/B ratio

b/B	0.0	0.2	0.4	0.8	1.0
K_b	2.4	2.7	3.6	4.2	(-) 0.9

Limitations

(i) Crest thickness & d/s chamfer should be strictly according to figure7 (a)

(ii) $b/p < 2.5$; $h > 0.03m$; $b > 0.15m$; $p > 0.10m$ and $(B-b) > 0.2m$.



(B) Submerged Orifices :-

An orifice used as a flow measuring device is a well defined, sharp edged opening in a wall or bulkhead which is placed perpendiculars to the sides and bottom of a straight reach. The orifice may be circular or rectangular and for true orifice flow to occur, the U/S water level must be always well above the top of the opening so that vortex flow with air entrainment is not evident. Earlier orifices were used as free flow devices resulting in excessive head loss. To overcome this, orifices are now arranged with tail water well above the top of the opening and the submerged orifices therefore conserve head.

Submerged orifices may be either contracted or suppressed. In the former type, the perimeter of the opening is kept so far away from the bed and sides of the approach channel, that the filaments of water fully contract to form Vena-contracta after they pass through the orifice. In suppressed orifice, its perimeter partially or fully coincides with the side and or bed of me approach channel resulting in complete or partial elimination of contraction. The difference in two conditions is different values of coefficient of discharge.

(i) Circular Submerged orifices :

The standard formulae in use are:

(i) Without velocity of approach.

$$Q = C_d \times A \times (2_g \times \Delta H)^{1/2}$$

Where Q = discharge A = X-Sectional area of orifice g = acceleration due to gravity

C_d = Coeff. of discharge and ΔH = difference in U/S & D/S Water levels.

(i) With velocity of approach.

$Q = C_d \times A \times \{2g \times (\Delta H + h)\}^{1/2}$

$h = V_a^2/2g$ is Velocity head

Va = approach velocity

Average values of discharge coefficients C_d as actually worked out are given in table-5 below.

Table -4: Discharge coefficients in circular submerged orifices

Orifice diameter (cm)	2	2.5	3.5	4.5	5.0	6.0	> 6.
C_d	0.57	0.58	0.61	0.61	0.61	0.60	0.60

Limitations of Circular Orifices:

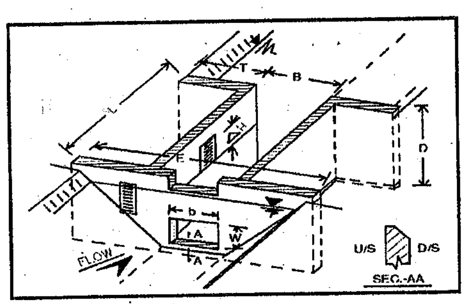
To ensure full contraction and accurate flow measurements, the limits of applications of submerged circular orifices are:

- The edge of the orifice should be sharp and smooth and in accordance with the profile shown in figure 9(a).
- The distance from the edge of the orifice to the bed and sides of approach channel and tail should be not less than radius 'R' of the orifice as shown in figure 9(b)
- Water level u/s of the orifice plate should be above the crown of orifice by at least 2R as the diameter of the orifice as shown in figure 9(b)
- U/S face of the orifice plate must be vertical and smooth and placed perpendicular to the direction of flow.
- For avoiding effect of velocity of approach, x-sectional area of channel must be at least 10 times the area of orifice.
- The lower limit of differential head ΔH is 3 Cm.

Advantages :

- These are simple, inexpensive and easy to install and are best suited to measure low discharges in furrows and small field channels up to about 2.5 cusecs. In a properly fabricated orifice, accuracy to the order of 99% can be obtained.

(ii) Rectangular Submerged Orifices



Since the ratio of depth of flow to width in irrigation channel is generally small and change of depth of flow has no influence on discharge coefficient in rectangular orifices, height of rectangular orifices is considerable less than width of the opening. Figure and table-5 give standard dimensions of rectangular orifice as recommended by U.S.B.R.

The discharge formulae for various conditions of flow are.

(a) Standard Submerged Rectangular Orifice (fully contracted)

(i) Without effect of velocity of approach.:

$Q = 0.61\ A\ \{2g\Delta\ H)\}^{1/2}$

(ii) With effect of velocity of approach.:

$Q = 0.61\ A\ \{2g(\Delta H + h)\}^{1/2}$

Where $h = V_a^2 / 2g$

(b) Standard Submerged Suppressed Orifice :

(i) Without effect of velocity of approach.

$$Q = 0.61(1+0.15r)\ A\ \{2g\ \{\Delta\ H + h)\}^{1/2}$$

Where 'r' is a ratio of suppressed portion of the perimeter of the orifice to the total perimeter.

(ii) With effect of velocity of approach.

$$Q = 0.61(1+0.15r)\ A\{2g(\Delta\ H + h)\}^{1/2}$$

Figure and Table-5 give standard dimensions of rectangular orifice as recommended by U.S.B.R.

Table-5 : Recommended box size & dimensions for submerged orifices by USBR

Height of Orifice	Breadth of Orifice	Height of Structure	Width of Head Wall	Length	Width	Length of D/S Head Wall
W	b	D	E	L	B	T
Cms.	Cms.	Cms.	Cms.	Cms.	Cms.	Cms.
8	30	120	300	90	75	60
8	60	120	300	90	105	60
15	30	150	360	105	75	90
15	45	150	425	105	90	90
15	60	150	425	105	105	90
23	40	180	425	105	90	90
23	60	180	490	105	105	90

Conditions for accuracy of Standard Submerged Rectangular Orifices are:

(i) U/S edge of the orifice must be sharp and smooth and correspond to profile shown in figure 9(a).

(ii) The U/S face of orifice must be truly vertical.

(iii) Top and bottom edge of orifice should be horizontal and sides truly vertical.

(iv) The distance from edge of the orifice to the bed and side slopes of approach channel should be greater than twice the least dimensions of the orifice if full contraction is required.

(v) To make effect of velocity of approach negligible, X-sectional area of approach channel must be at least 8 times the X-sectional are of orifice.

(vi) Practical lower limit of H is 0.03m (i.e. 3cm).

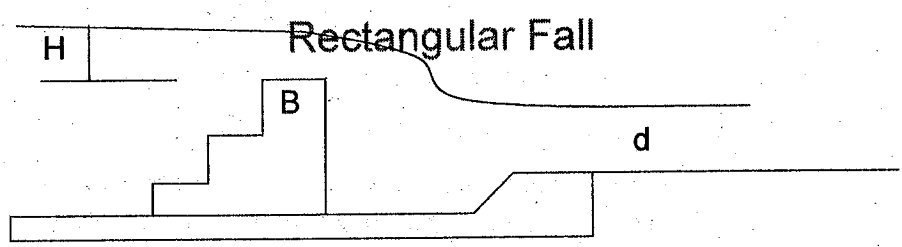
(vii) The upper edge of orifice must have on upstream submergence of 1.0W to prevent air-entraining vortices.

(viii) Lower practical limits of W is 2cm and U/S total depth of flow (Y,) should not be less than 0.15m (15 cm).

2.7.2 Long Base Weirs:

These are in fact existing falls in irrigation channels which can be used to meter the discharge. These may be rectangular or trapezoidal in shape. Standard shapes and formulae are:

(a) Rectangular Type



$$Q = 1.84\, L\, H^{3/2} \,($$

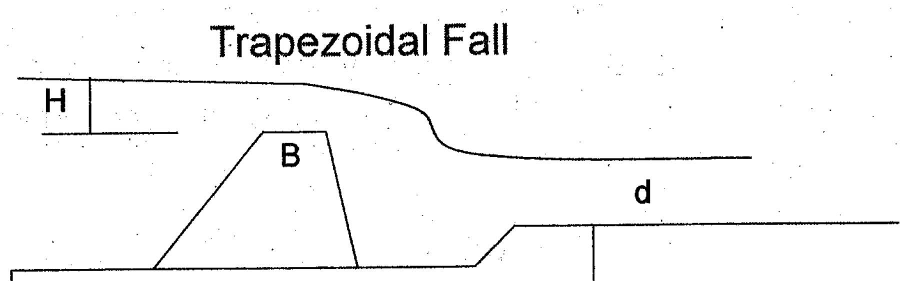
$$B = 0.5 \sqrt{d}$$

The free fall formula is

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

(for $B = 0.55\ d$)

(b) Trapezoidal Crest



The free fall formula is:

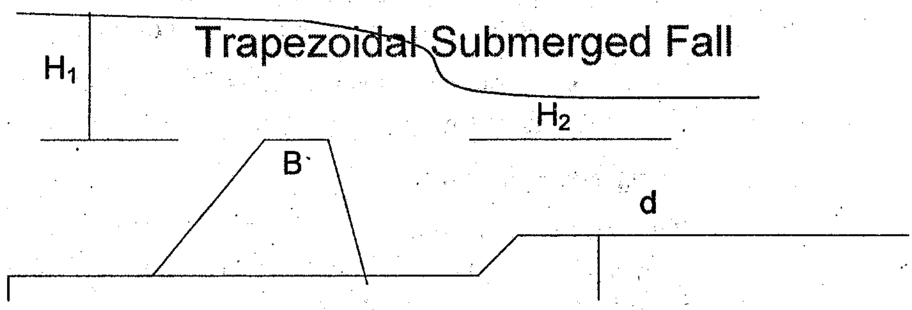
$Q = 1.99\ L\ H^{3/2}(\ H\ /\ B)^{1/6}$

(for $B = 0.55\ [H + d\ ]^{1/2}$)

Where L = Length of the Crest across direction of flow.

(c) Submerged Weir : The submerged weir formula is :

$$Q = (2/3)\, C_{d1}\, (2g)^{1/2}\, L\, [(H_L + V_a^2 / 2g)^{3/2} - (V_a^2/2g)]^{3/2} + C_{d2}\, h\, L[2g\, \{ H_L + (h/2) + (V_a^2 / 2g)\}]^{1/2}$$



Where

C_{d1} = 0.577 C_{d2} = 0.80 Va = Velocity of approach.

G = Acceleration due to gravity L = Length of the Crest

2.7.3 Critical Flow Flumes :

Flume is a flow-measuring device formed by constricting the X-section of an open channel. The constriction can be effected by

either (i) Narrowing the channel section.

or (ii) providing a hump in the entire width of channel.

or (iii) Combination of (i) and (ii) above.

Normally flow in a channel is sub-critical. The purpose of fluming is to change state of flow from sub critical to supercritical state in the flume portion. In between the two states, lies "Critical State" where there is a unique stage-discharge relationship, which is independent of d/s flow conditions and it is for this unique behaviour that measuring flumes are used.

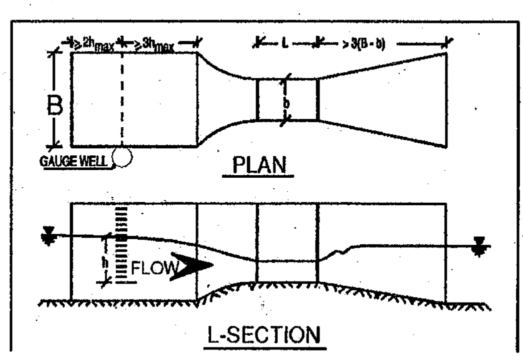
At a critical flow state, flow is characterised by following conditions.

(i) Specific energy is minimum for a given discharge :

(ii) Discharge is maximum for a given specific energy.

(iii) Velocity head is equal to one-half the hydraulic Mean depth is Froude No. is unity.

(iv) There is a definite discharge-depth relationship independent of channel roughness and flow conditions on U/S as well as D/S of flume.



Types of critical Flumes:

Flumes can be classified as

(i) Long throated

(ii) Short Throated.

(iii) Zero Throated

(or cut-throat)

(i) Long Throated Flumes :

Long throated flumes are structures where transition (contraction) is so smooth and gentle that contraction produces a small curvature in water surface profile, the flow in the throat becomes virtually parallel to the invert of the flume and there exists a well-predicted, mathematically analysed stage-discharge relationship given by formula.

$Q = (2/3)^{3/2} C_v C_d b h^{3/2}$

Where $Cv = (H/h)^{3/2}$ and is coefficient of velocity of approach.

$H = (h + V_a^2/2g)$

where Va = Velocity of approach and

C_d ranges from 0.94-0.97 for $0.2 < H/L < 0.97$.

Main Requirements are:

(i) Invert of the throat must be level throughout the flume.

(ii) Flow on U/S should be sub-critical - Froude No. (F) = 0.5.

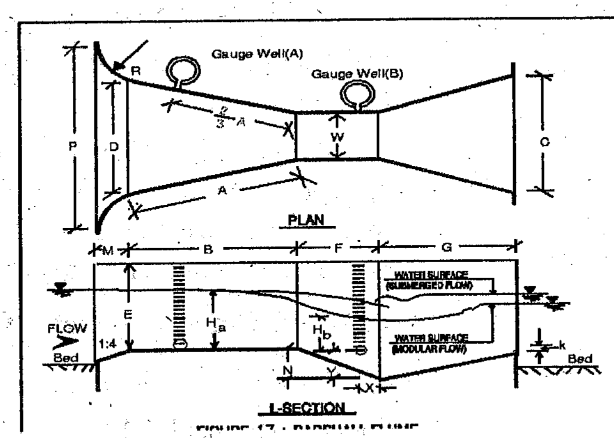
(iii) $h_{min} > 0.5L$.

(iv) $L > 2h$; $2\ m > b > 10cm$;

(v) Entrance and exit transition of either bank should not be steeper than 1 in 3.

(2) Short-Throated Flumes :

The principle of operation is similar to that for a long throated flume with a difference that due to shortened throat length, analytical formula is not available and it is essential to calibrate the flume in laboratory for determining stage-discharge relationship. Besides there is no freedom to vary any dimension in portable model from the one used in laboratory for calibration. The most extensively used such a flume is "PARSHALL FLUME" developed by R.G. Parshall in 1920 in U.S.A.



Based on the principle of venturi and critical flow, Parshall flume consists of:

(i) A converging section in up-stream.

(ii) A constricted throat and.

(iii) A diverging section in d/s of throat.

The floor in converging section is perfectly horizontal, slopes down below the bed in throat section and inclines upward up to canal bed level in the expansion. The control section at which the flow pattern becomes critical is just d/s end of converging section and just up stream of throat.

The width 'W' of the throat is used to designate size of the flumes. Parshall flumes can be used to measure discharges ranging from 1 cusec to 3000 cusecs for which Parshall had developed following empirical relationship:

Throat Width	Discharge equation.
3"	$Q = 0.992\ H_a\ 1.547$
6"	$Q = 2.06\ H_a 1.58$
9"	$Q = 3.07\ H_a 1.53$
1'-8'	$Q = 4W\ \{H_a\}1.522\ W0.026$
10'-50'	$Q = (3.6875W+2.5)\ H_a 1.6$

The relationship is true for F.P.S. System only and

Where W represents Throat Width and H_a the Up Stream gauge reading and

Modular flow occurs when:

H_b / H_a > 0.6 for 3",6" and 9" Flumes.

> 0.7 for 1' to 8' Flumes.

> 0.8 for 10' to 50' Flumes.

and that to in case flume is fabricated and installed strictly according to table enclosed at end.

For submergence ratio higher than those specified above, the flow no more remains free and discharge gets reduced. Parshall has suggested correction methods which are explained below. It is however advised that submergence ration should not exceed 0.65.

Table - 6 Correction factor for flumes 1' - 50'

Flume Size (ft.)	1	1.5	2	3	4	6	8	10	12	15	20	25	30	40	50
Correction factors	1	1.4	1.8	2.4	3.1	4.3	5.4	1.0	1.2	1.5	2.0	2.5	3.0	4.0	5.0

Factors governing Size of the Flume :

To select a particular size of flume, minimum and maximum discharge should be estimated in the Parent Channel and Full Supply Depth should be determined accordingly. Attempt should be to provide smallest size flume to suit age discharge range, width of the flume should be made also adjusted to minimize size of wing walls.

Advantages: (i) Can operate with relatively small head loss.

(ii) Is insensible to velocity of approach.

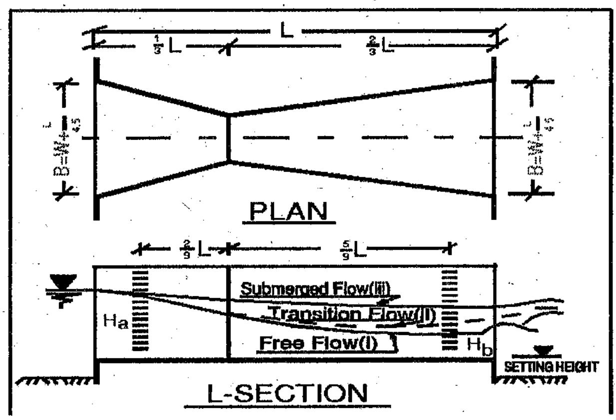
(iii) Can function in free as well as submerged flow conditions.

Disadvantages: (i) Can not function in closed coupled combination structure.

(ii) Is more expensive and requires accurate workmanship.

(iii) Require solid, water light foundations base.

3. Cut-throat flume : Developed in mid sixties by Skogerboe G.V. and Hyatt M.L. of USA, Cut throat flumes consist of only a Converging Inlet Section followed by a Diverging Section on a flat bottom. Being easy to fabricate and install, they give fairly accurate discharge both under Free Flow and Submerged Flow conditions.



Free Flow conditions in a cut throat occurs when the flow is critical near the throat and under this condition, the D/S flow conditions do not influence U/S Depth-discharge relationship which is given by :

$$Q = K \times W^{1.025} H_a^n$$

Where

Q = Discharge in cumec   W = Throat width in metres

K = Free flow Discharge Coefficient.

N = Exponent for free flow and Ha = U/S gauge in Metres.

The flow is termed as submerged when at all points through the flume, depth of flow is greater than critical depth. In this case both U/S and D/S gauges Ha and Hb are measured and discharge is given by formula :

$$Q = K_s \times W^{1.025} \times (H_a - H_b)^n \times [(-) \log S]^{(-ns)}$$

Where

K_s and n_s are discharge coefficient and exponents for submerged flow conditions and n is exponent for free flow,

W = throat width in metres ,

H_a & H_b are U/S and D/S gauges in metres and

$S = H_b/H_a$ the submergence ratio.

Table 7 gives relationship between Cut-throat flume length (L); the transition submergence coefficients (S_t.), the ratio for values lower than which the discharge is free and at higher values the flow becomes submerged. and exponents 'n' for free flow

& ' n_s ' for submerged flow.

Table - 7 : Summary of coefficients and transition submergence for Selected Flumes :

L (m)	S_t (%)	Free Flow n	Conditions K	Submerged Flow n_s	Conditions K_s
0.5	60.7	2.08	6.15	1.675	3.50
0.6	62.0	1.989	5.17	1.600	2.90
0.7	63.0	1.932	4.63	1.550	2.60
0.8	64.2	1.880	4.18	1.513	2.35
0.9	65.3	1.843	3.89	1.483	2.15
1.0	66.4	1.810	3.60	1.456	2.00
1.2	68.5	1.756	3.22	1.427	1.75
1.4	70.5	1.712	2.93	1.407	1.56
1.6	72.0	1.675	2.72	1.393	1.45
1.8	73.8	1.646	2.53	1.386	1.32
2.0	75.5	1.622	2.40	1.381	1.24
2.2	77.0	1.600	2.30	1.378	1.18
2.4	78.4	1.579	2.20	1.381	1.12
2.6	79.5	1.568	2.15	1.386	1.08
2.7	80.5	1.562	2.13	1.390	1.06

Installation of flumes :

(i) Sizing of Flume : It should be selected to pass maximum discharge likely to be passed and measured. Since down stream depth of flow will essentially remain the same as it was before installation of the flume, there will be increase in U/S depth due to head loss, which may be taken as (H_a - H_b). The flume should be selected to ensure no over topping on U/S side.

It has been experienced that $(H_a)_{max}$: L ratio should not exceed 0.4 otherwise accuracy will be low.

(ii) Installation : If circumstances permit, it is always preferable to install Cutthroat so that it operates under free flow conditions. The obvious advantage is that for this state, only U/S gauge H_a is required to be read.

Following steps are involved.

(a) Determine maximum flow rate to be measured.

(b) Locate highest water level and determine maximum depth of flow.

(c) Using equation $Q=KW^{1.025} H_a$ for the flume proposed to be used, calculate H_a corresponding to Q_{max}.

(d) From Table - 10 note down corresponding value of transition submergence S_t.

(e) Work out $H_b = S_t \times H_a$

(f) To ensure free flow, floor of the flume shall be so placed that height above canal bed >= $(d_{max} - h_b)$. This floor height $(d_{max} - h_b)$ is called Setting - height.

On the other hand, advantage of submerged conditions is that flume can be placed directly at channel bed, thereby reducing head loss.

Please Note: Floor of the flume must be perfectly levelled in longitudinal as well as transverse direction to ensure accuracy.

Table-8 : State -Discharge range for various flume sizes

S.No.	Flume Size	Range of Ha	Range of Discharges	
	Cm x Cm	Cm.	Cumecs	Cusecs
1	10x90	5-60	0.0015 - 0.143	0.187 - 5.05
2	20x90	5-60	0.003 - 0.291	0.39 - 10.28
3	30x90	10-60	0.016 - 0.442	0.57 - 15.60
4	40x90	10-75	0.022 - 0.895	0.78 - 31.00
5	50x120	10-150	0.020 - 3.220	0.70 - 113.71
6	75x180	10-150	0.04 - 3.713	1.41 - 131.12
7	90x220	10-200	0.054 - 6.155	1.91 - 217.36
8	110x270	10-200	0.064 - 6.932	2.26 - 244.80

2.8 Measurement with Stage-Discharge Curve

This is an inexpensive and simple method of measurement of flow in the system, and no structures or installations of any kind are needed. Only the following three sets of data are required for this :

a. The depth of the flow of water in a specified reach

b. The cross-sectional area of the channel, at the depth through which water is flowing; and

c. The average velocity of the flow.

Based upon the data, the flow in a channel is calibrated for different depths of flow & accordingly discharges are worked out. This will result in tabulation of relation between discharge & stage (depth). Whenever the flow is required to be measured, stage is noted from gauge plate & accordingly discharge is reported.

2.9 DESIGNING OF STANDING WAVE FLUME FOR DISCHARGE MEASUREMENT

Standing wave flume is a modified broad crested weir with rectangular control section. The flume was developed at the Central Water & Power Research Station, Pune India based on the results of experiments, which had started as long as 1927. Later the design of flume was standardized by the Indian Standard Institution. Standing wave flume is designed for a known range of discharge & for at least 15% loss of head.

Description :

The SWF has three section viz Bell Mouth converging inlet section, Throat section & diverging outlet section with hyperbolic expansion. A horizontal hump is provided at the throat & therefore is reference or sill level of flume. There is only one gauge, which is located in the upstream of the flume. The zero of the gauge must coincide with the sill level. This is known as zero setting.

Discharge Equation :

The discharge equation for SWF

$$Q = \frac{2}{3} \sqrt{\frac{2g}{3}} \; Cd \; B_2 \; H^{3/2}$$

Q = Discharge flowing through SWF in cumecs

g = Acceleration due to gravity=9.81 m2 / sec

B_2 = throat width in m

H = U/s head including velocity of approach in m

Cd = Coefficient of discharge

= 0.97 for Q = 0.05 to 0.3 cumecs = 0.99 for Q = 1.5 to 15 cumecs

= 0.98 for Q = 0.3 to 1.5 cumecs = 1.00 for Q = 15 cumecs & above

Data Required for the Design of SWF

1. Full supply discharge (Qmax) = Say 20 cusecs
2. Full supply depth (d) = 0.73 m
3. Canal Bed Width (B) = 0.90 m
4. Canal Bed slope (S) = 1 in 2500
5. Canal Side slope (Z) = 1:1
6. Mannings rugosity coefficient (n) = 0.023
7. Bed level of canal on the U/S = Say 100.000 m
8. Variation of discharge = Qmax to 1/3 Qmax

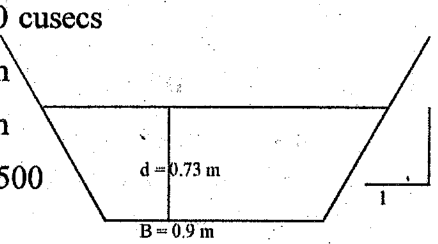


Fig Section

Design of Standing wave flume:

Step No. 1 Height of Hump

Generalized stage discharge relationship $Q = C\,d^x$

Taking log on both sides Log Q = Log C + x Log d which is a straight line between Log Q & Log d with x as slope of that line. The value of exponent x is found by least square straight-line curve fitting method. Mathematically the value of x can be found out by

$$X = \frac{\Sigma(\text{Log } Q.\ \text{Log } d) - \frac{(\Sigma \text{Log } Q)\ (\Sigma \text{Log } d)}{M}}{\Sigma(\text{Log } d)^2 - \frac{(\Sigma \text{Log } d)^2}{M}}$$

where M is the no. of sets

Mannings Formulae $Q = \frac{1}{n} A R^{2/3} S^{1/2}$

$A = (B + Zd)\, d$

$P = B + 2\sqrt{(Z^2 + 1)}\, d$ &

$R = A/P$

S No	Conditions of flow	d in m	A in m^2	P in m	R in m	$R^{2/3}$	Q in cumecs	Q in cusecs
1	Flow at FSD	0.73	1.1899	2.964732	0.401352	0.5425	0.5613	19.8214
2	Flow at 80% FSD	0.584	0.86666	2.551786	0.339627	0.485	0.3655	12.9086
3	Flow at 60% FSD	0.438	0.58604	2.138839	0.274001	0.42	0.2141	7.55937
4	Flow at 33% FSD	0.2409	0.27484	1.581362	0.173801	0.3096	0.0740	2.61325

Computation of exponent X

S No.	d	Q	Log d	Log Q	Log d X Log Q	(Log d)2
1	0.73	0.5613	-0.137	-0.251	0.0343	0.01868
2	0.584	0.3655	-0.234	-0.437	0.1021	0.05456
3	0.438	0.2141	-0.359	-0.669	0.24	0.12854
4	0.2409	0.074	-0.618	-1.131	0.699	0.38213
		Total	-1.347	-2.488	1.0754	0.58391

Therefore exponent X =

$$X = \frac{\Sigma (\text{Log } Q . \text{Log } d) - \frac{(\Sigma \text{Log } Q)\ (\Sigma \text{Log } d)}{M}}{\Sigma (\text{Log } d)^2 - \frac{(\Sigma \text{Log } d)^2}{M}}$$

where M is the no. of sets

$$= \frac{1.0754 - \frac{(-2.488)\ (-1.347)}{4}}{0.58391 - \frac{(-1.347)^2}{4}} = 1.823$$

for X = 1.823 & discharge range Qmax to 1/3 Qmax ;

Value of Hump height Z can be taken from figure

Z= 0.128 d = 0.128 X 0.73 = 0.0934 m

Therefore provide hump height equal to 10.0 cm

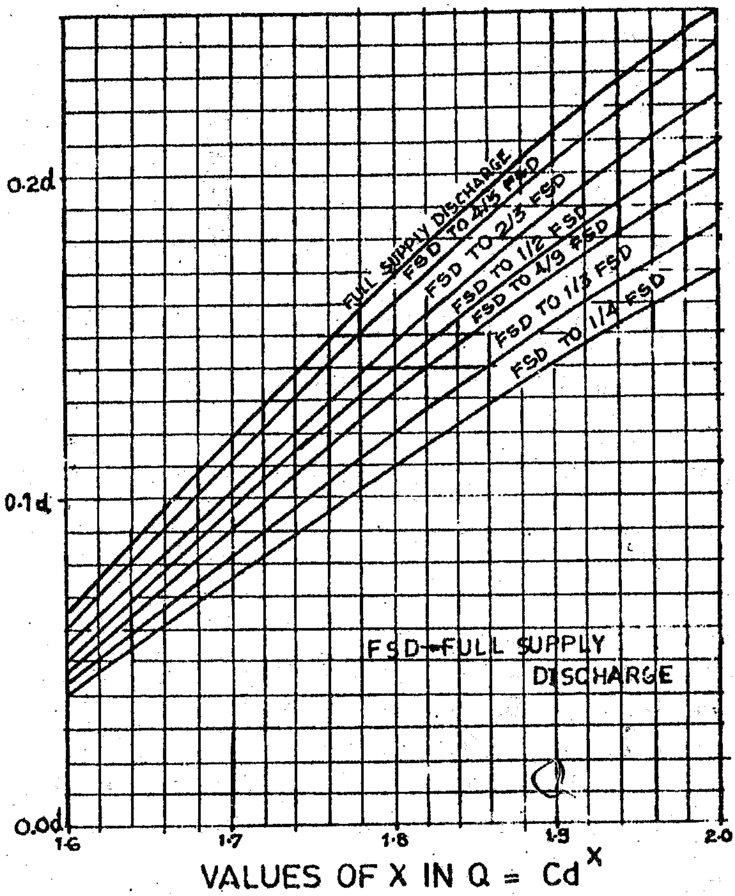


Fig5. Height of Hump to Attain Bulk Proportionality

Step No. 2 Calculation of H_{max}

For Qmax = 0.561 m^3/s, d = 0.73m, Area of flow in Parent Canal (A)= 1.19 m^2

Average Velocity of Approach Va = Q/A = 0.4714 m/s

Therefore velocity head hv = Va^2 / 15.2 = 0.0146 m = 0.015 m

Here velocity head is taken as $Va^2 / 15.2$ instead of $Va^2 / 2g$, since velocity in center of canal will be more than average velocity. Therefore higher velocity head is taken to cater more velocity in center of canal.

Height of flow above sill of hump (D) = d - Z = 0.73 - 0.10 = 0.63 m

Therefore Hmax = D + hv = 0.62 + 0.015 = 0.635 m

Step No. 3 Calculation of Throat Width

Discharge in Standing wave flume is given by equation 8

$$Q = \frac{2}{3} \sqrt{\frac{2g}{3}} \; Cd \; B_2 \; H_{max}^{3/2}$$ where Cd is coefficient of discharge

Cd = 0.97 for Q = 0.05 to 0.3 m^3/s = 0.98 for Q = 0.3 to 1.5 m^3/s

= 0.99 for Q = 1.5 to 15.0 m^3/s = 1.00 for Q = 15.0 m3 / s & above

For Qmax = 0.561 m^3/s; Cd = 0.98; H_{max} = 0.635 m

$$0.561 = \frac{2}{3}\sqrt{\frac{2 \times 9.81}{3}} \times 0.98 \times B_2 \times 0.635^{3/2}$$

Therefore B_2 = 0.663 m = 0.66 m

Minimum throat width required = B_2 = 1.5 H_{max} = 1.5 x 0.73 = 1.095 m

As far as possible, the throat width should not be less than Hmax to minimize the head loss or afflux. However, designed throat width should not be increased to satisfy this condition. Otherwise design of hump height will have to be modified accordingly.

Therefore provide B_2 = 0.66 m

Step No. 4 Shape of Standing Wave Flume

A) Bell Mouth Entrance

The radius of sidewalls of the bell mouth entrance is as given below. The curve is to start from throat & should continue till it subtends an angle of 60^0 from where it should be continued tangentially to meet the side of the channel upstream.

For Hmax > 0.3 m; Radius of side walls of Bell mouth R = 3.6 $H_{max}^{1.5}$

For Hmax < 0.3 m; Radius of side walls of Bell mouth R = 2 H_{max}

Therefore as Hmax > 0.3m ; R = 3.6 $H_{max}^{1.5}$ = 3.6 x $0.635^{1.5}$ = 1.82 m

Length of Converging Section L_1

$$L_1 = \sqrt{\left(2R - \frac{(B_1-B_2)}{2} \quad \frac{(B_1-B_2)}{2}\right)}$$

where B_1 = Canal Bed width; B_2 = Throat width; R = Radius of converging section

Therefore L_1 = 0.65 m = 0.65 m

B) Throat Section

The throat width is calculated as above at step 3;

Length of throat section L_2 is equal to 2.5 H_{max} = 2.5 x 0.635 = 1.5875m =1.6 m

C) Diverging Outlet Section

Length of diverging section L_3 is kept 4 H^{max} for better functioning of the flume. The sides of diverging section should be given hyperbolic expansion to join the downstream channel. The width of diverging section B_y at a distance Y from the throat is given by:

$$By = \frac{B_1 \, B_2 \, L_3}{B_1 \, L_3 - (B_1 - B_2) \, Y}$$

Where B1 Canal Bed width, B2 Throat width L_3 Length of diverging section, Y distance from throat

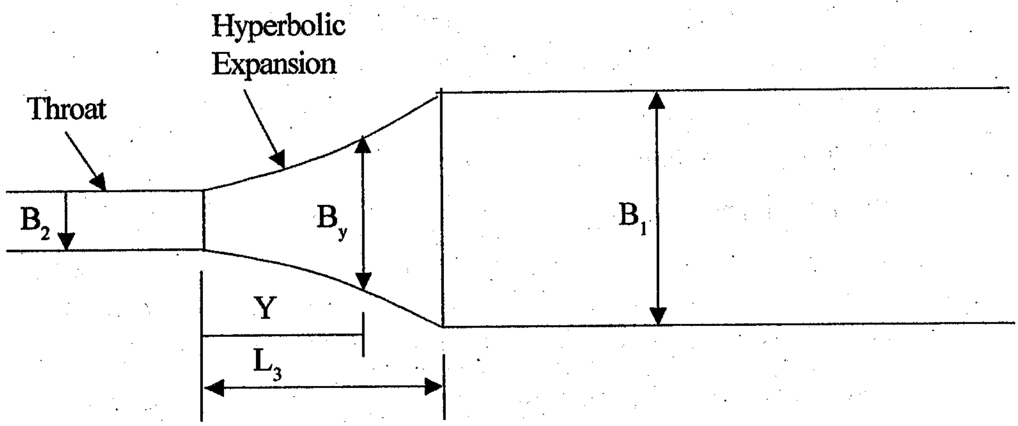


Fig. 6. Hyperbolic Expansion of Diverging Section.

Therefore L_3 = 4 x H_{max} = 4 x 0.635 = 2.54 m = 2.54 m

Hyperbolic Expansion

$$By = \frac{B_1 B_2 L_3}{B_1 L_3 - (B_1 - B_2) Y} =$$

When Y = H_{max} By = 0.707 m

When Y = 2 H_{max} By = 0.7615 m

When Y = 3 H_{max} By = 0.825 m

When Y = 4 H_{max} By = 0.9 m = B1

D) Sloping Glacis

Head recovery = 85 % or loss of head = 15%

Level of hump = U/s CBL + height of hump = 100.000 + Z = 100.000 + 0.100 = 100.10 m

D/s CBL = U/s CBL - Loss of head X Hmax = 100.00 - 0.15 X Hmax =100.00 - 0.15 X 0.635

D/s CBL = 99.90475 m = 99.905 m

Height of hump above toe of glacis = Level of Hump - D/s CBL =100.10 - 99.905 = 0.195 m

Compare 20 X Height of hump above toe of glacis with 4 H_{max} (i.e. Length of diverging Section). If L_3 is less than 20 times height of hump above toe of glacis, for the half the horizontal length of glacis (2H_{max}), the slope should be 1 in 20 & remaining level difference will be accommodated in the remaining 2 H_{max} horizontal length of glacis.

L_3 =2.54 m<20 X height of hump above toe of glacis = 20 X 0.195 = 3.9 m

Therefore drop provided in first half of glacis;

= 2 H_{max} / 20 = 2 x 0.635/ 20 = 0.0635 m

Remaining level difference = 0.195-0.0635 = 0.1315 m

Therefore remaining slope = 2.54/(2 x 0.1315) = 9.657 Say 1 in 10.0 m

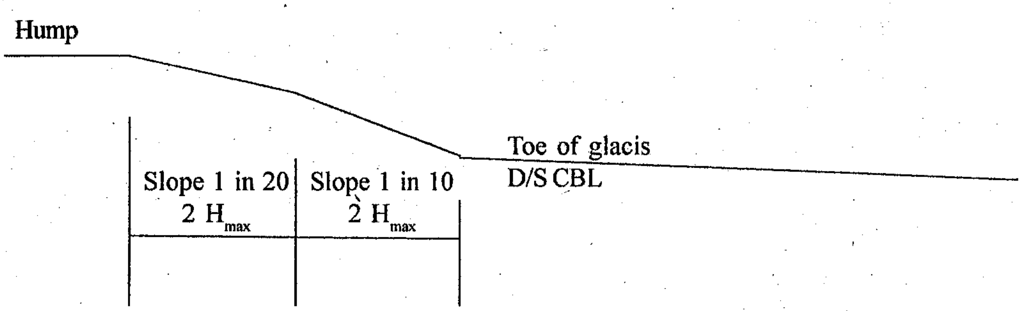


Fig 7. D/S Sloping Glacis

E) Location of Gauge Chamber

The gauge chamber is to be constructed at a distance of 4 H_{max} on the U/s from the starting of converging section. The zero of gauge must coincide with the hump level (Sill of Flume).

Gauge Location = 4 X 0.635 = 2.54 m

IMPORTANT FEATURES OF THE DESIGNED FLUME :

A) Bell Mouth Converging Inlet Section :

U/S Canal Bed = 100.00 m

Length of Converging Section (L_1) = 0.65 m

Radius of Bell Mouth Entrance R_1 = 1.82 m

B) Throat Section :

Hump Height (Z) = 0.10 m

Level of Hump = 100.10 m

Throat Width B_2 = 0.66 m

Length of Throat Section L_2 = 1.6 m

C) Diverging Outlet Section :

Level of toe of Glacis = 99.905 m

Length of Diverging Section L_3 = 2.54 m

Details of Hyperbolic Expansion:

Y	=	0.635 m	1.27 m	1.905 m	2.54 m
By	=	0.707 m	0.7615 m	0.825 m	0.9 m

Slope of Glacis :

Horizontal Length	Slope
First 1.27 m	1 in 20
Remaining 1.27 m	1 in 10

Discharge Table

Discharge Equation

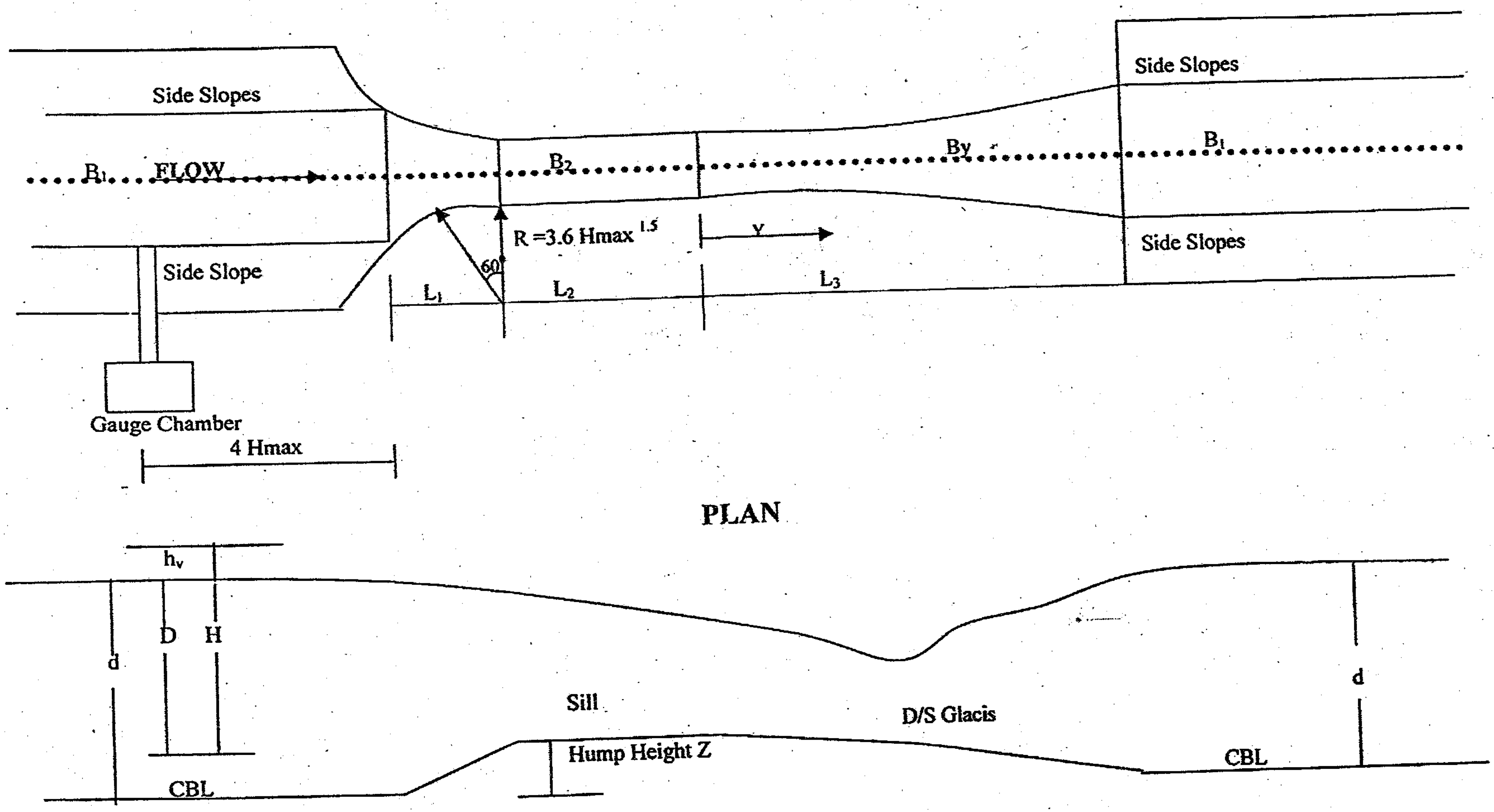
$$Q = \frac{2}{3}\sqrt{\frac{2g}{3}}\quad Cd \quad B_2 \quad H^{3/2}$$

$Cd = 0.98$ $B_2 = 0.66$ m $g = 9.81$ $m^2/_s$

H is Gauge over hump including velocity head in m

Therefore $Q = 1.1027\ H^{3/2}$

S No	D = d-z	d in m	A in m^2	P in m	R in m	$R^{2/3}$	V_a	h_v	H= D+h_v	Q cumecs	Q cusecs
1	0.63	0.73	1.19	2.96	0.40	0.54	0.47	0.015	0.64	0.57	20.2
2	0.56	0.657	1.02	2.76	0.37	0.51	0.45	0.013	0.57	0.47	16.8
3	0.49	0.5913	0.88	2.57	0.34	0.49	0.42	0.012	0.50	0.39	13.9
4	0.43	0.53217	0.76	2.41	0.32	0.46	0.40	0.011	0.44	0.32	11.5
5	0.38	0.47895	0.66	2.25	0.29	0.44	0.38	0.010	0.39	0.27	9.4
6	0.33	0.43106	0.57	2.12	0.27	0.42	0.36	0.009	0.34	0.22	7.7
7	0.29	0.38795	0.50	2.00	0.25	0.40	0.34	0.008	0.30	0.18	6.3
8	0.25	0.34916	0.44	1.89	0.23	0.37	0.33	0.007	0.26	0.14	5.0
9	0.21	0.31424	0.38	1.79	0.21	0.36	0.31	0.006	0.22	0.11	4.0
10	0.18	0.28282	0.33	1.70	0.20	0.34	0.29	0.006	0.19	0.09	3.2
11	0.15	0.25454	0.29	1.62	0.18	0.32	0.28	0.005	0.16	0.07	2.5
12	0.13	0.22908	0.26	1.55	0.17	0.30	0.26	0.005	0.13	0.05	1.9
13	0.11	0.20617	0.23	1.48	0.15	0.29	0.25	0.004	0.11	0.04	1.4
14	0.09	0.18556	0.20	1.42	0.14	0.27	0.23	0.004	0.09	0.03	1.0
15	0.07	0.167	0.18	1.37	0.13	0.25	0.22	0.003	0.07	0.02	0.7



ELEVATION

Fig. 8.. Details of Standing Wave Flume (Not to the Scale)

Table 9 "Dimension and Discharging Capacities of PARHALL FLUMES for various throuat without - W.

A	2/3 A	B	C	D	E	F	G	K	N	R	M	P	X	Y	Free Flow Capacity (Cusecs)	
															Min.	Max.
1'-6 3/8"	1'-0 1/4"	1'-6"	0'-7"	0'-10 3/16"	2'-0"	0'-6"	1"-0"	0'-1"	0'-2 1/4"	1'-4"	1'-0"	2'-6 1/4"	0'-1"	0'-1 1/2"	0.03	1.90
2'-0 7/16"	1'-1 5/16"	2'-0"	1'-3 1/2"	0'-3 5/8"	2'-0"	1'-0"	2"-0"	0'-3"	0'-4 1/2"	1'-4"	1'-0"	2'-11 1/2"	0'-2"	0'-3"	0.05	3.90
1'-10 5/8"	1'-11 1/8"	2'-10"	1'-3"	0'-10 5/8"	2'-6"	1'-6"	1"-0"	0'-3"	0'-4 1/2"	1'-4"	1'-0"	3'-6 1/2"	0'-2"	0'-3"	0.09	8.90
4'-6"	3'-0"	4'-4 7/8"	2'-0"	2'-9 1/4"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	1'-8"	1'-3"	4'-10 3/4"	0'-2"	0'-3"	0.11	16.10
4'-9"	3'-2"	4'-4 7/8"	2'-6"	3'-4 3/8"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	1'-8"	1'-3"	5'-6"	0'-2"	0'-3"	0.15	24.60
5'-0"	3'-4"	4'-10 7/8"	3'-0"	3'-11 1/2"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	1'-8"	1'-3"	6'-1"	0'-2"	0'-3"	0.42	33.10
5'-6"	3'-8"	5'-4 3/4"	4'-0"	5'-1 7/8"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	1'-8"	1'-3"	7'-3 1/2"	0'-2"	0'-3"	0.61	50.40
6'-0"	4'-0"	5'-10 5/8"	5'-0"	6'-4 1/4"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	2'-0"	1'-6"	8'-10 3/4"	0'-2"	0'-3"	0.30	67.90
6'-6"	4'-4"	6'-4 1/2"	6'-0"	7'-6 5/8"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	2'-0"	1'-6"	10'-1 1/4"	0'-2"	0'-3"	0.60	85.60
7'-0"	4'-8"	6'-10 3/8"	7'-0"	8'-9"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	2'-0"	1'-6"	11'-3 1/2"	0'-2"	0'-3"	0.60	103.50
7'-6"	5'-0"	7'-4 1/4"	8'-0"	9'-11 3/8"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	2'-0"	1'-6"	12'-6"	0'-2"	0'-3"	0.00	121.40
8'-0"	5'-4"	7'-10 1/8"	9'-0"	11'-1 3/4"	3'-0"	2'-0"	3'-0"	0'-3"	0'-9"	2'-0"	1'-6"	13'-8 1/4"	0'-2"	0'-3"	0.50	139.50

Parameters of Parshall flume

W	A	2/3A	B	C	D	E	L	G	K	M	N	P	R	X	Y
25.4	363	242	356	93	167	229	76	203	19	-	29	-	-	8	13
50.8	414	276	406	135	214	254	114	254	22	-	43	-	-	16	25
76.2	467	311	457	178	259	457	152	305	25	-	57	-	-	25	38
152.4	621	414	610	394	397	610	305	610	76	305	114	902	406	51	76
228.8	879	587	864	381	575	762	305	457	76	305	114	1080	406	51	76
304.8	1372	914	1343	610	845	914	610	914	76	381	229	1492	508	51	76
457.2	1448	965	1419	762	1026	914	610	914	76	381	229	1676	508	51	76
609.6	1524	1016	1495	914	1206	914	610	914	76	381	229	1854	508	51	76
914.4	1676	1118	1645	1219	1572	914	610	914	76	381	229	2222	508	51	76
1219.2	1829	1219	1794	1524	1937	914	610	914	76	457	229	2711	610	51	76
1524.0	1981	1321	1953	1829	2302	914	610	914	76	457	229	3280	610	51	76
1828.8	2134	1422	2092	2134	2667	914	610	914	76	457	229	3442	610	51	76
2133.6	2286	1524	2242	2438	3032	914	610	914	76	457	229	3810	610	51	76
2438.4	2438	1626	2391	2743	3397	914	610	914	76	457	229	4172	610	51	76
3048.0	-	1829	4267	3658	4756	1219	914	1829	152	-	343	-	-	305	229
3658.0	-	2032	4877	4470	5607	1524	914	2438	152	-	343		-	305	229
4572.0	-	2337	7620	5588	7620	1829	1219	3048	229	-	457	-	-	305	229
6096.0	-	2845	7620	7315	9144	2134	1829	3658	305	-	686	-	-	305	229
7620.0	-	3353	7620	8941	10667	2134	1829	3962	305	-	686	-	-	305	229
9144.0	-	3861	7925	10566	12313	2134	1829	4267	305	-	686	-	-	305	229
12192.0	-	4877	8230	13818	15481	2134	1829	4877	305	-	686	-	-	305	229
15240.0	-	5893	8230	17272	18529	2134	1829	6096	305	-	686	-	-	305	229

2.9 Self Assessment Test

1. Why is flow measurement required?
2. What are the basic methods to measure flow?
3. What are the direct & indirect methods? Explain briefly.
4. Define various hydraulic structures used for discharge measurement with their merits & demerits.
5. When no structure is available, how can discharge be measured? Explain the method.

2.10 Key words

Stage : depth of water flowing in a stream with respect to assumed datum.

Discharge : rate of flow of water per unit time.

Velocity : the distance traveled per unit time.

Mean velocity : average velocity across the depth of flow.

Slope : rate of change in bed elevation with respect to distance; a dimensionless unit. Generally defined in ratio of vertical height to horizontal length.

Free flow condition : when downstream water does not affect the flow at control section, flow is termed as free flow condition.

Submerged flow condition : when downstream water affects the critical flow condition at control section, flow is termed as submerged flow condition.

Critical flow condition : a stage at which specific energy of flow is minimum. At this stage, discharge depends directly on the flow depth at upstream control point.

2.11 Suggested readings

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

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UNIT-3

ON FARM WATER MANAGEMENT & WATER BUDGETING

STRUCTURE

3.0 Objectives

3.1 Introduction

3.2 Policy adjustments in water sector

3.3 SAQ - Activity I

3.4 Role of water in plant development

3.5 Irrigation may have harmful effects

3.6 What is irrigation?

3.7 The Water needs of the crop.

3.8 Self Assessment Questionnaire-2

3.9 Suggested Readings

3.0 Objectives

Have you ever read about any irrigation project, which has achieved the objectives as desired at the time of inception. There is always a gap between irrigated area projected and the actual culturable command area. Even the projected benefit over cost is not met as per project expectation. Why is it? so, "have you ever thought deeply over this matter"? What do you find behind all this? You will certainly agree that lack of proper irrigation management is the main cause behind all this performance gap of irrigation project. We generally forget the management aspects of created irrigation potential after constructing the dam.

Have you ever observed the farmers while irrigating their fields. Do you think that they may improve a lot in irrigation management? Different farmers act differently while irrigating their fields. Some farmers do irrigation in efficient manner. They use every drop of water in a very wise manner, while others do not. What is the basic cause of this differentce? Certainly the management aspect plays a vital role in efficient utilisation of irrigation water. So there is a strong need of on farm water management.

You must have also noticed that if farmers are well informed about any new technology, they act accordingly and in a very wise manner. They modify the technology according to resource availability and their requirement.

So the first step in self-dependence in food production is to provide the complete information to farmer on irrigation management. As you (officers of irrigation & Agriculture department) have the direct contact with farmers, it is very essential for you also to know each & every aspect of irrigation management, so that the farmers may clarify their confusion and curiosity during discussion with you.

In this section, we will therefore, help you to refresh some basic facts about irrigation management. Before moving to the next page please answer the following questions in the space provided.

3.1 INTRODUCTION

The performance of irrigation development in India has been very impressive in terms of capacity expansion. However, in regard to capacity utilization and efficiency of water use, the main problems are.

1) Potential created is not getting fully utilized resulting in a current gap of 8.36 m ha.

2) For some major reservoirs the average filling of the live storage has been less than desirable.

3) Another shortcoming in the performance of the irrigation sector is the comparatively low yield of irrigated crops particularly in the central and eastern states.

4) Waterlogging and salinity appear to be large problems. By a preliminary estimate, the total affected area by waterlogging and salinity is about 7% of the irrigated area. inequity in water distribution within the command can be important for waterlogging and salinity.

5) Poor maintenance of irrigation systems has caused considerable concern. Per hectare maintenance grant in 1986-87 varied from Rs 40 to 180, which is in general below the norms fixed by the Finance Commission. The percentage of working expenses recovered through water charges have steadily declined from around 90% in 1975-76 to around 35% by 1986-87, whereas the staff expenditure in the working expenses has shown an increase.

6) The reservoir sedimentation in major and medium storage projects does not seem to be a major problem considering that the annual loss of live storage due to sedimentation is only 0.5 km'. The equivalent loss of potential is only about 4% of what is being added.

7) The irrigation sector has sometimes been criticised for the lopsided regional distribution of the facilities. Considering that irrigation projects are the outcome of favourable topographic as well as hydrologic combinations and its equitable distribution is not practicable. However, within the various States of India, the gross irrigated area per thousand persons varies from 13 ha in Kerala to about 350 ha in Punjab. Similarly the percentage of gross sown area irrigated varies from 11 % in Maharashtra to 94% in Punjab.

3.2 Policy Adjustments in Water Sector

Macro planning or inter-sectoral policies with regard to water development currently favours a mix of small and large projects, surface water and groundwater development, lift irrigation and gravity irrigation etc. Irrigation schemes tend to be location specific and in most cases alternatives do not exist. Hence the policy of a judicious mix will have to continue.. Where option exists, it would have to be evaluated. However, conjunctive use of groundwater may have to be insisted upon for surface irrigation schemes as a result of sustainability. With regard to project planning, the recent policy already includes provision for additional live storage to allow irrigation benefits to continue undiminished for at least 50 years. A stricter and more meticulous planning of the conjunctive use at project planning stage seems essential and the CWC has already formulated a draft policy in this regard.

With regard to project design, canal design practices based on the regime theory design of channels has proved successful in terms of sustainability. However, allowing partial, flow design particularly in the secondary channels seems to create considerable hydraulic problems and this practice may have to be changed. The present policy does not favour canal lining except for special problematic reaches and this seems to be a sound practice. Planning policy changes which favour shift to high technology through drip and sprinkler irrigation. Provision of "Off line" storages for maintaining supplies in the inter-rotational period is to be incorporated in future designs.

With regard to the complex problem of operation and maintenance and financial sustainability, policy changes favouring increased water prices and turn over of tertiary water distribution to water users associations have been incorporated in the new irrigation management policy.

The policy changes are also necessary to improve the irrigation organisation and the procedures followed by the organisations. An irrigation organisation has to become inter-disciplinary-and has to be organised in a way where specialisation such as irrigation management, project construction, project planning and design etc. would be nurtured.

Human resource development with a particular stress on equipping the staff with management skills with regard to problem diagnosis, inter-personal communication, conflict resolutions etc. are necessary. Also attitudal changes to shift from administering water through bureaucratic hieerarchy towards cooperation resource management are necessary. These ideas are already included in the draft approach paper to organisational and procedural changes as prepared by CWC.

Apart from human resource development, applied and action research, and also policy analysis and research are important tools for better irrigation management. A long term policy favouring these activities needs to be implemented.

Lastly, the policy changes may have to cover the institutional aspects. The responsibility with regard to water and irrigation even within a state is currently fragmented between surface water and groundwater, amongst major and medium and minor projects, amongst hydropower irrigation and water supply etc. While specialisation with regard to each type would have to be maintained, proper coordination would require that these activities are made the concern of a single institution. Similarly a constant review of the performance of the water sector as a whole through an independent inter-disciplinary team would go a long way in giving information about the need for continuous policy changes.

So to cope up with all the above complex problems, we should know about the concept of on farm water management and it should be extended to the farmers, who are the actual users of water.

3.3 SAQ Activity I

1. Why did you decide to join this course? Write at least five reasons.

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2. What advantages or benefit's do you think you can derive from knowledge of irrigation management.

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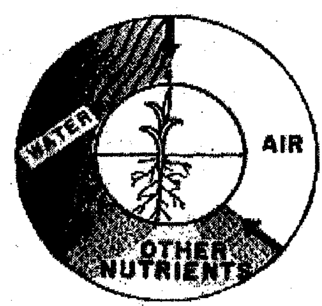
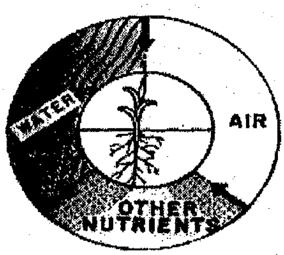
The probable reasons may be drawn from our own experience, about joining this course, is to get the complete information on irrigation management and role of farmers in irrigation management. From our own experience, we can say easily that in every problem related to crop production, the basic cause is the mismanagement of natural resources. For crops to grow well they need soil, sunlight, nutrients, we are only concerned here about irrigation water and its proper utilisation and management.

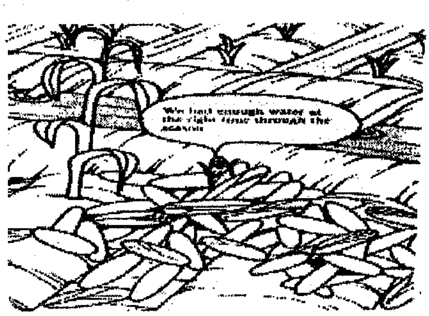
3.4 Role of water in Plant Development

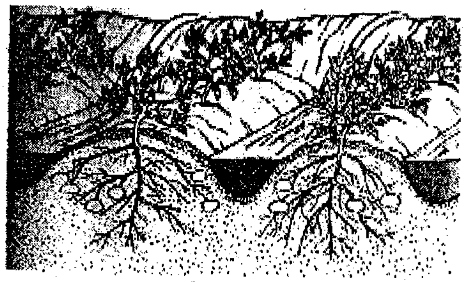
Growing plants need water, sun, air and nutrients to form roots, stems, leaves, fruits and seeds. Water is a large part of the plant's structure. It carries food through the plant and it cools the crop during hot weather.



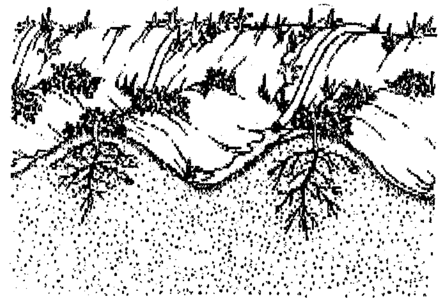


Roots can't get enough air if there is an excess of water. A lack of water makes plants unable to draw needed nutrients (food) from the soil. Too





Sufficient



Insufficient

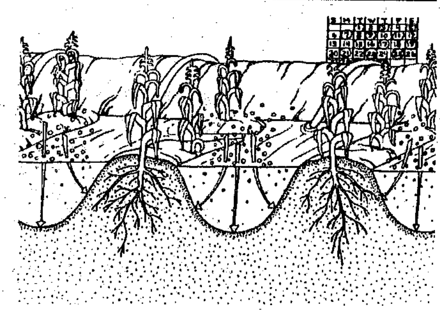
much or too little water results in lower yields.

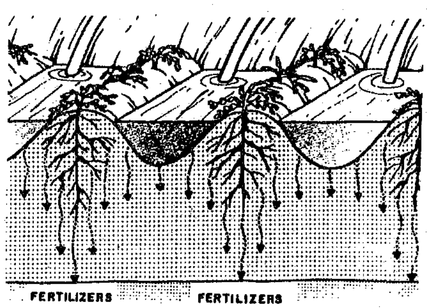
For good production, crops need the right amount of water throughout their development.

Sufficient water throughout the growing season helps ensure healthy crops, thus enabling the plants to resist insects and disease better.

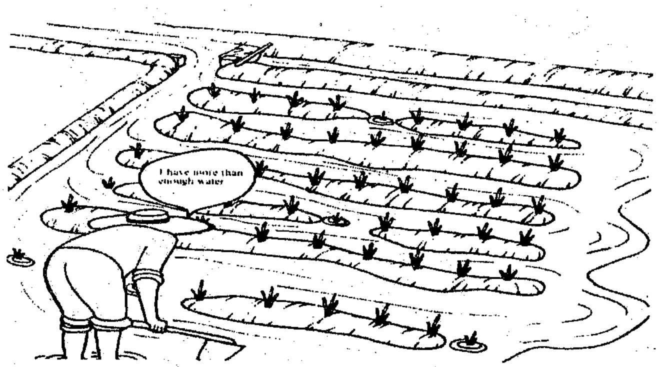
3.5 Irrigation may have harmful effects

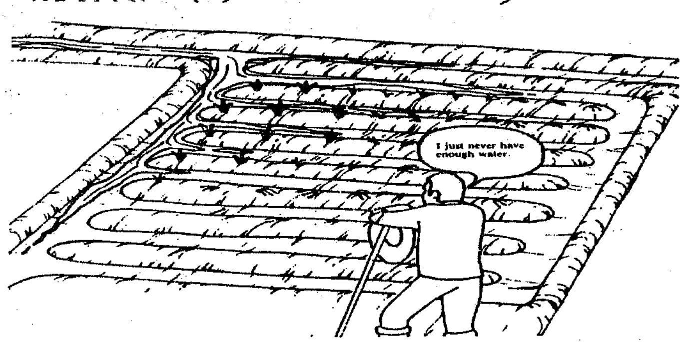
More frequent irrigations than necessary result in a root zone which stays too wet for too long. Insufficient aeration and root rot may result.





Excessively heavy water applications may wash fertilizers and other nutrients a way from the root zone.





Some farmers waste water when they irrigate, which means that other farmers may not have enough water for their fields

So now we know about the importance of irrigation water in crop production

3.6 What is irrigation?

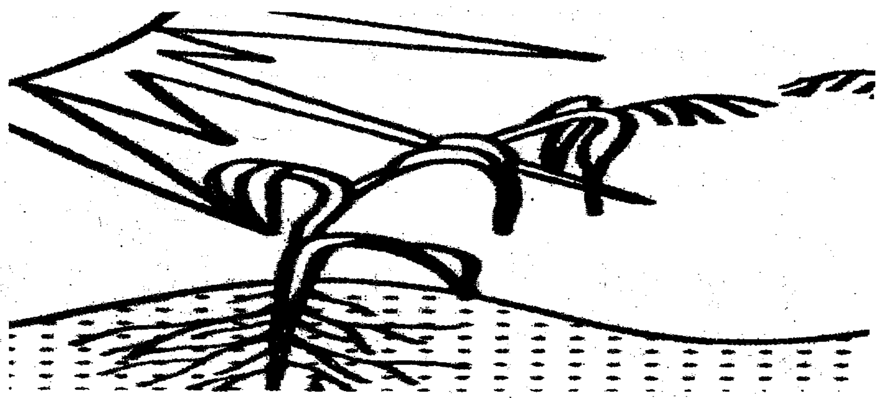
Irrigation is supplying of water to the crop for food production. Do you agree with this definition? I don't think you do. After going through the basics of irrigation now you can easily define the irrigation. The right definition of Irrigation is "the artificial application of water to the land for the purpose of producing optimum crop yield. It means maximum crop production per unit of land per unit of water application.

What is a good irrigation?

A good irrigation is when:

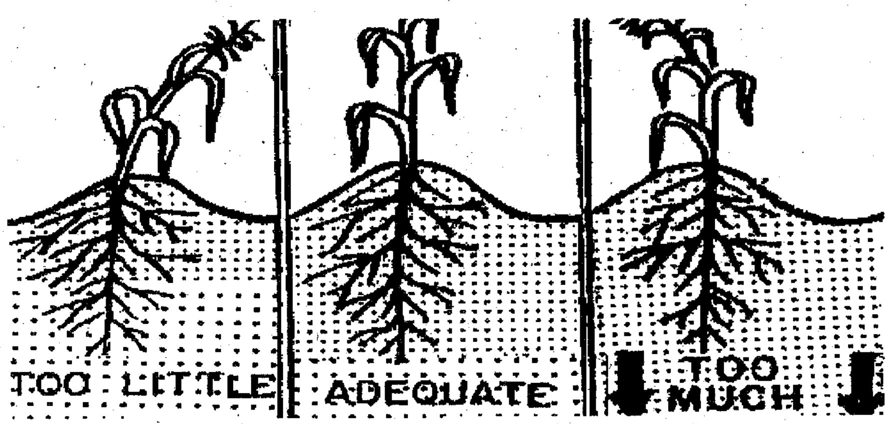
Water is applied when the crop needs it................

not when the plants look like this...........................



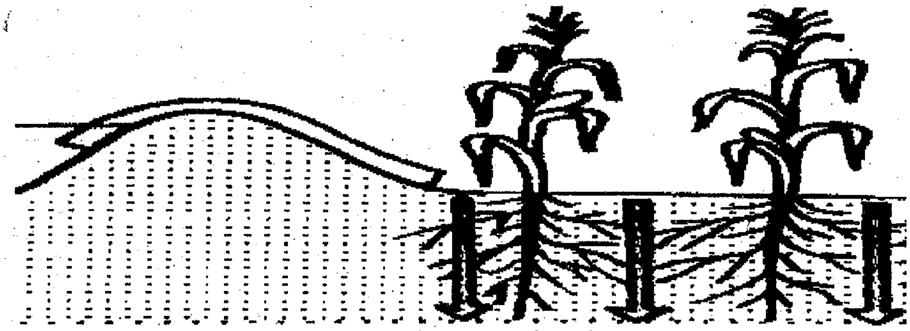
(Sometime plant vision gives wrong picture of available moisture)

The right amount of water is applied to the root zone.

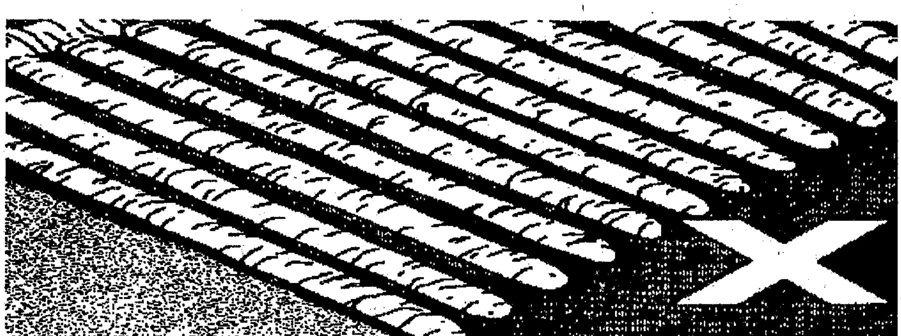


(Middle picture shows the adequate amount of moisture in the rootzone depth)

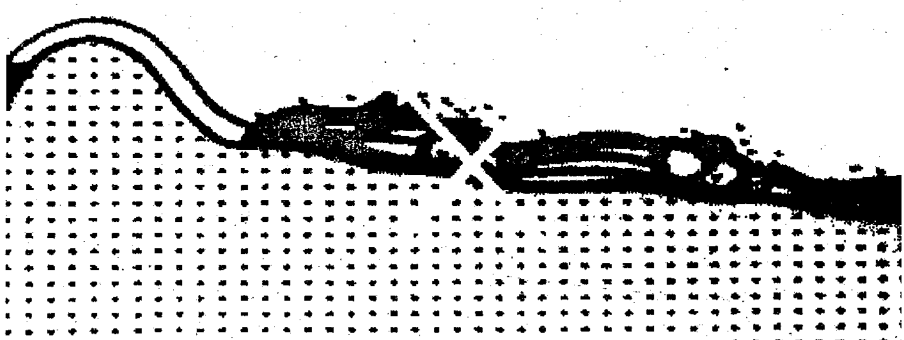
The penetration is uniform or almost uniform.



Irrigation does not result in excessive runoff and wasted water



The water does not erode the soils.



So for irrigation, we must know:

Importance of irrigation water,

Role of management in optimum crop production,

Field soil, its fertility status, its texture, its structure,

What are the factors that govern the crop production.

The farmer must also know:

3.7 The Water needs of the crop.

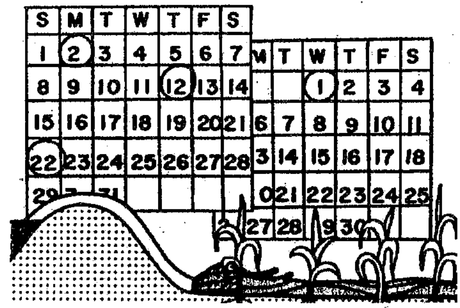
The approximate time that must elapse between irrigation.

- When to cut off the water

➢ How to keep runoff losses low

➢ How to identify erosion problems and eliminate them

➢ If the irrigation it uniform, If not, how to improve it.



So the efficient use of irrigation water is called irrigation water management. It aims to get optimum crop production per unit area per unit the on a sustainable basis. Dear friend, by going through this example, you will realize i.e. importance of irrigation water management. This concept improves a lot in sustainable crop production in Chambal Command Area. (Presented in Quebec, Canada-D.Srivastava).

IWM preliminary results (just after one year)

Individual activity	Observed Results
Canal Rehabilitation acteristics	Canal section improvement and better flow char-
Flow regulation saving	Early closure of water courses resulting in water
Cleaning of water courses	Improved conveyance efficiency(40-60%) reuse potential of drainage water
Cleaning of surface drains	Lowering water table
Agronomic improvements	Reduced fertilizer use and weed management in 300 sqm of cropped area improved wheat yield by 20 %.

The above results inference that if farmers are well informed and motivated then, they will certainly accept this. It also clarifies, how poor management of irrigation at farm level leads to soil salinity and water logging problem, inequitable distribution of water between head and tail reach farmers. So ultimately this is the only solution of all the socio-economic problems of the farmers. This ultimately improves the environment too.

3.8 SAQ Activity-2

During visit at your working site, what do you feel about farmers perception of basic concepts of irrigation?

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Do they really work according to this?

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Do they need improvement?

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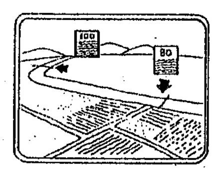
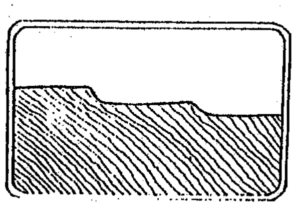
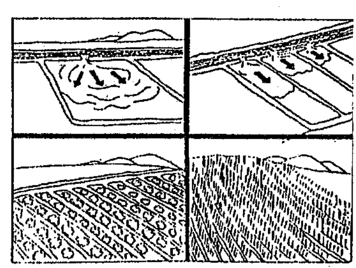
Conveyance of water from the outlet to the field with minimum losses. Well laid out watercourses and field channels save losses.

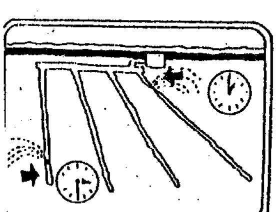




Land levelling and shaping for uniform and time saving application

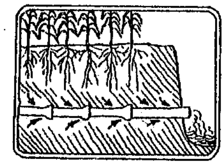
Appropriate choice of irrigation method leading to efficient application. Some methods are basin, border, furrow and pressurized irrigation like drip & sprinkler.





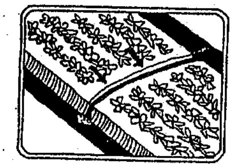
Application of water to the crop at the right time and in right quantities

Drainage of excess water : This is essential to keep the crops and soil in healthy condition for crop growth.



So in brief, the irrigation water management requires answers of the followings

When to irrigate?



How to irrigate?

How much to irrigate?

3.9 Suggested Readings

Michael, A.M. 1978. Irrigation - Theory and Practice. Vikas Publishing House, Pvt, Ltd.

Michael, A.M. & Ojha T.P., 1978. Principles of Agricultural Engineering, Vol-II. Jain Brothers, New Delhi.

Brouwer, C., International Institute for Land Reclamation and improvement. Irrigation Water Management Training Manual no.5- Irrigation Methods., FAO, Land and Water Development Division.

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UNIT- 4

HOW TO APPLY IRRIGATION

STRUCTURE

4.0 Objectives

4.1 Introduction

4.2 Differet Methods Of Water Application

4.3 Selection Criteria

4.4 Factors In Planning

4.5 Rate Of Water Entry Into Soil (Infiltration Or Intake Rate)

4.6 Deep Percolation

4.7 Uniformity Of Water Penetration

4.8 Surface Irrigation

- 4.8.1 Border Irrigation
- 4.8.2 Basin Irrigation
- 4.8.3 Furrow Irrigation

4.9 Pressurised Irrigation Methods

- 4.9.1 Sprinkler Irrigation Methods
- 4.9.2 Drip Irrigation Methods

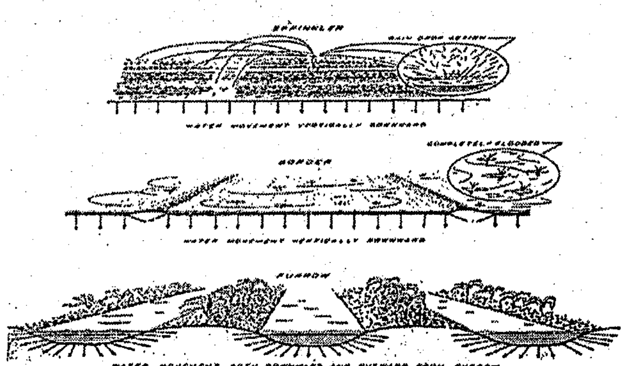
4.10 Sub-Irrigation

4.11 SAQ Activity

4.12 Suggested Readings

4.0 Objectives

- The economic development of the country is highly dependent upon judicious use of the natural resources. Land and water two most natural resources are very limited in our country. The country & the state of Rajasthan are already using respectively about 70% & 60% of their total surface & ground water resources. The annual rate of exploitation of ground water has generally exceeded the annual rate of its replen-



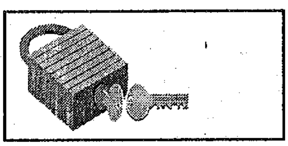
Water movement variation with method of irrigation ishment. Keeping in view such an alarming situation of ever increasing demand for agricultural products and the requirements of other sectors emphasises the need of conservation of these resources and agricultural production on sustainable basis. In recent years, priority to consolidating the already developed Irrigation potential is gaining through irrigation water management with optimising Irrigation efficiency.

There is considerable gap between the state-of-art technology of design, construction, operation & maintenance of surface irrigation systems and the formal educational curriculum of the Universities. To bridge this gap a training course on water application is a must to educate the irrigation, agriculture personnels and farmers about how much to apply, when to apply and which method of water application to use to optimise the crop production per unit of water without compromising the environment The irrigation manager must know the capabilties and limitations of the system and how it should be operated -and maintained for optimum efficiency.

4.1 INTRODUCTION

Most irrigated areas have individual land features and characteristics differing from those in other areas. This may be true of individual farms; therefore, It Is important that methods of irrigation be selected to fit the land. The adoption of a certain method should not be necessarily based on the common practice in the community or the adjoining farm. One of several factors may determine the best method to irrigate land. Among these are its slope, the crops to be irrigated, the water supply, the permeability of the soil, and its water holding capacity. Continuous good production can be obtained from irrigated land only if the water is applied wisely and in a manner which provides sufficient amounts to satisfy the needs of the plant, but not enough to cause waste and damage. The method of irrigation selected should conserve the soil as well as the water. In doing so it may be necessary, or desirable, to use more than one method of irrigation in an area.

Dear friend, you will certainly realise the importance of selection of the appropriate irrigation methods by reading the following case study.



A comparison of applied depth in border experiments conducted in IWAM plots in Chambal Command Area through RA]AD project reveals that the depth applied under conventional water application following with flooding (with surface runoff checked) showed that an average 40% in First irrigation and 64% in second irrigation, more water has been applied in conventional irrigation over border irrigation.

Looking at the above results, you may easily understand, if correct irrigation method is selected, a lot of water will be saved. The same water can be utilised for irrigating the tail end area and non-command area.

Now, please recall the different irrigation methods. I think, you all will agree that we can classify the irrigation methods as follows:

4.2 DIFFERENT METHODS OF WATER APPLICATION

Surface (gravitation) irrigation methods:

- by flooding, thus wetting all the land surface

- Border & Basin;
- by furrows, thus wetting only part of the ground surface;

Pressurised Irrigation Method

- by sprinkler, in which the soil is wetted in much the same way as rain;
- by localised irrigation, in which water is applied at each individual plant.
- Subsurface Irrigation:
- by sub-irrigation, in which the surface is wetted little, if any, but the subsoil is saturated;

4.3 SELECTION CRITERIA

Since the objective is to apply water efficiently to provide favourable environment for the plants, it is therefore, essential to consider the factors, which have significant effect in the process of water application. The important factors affecting this phenomenon are as under:

- Slope, topography, field size and geometry
- Crop type
- Soil texture, soil depth
- Available irrigation stream size
- Amount and intensity of rain
- Economic and social aspects (labour, materials, other costs).
- Farm Machinery

4.4 FACTORS IN PLANNING

4.4.1 PRELIMINARY PLAN

- Locate the high points in a field and determine the direction of irrigation and drainage.
- Determine soil boundaries, probable crop rotations and feasibility of land levelling
- Locate field boundaries and farm roads
- From this preliminary plan it should be possible to determine the best delivery point for the water.

4.4.2 PLANNING PROCEDURE

After a preliminary plan has been made, studied and discussed with the farmers, detailed plans for any area on the farm can be prepared, First select a method of water application for each field and prepare a layout. Then design the delivery, application, and disposal facilities as well as necessary roads.

4.4.3 LAYOUT

Planning a general layout for subdividing and irrigating the area in the units of suitable dimensions is the next step. Area delineated according to slope and soil characteristics provide a basis for selecting the best field arrangements and for locating field ditches. Consider alternative layout.

4.4.4 APPLICATION

Design the application facilities. Determine

- The amount of water that must be applied in a normal irrigation
- The time allowed for applying it and
- The rate at which it can be applied.

Then determine the amount of water that must be delivered to the field. Plan for land levelling if it is needed. Locate and design the head ditch or pipeline to fit the method irrigation used. Locate and design ditches, pipes levees and the other structures needed to apply water to the field in the amount and rate required by the crop and soil.

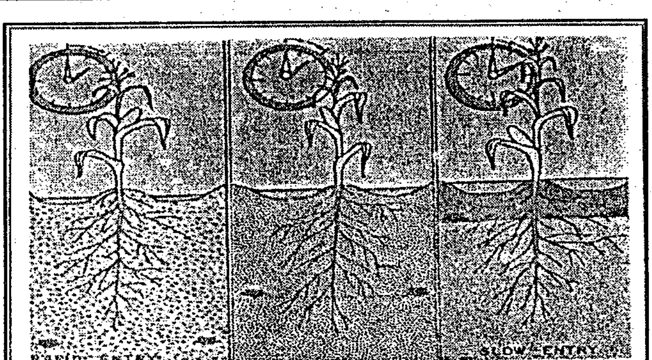
4.4.5 DELIVERY

Plan the delivery facilities so that they permit delivery of water to the different fields in the volume and rate required by the method of application-previously selected. Select and design the method of conveyance-either ditch or pipe line, Locate and design all the necessary grade control or distribution - control structures, including measuring devices.

4.4.6 DISPOSAL

Plan for the disposal of any irrigation wastewater and excess rainfall promptly and safely. Consider recovery of wastewater for reuse. Include all necessary disposal facilities= channels, pipelines, tiles and pumps.

4.5 RATE OF WATER ENTRY INTO SOIL (INFILTRATION OR INTAKE RATE)



How quickly water penetrates into a soil varies with the kind of soil, the amount of moisture already present in the soil and the condition of the soil surface. Water penetrates faster

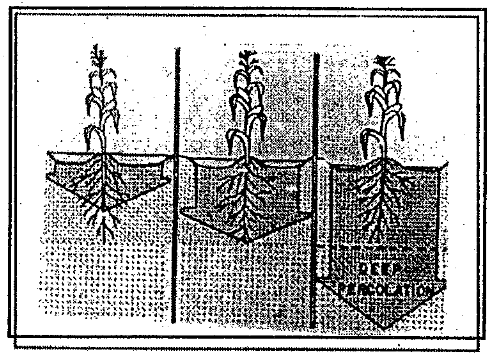
- through sandy soil than clay soil
- through dry soil than wet soil
- through well-structured soil than compacted soil
- Early in the irrigation season than later.

Soil infiltration rate governs the selection of suitable irrigation method. While irrigating a field, the following points should be kept in mind :

- deep percolation must be avoided
- uniform water application must be used.

4.6 DEEP PERCOLATION

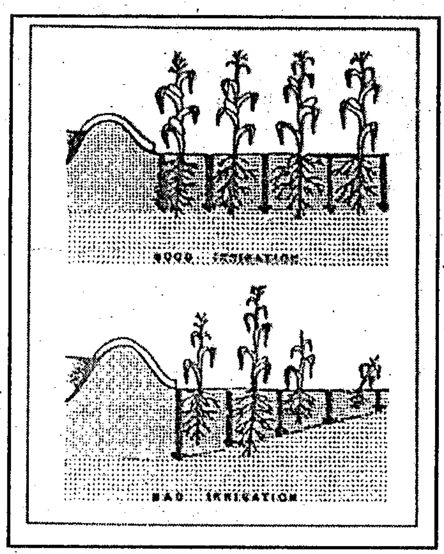
The penetration of water below the root zone is called deep percolation. Sometimes it is necessary to apply excess water so that accumulated salts can be washed from the root zone.



This excess water may be precious, and it carries nutrients away. Thus, it should be limited to the amount necessary to eliminate harmful salts from the root zone.

This excess water may be costly, and it carries nutrients away. Thus, it should be limited to the amount necessary to eliminate harmful salts from the root zone.

4.7 UNIFORMITY OF WATER PENETRATION



In a uniform irrigation, water penetrates to the same depth or about the same depth over the entire field.

Uniform penetration of water results in a uniform crop.

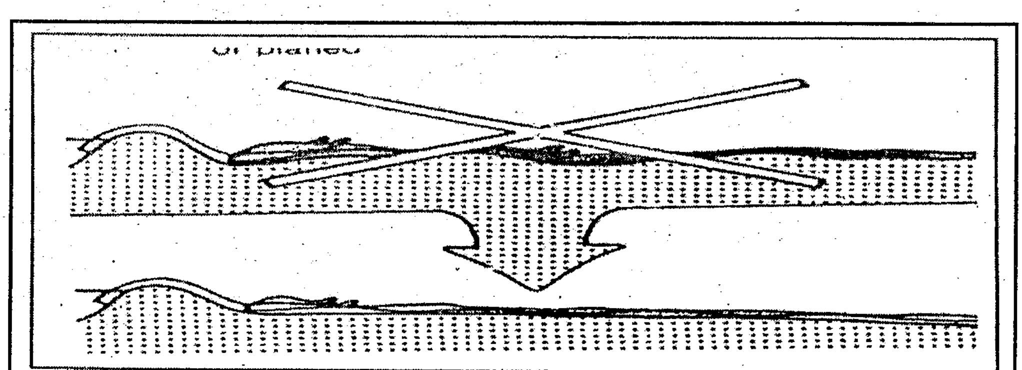
Non uniform penetration of water creates uneven growth and yield.

Causes of non-uniform penetration:

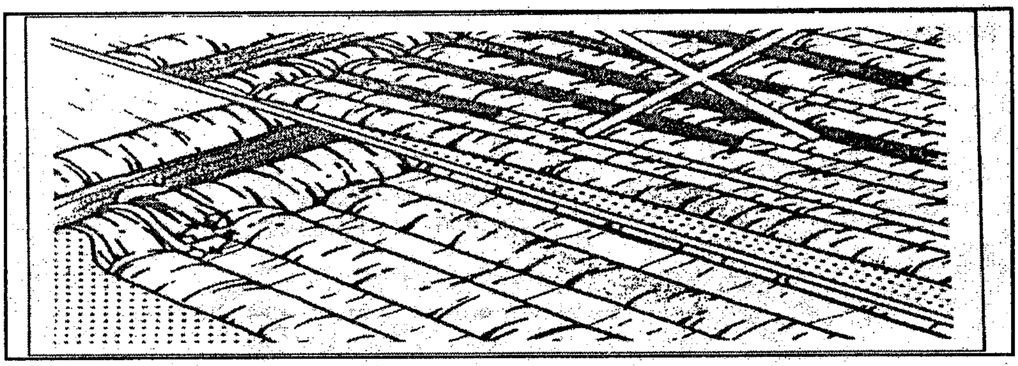
- Variation of texture within the field
- Uneven soil surface
- Improper water management.

These are the usual solutions to the problem of non-uniformity.

1. An uneven soil surface can be levelled or planned?



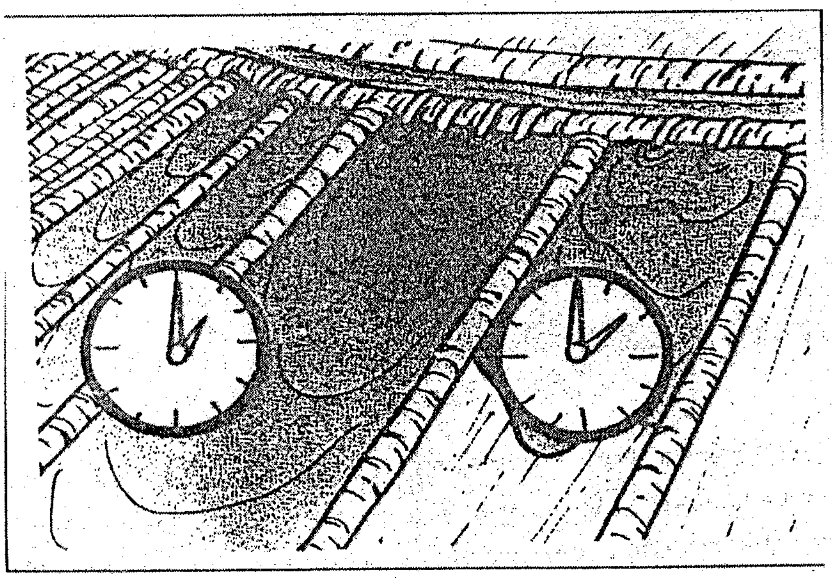
2. Soils of different textures or structures and depths may be irrigated separately



3. If the difference in time that water stands on the surface at the head and tail end of the system is great, we may :

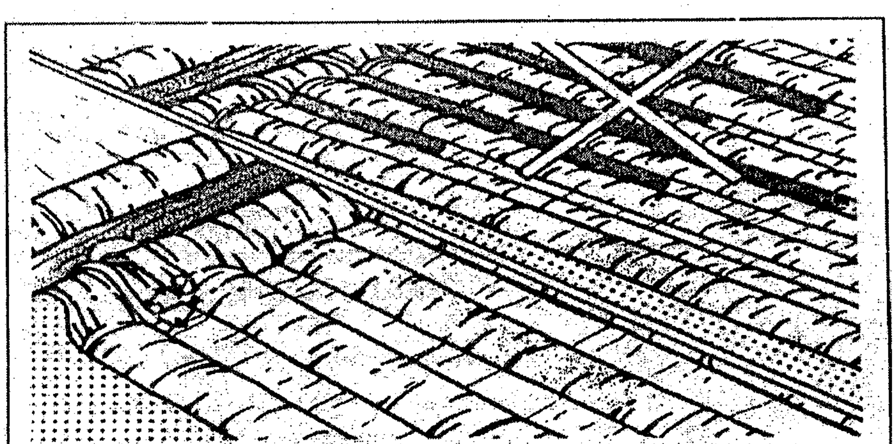
a. cut down the length or width of furrows, borders, or basins

b. increase the size of stream at the inlet of the furrow, border, or basin.

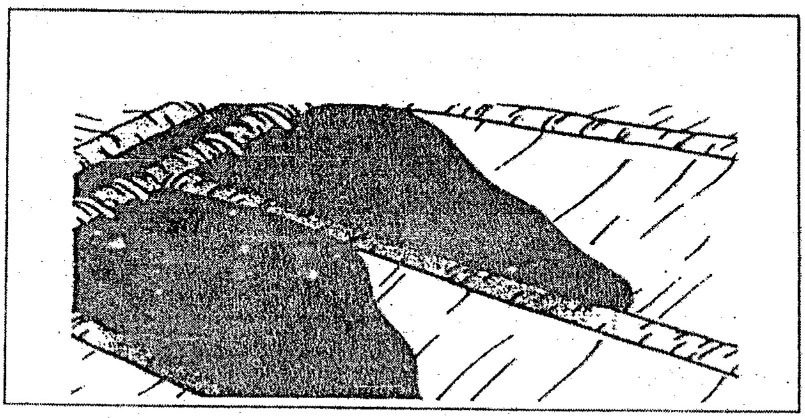


c. increase the irrigation duration.

4. If the water does not advance evenly in all the furrows, you may change your irrigating tools. Use siphons and adjust them so that the necessary amount goes into each furrow.



5. When water in a border tends to flow in one side, change the direction of the borders to that of primary slope, or level border to eliminate cross slope.



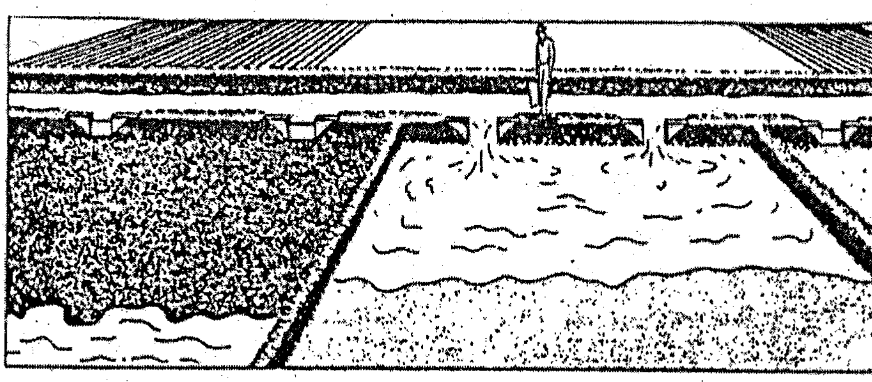
6. Decrease sprinkler spacing and/or increase pressure

4.8 SURFACE IRRIGATION METHODS

In surface irrigation method, water is applied directly to the soil surface from a channel located at the upper reach of the field. Water may be distributed to the crops on border strips, check basins or furrows. Two general requirements are property constructed water distribution systems and proper land preparation.

4.8.1 BORDER IRRIGATION

Borders are strips of land surrounded by dikes (borders) that run in the



direction of the slope. The dikes guide the water over the field when it leaves the head ditch.

CROPS : close growing crops such as wheat, barely, oats, pasture grasses and alfalfa.

SOILS AND TERRAIN : Slopes are usually up to one percent. Border gives good results in moderate soils.

ADAPTABILITY:

✓ It is adapted to most soils where depth and topography permits the required land levelling at a reasonable cost and without permanent reduction in soil productivity.

- ✓ It is more suited to soils having moderately low to moderately high infiltration rates, but not suited in coarse sandy soils.
- ✓ It is suitable for all close-growing crops like wheat, barley, fodder crops and legumes.

ADVANTAGES:

1. The ridges can be constructed cheaply with simple farm implements.
2. It requires less manpower than check basin method.
3. Uniform distribution & high water use efficiencies are possible.
4. Large irrigation streams can be used efficiently.
5. Operation of the system is simple and easy.
6. Purposely laid border strips provide for excellent surface drainage if adequate outlet facilities are provided.

To design any irrigation system, you should know about hydraulics of irrigation systems. So to design border irrigation we must know about water advance, recession and soil infiltration rate.

General Principles related to the Design of Border Strips

Width of Border Strip: It usually varies from 3 to 15 m depending on the size of the irrigation stream and the degree of land levelling practicable.

Border length: It depends upon the infiltration rate of the soil, the slope of the land and the size of irrigation stream. The recommended border lengths are:

Sandy & sandy loam soils	60 to 120 m.
Medium loam soils	100 to 180 m
Clay loam and clay soils	150 to 300 m

Border Slope: The borders have a uniform longitudinal gradient. Excessive slopes will cause insufficient irrigation at the upstream end and deep percolation losses and breach of bund at the downstream. Too flat slopes will cause deep percolation losses at the upper reaches and inadequate wetting downstream. The recommended safe units are:

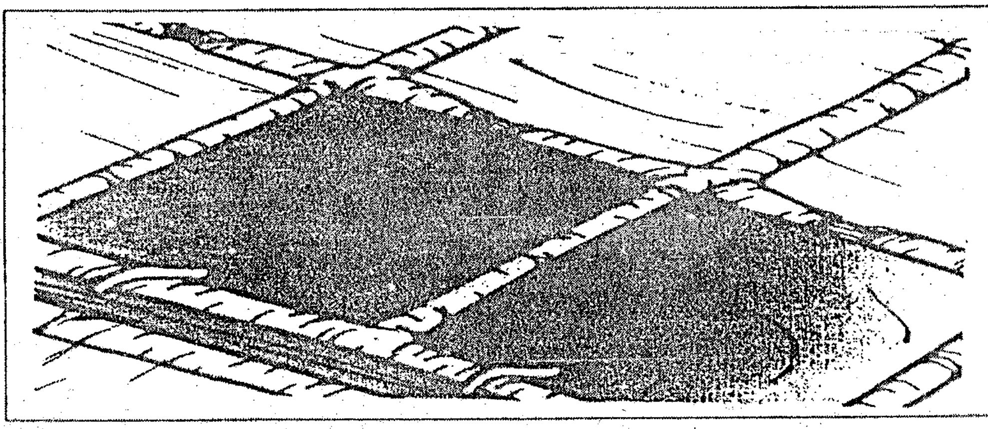
Sandy loam to sandy soils	0.25 to 0.65%
Medium loam soils	0.20 to 0.40%
Clay to Clay loam soils-	0.05 to 0.20%

Size of irrigation stream: The size of the irrigation stream needed depends upon the infiltration rate of the soil and the width of border strips. The typical sizes for different soil types and slopes are:

Soil type	Infiltration m width of Cm/hr	Border Slope %	Unit flow per border strip lps
Sandy soil	2.5	0.20-0.40	10-15
		0.40-0.65	7-10
Loamy Sand	1.8-2.5	0.20-0.40	7-10
		0.40-0,60	5-8
Sandy Loam	1.2-1.8	0.20-0.40	5-7
		0.40-0.60	4-6
Clay Loam	0.6-0.8	0.15-0.30	3-4
		0.30-0.40	2-3
Clay soil	0.20-0.6	0.10-0.20	2-4

4.8.2 BASIN IRRIGATION

Basins are small, level pieces of land surrounded by dikes which can be filled with water. The dikes contain the water in the basin while it penetrates into the soil.



CROPS : Fruit trees, pastures, cereals such as wheat, oats, barley, rye, rice.

SOILS AND TERRAIN : Small basins are used on steep slopes, but are not recommended on slopes over 10 percent with soils that crack as the dikes may break easily. Also, the necessary levelling on steep slopes may be very costly.

ADAPTABILITY:

✓ It is suited in heavy soils with low infiltration rates.

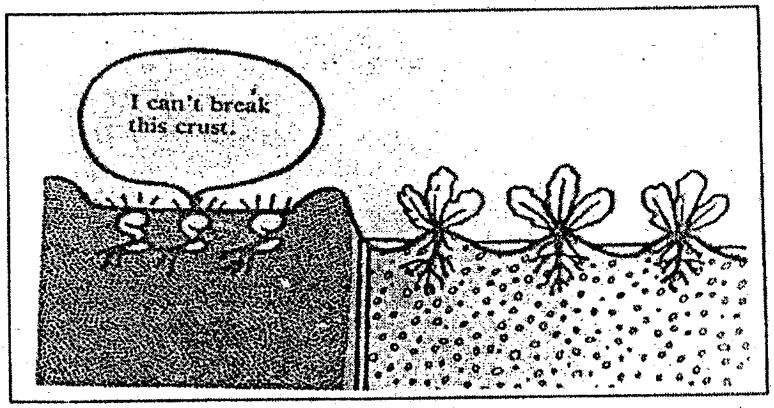
✓ It is also suited to highly permeable soils like deep sand, which must be covered with water rapidly to prevent excessive deep percolation losses at the inlet end.

✓ It is suited to irrigate grain and fodder crops. Row crops and orchards too, are often irrigated by this method.

RECTANGULAR CHECKS: In this method, the field is divided into a series of small rectangular plots surrounded by ridges to hold water within the compartments. This method is suited to nearly level areas.

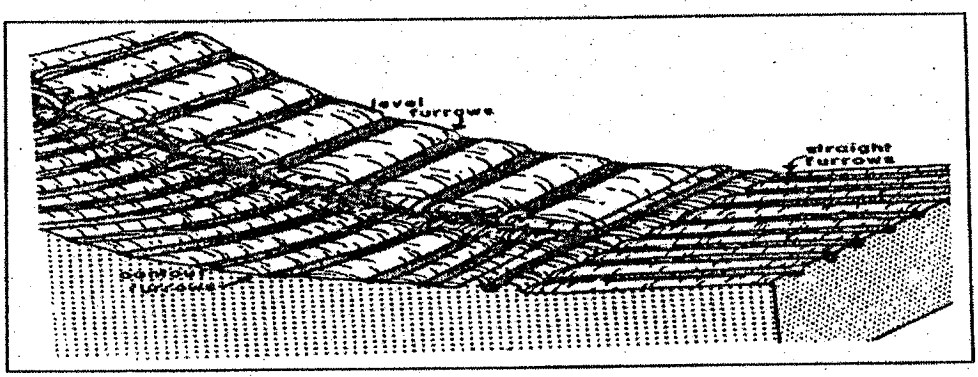
CONTOUR CHECKS: These are prepared by constructing ridges along the contour at vertical interval of 6 to 12 cm and connecting them with cross ridges at intervals. This method can be used on sloping land and requires a little land levelling.

RING CHECKS: When the plants are widely spaced as in orchards, the ring method of basin irrigation may be adopted. The rings are circular basins formed around each tree. The ring basins are small when the plant is **young and the** size gradually increases as the plant grows. As the entire area is not flooded, we can obtain a high water-use efficiency.



Small basins permit efficient irrigation with small stream sizes without runoff, but much productive land is lost to ditches and dikes. Basins are not used on soils which form hard, dry crusts that interfere with emergence and growth, or with crops not be immersed in water. Small basins may be constructed without technical assistance.

4.8.3 FURROW IRRIGATION



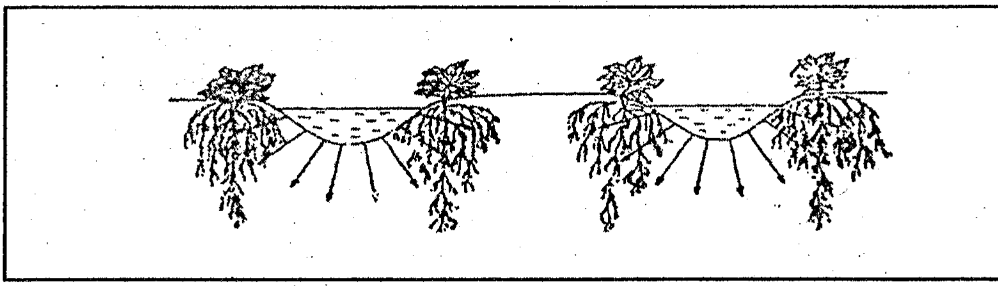
Furrows are small, closely spaced channels that carry water to the crops that are planted on their banks. Typical spacing between furrows may vary from 50 cm to over 1 meter. The height of the furrows may vary from 10 to over 30 cm.

CROPS : Corn, potatoes, beans, vegetables and other crops that must be cultivated.

Adaptability :

✓ It can be used to irrigate all cultivated crops planted in rows, including orchards and vegetables like maize? sorghum, sugarcane, cotton, tobacco, ground?

✓ Furrows are particularly well adopted to irrigating crops which are subject to injury from ponded water or susceptible to fungal root rot.



✓ It is suitable to most soils except sands that have a very high infiltration rate and provide poor lateral distribution of water between furrows.

ADVANTAGES

1. Water in the furrows contacts only one-fifth to one half of the land surface, thereby reducing puddling & crusting of the soil and evaporation losses.
2. Earlier cultivation is possible which is a distinct advantage in heavy soils.
3. The method may be adapted to use, without erosion, on a wide range of natural slopes by carrying the furrows across a sloping field rather than down the slope.
4. It is especially suited to crops like maize that are injured by contact with water.
5. The method reduces labour requirements in land preparation and grading.
6. Compared to check basin method, there is no wastage of land in field channels.
7. Furrows can be used for either large or small volumes of irrigation water.

4.9 PRESSURISED IRRIGATION METHODS

This is an advanced method of irrigation, in which water is carried through the net work of pipes from the source to the point of utilisation. This method can be introduced for all types of crops depending upon the soil, slope, water source, farmers' capacity, etc. This method replaces the surface/gravity methods of irrigation in all the developed countries due to higher water use efficiency, adaptability to hilly areas, possibility of application of soluble fertilizers, frequent application of irrigation water at short irrigation intervals thus maintaining favourable soil moisture conditions in the root zone.

The merits of pressurised irrigation systems are:

a. All losses such as conveyance, deep percolation and runoff are almost avoided.

b. Light and higher frequency of irrigation is possible.

c. Low stream size can be efficiently used.

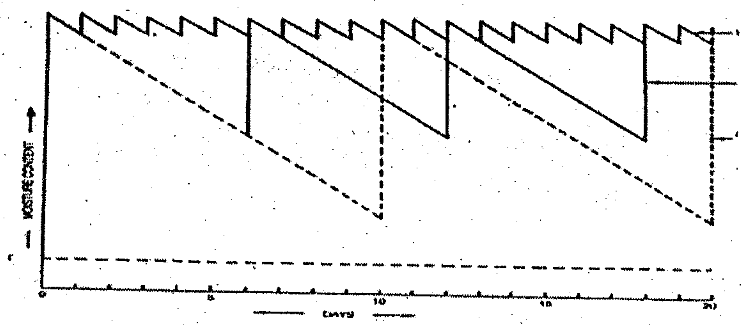
d. Fertigation and chernigation is possible.

e. Higher irrigation efficiencies are possible.

f. Land grading and levelling is not required.

h. Higher uniform application of irrigation water is possible.

i. Water is also controlled and only the required quantity of water is given to each plant based on the evapotranspiration requirements.

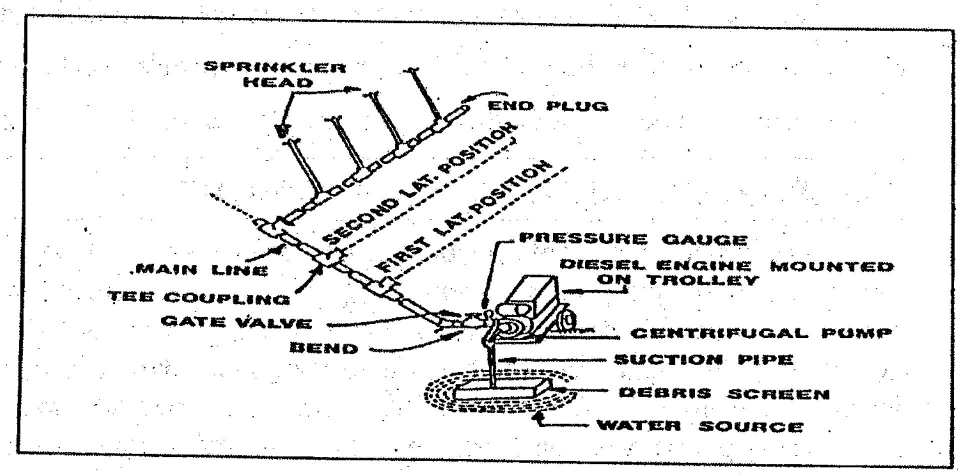


Moisture availability for crops in different irrigation methods.

j. Yields of the crops are better in addition to the saving of water with these methods. The reasons attributed for increased yields are:

- Water is applied once in 3-6 days period in sprinkler irrigation which in turn reduces the moisture stress to some extent. Further, the water application being controlled, only the needed water can be regulated in this system.
- Water is applied daily in drip irrigation and hence the growth is uniform. As there is no water/moisture stress, the crop growth is not affected at all.

4.9.1 SPRINKLER IRRIGATION

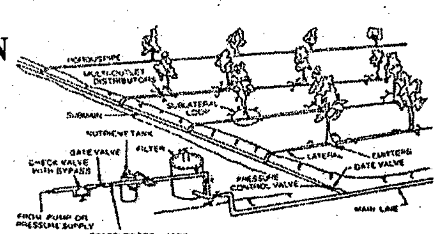


Mechanical devices apply water to the soil surface as water droplets, similar to rainfall. Sprinkler irrigation systems usually are designed and installed by trained persons. They may be very expensive, but at times they are the best way to irrigate well. In this case, the additional yield may easily pay for the cost.

CROPS : All except those damaged by water on their leaves. Be careful when using saline water because some crops have leaves which can be damaged by salts.

SOILS AND TERRAIN : Sprinklers can be used in all types of soils, on uneven terrain and slopes to more than 30 percent. With sprinkler irrigation, water is not wasted and soils are not eroded.

4.9.2 DRIP (TRICKLE) IRRIGATION

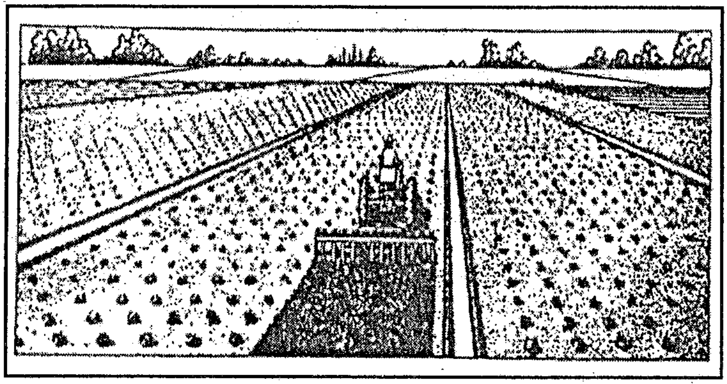


Water (and usually fertiliser) is applied to each plant individually. Drip irrigation is well adapted to all soils and terrains, but it can be very costly and is used only on high cash value crops.

CROPS : Fruit trees, shrubs, vegetables

In some countries efficient, low cost, simple methods have been devised which are much like drip irrigation without the clogging problems and pressure requirements.

4.10 SUB IRRIGATION



Water is applied below the ground surface by maintaining an artificial water table at some depth, depending upon the soil texture and the depth of the plant roots. Watter reaches the plant roots through capillary action. Since the method requires an unusual combination of natural conditions, it can be used in only a few areas.

Water having high salt content cannot be used. In India, sub irrigation is practised to a limited extent for growing vegetable crops around, 'Dal' lake in Kashmir and for irrigating coconut palms in the organic soils of Kerala.

Adaptability

✓ It can be used for soils having a low water holding capacity and a high infiltration rate where surface irrigation methods can not be used and sprinkler irrigation is expensive.

✓ The method is suited to soils having reasonably uniform texture and permeable enough for water to move rapidly both horizontally and vertically within and for some distance below root zone.

4.11 SAQ ACTIVITY

Please go through your working field area and find out by which method the farmers are irrigating their field?

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Are they following the technical guidelines?

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How can you justify their approach?

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Do you feel that they need improvement?

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4.12 SUGGESTED READINGS

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UNIT-5

HOW MUCH TO APPLY IRRIGATION

STRUCTURE

5.0 Objectives

5.1 Introduction

5.2 Consumptive Use

5.3 Crop Water Requirement

5.4 Depth Of Water Required In Cm.

5.5 Seasonal Consumptive Use

5.6 Peak Period Consumptive Use

5.7 Irrigation Requirement

5.8 Rooting Characteristics & Moisture Use Of Crops

5.9 How to Calculate

5.10 SAQ Activity

5.11 Conclusion

5.12 Self Check

5.13 Suggested Readings

5.0 Objectives

The achievements in the field of irrigation, though impressive, do not go for enough to meet the country's requirements. The continued shortage of food, frequent drought conditions, rapid growth of population and increased standard of living have made it necessary to increase the irrigation potential to the maximum possible extent. The attention of our irrigation engineers, till recently, has been confined up to the canal outlet where the water is delivered, but has, by and large, not been related to the qualitative and quantitative aspects of water use on the farm.

An analysis of the net available supply of water and the requirement for the intensive cropping reveal that the available water supply in canal-irrigated areas is far less than the requirement. It is estimated that during the next three decades almost the entire utilisable water resources would be used up. It may be realised that the easiest and cheapest water sources would be exploited earlier. It would, therefore, become relatively difficult and costly to harness the water sources in the later part of the century. The rapid increase in the utilisation of the available water resources calls for intensified efforts to increase the efficiency of water conveyance and water use. It also calls for efforts to develop new water supplies like desalinisation of sea water for meeting a part of the consumptive use requirement, artificial rain making and intensified efforts in water harvesting.

An analysis of the water resources potential, utilisation and requirement projected on a national level may not indicate farmers a clear picture of the regional requirements. So it is utmost necessary to educate about the efficient use of water. Every drop of water should be used for the maximum output. So to know how much to apply irrigation is again an important question. So we should learn, how to calculate the crop water need or crop water requirement.

5.1 INTRODUCTION

Water is one of the most valuable natural resources and its excess or deficit in the soil is a limiting factor for crop production. Successful production requires adequate and timely soil moisture supply with judicious use through out the life cycle of the crop. The contribution of irrigation water in increasing crop productivity and it is second next to fertilizers. The green revolution of present day has been brought in sight through the development of high yielding varieties. It appears the next break, through in agriculture in India has to come through water management, which has been one of the neglected fields so far.

Water is the most critical input for Indian Agriculture today. It is a manageable monetary input, therefore, all available supply of water should be used in best possible advantage to achieve the main aim of increasing agricultural production per unit volume of water/unit area of cropped land and per unit time. The productivity of crop per unit quantity of water can be increased even up to 200 percent of more or proper water management is observed.

5.2 CONSUMPTIVE USE

Consumptive use, commonly known as evapo-transpiration, is the amount of water used by growing plants in transpiration and building of plant tissues and that evaporated from adjacent soil and from intercepted precipitation in the plant foliage in a specified time.

5.3 CROP WATER REQUIREMENT

Water requirement of crop implies the total amount of water required by crops regardless of its source in a given period of time for its normal growth. It thus includes water needed to meet the Losses through evapo-transpiration, application Losses, and special needs

5.4 DEPTH OF WATER REQUIRED IN CM.

$$D = \frac{As \times D \times (fc - pa)}{100}$$

Where :

D	=	Depth of water required in cms.
As	=	Specific gravity of the soil.
D	=	Root zone depth in cms.
Fc	=	Field capacity in percentage.
Pa	=	Available moisture in soil in percentage

Crop water requirement is therefore, a demand and may be expressed as :

WR = ET or Cu + application losses + Special needs

5.5 SEASONAL CONSUMPTIVE USE

The total amount of water used in evapo-transpiration by a cropped area during the entire growing season is called seasonal consumptive use. It is expressed as the depth of water in cm or volume in hectare cm per hectare. Seasonal consumptive use values are required to evaluate and determine the seasonal irrigation water supplies.

5.6 PEAK PERIOD CONSUMPTIVE USE

The average daily use rate during the few days of the highest consumptive use of the season is called the peak period use rare? This is the design rate to be used in planning an irritation system. The peak use period for various crops in a given area may occur at different times in the crop season. In Irrigation project design, the peak period of consumptive use is the period during which the weighted average daily rate of consumptive use of the various crops grown in the project area is the maximum.

In planning the cropping pattern for an area we may have such crop combination that has its peak consumptive use rates spread out in such a way as to use the available supply in the most efficient manner. Some typical values of the peak rate of soil moisture removal by crops under different climatic conditions are given in Table below:

Maximum Rates of Soil Moisture used by crops under different climatic conditions:

Climatic Conditions	Peak rate of soil moisture removal (mm/day)
Cool, humid	3
Cool, dry	4
Moderate, humid.	4
Moderate, dry	5
Hot, humid	5
Hot, dry	8

5.7 IRRIGATION REQUIREMENT

The net irrigation water requirement is the amount of water exclusive of precipitation; carry over soil moisture and the ground water (capillary) contribution required for crop production.

The gross irrigation requirement includes the net requirement, as also the losses incurred in conveying and applying water. The losses are reflected in terms of irrigation efficiency.

The amount of irrigation water availability also decides the time and frequency of irrigation. Under adequate irrigation water supplies, the irrigation can be scheduled with fewer intervals. However, under limited irrigation water supplies, the critical growth stage approach provides the better solution for efficient water use.

5.8 ROOTING CHARACTERISTICS & MOISTURE USE OF CROPS:

The water requirement for crops plants is dependent on its root system and their response to water shortage or drought due to-delayed rain or irrigation. The total quantity of water contribution to the plant physiological function may be less than 5 % of the total absorption in the field, most of it being lost in evaporation or transpiration contributing little to the plant growth.

Failure to replace the water lost by transpiration, results in cessation of growth. Thus the importance of applying irrigation water in the right quantity at the right time for optimum results needs no further stress. The root zones and depths govern the gross requirement, a shallow root-crop may need frequent watering than a deep rooted crop. It is here that function of soil profile comes into play. Because it is the depth of soil that would be irrigated and its responses in retaining the water given.

Plants vary genetically in their rooting characteristics. The depth to be irrigated is also different for different crops as apparent from the table below:

Irrigation Depth 30 cms	Irrigation Depth 60 cms	Irrigation Depth 75 cms
Cucumber	Peas	Alfa alfa
Flower	Pepper	Corn
Radish	Pototo	Soybeans
Onion	Small grain	Sugarbeet
Turf	Snap beans	tomato

The deeper the root zone, the more water is absorbed for crop growth and yield. A few examples including that of a menous plant (seed Vessel - cocoon of silkworm) are :

The above would show that:

(a) Vegetable crops have a sparse and shallow rooting system (0.3 - 0.6 m).

(b) Field crops have a dense and moderately deep to deep rooting system (0.5 - 0.9 m)

(c) Fruit crops are very deep rooted (0.7 - 1.0 m)

The depth from which the roots of an average mature plant are capable of absorbing soil moisture is referred to as the effective root zone depth. It is seen that the root system is extremely variable in different crop plants. The variability exists in rooting depth, root length and horizontal distribution of roots. Both the properties of soil and the roots determine the water uptake by roots.

Water absorption by roots is dependent on the supply of water at the root surface. When the soil dries out from a wet stage, water movement rate in the soil decreases sharply. Thus, under the conditions where the water extracted by roots is not frequently replaced by rain or irrigation, the root system must expand continuously to occupy a large enough volume of soil to replace the transpiration losses of water.

Conditions often occur that the rate of water loss exceeds the rate of water absorption, causing an internal water deficit in the plant. It is this internal water deficit, through many of the physiological process in the plant that is directly responsible for the growth and yield of a crop in the prevailing conditions.

5.9 HOW TO CALCULATE:

One of the important safeguards by nature against drought injury is a deep wide - spreading root system such as that of sorghum and corn. Plants with shallow sparsely branched root system (Potato, onion etc.), suffer from drought sooner than deep-rooted species like corn.

Dear friends, Depth of water required for each of the stages of crop growth is worked out as per climatic condition e.g. temperature, moisture, wind velocity & rainfall etc. So the term water requirement of crop is total water required at the field head to mature the crop & does not include transit losses. The consumptive use means the water loss due to evapo-transpiration plus that which is used in the metabolism of the plant. The amount of water required to replenish the soil moisture deficit back to field capacity for the entire growth period is known as total water required. The effective rainfall is also taken into account while arriving at the water requirement.

- Water requirements vary as the crop develops, but in general:
- Some crops withstand lower soil moisture levels better than others without lowering yield.

Not tolerant to low moisture	Semi-Tolerant to low moisture	Most Tolerant to low moisture.
Potato	peas	corn
lettuce	clover	wheat
onion	beans	oats
spinach	pasture grass	alfalfa
celery	cabbage	cotton
strawberry	turnip radish	

Net depth of irrigation to be applied

The depth of water to be applied every alternate day will depend on evapo-transpiration rate. The pan evaporation (climatological) can be used for computation.

ET_0 = Pe x Pf

ET_C = ET_0 x kc

Where

ET_0 = Reference Evapotnspiration, mm

Pe = Open Pen Evaporation For Two Days, mm.

Pf = Pan Coefficient

ETC = Crop Evapotranspiration, mm.

Kc = Crop Coefficients According to the Crop Growth.

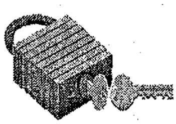
Example :

Crop: Sugarcane, Pe = 23 mm for two days, Pf = 0.7, kc = 1.15

ET_C = Pe x Pf x kc

= 23 x 0.7 x 1.15 = 18.52

To calculate the depth of irrigation to be applied for a specific crop let us take a case study:



Usually in Chambal Command Area, clay or clay loam is found. For these soils the available water for effective root zone of 50 cm taking an average water holding capacity of 22cm/m is only 11 cm. Irrigation in wheat is recommended at 50% depletion of available water in the root-zone . Therefore 5.5 cm irrigation depth should be applied for 100% irrigation water application efficiency. By assuming 75% irrigation efficiency the actual depth of application would be 7.5 cm instead of 5.5 cm. It is seen in the 2 years of field experiments that the applied depth following a cutoff ratio of 75% to 80% in the range of 8 to 9.6 cm.

5.10 SAQ ACTIVITY

Please go through your field area, and find out how farmers calculate the quantity of irrigation water to be applied at their field.

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Do they need improvement ?

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With the help of the following example we can easily understand how much water is to be applied in irrigation.

Crop	-	Wheat
Active Root Depth	-	75 cm.
Net Water Requirement	-	450 mm
Total Growing period of the Crop	-	130 days.
Date of sowing	-	25th Nov.
Date of Harvesting	-	4th April.
Soil Texture	-	Clay Loam
Bulk Density	-	1.4
Moisture % of soil at F.C. on weight basis	-	29%
Moisture % of soil at P.W.P. on weight basis	-	14.7 %
Available water in soil	-	14.3%
Available water mm / m	-	200 mm/m

Growth State	Est. Nov. -Dec.	Veg. Dec.- Jan.	Flow Feb.	Yield Feb.- March	Ripening March- April
Days	15	45	20	35	15
Et per day (mm)	2	2-3-4	4-5	5-4	4-2
Water Req. (mm)	30	140	90	150	40
Soil water depletion fraction	0.8	0.6	0.55	0.55	0.8

Calculation (I Irrigation)

A.S.M.	=	200 mm / m	
Active Root Zone (D)	=	75 cm	
At Ist Irrigation the root zone depth	=	2/3 D	
	=	50 cm.	
A.S.M. in the Root Zone	=	100 mm / 50 cm.	
R.A.W.	=	100 x 0.8	
	=	80 mm	

At the time of sowing about 20 % of ASM is lost i.e. 20 mm.

Net R.A.W.	=	80-20 =	60 mm
Av. Et.	=	2.2 mm /day	
Interval of irrigation	=	60/2.2	
	=	28 Days	

Net Irrigation Requirement	=	80 mm.

II Irrrigation

A.S.M.	=	200 mm / m
Active Root Zone (D)	=	75 cm
A.S.M. in the Root Zone	=	150 mm / 75 cm.
R.A.W.	=	150 x 0.6
	=	90 mm
Av. Et.	=	3.0 mm /day
Interval of irrigation	=	60/3.0
	=	20 Days
Net Irrigation Requirement	=	90 mm.

III Irrrigation

A.S.M.	=	150 mm / m
R.A.W.	=	150 x 0.55
	=	82.5 mm
Av. Et.	=	4.5 mm /day
Interval of irrigation	=	82.5/4.5
	=	19 Days
Net Irrigation Requirement	=	82.5 say 85 mm.

IV Irrrigation

A.S.M.	=	150 mm / m
R.A.W.	=	150 x 0.55
	=	82.5 mm
Av. Et.	=	4.25 mm /day
Interval of irrigation	=	82.5/4.25= 20 Days
Net Irrigation Requirement	=	82.5 say 85 mm

Irr. No.	Interval of irr. days	Cum	date of irr.	Net irr. req.(mm)	Gross irr. req. (mm)
I	28	28	23rd Dec.	80	100
II	30	58	22nd Jan	90	110
III	19	77	10th Feb	85	105
IV	20	97	2nd Mar	85	105

5.11 CONCLUSION

In this section we have discussed the role of water & its management in crop production. We have seen that to get optimum crop production, the irrigation should be given at right time, in right quantity and with right method of water application. The farmers do irrigation according to this concept, but due to some external factors they sometime overlook. The next unit explains those factors which contribute to non-participation of farmers. Please go through the following questionnaire and find out your answers. Are they still "yes"? If not, please go through the next unit.

- Do you really think that canal must run continuously throughout the growing season?
- Do you think that canal carries less water than designed?
- Do you feel that large quantity of water helps in optimum crop production?
- Do you observe that water courses function as desired?
- Do you think that all the water courses should run at a time to achieve other crop production?
- Do you feel that farmers should irrigate their field at a right time?
- Do you think that farmers should apply water as per their crop requirement?
- Do you still feel that farmers should use correct method of water application?

5.12 SELF CHECK

Please think and decide how you feel about the work you have done in this unit. What do you plan for the next? The learning objectives are listed below. Make a note of:

- Points on which you want to take action and pursue with local supervisor.
- Portfolio evidence of your field based working activity.
- Points which are still unclear. Your future plan for discussion.

Objectives	Notes
Assess the correct water application method	
Calculate the correct quantity of water application	

5.13 SUGGESTED READINGS:

Michael, A.M. 1978. Irrigation - Theory and Practice. Vikas Publishing House, Pvt, Ltd.

Michael, A.M. & Ojha T.P., 1978. Principles of Agricultural Engineering, Vol-II. Jain Brothers, New Delhi.

Sewa Ram, 1975. Inflow cutoff ratio for irrigation in ponded border strips. Proceedings of Second World Congress, IWRA, Vol. I, pp 1-7.

Sewa Ram, 1995. Crop factor for estimation of ET from Pan evaporation. Paper presented in National Seminar on SSD held at Jaipur, May 24-26, 1995.

Brouwer, C., International Institute for Land Reclamation and improvement. Irrigation Water Management Training Manual no.5- Irrigation Methods., FAO, Land and Water Development Division.

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UNIT 6

WHEN TO APPLY IRRIGATION

STRUCTURE

6.0 Objectives

6.1 Introduction

6.2 Stages Of Critical Growth Of Crops

6.3 Computation Of Time Required For Irrigation (A Case Of Drip Irrigation)

- 6.3.1 Net Depth Of Irrigation To Be Applied
- 6.3.2 Computation Of Volume Of Water To Be Applied Per Emitter Per Alternate Day
- 6.3.3 Computation Of Irrigation Prriod

6.4 Determination Of Crop Water Requirement For Orchards

6.5 Suggested Reading

6.0 OBJECTIVES

Dear friend, when to irrigate is the most crucial question in irrigation. So this needs further clarification. You may easily understand the importance of this. Due to lack of knowledge of when to apply and absence of information on water availability in canal causes a drastic problem in irrigation management. The farmers at headender give a number of times the irrigation water to their crop without identifying the need. So it leads to unequal distribution among farmers of head and tail reach and also the crop failure and economic loss.

6.1 INTRODUCTION

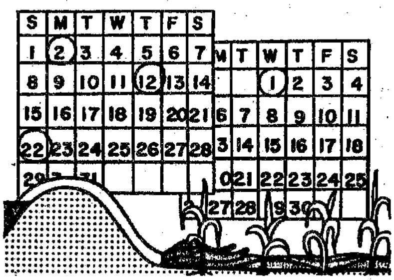
Water is mainly applied to the crop plants to meet their requirement of evaporative demand of atmosphere. In general, the crop water requirement and irrigation scheduling is governed by:

- Climate factors such as temperature, wind velocity, humidity sunshine hours and hence depends on the season during which the crop is grown. The crop water requirement are high and more frequent during summer followed by rainy season and winter. For example, groundnut down during Kharif requires about 450 mm water as against 750 mm during summer season.
- Crop factors such as duration of crop and crop growth. The Longer the life, the higher is the water used. Thus, crop/variety/maturing in 120 days requires more water to complete the life cycle compared to crop/variety maturing in 90 days. Similarly, the water needs of the crop are not uniform during crop growth from germination till maturity. Generally, crop water needs are relatively small during the initial stage and the maturity period. Flowering to grain formation is important stage during which water needs are higher.

- Soil factors such as texture, structure, soil depth etc. If the soil is deep, water storage capacity is more. In shallow soils, water storage is limited. Thus crop growing on shallow soils require more frequent irrigation than deep soils.

Depth of Soil	Total available water storage capacity	MAD %	ETC	Irrigation interval (days)
30 cm	50 mm	50	5 mm	5
60 cm	120 mm	50	5 mm	12

The frequency of irrigation depends on the amount of water used by the crop and the amount of water which can be removed from the soil by the crop without stress to the plant.

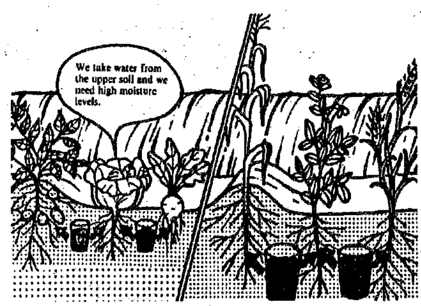


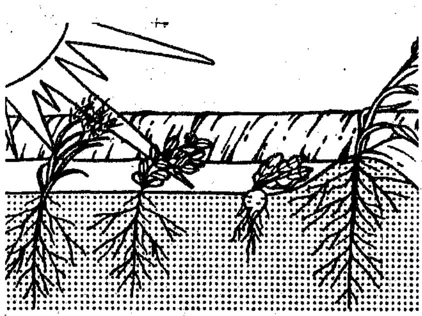
Consider the same crop & the same soil depth:

Sandy soils hold less water so irrigation must be more frequent than on fine soils --- but less water should be applied at each irrigation.

Consider the same soil & different crops:

Crops with shallow roots have less water within their reach, so the irrigations should be more frequent and lighter (less depth per irrigation) than deeper rooted crops.





On sunny hot days, crops use more water than on cool cloudy days and irrigation must be applied more frequently.

6.2 STAGES OF CRITICAL GROWTH OF CROPS

The crop plants in the given environment when water for use in the metabolism in supplied through a conveyance system. The water loss, due to evaporation has to be replenished from time to time. Supply of water at all times may not be as conducive to optimum yield as would be ensuring it at their various stages of growth called "critical stage of growth". Agriculture research has now been able to identify these growth periods of various crops. Supply of water at these stages would be most useful for the crop. An example for wheat crop (Rabi) is given below.

Growth stage (Wheat)	No. of days after sowing
a. CRI (Crown root initiation)	20 - 25
b. Tillering	40 - 45
c. Jointing	55 - 60
d. Flowering	85 - 90
e. Milk formation	100 105
f. Dough	115 120

So in brief we can say that irrigation should be applied when there is 50% depletion of soil moisture in the root zone. There is mathematical formula for calculating the irrigation interval:

$$\text{Irrigation interval(days)} = \frac{\text{Applied Irrigation depth(cm)}}{\text{Daily crop water use(cm)}}$$

Critical Stages of Different Important Crops

S. No.	Crop	Critical Stages	Most Critical Stages
1.	Wheat	Crown root initiation, Tillering, Late Jointing, Flowering, Milk	Crown root initiation and flowering
2.	Gram	Branching, Pod initiation, Pod filling	Pod initiation
3.	Mustard	Pre flowering and post flowering	Initiation of flowering
4.	Lentil	Branching, flowering, Pod filling	Flowering
5.	Potato	Stolanization to tuber initiation, Yield formation	Stolanization to tuber initiation
6.	Sugarcane	Tillering, Grand growth period	Tillering and Grand growth period
7.	Tobacco	Period of rapid growth	Vegetative growth period
8.	Barley	Tillering, Jointing, Flowering, Milk	Tillering and Flowering
9.	Linseed	Initiation of flower and Grain filling	Initiation of flower
10.	Peas	Initiation of flower and Grain filling	Initiation of flower
11.	Berseem	Through out the growth period	Initial one month after each cutting

Critical Stages of Different Important Crops

S. No.	Crop	Critical Stages	Most Critical Stages
1.	Paddy	Seeding establishment, Tillering, Primorida formation, Flowering & Milk	Tillering and Flowering to grain filling
2.	Cotton	Commencement of Sympedial, Branching, Flowering, Ball formation, Ball Bursting	Branching and initiation of ball formation
3.	Maize	Tasselling to silking grain filling	Tasselling to silking
4.	Groundnut	Flowering to Yield formation (Particularly during the pod setting)	Flowering/pegging
5.	Sorghum	Flowering, Grain formation	Flowering
6.	Black Gram/ Green Gram	Flowering to Filling	Flowering
7.	Pearl Millet	Flowering, Grain formation	Flowering
8.	Pigeon Pea	Flowering, Grain formation	Flowering
9.	Sesamum	Flowering to pod development	Flowering

6.3 COMPUTATION OF TIME REQUIRED FOR IRRIGATION (A CASE OF DRIP IRRIGATION)

In scheduling of irrigation through drip, the major aspects like time of irrigation application and quantity of water to be applied at each irrigation are considered. For this purpose, the net depth of irrigation or crop evapo-transpiration, volume of water to be applied through each emitter and irrigation period are computed with the help of the following steps:

6.3.1 NET DEPTH OF IRRIGATION TO BE APPLIED

The depth of water to be applied per alternate day will depend on evapo-transpiration rate. The pan evaporation (climatological) can be used for computation.

$ET_0 = Pe \times Pf$

$ET_C = ET_0 \times kc$

Where

ET_0 = Reference Evapotnspiration, mm

Pe = Open Pen Evaporation For Two Days, mm.

Pf = Pan Coefficient

ET_C = Crop Evapotranspiration, mm.

Kc = Crop Coefficients According to the Crop Growth.

Example :

Crop: Sugarcane, Pe = 23 mm for two days, Pf = 0.7, kc = 1.15

ET_C = Pe x Pf x kc

= 23 x 0.7 x 1.15

= 18.52

6.3.2 COMPUTATION OF VOLUME OF WATER TO BE APPLIED PER EMITTER PER ALTERNATE DAY :

Total volume of water required per emitter per alternate day (litre/emitter / alternate day = Spacing between two laterals (m) x Spacing between two emitters (m) x Wetted area factor x Depth of water (mm)

Q = Si x Se x Wf x ET_C

Si = 2.25 m , Se = 0.75 m, Wf = 0.60, ET_C = 18.52

Q = 2.25 x 0.75 x 0.60 x 18.52 = 18.75 lit/emitter/alternate day.

= Say 19 lit/emitter/alternate day

6.3.3 COMPUTATION OF IRRIGATION PERIOD

Irrigation Period (T)

= vol. of water to be applied (lit./emitter/alternate day) / Discharge rate of emitter (Lph)

e.g. Emitter discharge = 4 lph

T = 19/4 = 4.75 hours i.e. 4 hours and 45 minutes.

Table-1: Quantity of water to be delivered through each emitter in sugarcane (Anonymous, 1997)

S.No.	Month	Av. Pan evaporation (daily)	C/F	Lit/day	Time of operation for 4 lph dripper	
					hrs.	min.
1	January	3.82	0.6	2.1	0	32
2.	February	5.07	0.65	3.0	0	45
3.	March	7.83	0.90	6.5	1	37
4.	April	10.83	0.90	9.0	2	15
5.	May	11.73	1.10	11.9	2	58
6.	June	8.16	1.10	8.3	2	04
7.	July	5.92	1.15	6.3	1	35
8.	August	4.71	1.15	5.0	1	15
9.	September	4.85	1.15	5.1	1	17

S.No.	Month	Av. Pan evaporation (daily)	C/F	Lit/day	Time of operation for 4 lph dripper	
					hrs.	min.
10.	October	5.35	1.0	3.5	0	53
11.	November	4.45	0.85	3.5	0	53
12.	December	3.78	0.85	3.0	0	45

6.4 DETERMINATION OF CROP WATER REQUIREMENT FOR ORCHARDS

e.g. Grapes : Spacing = 3 x 1.5 m

Wetted area = 40%

Pan evaporation = 10 mm / day

Pan factor = 0.8

Crop factor = 0.7

water requirement/day/tree = pan evaporation x pan factor x crop factor x wetted area

= 10x0.8x0.7x(3x1.5)x0.4

= 5.60 x 1.8

= 10.08 lit.

The percent wetted areas and common spacing for selected crops are indicated in Table-2 and Table-3. Commonly used crop coefficient (kc) for different crop growth stages and perverting climate conditions are given in Table-4 (Dnoenbos and Purist, 1977). Some selected experimental evidences interrelation to different irrigation scheduling approaches adopted by the research workers are indicated below.

Table-2. Crop percentage wetted area.

Crop	% wetted area	No. of emitters / tree
Pomegranate	20	2 - 4
Lime	20	2 - 4
Orange	30	3 - 6
Grape	50	1 - 2
Banana	50	1 - 2
Sugarcane	60	75 cm spacing
Chilli	75	-do-

Table-3 : Common spacing of some important crops

Name of Crop	Spacing
Chikku/Mango	10 m x 10 m
Coconut	7 m x 7 m
Sapota/Citrus / Lemon	6 m x 6 m
Pomegranate / Sitaphal	5 m x 5 m
Setelvines	3 m x 3 m
Grapes	3 m x 1.6 m
Banana	1.5 m x 1.5 m
Sugarcane	1.0 m x 0.75 m
Cotton	1.2 m x 1.2 m
Tomato / Chillies / Brinjal	1.0 m x 0.5 m

Table-4 : Crop coefficients (kc) for field crops for different stages of crop growth and prevailing climatic conditions.

Crop	Humidity	RH 70% min.		RH 20 % min.	
	Wind speed (m/sec)	0-5	5-8	0-5	5-8
All field crops	1	0.3	0.4		
Barley	3	1.05	1.1	1.15	1.2
	4	0.25	0.25	0.2	0.2
Maize	3	1.05	1.1	1.15	1.2
Forage	4	0.95	1.0	1.05	1.1
Maize (grain)	3	1.05	1.1	1.15	1.29
Cotton	3	1.05	0.55	1.2	1.25
	4	0.65	1.15	0.65	0.7
Groundnut	3	0.95	1.0	1.05	1.1
	4	0.55	0.55	0.6	0.6
Millets	3	1.0	1.05	1.1	1.15
	4	0.3	0.3	0.25	0.25
Pulses	3	1.05	1.1	1.15	1.2
	4	0.3	0.3	0.25	0.25
Sunflower	3	1.05	1.1	1.15	1.2
	4	0.25	0.25	0.2	0.2
Sorghum	3	1.0	1.05	1.1	1.15
	4	0.5	0.55	0.55	0.55

Soybean	3	1.0	1.05	1.1	1.15
	4	0.45	0.45	0.45	0.45
Sunflower	3	1.05	1.1	1.15	1.2
	4	0.4	0.4	0.35	0.35
Wheat	3	1.05	1.1	1.15	1.2
	4	0.25	0.25	0.2	0.2

The results of the experiment conducted at MPKV Rahuri during 1993-95 on suru sugarcane indicated that daily or atleast alternate application of irrigation water through drip based on pan evaporation data was beneficial giving higher yields and WUE. In another attempt, to simplify the irrigation scheduling technique in drip irrigation one cucumber at Igatpuri in Maharashtra during 1996-96, the data obtained indicated that, maximum yield of 19.50 was recorded with 0.85% CPE treatment, which gave 41% higher yields and 29 percent water saving compared with conventional method of irrigation.

An experiment on irrigation scheduling under surface and sub-surface drip irrigation in different agro-climatic conditions of Maharashtra State during 1990-91 (Deshmukh et al. 1998). The irrigation was scheduled based on daily pan evaporation date with 1.75 Etc, 150 ETc, 1.25 ETc and 1.00 ETc under both surface and subsurface drip in comparison with furrow method of irrigation. The highest yield (96.52 MT/he) was recorded with 1.25 ETc under both the systems and increase in yield was to the extent of 22.2 to 30.75 percent in surface and sub-surface drip as compared to furrow method.

Another experiment on evaluation of automatic controlled drip with manually controlled drip and conventional method of irrigation was conducted on sugarcane at VSI, Manjri during 1994-95 (Deshmukh et al. 1998). The automatic system was based on soil moisture depletion approach almost at 10 to 20% of depletion of available soil moisture using sensors placed at different locations in the field. Maximum yield (143.54 Mt./ha) was recorded in automatic drip irrigation and lowest yield was recorded with conventional method.

Consumptive Water requirement for important Kharif crops in mm

S. No.	Crops	Duration	June	July	August	Sept.	Oct.	Total
1.	Groundnut	25th June to 31st October (128 days)	20.55	107.66	123.08	143.82	129.37	524.43
2.	Maize (Sathi)	25th June to 20th September (87 days)	18.27	107.95	147.78	101.28	-	375.28
3.	Maize (Hybrid)	25th June to 21st October (118 days)	18.27	101.74	120.38	157.92	134.04	532.35
4.	Soybean	14th July to 31st October (110 days)	-	136.15	99.15	150.72	130.93	416.95

5.	Sorghum (Fodder)	25th June to 10th October (107 days)	15.98	96.28	124.93	140.99	37.50	415.68
6.	Kharif Pulses	15th July to 10th October (87 days)	-	32.15	107.12	144.10	34.09	317.46
7.	Kharif Vegetables	25th June to 31st October (128 days)	15.98	91.69	118.08	143.82	142.82	512.39

Consumptive Water requirement for important Rabi crops in mm

Duration	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	Total
th Nov. to 10th April 45 days)	-	-	18.02	53.30	80.02	119.84	168.80	62.40	502.38
th Dec. to 15th April 26 days)	-	-	-	20.38	58.56	108.53	197.95	94.40	479.82
th Oct. to 28th Feb. 36 days)	-	27.27	64.88	76.31	94.88	83.72	-	-	347.06
: Oct. to 31st Jan. (122 ys)	-	73.55	79.31	96.32	91.09	-	-	-	340.27
th Oct. to 10th March 36 days)	-	13.15	58.42	68.16	94.08	116.78	64.54	-	415.13
th Oct. to 15th March 58 days)	-	21.92	44.62	60.20	84.41	97.06	58.81	-	367.02
th Sept. to 15th Jan 12 days)	10.57	98.64	97.57	95.09	36.58	-	-	-	338.45
: Oct. to 19th April)0 days)	-	62.10	82.40	74.13	94.08	119.04	209.44	167.39	808.58

6.5 SUGGESTED READINGS:

Michael, A.M. 1978. Irrigation - Theory and Practice. Vikas Publishing House, Pvt, Ltd.

Michael, A.M. & Ojha T.P., 1978. Principles of Agricultural Engineering, Vol-II. Jain Brothers, New Delhi.

Sewa Ram, 1975. Inflow cutoff ratio for irrigation in ponded border strips. Proceedings of Second World Congress, IWRA, Vol. I, pp 1-7.

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Brouwer, C., International Institute for Land Reclamation and improvement. Irrigation Water Management Training Manual no.5- Irrigation Methods., FAO, Land and Water Development Division.

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UNIT 7

SPRINKLER IRRIGATION SYSTEM

STRUCTURE

7.0 Objectives

7.1 Introduction

7.2 Suitability of Sprinkler Irrigation Systems

7.3 Limitations of Sprinkler Irrigation System

7.4 Sprinkler Types

7.5 Summary

7.6 Self-Assessment Test

7.7 Key Words

7.8 Suggested Readings

7.0 OBJECTIVES

Rainfall is the primary natural source of irrigation. Only a limited part of rain is used for irrigation and much of it is lost due to runoff and deep percolation. A sprinkler is an irrigation device that tends to simulate rainfall but in a way the runoff and deep percolation losses can be avoided and at the same time, the uniformity of application can be made as close as would be obtained under rainfall condition. This is, however, difficult to achieve as in the case of sprinkler, the water comes from a point source whereas in the case of rainfall, the source is uniformly distributed over the entire area of application.

7.1 INTRODUCTION

In a sprinkler system, water under high pressure is forced through a nozzle of small diameter. The issuing jet, therefore, has a very high Reynold's number and considerable number of eddies within it due to turbulence. Once the jet leaves the rigid boundary of the nozzle, the eddies tend to disintegrate the jet. This is further assisted by the air resistance. As a result the jet disintegrates and is converted into a large number of independent water bodies (drops), which descends under the action of gravity like rain. An ideally designed and laid sprinkler system is one that produces a drop size distribution close to rainfall or of such type that will have no adverse effect on the soil structure, and on the uniformity of distribution due to drift. These are the characteristics determined by nozzle size and nozzle pressure. The break up of the jet is also done by introducing barriers in the direction of the flow of the jet, such that the distribution of water along the radius of throw becomes reasonably uniform. In most conventional sprinkler systems, design application rates are less than the infiltration rates of the soil. Thus all water reaching the ground surface infiltrates directly into the soil, and there is no movement of water over the soil surface. Failure to either limit application rates or design the system to allow for surface water movement can result in non-uniform applications of water or serious erosion problems. Therefore, it is possible to attain a high irrigation efficiency using the sprinklers, which is not generally feasible in the conventional methods of irrigation. Also, sprinklers can be used for irrigating a wide variety of crops except those crops whose water requirements are very high. In spite of many advantages of the system, this has been adopted only in limited places in the country. A major reason is its high initial and running costs, though there are subsidies available for the purchase of sprinkler sets.

7.2. SUITABILITY OF SPRINKLER IRRIGATION SYSTEMS

Because of the way the jet distributes water these systems have several advantages. Some of which are listed below:

7.2.1 CONTROL OVER APPLICATION RATE

Sprinkler system provides positive control over amount and rate of application of water. Most sprinkler systems apply water at a rate less than or equal to the maximum intake rate of the soil at any time. Therefore, sprinkler systems are adaptable to:

a) Variable soils

b) Crops requiring light frequent irrigations

c) Soils with low water-holding capacities

d) Heavy soils not having high lateral water movement capabilities.

e) Light soils not having high lateral water movement capabilities

f) Areas with high water tables

g) Drainage and runoff reduction.

7.2.2 TOPOGRAPHY

The method is well suited to lands of uneven or sloping topography in addition to the flat land region. Any undulating area can be satisfactorily irrigated and land leveling which is an expensive operation can be avoided if sprinkler system is used. In uneven topography, therefore, the work and cost of extensive land leveling, which is a must for any other conventional surface irrigation method, can be avoided if sprinklers are used. Therefore, the land can be put into production rapidly. Apart from saving in cost in this operation, land leveling results in shifting rich surface soil, exposing poorer subsoil for cropping. This is also avoided if sprinkling system is adopted. This is very much significant where the top soil layer is shallow with less fertile underlying soil layers. Plantation crops such as tea, coffee, etc., which are some times grown in hill slopes as steep as 100% or even more, can be irrigated by this method. This is done by controlling the outflow from the nozzle, done by proper selection of nozzle size and operating pressure.

7.2.3 SOIL CONDITIONS AT THE SURFACE

The fact that torrential rain produces runoff is because the rainfall rate exceeds the infiltration rate. Depending upon the soil type and also its chemical composition, the infiltration rate varies. That is why same amount of rainfall produces different amounts of runoff in different types of soil. This variation in soil properties can be adequately taken care of by sprinkler irrigation method as the rate of application can be matched with the infiltration characteristics of the soil. In sprinkler system water is usually applied at a rate less than the infiltration rate of the soil. This helps in total elimination of runoff losses. In fact, the infiltration characteristic is a major parameter, which is taken into consideration while designing a sprinkler system, particularly in the selection of nozzle characteristics and operating pressure. This is not possible usually in conventional irrigation methods as practically little choice is available to the farmers in varying the inflow discharge to his field.

The sprinkler system is also suitable for excessively or relatively impermeable soils, which are difficult to irrigate efficiently and safely by other methods of irrigation, e.g. sand dunes and alkaline soils.

7.2.4 SOIL DEPTH

The soil moisture and soil depth influences the depth of irrigation requirement per application. This concept, however, is not utilized in irrigating the crop in the irrigation command areas, whether it is a canal command area or a tube well command area. The estimated depth of irrigation application is usually worked out as a function of irrigation interval and the consumptive use between two consecutive irrigations. This tends to yield about the same volume of water application under similar climatic condition for a particular crop. However, if the soil depth is limited, the effective root zone also gets limited. Any water which goes beyond the effective root zone is a loss for the crops. Under conventional irrigation systems the depth of application of water cannot be varied depending on the soil depth. Thus, in soils of shallow depth, much of the applied irrigation water goes waste as deep percolation loss. The schedule of water delivery in canal command areas does not permit variation in application from one place to another depending on the depth of soil. This difficulty can be overcome by the use of sprinkler as both the rate and duration of application can be well adjusted to soak the soil up to a given depth. Similarly, the irrigation frequency can also be changed to suit the varying consumptive use demand depending on the depth of wetting in the soil profile.

Sprinkler system is also suitable where profile of light soil is shallow with underlying hard and compact impermeable strata, which lead to the waterlogging conditions under flow irrigation.

7.2.5 WATER HOLDING CAPACITY

Not all the water present in the soil is utilizable by the plants. Roughly speaking, the water held in the soil between field capacity and wilting point (i.e. the moisture contents respectively under 1/3 bar and 15 bar) is available to the plant. The plants, however, start showing signs of water stress when 50% of the available water is depleted. Since the range of moisture content between 1/3 bar and 15 bar is low for light soils and high for heavy soils, the frequency of irrigation in these two soils differ. Saturating a light soil (as is usually achieved by the conventional surface irrigation methods) is not useful, as the water will not be held in the soil for long and will drain. Under such situations, sprinkler irrigation is ideally suited. Irrigating light soils by conventional methods in fact are highly inefficient. If one wants to irrigate long borders or long furrows, there is much wastage of water as application loss. On the other hand, if one wants to irrigate in small borders and short furrows, the number and length of conveyance channels will increase and will result in considerable seepage loss. Further, it is not feasible to line the entire network of channels because of high costs and because these will be impediments in the normal farming operations. In sprinkler system, since the conveyance is through pipes and since the application rate can be controlled, the adverse effects of conventional irrigation methods in light soils are not felt. Since sprinkler systems are portable, it does not interfere with the normal farming operations.

7.2.6 WATER SCARCITY

With careful maintenance of slope, stream size, etc., the maximum application efficiency achievable has been reported to be about 80%. Studies under field condition, however, reveal that the application efficiency is seldom more than 50%. This means that there is a loss of 50 % water. In water scarcity areas one cannot afford to waste water like this. Since it is possible to achieve very high application efficiency with a sprinkler, the wastage of water is minimum. Further, the crop water requirement is not uniform throughout the growing season. At young or seedling stages the root activities are limited to only shallow depths. A conventional irrigation with a 10 cm gross application per irrigation will wet about a meter depth of soil, which is just not required when the roots are active in the 0-20 cm depth. If the water is scarce, one must attempt to use limited quantity of water to achieve the desired goal of irrigation. If the available water is 10 cm per meter depth of soil and irrigation is given at the half depletion of available water, one needs to give only 1 cm of irrigation water for a 20 cm root zone depth. It is never possible to give even double this depth in the conventional surface irrigation method. Since, however, this is possible by a sprinkler system, it becomes ideal for water scarcity areas.

Sprinkler systems make it possible to apply exact quantity of water to soil according to requirement and also apply it evenly. In conventional surface methods a considerable amount of water is wasted in channels due to seepage & percolation (about 35%) and it is almost impossible to control the quantity of water to be applied and distribute it uniformly. Invariably some part of field will receive more water than other parts. It is possible to save as much as 50-70% water that is used by surface method if sprinkler system is adopted (Table 1). Highly sandy soils cannot be irrigated by any method except by sprinklers.

Table 1 Water used in Sprinkler and Surface Irrigation Method.

Crop	Water Requirement Surface (cm)	Sprinkler (cm)	Water Saving %
Bajra	17.78	7.82	56
Jowar	25.40	11.27	56
Cotton	40.64	29.05	29
Wheat	33.02	14.52	56
Barley	17.78	7.82	56
Gram	17.78	7.82	56

Source: Malhotra, A.N., 1984. Sprinkler Irrigation Case Study. Proceedings of the Seminar on Sprinkler and Drip Irrigation Systems, Delhi, 1984.

7.2.7 SAVING IN CULTIVATION EXPENSES

Expenses for preparing land for irrigation by laying channels and bunds etc. will be saved. Further frequent expenses incurred for maintaining channels and other structures are also eliminated. Absence of channels etc. enables better and easier inter-cultivation and weeding operation. Channels and ridges also hinder mechanized farming. Unlike in surface irrigation where surface compacting of soil takes place, in sprinkler system the soil surface remains comparatively loose affording easier inter-cultivation operation and reduced tillage operations.

7.2.8 SAVING IN LABOUR EXPENSES

For distribution of water, labourers are required to be continuously engaged in surface method of irrigation. Since this is not required in sprinkler system, which operates automatically without anybody to attend, there is a saving in labour expenses to an extent of about 50 - 70%. Labour is only required for shifting equipment but this is very less and required for only a few minutes a day.

7.2.9 SAVING IN LAND FOR CULTIVATION

More area is available for growing crops under sprinkler system as it eliminates ditches, levees (bunds), etc., whereas field channels and bunds in surface method occupy some area. On an average 10 to 16% more land is available for crops because channels and ridges are not required.

7.2.10 BETTER LIVEABILITY

Crops such as Chilies, Ragi, Vegetables, Onion, etc. which are transplanted, set much better under sprinkling. In sugarcane, germination of planted sets is reported to be much better under sprinkling since under furrow irrigation some buds do not germinate due to excess moisture in the furrows at some places. The sprinkler system often ensures adequate seed germination with only one light application of water after seeding. Such applications are more efficient than surface irrigation methods. Transplanting and planting of seeds can be done at any most convenient time without depending upon weather conditions.

7.2.11 LESS EROSION

A sprinkler system can apply irrigation at a rate, which is less than the infiltration rate of the soil. This helps in the total elimination of runoff losses or it is very less, therefore chances of soil erosion under sprinkler irrigation will be also very low.

7.2.12 BETTER CROP GROWTH

It is found that due to washing of foliage, every time a crop is sprinkler irrigated, there is more luxuriant growth. Quality of crop is also improved. In crops like mulberry the leaves are large, tender and clean and very much better for feeding silk worms. Vegetables are decidedly better under sprinkler irrigation. Crops like groundnut have better pod development due to loose soil condition. Tobacco and tomato produced under sprinkler irrigation are reported to be of superior quality, apart from high yields obtained.

Table 2 Percent Increase in Yield using Sprinkler as compared to Flood Irrigation.

S.No.	Crop	% increase in Yield
1	Coconut	14
2	Coffee	17
3	Sugarcane	11
4	Vegetables	9-30

Source: Pandhye A.H., 1989. Micro and Sprinkler Irrigation in India. Proceedings International Congress on the use of Plastics in Agriculture, New Delhi, 1989.

7.2.13 INCREASED OVERALL INCOME

Since from a given quantity of water more area can be sprinkler irrigated, there is an overall increase in income from the harvest. In most cases, the cost of equipment is almost recovered in 3 or 4 seasons only.

7.2.14 APPLICATION OF FERTILIZERS AND CHEMICALS

Water-soluble fertilizers and chemicals can be applied through sprinkler system without any extra cost with irrigation water. These materials are distributed uniformly and can be leached to the desired depth. Fertilizers can be applied in increased split doses and this practice results in better utilization and economy in fertilizers. A minimum of equipment is required and once the apparatus for adding the fertilizer to the irrigation water is set up the crop being irrigated can be fertilized with less effect than is required for mechanical application.

7.2.15 Less Chances of Salinity/Alkalinity Development

Excess irrigation (as it often happened in surface methods of irrigation) is harmful to soils. This excess water going beyond root zone drops into sub soils, tends to move up as the top soil starts drying. The upward movement of soil moisture brings along with it salts to the surface. Gradually these salts accumulate in the surface layers, leading to conditions of salinity and alkalinity in the soils. Such soils can even become unfit for cropping eventually. However, by adopting sprinkler system, this will not happen, since only required quantity of water is applied.

7.2.16 Less Pests and Diseases

When sprinkler system is used reduction in incidence of pests and diseases are reported.

7.2.17 Night Irrigation

Night irrigation is very difficult in surface irrigation methods, but it is very easy by sprinklers.

7.2.18 Green Manuring

Presently green manuring is done only during rainy season because immediately after plowing down the green matter there should be sufficient moisture for decomposition. With sprinkler unit green manuring can be adopted during any part of the year to a very great advantage to the farmer.

7.2.19 SPECIAL SITUATIONS

- In some parts of the country in clay soil regions, surface soil moistening is required to soften the soil crust such that germination can take place. Sprinkler irrigation is ideal for such situations. After harvest of one crop and before second crop is sown land has to be tilled. Usually land is hard and difficult to till. One light irrigation by sprinklers makes the soil soft for easy tilling.
- By using sprinklers in frosty nights the microdimate around the crop can be enriched in water vapour which will prevent frost damage to the crops.
- In the same way, in scorching dry summer season, sprinkling causes water to evaporate taking the latent heat of vaporisation from the atmospheric air. The microdimate around the crop thus gets cooled.
- Sprinkler irrigation can be adopted for almost all crops (except rice and jute) and on most soils for variable topographic conditions. This method is particularly suited to sandy soils but not suited for very fine textured soils where the infiltration rates are less than 4 mm/hr.
- Where stream sizes are small (7.5-15 lps) for efficient surface irrigation, considerable areas are lost in construction of channels and bunds. In these conditions sprinkler system can be used effectively.
- Sprinkler systems are also suitable for areas of high water table where a precise control on irrigation is required. The sprinkler system permits small application of water, which would not cause any further rise in the water table.

- Poultry and cattle sheds when sprinkled over roof will bring down temperature during noon. Such cooling of sheds is reported to increase egg and milk production considerably.

7.3 LIMITATIONS OF SPRINKLER IRRIGATION SYSTEM

- The major limitation in using sprinkler system is its high initial cost. The farmers in water scarcity areas are by and large much less economically solvent to invest in buying a sprinkler set. The probable investment for creating water resource for a hectare in case of major irrigation project is estimated at Rs. 1,00,000 per ha. When it is compared to the cost of sprinkler system per ha it is quite low. Thus, the government is promoting the farmers from well-irrigated areas giving financial incentives for adoption of sprinkler method of irrigation. This will help in bringing more area under command with the existing developed water resource with less investment compared to huge investment required for creating new surface water resource.
- Sprinkler irrigation is not suitable for crops requiring frequent irrigation as in case of rice.
- The second major bottleneck with sprinkler in the context of the power situation in the country is that in most cases, it may not be possible to run the system for the desired duration, due to non-availability of power. This problem can be solved by promoting the non-conventional sources of energy such as solar and wind for operating the sprinkler system. Solar pumping system has already been introduced on experimental basis and proved very encouraging for operating drip and micro sprinklers. The cost of solar panels is comparatively high today. However with the development in technology this cost is going to be reduced and energy problem for pumping of irrigation water can be solved to a large extent.

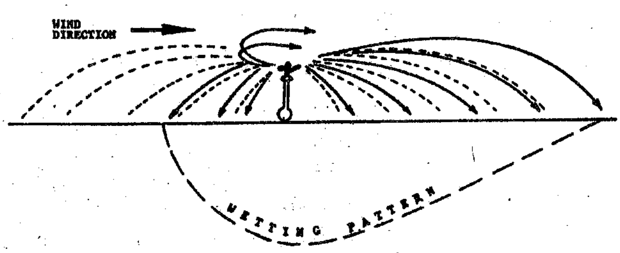

Figure 1. Effect of wind on sprinkler irrigation.

- The system is not suitable for windy and arid regions due to resulting non-uniformity due to wind drift and high evaporation losses. Uniformity of water application is poor when wind velocity exceeds 16 km/hr. This can be considerably offset by adopting closer spacing and laying laterals across wind direction and adopting low working pressure. In most cases the problem is solved by selecting working hours when wind is not high.
- In case of sticky soils, movement of system may be difficult. In some soils there might be some damage to the soil surface due to drops.
- Under high temperature, high wind velocity and low humidity, there are considerable (10-15%) evaporation losses from a spray coming from the nozzle to the ground surface. These losses can be reduced if irrigation is applied during night.

- In case the irrigation water contains sodium chloride, sprinkling this water on the plant foliage will scorch the leaves and damage the plant. At the same time maintenance requirement of the system will be more.
- The system is not suitable for very small holdings, and it needs careful handling for getting long operating life.
- Crops during flowering stage cannot be sprinkled since this interferes with pollination and setting. It may also damage blossom (and hence reduce fruiting). This can be however overcome by giving a heavy irrigation just before expected opening time of flowers and another irrigation immediately after setting.
- Soil borne micro-organism are some times transported to the foliage through the splashing of soil and may result in spreading infectious diseases.
- It may wash off pesticides, which have been applied before irrigation. Pesticides may be applied after irrigation.
- Sprinkler irrigation requires a continuous supply of water till the required application has been made. In case of canal irrigation, which is supplied to the farmers for fixed hours on turns basis (warabandi), use of this method is rather difficult.
- For sprinkler system water must be clean and free of sand, debris and large amounts of dissolved salts.
- Sprinkler system may be mechanically complex and difficult to maintain.

7.4 SPRINKLER-TYPES

Sprinkler system may be classified on the basis of arrangement, portability and based on operating pressure & adoption.

7.4.1 ON THE BASIS OF ARRANGEMENT

On the basis of the arrangements for sprinkler irrigation water, sprinkler systems are classified into three types:

i) Fixed nozzles attached to a pipe.

ii) Rotational head/revolving sprinkler

iii) Perforated pipe system.

- FIXED NOZZLE

Earlier sprinkler systems were 'fixed nozzle' types. Parallel pipes are installed about 15 m apart and supported on rows of posts. Water is discharged at right angles. The entire 15-m width between pipelines may be irrigated by turning the pipes through 135^0.

- ROTATING HEAD SPRINKLER SYSTEM

Water is spread through a rotating sprinkler head at an operating pressure of about 1.7 to 3 kg/cm^2. This can be again divided into three categories namely:

- Conventional system/small rotary sprinkler,
- Boom type /self propelled, and

- Mobile rain gun/large rotary sprinkler.

❐ Conventional/Small Rotary Sprinkler System

In conventional rotary sprinkler system (Figure 2), small nozzles are placed on riser pipes. They are fixed at uniform intervals along the length of a lateral pipe in which water is conveyed from source to the sparing device under pressure. The lateral pipes are usually laid on the surface of the ground. In this method, the most common device to rotate the sprinkler head is with a small hammer activated by the thrust of the water striking against a vane connected to it.

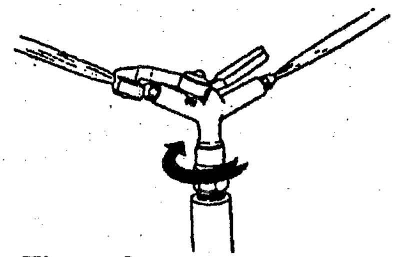

Figure 2
Rotating head sprinkler

This is commonly used since it is operated at low to medium pressure (2-4 bar) and can irrigate an area of 9 to 24 m wide and up to 300 m long in one setting. Application rate can be 5 to 35 mm per hour.

❐ Boom Type/Self Propelled Sprinkler System

This system employs one boom sprinkler (large) in each lateral (Figure 3). The boom is a nozzle slowly rotating from a pipeline, which is suspended from a portable tower. The boom sprinkler is moved by towing the towers to the next position along the laterals with a tractor. The large sprinkler irrigates a width of 75-100 m depending on nozzle size and pressure and is particularly useful to tall crops such as corn and sugarcane, where space at regular intervals is available for maneuvering the portable towers.

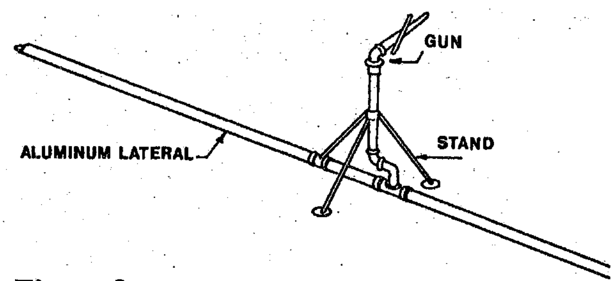

Figure 3
Rain Gun Sprinkler

❐ Mobile Rain gun/Large Rotary Sprinkler

This system operates at high pressure to irrigate large areas. It is able to throw a large quantity of water over wide areas. It can irrigate areas up to 4 ha at one setting with an application rate of 5 to 35 mm per hour. There are two types in the system namely, hose pull system and hose reel system.

(a) Hose Pull System

Here the rain gun is mounted on a wheeled carriage. Water is supplied through a flexible hose which is up to 200 m long and 50 to 100 mm in diameter and which is pulled along behind the carriage. The main line is laid across the center of the field from the pumping station. A strip up to 400 m long can be irrigated at one setting, although the flexible hose may only be 200 m long.

The pressure at the raingun controls the application rate. The forward speed of the machine controls the depth of water, whose speed varies from 10 to 50 mm an hour.

(b) Hose Reel System

The hose reel machine has a raingun (Figure 4) mounted on a wheeled carriage. Water is supplied through a more rigid hose than that used for the hose pull although it is still flexible enough to be wound on to a large reel. The hose is used to pull the raingun towards the hose reel positioned at the edge of the field. Machines are available with hose lengths ranging from 200 to 400 m. The mainline is placed across the centre of the field from the pumping station. The hose reel is placed close to the mainline at the start of the first run connected to the water supply. The raingun is slowly pulled back across the field by winding the hose on to the hose reel. Power to drive the hose reel can be provided by a water motor, an internal combustion engine or the power takeoff point on a tractor.

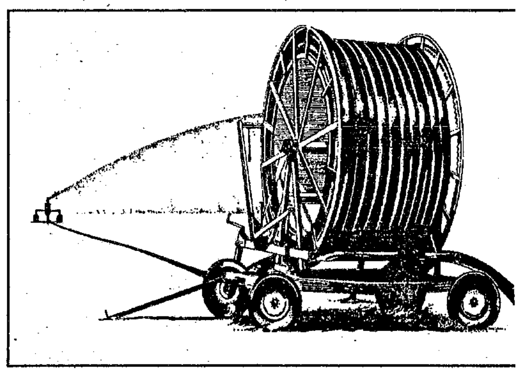

Figure 4
Hose Reel System

❑ Perforated System

This method consists of drilled holes on lateral irrigation pipes (Figure 5) in a specially designed pattern along their length through which water is sprayed fairly uniform and under pressure. This system is usually designed for relatively low operating pressure of about 0.5 - 2.5 kg/cm^2. The pressure is so low that the system can be connected to an overhead tank to obtain necessary pressure head. The sprays are directed on both sides of the pipes and can cover a strip of land from 6-15 m wide. It is suited for soils having moderately high infiltration rates, as the water is applied at relatively high rate.

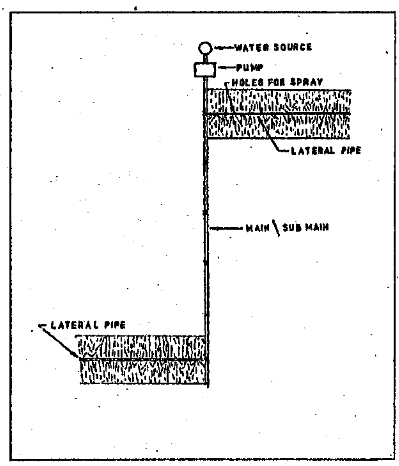

Figure 5
Perforated Sprinkler System

The application rate is 1.25 - 5 cm per hour for various pressures and spacings. This system is suited for irrigation of lawns, gardens, and small vegetable fields and other plants when height does not exceed 40 to 60 cm. The water should be cleaned through a filter to prevent clogging of the small perforations. There are three types of spraying systems namely :

a) Stationeary (b) Oscillating and (c) Rotating.

7.4.2 ON THE BASIS OF PORTABILITY

- Portable system
- Solid/permanent system
- Semi-permanent system.

· PORTABLE SYSTEM

A portable system has portable main lines, and laterals and a portable pumping plant (Figure 6). It is designed to be moved from field to field or to different pump sites in the same field. Laterals may be hand moved or mechanically moved.

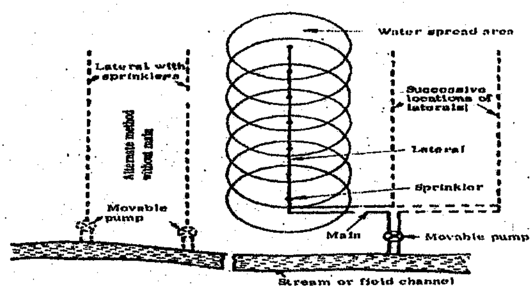

Figure 6
Portable System

❒ **Hand Move System**

The Simplest portable system is designed such that it can be moved by hand (Figure 7). The system has the lowest investment cost but the highest labour requirement. With giant sprinklers, the spacing can be increased thereby reducing labour, but higher pressure is required which increases the pumping cost. These sprinklers are most suitable for low growing crops. It consists of a pump, main line, lateral and rotary sprinkler spaced at 9 to 24 m apart.

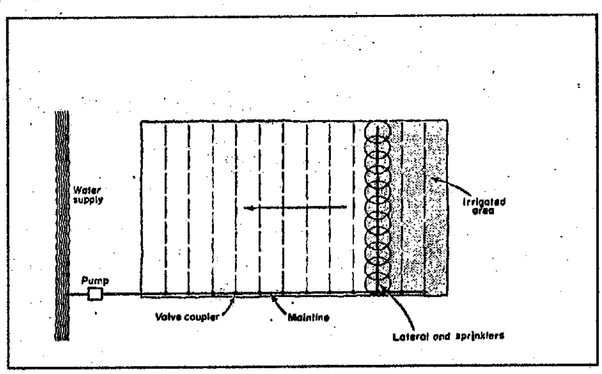

Figure 7
Hand Move System

The lateral is usually between 50 mm to 100 mm in diameter so that it can be moved easily. It remains in position until irrigation is complete. The pump is then stopped and the lateral disconnected from the main line and the water is allowed to drain. It is then dismantled and moved by hand to next point and reassembled. Usually it is moved about one to 4 times each day. It is gradually moved around the field until the entire field is irrigated (Figure 7 and Figure 8).

In some cases to irrigate large areas, two or three laterals (Figure 9) are used. They are connected to the mainline using valve couplers. This allows irrigation to continue while one of the laterals is being moved. In this system only laterals are moved during the irrigation while the main line remains permanently in the same place.

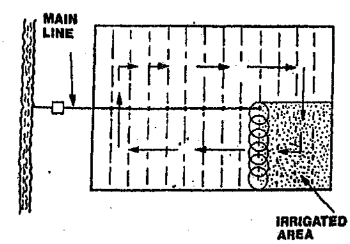

Figure 8
Hand Move System

In some cases the entire system including pump and the main line is moved from field to field (Figure 6). Portable System is common in India since the capital investment is low and it is simple to use. They are used to irrigate wide range of field and orchard crops.

At places where labour is short or expensive, it may not be possible to use hand move systems. Under these circumstances, mechanical move system employing a variety of devices for moving the lateral line rotating booms to drag, winches or wheel lines or sprinklers on a rotating tower arrangement may be used.

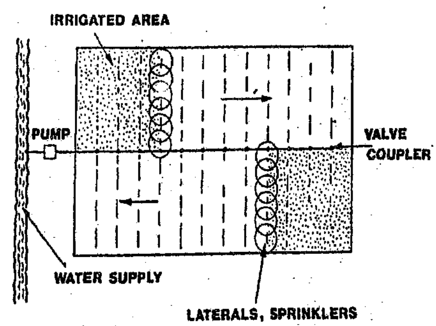

Figure 9
Hand Move System with 2 laterals

❒ End Pull System

With the end pull system, the lateral is moved to the next position by pulling the line with a tractor to the opposite side of the main. Generally, main is buried in the center of the field. This method is suitable for low-growing crops and in places where adequate moving space is available. It is also practical for tree crops. Labour is greatly reduced compared to hand move systems.

❒ Rotating Boom Type System

The rotating boom type system (Figure 10) operates with one trailer unit per lateral at spacing up to 110 m.

The boom sprinklers have rotating arm of 28 to 36 m length provided with nozzles. The discharge is in the range of 6 to 30 lps. The trailer and boom unit is moved to the next position along the lateral with a tractor. The lateral line is added or picked up as the trailer is moved progressively through the field away from or toward the mainline. The boom type unit will cover about the same area as a giant sprinkler, but the pressure required is not as high.

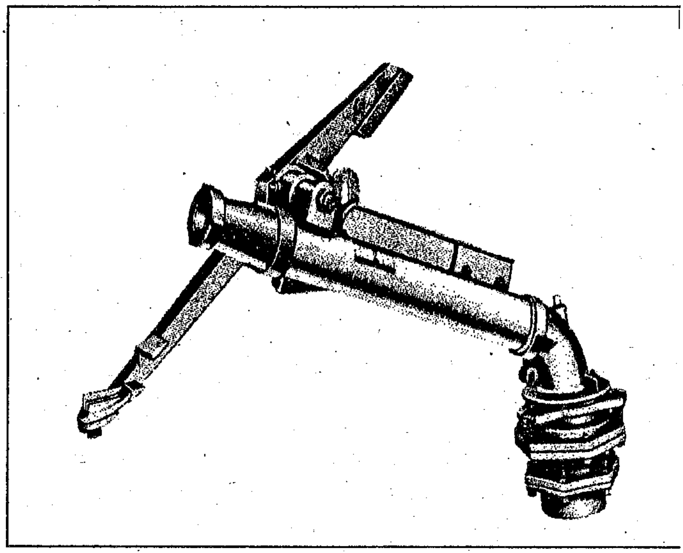

Figure 10 Rotating Boom Type System.

❐ Side Roll Lateral System

The side roll lateral system (Figure 10) utilizes the irrigation pipe as the axle of large diameter wheels that are spaced about 9 m apart. The side roll lateral is limited to crops that will not interfere with the movement of the pipe. Unless a flexible pipe is attached to the main, the lateral must be disconnected for each move. Labor requirements are about the same as for the end-pull system, but much less than for the hand move systems.

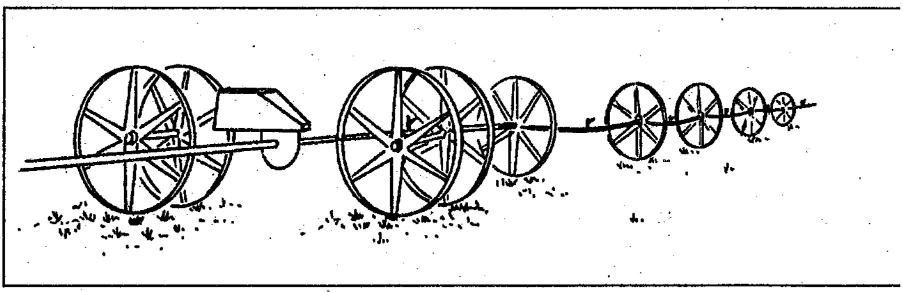

Figure 11 Side Roll Lateral System

❐ Centre Pivot System

The self propelled centre pivot system (Figure 12) consists of a radial pipe line supported at a height of about 2 m at intervals of about 30 m. Self propelled lateral is fixed at one end and rotates to irrigate large circular area. Fixed end is called pivot. The radial line rotates slowly around a central pivot by either water pressure or electric motors. Conventional sprinklers mounted on the pipe then distribute water to the field, as the pipeline is moving. The towers are supported by wheels or skids and are kept in alignment with supporting wires. The nozzles increase in size from the pivot to the end of the line, at which is placed a large sprinkler in order to obtain the maximum diameter of coverage. The nozzles are selected to provide a uniform depth of application, varying from 13 to 100 mm per revolution. This system covers about 10 to 100 ha and the total capacity range is from 1500 to 4500 lit per min. (Sivanappan, 1987). The system is best suited to sandy soils, but it will operate in heavier soils if the depth of application is greatly reduced. A common size system designed for 65 ha is 392 m in length. Some manufacturers provide a fold back extension arm that will irrigate nearly all of the corners of a square field and odd-shape fields. Normally, the system once set up, remains permanently in place; but some can be towed to another field. One rotation is completed in 10 to 72 hours. The precipitation rate is around 25 to 250 mm per hour. The major advantage of the centre - pivot system is the saving of labour; the major disadvantage is high investment cost.

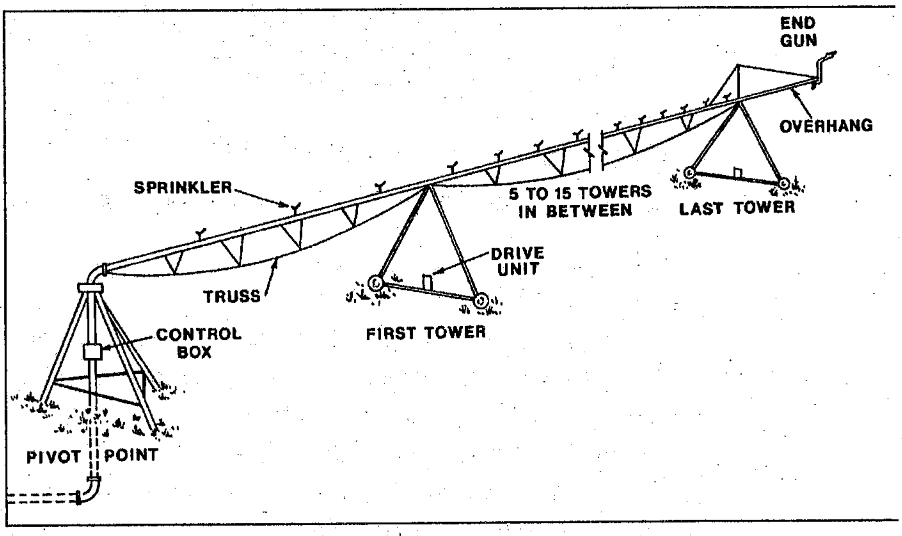

Figure 12 Centre Pivot System

- **SOLID SET OR PERMANENT SYSTEM**

When sufficient laterals and sprinklers are provided to cover the entire area to be irrigated, there is no need to move the equipment from place to place. The laterals are positioned in the field early in the crop season and remain there for the season. It has stationary water source and pumping plant. This system is termed as solid set or permanent system (Figure 13). Mains, sub-mains and laterals are usually buried below plough depth and sprinklers are permanently located on each riser. The system is used for crops requiring short and frequent irrigation. The purpose of this system is to reduce labour costs and eliminate moving of lateral lines especially where tree foliage is heavy. Such systems are costly and are suited to automation of the system with moisture sensing devices particularly where labour is very expensive. Because of high investment costs, solid set systems are practical only for high - value crops such as in orchards, vine yards, etc.

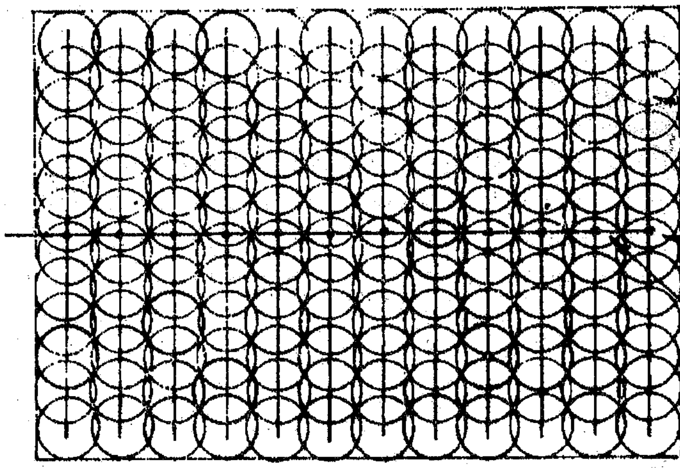

Figure 13 Solid Set or Permanent System

- **SEMI PORTABLE/SEMI PERMANENT SYSTEM**

Many new sprinkler systems have been developed in recent years with the advantage of being both portable and solid set, thus reducing capital cost and labour requirements. The system is similar to portable system except that the locations of water source and pumping plant are fixed. Such a system may be used on more than one field, where there is an extended main line. Generally, it has portable lateral lines, permanent main lines and sub-mains and a stationary water source and pumping plant. These are known as semi-permanent systems. The main lines and sub-main are usually buried with riser for nozzles located at suitable intervals.

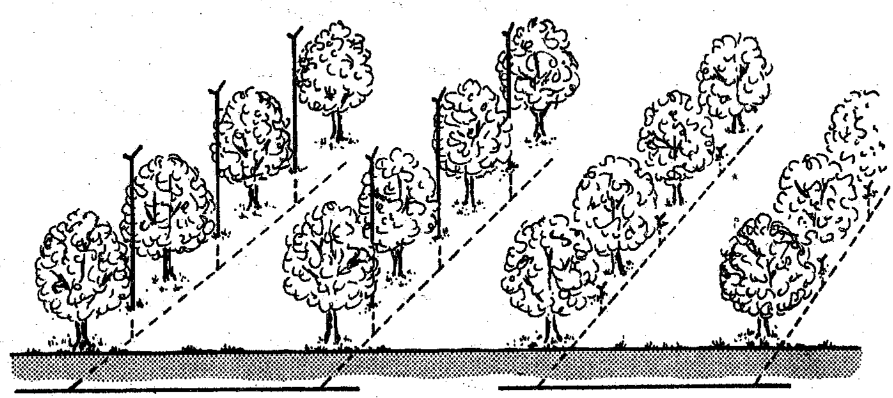

Figure 14 Semi Portable System

The following are the most common:

a) Sprinkler hop, b) Pipe grid and c) Hose pull.

- *Sprinkler Hop*

This is similar in many ways to portable systems, but sprinklers are placed only at alternate positions along the lateral. When sufficient water has been applied the sprinklers are disconnected and moved or hopped along to the next position where they irrigate for a similar period. This is done without stopping the flow in the lateral. Each sprinkler connection is fitted with a special valve which automatically stops the flow when the sprinkler is removed. This lateral is moved to the next position and the hopping process repeated.

- **Pipe Grid System**

This is similar to the solid set or permanent system. Small diameter laterals about 25 mm are used to keep system costs low. The pipes are laid out over the entire field and they remain in place throughout the irrigation season, thus eliminating movement of pipes. Two sprinklers are connected to each lateral, one near the top, the other half way down. When sufficient water has been applied each sprinkler is disconnected and moved along the lateral to the next position. This is repeated until the whole field has been irrigated.

- **Hose Pull System**

In this method, the mainline and laterals are usually permanently installed either on or below the ground surface. Small diameter plastic hoses supply water from the lateral to one or two rotary sprinklers. The hose length is about 50 m because of friction losses in the pipe. This reduces a number of laterals and provides great flexibility in irrigation. A sprinkler can be easily moved where it is needed and can be adjusted to compensate for the distortion of spray patterns caused by wind. This system is used for tree irrigation for orchards crops and other row crops.

7.4.3 BASED ON OPERATING PRESSURE AND ADAPTABILITY

Sprinkler systems are also classified on the basis of operating pressure. It is important that the proper pressure be provided for the sprinkler heads to be used. Pressures too low or too high for a particular sprinkler head will cause poor water distribution patterns.

7.5 SUMMARY

In a sprinkler system, water under high pressure is forced through a nozzle of small diameter. An ideally designed and laid sprinkler system is one that produces a drop size distribution close to the rainfall or of such a type that will have no adverse effect on the soil structure, and on the uniformity of distribution due to drift. Thus all water reaching the ground surface infiltrates directly into the soil, and there is no movement of water over the soil surface. It is possible to attain a high irrigation efficiency using the sprinklers, which is not generally feasible in the conventional methods of irrigation. Also, sprinklers can be used for irrigating a wide variety of crops except those crops whose water requirements are very high. In spite of many advantages of the system, this has been adopted only in limited places in the country. A major reason is its high initial and running costs, though there are subsidies available for the purchase of sprinkler sets.

Sprinkler system provides positive control over amount and rate of application of water. Most sprinkler systems apply water at a rate less than or equal to the maximum intake rate of the soil at any time. Sprinkler systems are adaptable to variable soils; crops requiring light frequent irrigations; soils with low water-holding capacities; heavy soils not having high lateral water movement capabilities; light soils not having high lateral water movement capabilities; areas with high water tables and for drainage and runoff reduction.

7.6 SELF-ASSESSMENT TEST

- In which conditions is sprinkler irrigation system most useful?
- What are the limitations of sprinkler irrigation system?
- What are the special situations where sprinkler irrigation system can be used?
- On the basis of arrangements how can sprinkler system be classified?
- On the basis of portability how can sprinkler system be classified?
- Explain side roll lateral system.

7.7 KEY WORDS

- Sprinkler: is an irrigation device that tends to simulate the rainfall but in a way that the runoff and deep percolation losses can be avoided and at the same time, the uniformity of application can be made as close to as would be obtained under rainfall condition.
- Water present in the soil: the water held in the soil between field capacity and wilting point (i.e. the moisture contents respectively under 1/3 bar and 15 bar) is available to the plant.
- Portable system: A portable system has portable main lines, and laterals and a portable pumping plant

7.8 SUGGESTED READINGS

- Bhattacharya, A.K., 1985. Sprinkler Irrigation-its uses and limitations. Short term course on Sprinkler and Drip Irrigation. WAPCOS, New Delhi.
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UNIT 8

DRIP IRRIGATION SYSTEM

STRUCTURE

8.0 Objectives

8.1 Introduction

8.2 Crops grown under drip system

8.3 Advantages of drip irrigation system

8.4 Limitations of drip irrigation system

8.5 Types of micro irrigation systems

8.6 Components of drip irrigation system

8.7 Computer based system

8.8 Summary

8.9 Self-assessment test

8.10 Key words

8.11 Suggested readings

8.0 OBJECTIVES

After going through this unit students will be able to appreciate :

- What is the drip irrigation system ?
- What are the advantages of drip irrigation ?
- What are the types of drip irrigation system ?
- What crops can be grown under drip irrigation system ?
- What are the components of drip irrigation system ?
- How computer can be used in drip irrigation ?

8.1 INTRODUCTION

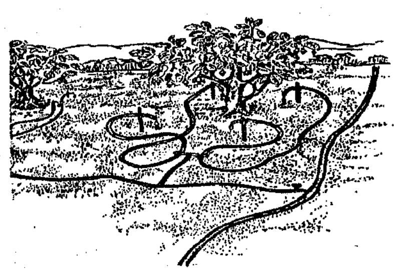


Figure 1 Drip Irrigation System

Drip irrigation (Figure 1) is a technique by which water and fertilizer can be placed directly near the root zone of the plants. It is a slow application of water on or below the soils as discrete or continuous drops, tiny streams or miniature spray through emitters or applicators placed along a water delivery line near the plants. The emitters achieve a three-dimensional spread of water maintaining low levels of soil water tension.

To replenish the depleted root zone moisture in the soil, water applications are frequent. If adequate control over performance of the system such as plugging of the nozzles is maintained, the method will improve the plant response to irrigation, even with poor quality water and soils prone to salinity hazards. There is considerable water saving since the water is applied precisely to the root zone and there is no need to wet the entire area as in other methods.

The use of drip irrigation system has been increasing in several states in the country, especially, Gujarat, Maharashtra, Kerala and Karnataka. This system is adaptable to most crops, under most soil and topographic conditions. It is particularly suitable to orchards and vegetable crops.

8.2 CROPS GROWN UNDER DRIP SYSTEM

A large variety of crops are being grown with drip system. However, the system is generally most successful for high-income crops because of the relatively high first cost of most installations. Crops, which have been grown with this system, include the following:

i) **Orchard crops** grape, citrus, apple, pear, deciduous fruits (peaches, apricots, plums, etc.). nuts (almonds, pistachios), banana, date, olive, mango, guava etc.

ii) **Vegetables** tomato, green pepper, eggplant, cucumber, lettuce, green peas, cauliflower etc.

iii) **Row and field crops** cotton, Sugarcane, sorghum and corn.

iv) **Others** berry, melon, alfalfa, flowers (carnations, gladioli, and rose) and other ornamental plants.

8.3 ADVANTAGES OF DRIP IRRIGATION SYSTEM

Drip irrigation system is gaining wide acceptance in various parts of the world including India due to several advantages, some of which are discussed below.

i) **Water savings**

Because of the high degree of control possible under this system of irrigation, water can be applied uniformly (Figure 2). Only that portion of the soil in which there are active roots need be irrigated, and evaporation losses can be reduced to a minimum. (The water neither passes through the air, nor does it remain on the ground surface for long periods of time).

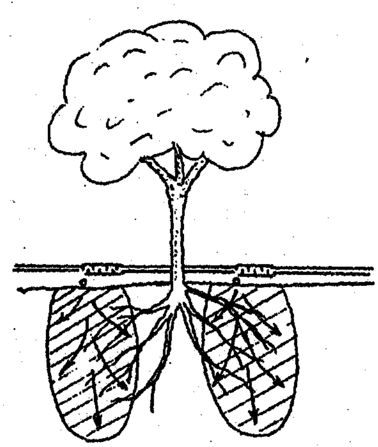


Figure 2. The restrictive wetting pattern under drip irrigation.

The low rate of application, which often is only slightly greater than the consumptive use rate, reduces deep seepage losses. Water savings up to 50 percent are not unusual. Under drip system water use efficiency as high as 90-95% can be obtained as compared to only 40-50% in the conventional system of furrow or flood irrigation.

ii) **Crop response**

A high average temporal soil water level, along with adequate soil air can be maintained with this system. This results in a favorable response by some crops, with high yield and high quality. Slow and frequent watering eliminates wide fluctuations in soil moisture content resulting in better growth. It has been reported that drip irrigation increases the yield from 15 to 30% depending upon soils and crops over conventional method of irrigation.

iii) **Labour savings**

Most drip systems are permanent or semi-permanent and so have low labour requirements to the extent of 30 to 40%. They may also be automated to further reduce labour needs.

iv) **Optimum use of fertilizer**

Fertilizer can be applied through drip irrigation system using special equipment. Because of the good control of water; this can also result in a close control over fertilizer application, with resultant savings. In addition, because of the small amount of water lost through deep seepage, the loss of fertilizer through leaching is minimized thereby increasing the fertilizer use efficiency.

v) **Weed control**

There is less weed growth and thus less weed control is needed. Because only a fraction of the soil surface is wetted with this system, there is a reduced area available for weed growth. Thus, weed control is much less than for other systems.

vi) **Savings in pesticides and disease control**

Above ground plant parts are completely dry under drip system. This reduces fungus incidence and other pests which depend upon a moist environment. Some pesticides - notably nematicides - have been effectively applied through drip systems.

vii) **Possible use of saline water**

Because matric and osmotic potentials are additive, the maintenance of a low matric potential, as is possible with drip systems, results in a lower overall potential, and hence a reduced stress under saline conditions than would otherwise occur. This has resulted in some crops being grown in areas which would otherwise be unsuitable for conventional systems.

viii) **Early maturation**

Experiments on tomato, grape and sugarbeet, to name but a few crops, have resulted in significantly earlier maturation than was attained with other irrigation systems.

ix) **Minimize soil crusting**

A significant problem in some soils is the formation of a hard surface crust. This can prevent emergence of crop, even if it has germinated properly. By maintaining a constant high moisture content, crusting can be eliminated.

x) **Field edge losses are reduced**

There is no loss at the edge of fields as can occur through wind drift of sprinkler systems or runoff from surface systems.

xi) **Improved root penetration**

In some soils, where root penetration is minimal or impossible at low water contents, the high average water content maintained with drip system alleviates this problem.

xii) **Irrigation of low intake soils**

Theoretically water can be applied with drip systems at rates equal to the water use rate of the plant. Thus, application rates can be as low as 0.25 mm per hour, with corresponding possibilities of decreased water runoff on low intake soils.

xiii) **Field operation easier to manage**

When a drip system is properly managed, the soil does not approach saturation, as is the case with other irrigation systems. Thus, its ability to bear a load remains, and so cultivation, harvesting, etc., can take place during irrigation. Due to fewer weeds the efficiency of operation also increases thereby reducing the operational costs even up to the extent of 50%.

xiv) **Energy saving**

Because of high irrigation efficiency less time is required to supply the desired quantity of water, thus it also saves energy.

xv) **Most suitable for poor soils**

Very light soils are difficult to irrigate by conventional methods due to deep percolation of water. Like wise , very heavy soils with low infiltration rates are difficult to irrigate even by sprinkler method. Drip irrigation has been found successful in both the types of soils.

xvi) **Flexibility in operation**

This system can be used during any part of the day when power is available.

xvii) **No soil erosion**

There is no soil erosion with drip irrigation.

xviii) **Easy installation**

This system can be installed with considerable ease and is equally beneficial to both small and big farmers.

xix) **No land preparation**

Preparation of leveled bed, bund and channels is not necessary. Only land smoothening will suffice.

8.4 LIMITATIONS OF DRIP IRRIGATION SYSTEM

Like any other system drip systems also have certain limitations. These are discussed below:

i) **Sensitivity to clogging**

The small openings used in many discharge mechanisms make them extremely sensitive to clogging. Thus, water must be finely filtered, and this can be expensive. In addition salt and chemical deposits can accumulate at discharge openings, causing them to become plugged.

ii) **Salinity hazards**

Although drip systems can be used under saline conditions, they must be managed properly. Otherwise reverse pressure gradients in the soil will cause flow of salts toward plant roots, resulting with detrimental effects.

iii) **Moisture distribution problems**

There is some evidence that not all crops respond well to localized wetting only. This procedure can restrict root development.

iv) **Economic limitations**

For the drip system there is high first cost compared to surface or portable sprinkler irrigation systems. This is one of the major drawbacks of drip irrigation systems. Although equipment now in use and being developed is significantly less costly than that originally used, high initial cost is still a major consideration in the selection of this type of irrigation system.

v) **Dry soil and dust formation during mechanical operations**

The fact that a large part of the soil surface may receive no water during irrigation causes any tillage operations which cross this area to result in extreme break-up of the soil. This can result in dust problems and soil erosion during windy periods.

vi) **High skill required for design, installation, operation and maintenance**

Any irrigation system can be efficient if properly designed. However, if a surface irrigation system is improperly designed, it can often be altered in the field with little problem or expense. The same is not true in drip systems because of the large amount of specialized equipment needed. In addition, the small discharge openings require that the equipment be properly placed to keep out soil particles. Finally, failure to properly maintain the filtration equipment can make the entire system inoperative and costly to repair. A high level of design, management and maintenance is required with drip than with other irrigation method.

vii) **Persistent maintenance requirements**

Emitters clogging is considered the most serious problem in drip irrigation unless preventive measures are taken. It is therefore necessary that water should be filtered properly and this can be expensive. Apart from this, salt and chemical deposits can accumulate plugging the discharge openings. Clogging will adversely affect the rate and uniformity of water application, increased maintenance costs (as it becomes necessary to check, replace or reclaim the clogged emitters) and result in crop damage and decreased yield, if not detected early and corrected timely.

Other maintenance problems include pipe line leaks and cracking of the tubes. Rodents, coyote, rabbits, etc. can chew and damage drip line; and ants and other insects occasionally enlarge openings in drip tubings. Drip lines can be cut or dug-up accidentally when weeding, replacing plant material or when replacing or repairing other pipe lines or utilities in nearby areas. Filters, chemical injectors, pressure regulators, water meters and pumps are also subjected to malfunctioning and are liable to be stolen.

8.5 TYPES OF MICRO IRRIGATION SYSTEMS

Normally following types of micro irrigation systems are common:

8.5.1 DRIP IRRIGATION SYSTEM

Drip systems vary according to topography, size and shape of irrigated area, crop type and planting pattern besides the drip equipment itself. However, a drip irrigation system basically consists of main line, sub-main, laterals, valves, drippers or emitters, a riser valve, vacuum breakers, pressure gauges, water meters, filters, fertilizer tanks or venturi pumps, flush valves and pressure regulators, etc. as shown in Figure 3.

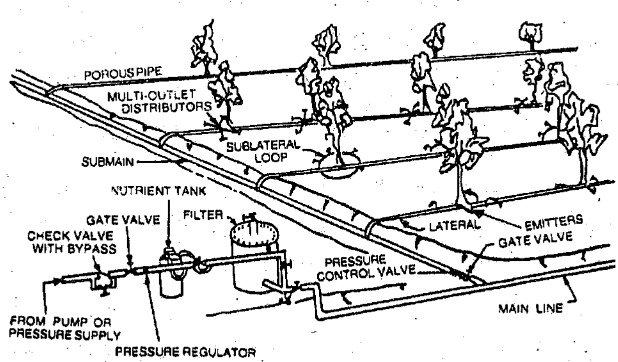


Figure 3: Drip Irrigation System.

From the main, feeder lines are run across the field and laterals are inserted on the same. Low density polyethylene pipes are laid along the plant or tree rows with outlets or drippers inserted at appropriate intervals. These are designed to supply the water at the desired rates (1 to 10 litres per hour) directy to the soil. Low pressures ranging from 0.35 to 2 kg/cm2 are sufficient to work. Usually 3.75 to 7.00 cm diameter pipes are used for mains, and 2.5 to 3.75 cm for sub-mains. For laterals, pipes of various ranging from 6 mm to 18 mm with a pressure rating of 4 atmospheres are generally used. Pressure compensating drippers are suitable for undulating land, hilly area, whereas non-pressure compensating are suitable for flat areas. Dripper/emitters system is suitable for widely spaced crops like mango, coconut, citrus, pomegranate, grapes, banana, etc. whereas inline-irrigation drippers are used for irrigation of row crops like sugarcane, vegetables, etc.

8.5.2 BIWALL IRRIGATION

There has been a constant effort to reduce costs of drip systems. One approach to this has been to combine the functions of laterals and drippers into a single unit. One of these consists of a tube made of porous plastic. Another type consists of a double plastic tube - one is inside the other. The water passes through holes in the inner tube to the space between the two tubes, with an associated pressure drop. The water then is delivered to ground surface through closely spaced holes in the outer tube. The result is irrigation with nearly a line source of water, rather than several point sources. If a few holes are plugged the result is not serious. This equipment is made from thin-walled polyethylene tubing and is relatively inexpensive. Its life is short and it is often considered to be expendable at the end of the irrigation season.

Biwall is extruded dual chamber micro-irrigation tubing, manufactured from a Linear Low Density Polythylene (LLDPE). Holes are drilled by laser beam at regular intervals (50, 75, 100 cm) along the tube to give even and equal amount of water to plants over long lengths (Figure 4). Water is delivered from the main chamber through a distribution chamber with evenly spaced supply orifices provided by laser beams. It is then slowly released through emission orifices. This system is suitable for all closely spaced row crops like sugarcane, cotton, vegetable, grapes, pineapple, onion, tea, etc.

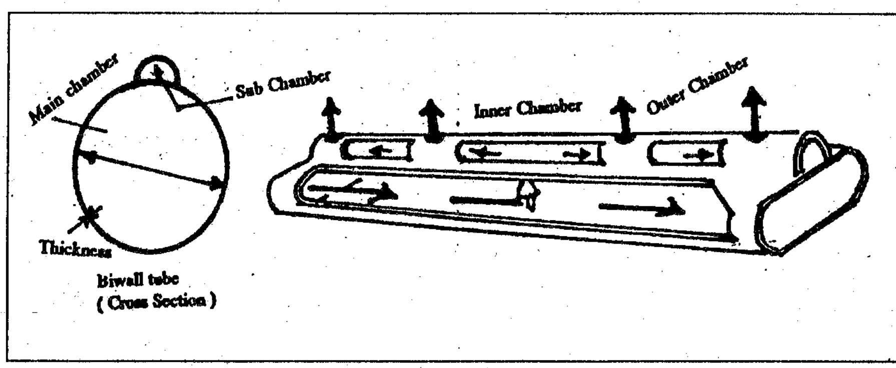


Figure 4: Biwall System.

8.5.3 MICRO JET SYSTEM

Micro-jets (Figure 5) are the spray emitting devices that operate at low pressure with higher discharge rate than the emitter. Additionally, Micro-jets wet a greater surface area than the dripper system. Water is sprayed through the

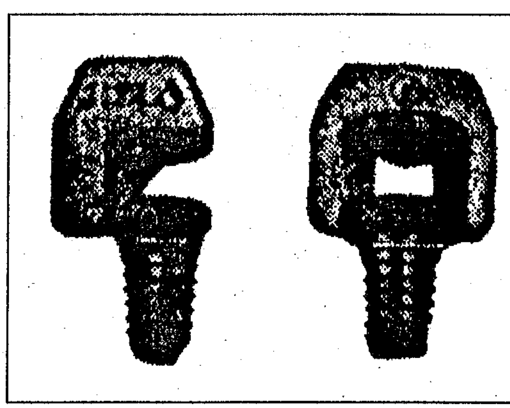


Figure 5. Micro jet system (half & full circle jet).

air in either fan spray or a number of discharge jets. However, because jets possess no moving parts, there is a limit to their distance of throw. Micro-jets are suitable for irrigation of fruit crops, nursery, flowerbeds, vegetables, etc. They are suitable for irrigation of crop in sandy soil, where the infiltration rate is high.

8.5.4 MICRO SPRINKLER AND MICRO SPRAYER IRRIGATION

This is a combination of sprinkler and drip irrigation. Water is sprinkled around the root zone of the trees with a small sprinkler (Figure 6) working under low pressure. This unit is fixed in a network of tubing but can be shifted from place to place around the area. Water is given only to the root zone area as in the case of drip irrigation but not to the entire ground surface as done in the case of sprinkler irrigation method. It is just like micro-jet, but it incorporates the moving part, which enables it to spray the water over a greater area then the jet. They are suitable for irrigation of crop in sandy soil, where the infiltration rate is high.

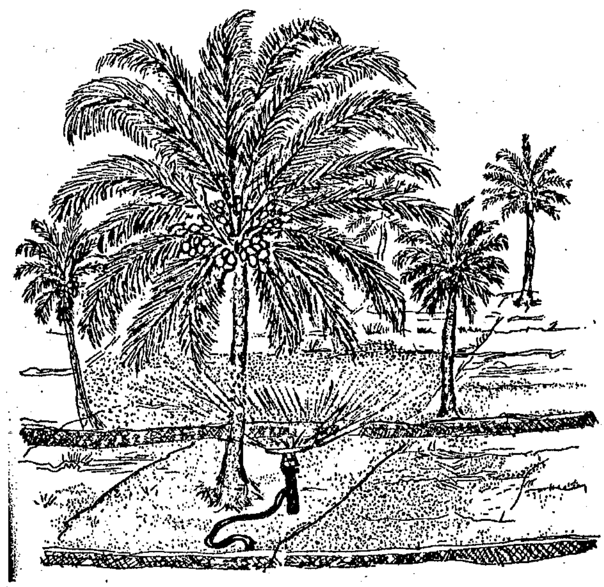


Figure 6 Micro/mini Sprinkler.

The other different drip systems are (i) single chamber tube; (ii) dual wall; (iii) twin wall; (iv) T-type; (v) Gal-drip; (vi) tri-wall triple Chamber; (vii) Leaky Pipe; (viii) Typhoon, etc.

8.6 COMPONENTS OF DRIP IRRIGATION SYSTEM

Drip irrigation is the discharge of low flow of water from small diameter orifices connected to or a part of distribution tubings situated on or immediately below the soil surface. The components of drip system can be grouped into three principal categories:

- Control Head.
- Water Distribution Network.
- Discharge Elements.

8.6.1 CONTROL HEAD

The control head of drip irrigation system includes the following components:

- **PUMP**

Pump or overhead tank is required to provide sufficient pressure in the system. Centrifugal pumps are generally used for low-pressure drip systems. Horse Power of the pump depends on the area to be irrigated. Pumps are generally recommended for larger areas under drip irrigation, undulating topography, closely spaced crops or where water requirement is comparatively high.

Instead of connecting direct to the pump, an overhead tank having a height of about 3 meters can also be used especially for small areas. In addition, where water is crucial, overhead tank is to be constructed to collect and store the water from other sources.

- **Filters**

The hazard of blocking or clogging necessitates the use of filters for efficient and trouble free operation of the drip system. The filter is an essential part of the drip system which minimises/ prevents emitters clogging. The type of filtration needed depends on water quality and on emitter types. Different types of filters include:

(a) Media Filter

(b) Centrifugal filters or sand separators/hydro cyclones

(c) Screen Filter

(a) Media Filter

Media filter consists of fine gravel and sand of selected sizes placed in a pressurised tank. It is required to remove organic matter such as algae mass and other vegetative material present in the water. The filters are made up of a circular tank filled with layers of coarse sand and different sizes of gravel with a provision of valves for flushing the filter assembly in case of clogging. The media filters are available in different sizes ranging from 500 to 900 mm diameter with an output of 15 to 50 Cum respectively depending upon the capacity.

(b) Centrifugal filters or sand separators/hydro cyclones

If the irrigation water has sand, hydro-cyclone type filters are required to remove the sand; it is also known as vortex sand separator. Hydro-cyclone type filters are produced in various sizes for different discharges and have been found most suitable for removing particles from water before it enters the drip irrigation system. Hydro-cyclones must be followed by a screen filter as a safeguard. The head loss caused by separators may be 4 to 10 m.

(c) Screen Filter

The screen filter is fitted in series with the sand filter in order to further remove the solid impurities like fine sand, dust, etc. from the water. In general, the screen filter consists of a single or double perforated cylinders placed in plastic or metallic containers for removing the impurities. Generally 100 to 200 mesh screens are used in this type of filters. It must be cleaned and inspected periodically for satisfactory operation of any drip system.

A different type of filter is the volumetric filter, which instead of screen has concentric grooved rings that are mounted on a longitudinal shaft. When tightened together, the rings form a cylindrical filtering body.

Automatic cleaning of filters either by electronic or hydraulic devices are now a days used in drip and micro-sprinkler systems.

- **Fertigation Unit**

The direct application of fertilizer through drip irrigation has increased the efficient use of fertilizer along with the saving in labour and money.

Application of fertilizer into pressurised irrigation system is done by either a by- pass pressure tank or by ventury pump or by direct injection system.

In by-pass system, closing main system valve, certain quantity, generally 10% flow quantity is allowed to by-pass through fertilizer tank. Then the by-passed water along with dissolved fertilizer goes into the system.

The ventury tube works on the principle that constriction in the main water flow pipe causes a pressure differential (vacuum), which is sufficient to suck fertilizer solution from an open reservoir into the water flow. The rate of water flow can be regulated by means of valves. This is simple and inexpensive method of fertilizer application, but it has some disadvantages. The pressure loss across ventury valve is high-about one - third of the operating pressure and precise regulation of flow is very difficult.

In direct injection type pumps of piston type or diaphragm type are also used. These pumps, operated by system pressure only, give fixed quantity of fertilizer in the water throughout irrigation.

- **Pressure regulators**

Pressure regulators are generally used to decrease the higher system pressure to the lower required system pressure. It controls pressures in one way only .e high to low. Pressure regulators are required on a large-scale design, undulating terrain and slopy land, etc. For normal small system, a simple by pass valve can be used to control pressure in the system.

A pressure regulator is often installed either before or after the main filtration element (mesh, sand etc.).

8.6.2 DISTRIBUTION NETWORK

The distribution network mainly constitutes main line, sub-main line, sub-sub main line and laterals (Figure 7).

- **Main Line**

Generally rigid PVC and high-density polyethylene (HDPE) pipes are

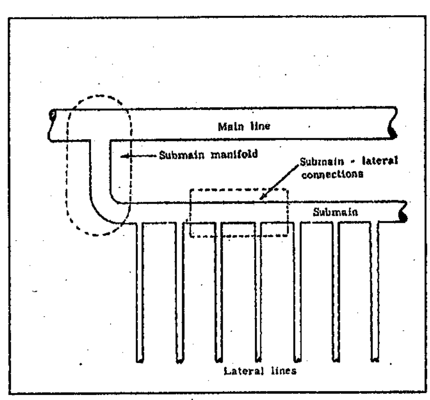


Figure 7 Main line, sub main and lateral connection.

used as main line. Pipes of 65 mm diameter and above with a pressure rating of 4 to 6 kg/cm2 are recommended for main pipes. These pipes laid underground, offer a long life of more than 20 years.

- **Sub main and Manifolds**

For sub main pipes rigid PVC, HDPE or LDPE (low density polyethylene) are recommended. Pipes having an outer diameter ranging from 32 mm to 75 mm with a pressure rating of 2.5 kg/cm2 are used as sub-mains. These pipes may be laid above the ground or underground.

- **Laterals**

Flow tubes are generally small for drip systems and therefore lateral pipes are of small diameters. Lateral lines (i.e. those with emitters) are attached to manifolds. These in turn, act as laterals with large emitters. That is, each lateral with emitters discharge an equivalent of several single emitter. Sub mains supply manifolds and mains supply sub mains.

The laterals/drip lines are normally manufactured from LDPE (low density polyethylene). These pipes are generally laid above the ground. Recently a linear low-density polyethylene (LLDPE) has been used. The linear low-density polyethylene gives more protection against ultra violet rays and longer life of pipe than LDPE. Generally pipes having 10, 12, 14, 16 and 20 mm internal diameter with wall thickness varying from 1 to 3 mm are used in drip system.

8.6.3 DISCHARGE ELEMENTS

One of the main components of a drip system is the element which discharges water onto the soil surface or below ground. It has the function of discharging water at the required flow rate at distinct, predetermined points throughout the field. Flow rates are generally quite low, often less than 4 lph, and system pressures are usually in the range of 7 m to 20 m. Thus, the discharge elements must have small openings. Possible arrangements around a tree are shown in Figure 8.

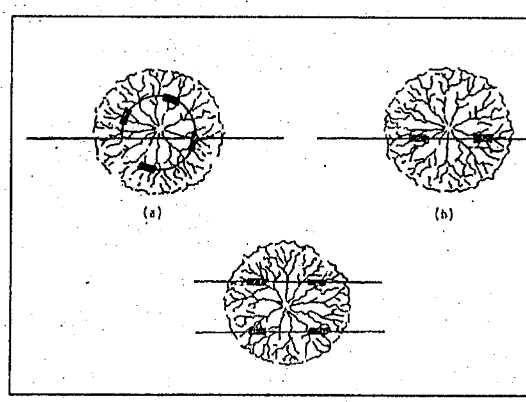


Figure 8. Possible Arrangement of Drippers around Tree.

Most discharge elements are called emitters, drippers or tricklers. Water may discharge direct on to the soil surface or into the soil profile or may be directed first through short tubes 0.60 m to 3.0 m long to points remote from the emitter. These are called multi-exit emitters. In other drip systems, water is discharged directly onto the soil surface through the walls of the lateral pipe.

The selection of an appropriate discharge element (usually called an emitter) requires consideration of many factors, such as ;

i) **General suitability**

Determine how well the emitter fits into the general layout of the system. Single point source emitters work well on small trees and shrubs, but larger trees and shrubs may require additional discharge and at several points. Perhaps a unit can be selected that will have a single discharge point when the trees are young and several discharge points when the trees are more mature. Usually, one two-outlet emitter is less expensive than two single-outlet emitters. For row crops line-source emitters, as provided by porous pipe or approximated by dual wall tubing, might be most appropriate.

ii) **Pressure-flow characteristics**

The discharge of any emitter varies with the pressure differential across the opening. This variation occurs even in the so-called pressure-compensated emitters. If all emitters are subjected to approximately same pressure, as might be the case when the lateral line runs down a slight slope, a variation of discharge with pressure across the opening is not important. In most cases, however this variation is important and must be considered in the design of the system.

iii) **Manufacturing variability**

It is physically impossible to fabricate two of anything exactly alike. This is even true of cast or extruded parts, such as those used in drip systems. Foreign matter can contaminate the raw materials; temperatures and humidity may change during the fabrication process; as parts are made, the fabrication machinery wears and changes in size; etc. All these factor's can and do affect the final product. Solomon (1979) has studied this and defines the manufacturing coefficient of variation as the coefficient of variation of discharge of several similar emitters, chosen at random, operating at the same pressure. He found that this coefficient of variation ranges from 0.02 to 0.35 depending on emitter model. He concluded that variability in discharge due to manufacturing is equally as significant as that due to pressure.

iv) **Sensitivity to temperature**

There are two effects caused by system temperature changes. System elements when heated or cooled change dimension and this can cause orifice opening, flow passages, etc. to be altered with consequent changes in flow characteristics. In addition, when the irrigation fluid changes temperature, its viscosity also changes. This too will change flow characteristics. This effect is present whether the emitter is pressure compensating or not.

vi) **Resistance to clogging**

Modern drip irrigation systems are usually provided with filtration systems designed to remove all particles large enough to cause closure of emitter openings. Unfortunately, contaminants still manage to enter the system and because the emitter is the ultimate filter, it may cause clogging. Some emitters are provided with an automatic flushing feature based on the pressure differential across the opening. This differential deforms the orifice and allows lodged particles to pass. In another type, the orifice openings are large at low pressures allowing a large flow which flushes out particles which might be present. These so-called flushing-emitters clean twice during each irrigation once when pressures build up as the water is turned on and again as pressures drop when the water is turned off. Less sophisticated elements have manually operated flushing features. Because of the labour involved and the number of emitters in a field (often over a 2500 per ha) these flushers may be used only at the startup of irrigation at the beginning of the season.

v) **Cost**

When emitters are evaluated on the basis of cost, one must consider not only the initial cost but also the installation, operating, maintenance and replacement costs. Those, which are highly sensitive to clogging, will need a relatively more sophisticated filtering system if they are to operate trouble free. Those discharging at high pressures will require increased pumping costs to raise pressures sufficiently. An emitter with a low manufacturing coefficient of variation will allow a high overall uniformity of distribution of water over the field. Thus, the water use will be less, with consequent savings.

Vii) **Risk**

The installation of a drip irrigation system costing from Rs. 10,000.00 to Rs. 25,000.00 per ha involves a risk, no matter how well designed and installed it is. The heart of this system is the emitter and involves a large portion of the initial cost. If emitters are provided by a reputable manufacturer who has a reputation for standing by its product, then essentially the manufacturer is accepting some of the risk of the investment in the system. This should be a consideration in emitter selection specially when the area irrigated is large.

- **Orifice Emitters/Drippers**

Dripper function as energy dissipaters, reduces the inlet pressure head (0.5 to 1.5 atmosphere) to zero atmosphere at the outlet. Small orifice openings (Figure 9 and Figure 10) have been used as emitters. However, they must be very small and as such are prone to clogging by particles in the water. For a normal discharge, a pressure differential of 2 atmosphere (20 m) and cross section of 0.025 mm diameter will be required. Clearly the water used in such a system must be filtered to remove all particles of this diameter or larger. If bridging is likely to occur, even smaller particles must be removed.

However, if pressures are reduced, larger orifice diameters may be used. Small diameter tubes have also been used as emitters. They depend primarily on viscous resistance to dissipate the energy in the lateral.

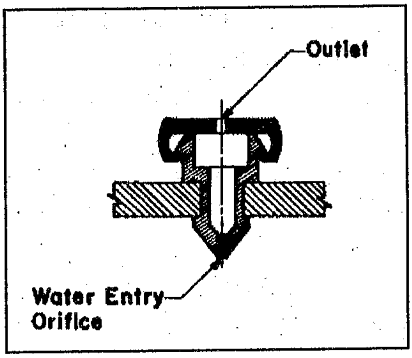


Figure 9. Orifice emitter.

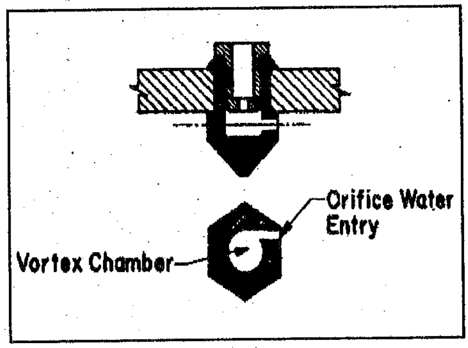


Figure 10. Orifice vortex emitter.

(a) Inline drippers

The inline drippers are fixed along with the line i.e. the pipe is cut and dripper is fixed in between the cut ends, such that it makes continuous row after fixing the dripper. The inline drippers have generally a simple thread type or labyrinth type flow path. With the labyrinth type flow path, it is possible to have larger cross section area and turbulent flow of water to prevent clogging of dripper. The inline drippers are available with discharge of 2, 3, 4, 8 litres/hr at 1 atmospheric pressure. These drippers can be fixed in 10 to 13 mm internal diameter pipes.

(b) Online Drippers

On line drippers (Figure 11) are fixed on the lateral by punching suitable size holes in the pipe. These drippers can be classified into simple or non-pressure compensating type and pressure compensating type.

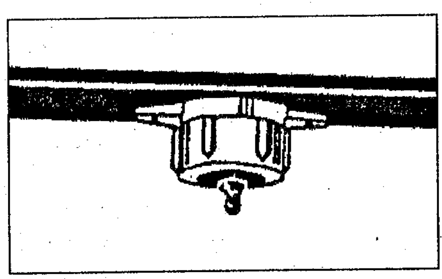


Figure 11. Dripper.

(i) Simple type

In simple type dripper, the discharge of dripper is directly proportional to the pressure. These drippers have either a simple thread type, Labyrinthype type, zig-zag path, vortex type flow path or have float type arrangement, to dissipate energy. Generally these types of drippers have discharge of 2, 3, 4, 8, 16 lit/hr relating to 1 atmospheric pressure. Some types of on-line

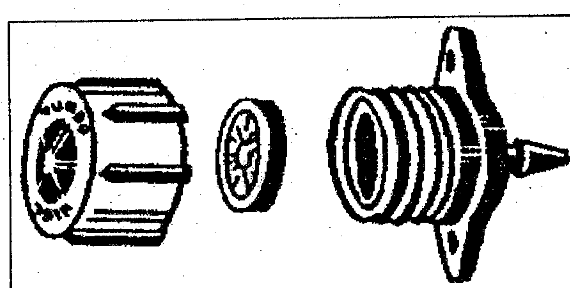


Figure 12. Disc inside the dripper.

drippers have multiple openings 2, 3 or 4 which can be used for spot irrigation.

Labyrinth Emitters are made of moulded plastic, which directs the water through a tortuous path, thus causing head loss. These are often designed to be either automatically or manually flushed, thus allowing them to be easily cleaned when clogged.

(ii) Turbo-key drippers

These are made from virgin and stabilized polymers and are available in 2,4 and 8 lit/hr discharge. It is blockage resistant and partially pressure compensating one (Figure 12).

(iii) Pressure compensating drippers

This type of dripper gives fairly uniform discharge at pressure varying from 0.3 to 3.5 atmosphere. Generally the drippers give 2,3,4, 8 lit/hr. discharge at varying pressure. This type of drippers are provided with a high quality rubber diaphragm to control pressure (Figure 13). The pressure compensating type drippers are most suitable on slopes and difficult topographic terrain.

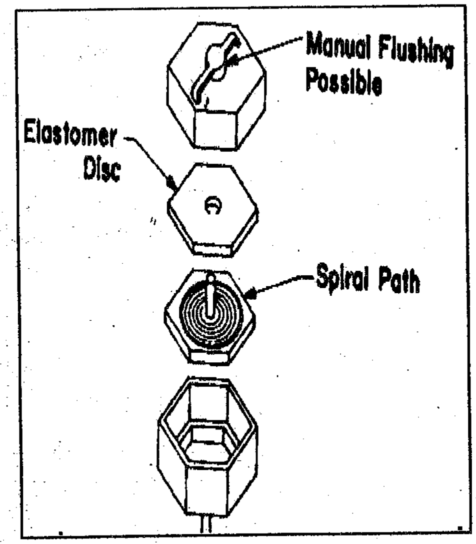


Figure 13. Pressure compensating emitter.

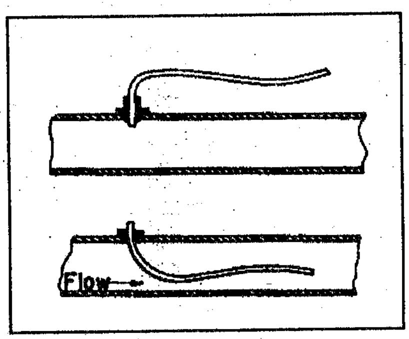


Figure 14. Micro tube emitter.

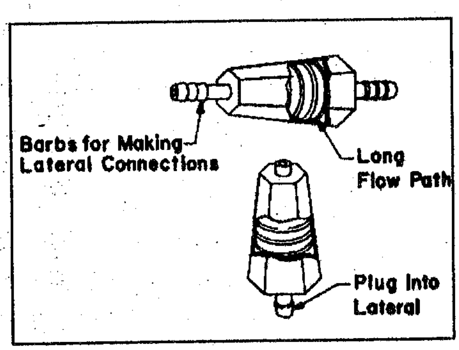


Figure 15. Long path emitter.

(iv) Built-in dripper tube

In this system, polyethylene drippers are inseparably welded to the inside of the tube during extrusion of polyethylene pipes. The drippers are provided with independent pressure compensat-

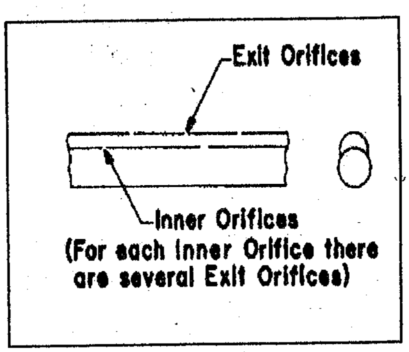
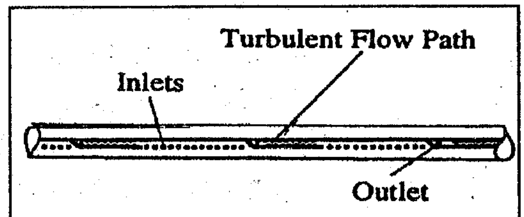


Figure 16. Built in drippers.

ing water discharge mechanism and extremely wide water passage to prevent clogging. These types of drip lines are available with 0.6, 0.75 and 1.0 m spacing with a capacity to 2 to 3.5 lph discharge at 0.5 to 4 atm pressure.

(v) Laser beam/Perforated polyethylene pipe drip line

In this system instead of dripper a hole is drilled longitudinally at 5°C to horizontal line by a laser beam. Drip lines are available in diameter of 12,16,20 mm with standard nominal discharge rate of 4 and 6 lit/hr at working pressure of 1 atmosphere.



Drip Tape - Cut View

Figure 17. Drip line system.

8.6.4 CONTROL VALVES

All systems must have a method of shutting off water entry to the system. For hand-operated systems this can be a simple gate valve. For automated systems, which apply water at a predetermined schedule, solenoid operated time controlled valves are used.

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8.6.5 OTHER ACCESSORIES

The other accessories (Figure 18) include take out/ starter, rubber grommet, end plug, joints, tees, elbows, reducers, clamps, air valves, manifolds, etc. All these components are available in 4,10,12,16 and 20 mm sizes. The take outs are used for taking out laterals/drip lines from submain.

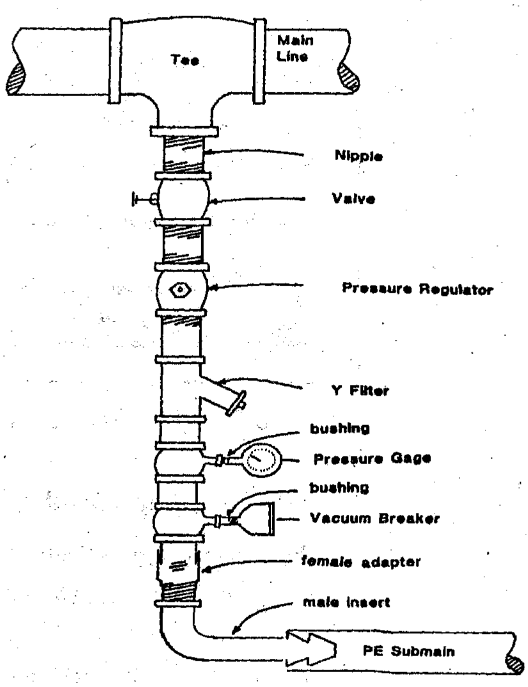

Figure 18. Various accessories used in drip irrigation system.

8.7 COMPUTER BASED SYSTEM

A Computer based system (Figure 19) consists of three main units.

- A master control unit (MCU), which may be located kilometres away from the field. It has a computer and issues instructions to the field units for operation of valve, pump, fertilizer injection, etc.
- The field units, which receive the instruction of MCU, transmit information from the field to MCU for processing.
- The communication link, an underground electrical cable, carries the instruction to the field unit and feed back information to the MCU and also supplies if necessary, power to the field units.

A large computerised system can control hundreds of valves and irrigated an extensive area.

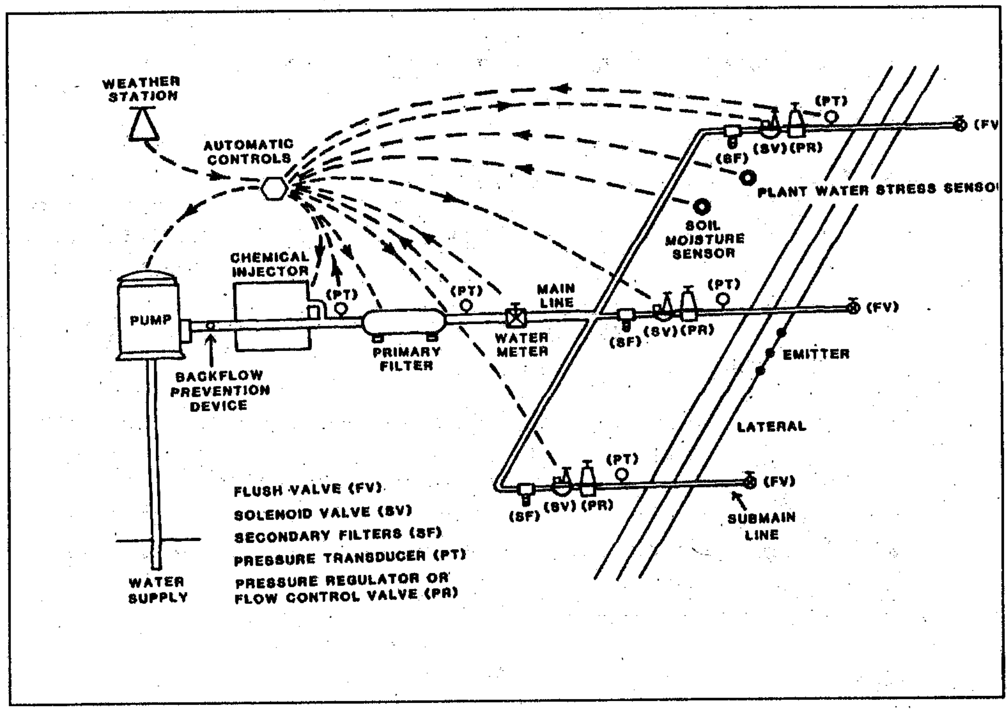

Figure 19. Computer based drip irrigation system.

8.8 SUMMARY

Drip irrigation is a technique by which water and fertilizer can be placed directly near the root zone of the plants. A large variety of crops are being grown with drip system. However, the system is generally most successful for high-income crops because of the relatively high first cost of most installations. Drip irrigation system is gaining wide acceptance in various parts of the world including India due to several advantages. Drip irrigation is the discharge of low flow of water from small diameter orifices connected to or a part of distribution tubing's situated on or immediately below the soil surface. The components of drip system can be grouped into three principal categories i.e. control head, water distribution network and discharge elements.

8.9 SELF-ASSESSMENT TEST

- Explain drip irrigation system.
- What are the advantages of drip irrigation system?
- What are the limitations of drip irrigation system?
- Which crops can be grown with drip irrigation system?
- What are the main components of the drip irrigation system?

8.10 KEY WORDS

- **Drip Irrigation System :** is a technique by which water and fertilizer can be placed directly near the root zone of the plants.
- **Biwall Irrigation :** is extruded dual chamber micro-irrigation tubing, manufactured from a Linear Low Density Polythylene (LLDPE).
- **Dripper :** functions as energy dissipaters, reducing the inlet pressure head to zero atmospheres at the outlet.

8.10 SUGGESTED READINGS

- Firake, N.N., 1998. Drip irrigation: Components, Layout and Design. Short Course on Pressurised Irrigation Systems. M.P.K.V. Rahuri (Maharashtra).
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- Irrigation Management and Training Programme, 1989. Irrigation methods, Training Module for Middle Level Officers, Technical Report No. 21-C. WAPCOS, New Delhi.
- Shinde, B.N. Drip Irrigation, Introduction, Importance, Advantages, Limitations, Prospects, Components. M.P.K.V. Rahuri.

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UNIT-9

ECONOMICS OF PRESSURISED IRRIGATION

STRUCTURE

9.0 Objectives

9.1 Introduction

9.2 Present Methods

9.3 Advanced Methods

9.4 Economics of Pressurised Irrigation Methods

9.5 Comparison of Pressurised Irrigation Methods with Traditional Lift Irrigation Method

9.6 Self-Assessment Test

9.7 Key Words

9.8 Suggested Readings

9.0 OBJECTIVES

After going through this unit students will be able to appreciate :

- The advantages of using pressurised irrigation methods.
- What are the methods and advanced method of pressurised irrigation ?
- What is the economics of pressurised irrigation ?
- Comparison of pressurised irrigation.

9.1 INTRODUCTION

Irrigation is an ancient art, as old as civilization but for the modern world, it is a science - the science for survival. The pressure of survival and the need for additional food are necessitating a rapid expansion of Irrigation in India, but in many parts water is becoming a scarce commodity.

Although, many changes had taken place in other spheres, there has not been much change in the field of irrigation and the age-old methods are being followed even now.

9.2 PRESENT METHODS

The dominant method of irrigation practised from time to time consists of diverting a stream from the head of a field into furrows or borders and allowing it to flow down the grade by gravity. No basic change has taken place in these surface or gravity irrigation methods over the years, though certain refinements or some degree of sophistication did take place. Under the gravity system, water infiltrates the soil while traversing the furrow, border or basin. By subsequent ponding and lateral movement of the water, the soil profile is filled to its water holding capacity to a depth which depends inter-alia on the quantity applied, the duration and rate of stream flow, the gradient, the soil structure and texture. The overall conveyance and application efficiency of irrigation water is the relationship between the quantity of water that has actually wetted the root zone of the crop besides deep percolation and the quantity of water released from the source.

Generally, under open ditch conveyance and surface irrigation methods, less than one half of the water-released reaches the plants. The plants actually use only about 50% of the water delivered. In projects, which may be assumed to be planned, designed and operated properly, the efficiency ranges from 30-50%. These low, efficiencies may be, partly due to conveyance losses resulting from seepage, evaporation and non-beneficial use of phreatophytes. The losses are also partly the result of poor farm distribution of water due to inadequate land preparation, and lack of farmer know-how in the application of water, with consequent excess applications and deep percolation. Moreover, in addition to these low efficiencies, erosion, salination and waterlogging take their toll of land productivity and water quality, degrading these two basic natural resources. Higher efficiencies in gravity irrigation can be obtained under certain conditions, like research stations and projects managed and operated by highly-skilled and trained personnel. These skills include the planning and execution of land-forming operations including levelling and shaping, the introduction of advanced techniques in the determination of irrigation frequencies, quantities, stream size and duration of irrigation, the installation of water measurement and regulation systems, lining of canals, the adaptation of surface irrigation delivery to suit the crop water requirements and providing proper drainage system for the removal of excess water.

To sum up, the gravity/surface irrigation has the following disadvantages compared to modern irrigation methods:

- More water is needed per unit area, and application of small doses of water is almost impossible.
- The absence of proper drainage arrangements would result in accumulation of excess water thereby causing waterlogging and salinity.
- Continuous care and vigilance are needed for proper water applications and adjustment of the head of water.
- Cumbersome & time-consuming surveying, levelling and land shaping cause temporary reduction in soil fertility.
- The crop root zone is subject to frequent alternate wetting & drying.

The advantages in using gravity irrigation are:

- Much lower initial capital cost is required to serve an irrigated area and also there are nominal operation and maintenance costs as no energy charges are involved like drip and sprinkler. This fact is highly attractive to world bodies for providing financial support to such projects.

9.3 ADVANCED METHODS

The advanced methods of irrigation, which are otherwise known as sprinkler, and drip which represent the broad class of pressurised irrigation methods, in which water is carried through the network of pipes from the source to the point of utilization. These methods can be introduced for all types of crops depending upon the soil, slope, water source, farmers' capacity, etc. These methods of irrigations are replacing the surface/gravity methods of irrigation in all the developed countries due to higher water use efficiency, adaptability to hilly areas, possibility of application of soluble fertilizers along with ease in frequent application of irrigation water at short irrigation intervals maintaining favourable soil moisture conditions in the root zone.

The merits of pressurised irrigation systems are:-

a. All losses such as conveyance, deep percolation and runoff are almost avoided.

b. Light and higher frequency of irrigation is possible.

c. Low stream size can be efficiently used.

d. Fertigation and chemigation is possible.

e. Higher irrigation efficiencies are possible.

f. Land grading and levelling are not required.

h. Higher uniform application of irrigation water is possible.

i. Water is also controlled and only the required quantity of water is given to each plant based on the evapo-transpiration requirements (Figure 1).

j. Yields of the crops are better in addition to the saving of water with these methods. The reasons attributed for increased yields are:

- Water is applied once in 3-6 days period in sprinkler irrigation, which in turn reduces the moisture stress to some extent. Further, the water application being controlled, only the needed water can be regulated in this system.
- Water is applied daily in drip irrigation and hence the growth is uniform. As there is no water/moisture stress, the crop growth is not affected at all.

9.3.1 Sprinkler Irrigation

The sprinkler irrigation is replacing the surface/gravity irrigation methods in all developed countries due to higher water use and application efficiency, less labour problems, adaptability to hilly terrain, ability to avoid frost attack, possibility of applying fertilizer in solution. In this method (Figure 2), water is carried through a network of pipes under medium or high pressures and sprayed like light rain/drizzle. Irrigation is given under controlled conditions and hence it is possible to give the required quantity at the required time. The saving of water is 30 to 50% and hence by introducing this method for closely spaced crops (high value crops) more than 50% additional area can be brought under irrigation besides increased yields.

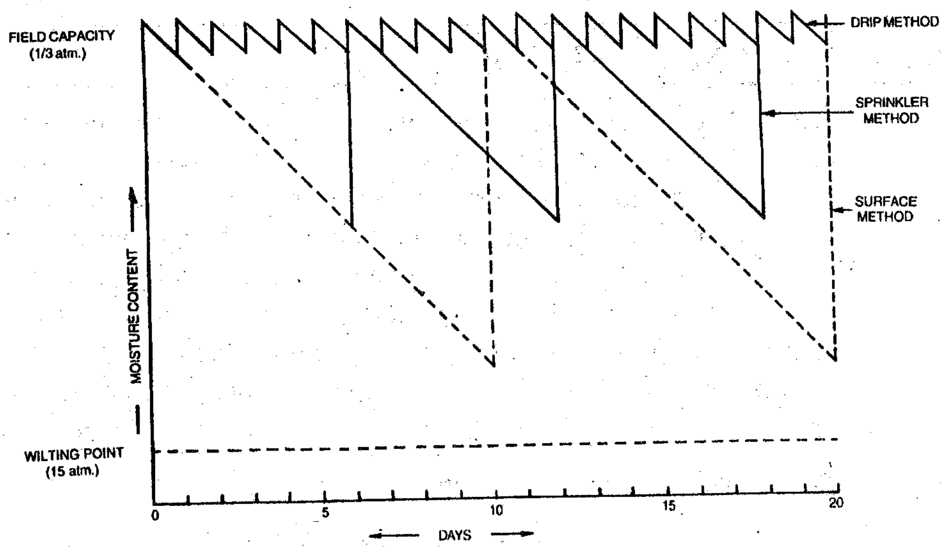

Figure 1: Moisture availability for crops in different irrigation methods.

9.3.2 Drip Irrigation

This method is very well suited for wide spaced high value crops. The required quantity of water is provided to each plant daily at the root zone through a network of piping system (Figure 3). Hence, there is no loss of water either in the conveyance or in the distribution. Evaporation loss from the soil surface is also very little since water is given only to the root zone and crop canopy provides shade to prevent evaporation. This new Agro-Technology can be adopted for undulating terrain having shallow and porous soils and in water scarcity areas. Saline/brackish water can also be used

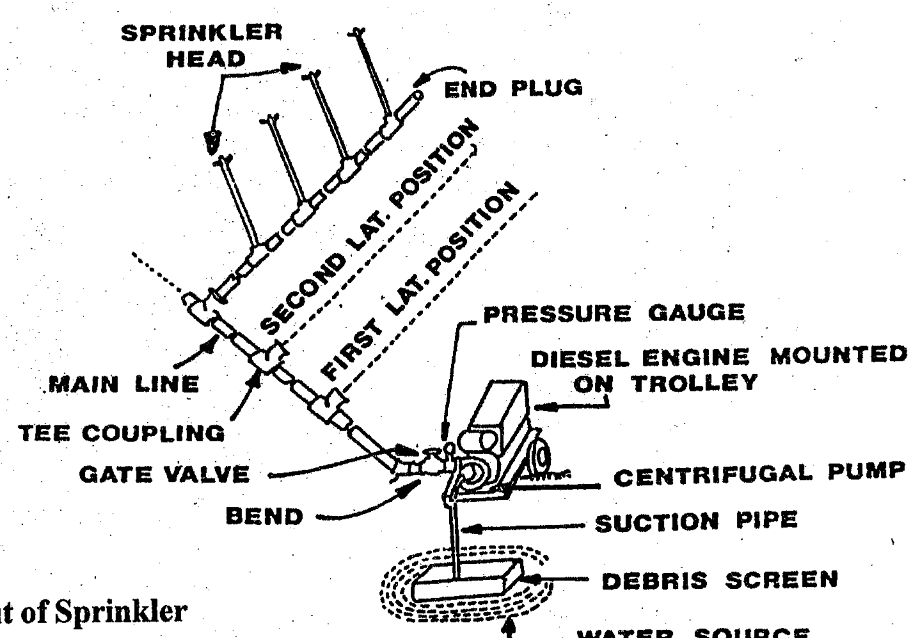

Figure 2: Layout of Sprinkler Irrigation System.

to some extent for crop cultivation since it is watered daily in this method, and the salt is pushed to the periphery of the moisture zone i.e. away from the root zone of the crop. Research studies have indicated that the water saving is about 40-70 % and the yield is increased by 10 -100% for various crops, if the drip method is used.

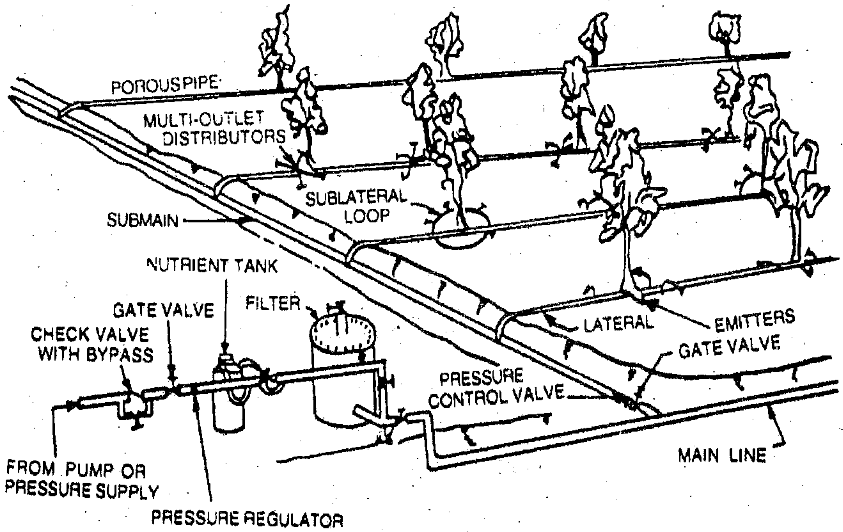

Figure 3: Layout of Drip Irrigation System.

9.3.3 Micro Sprinkler and Micro Sprayer

This is a combination of sprinkler and drip irrigation. Water is sprinkled or sprayed around the root zone of the trees with a small sprinkler (Figure 4) which works under low pressure. This unit is fixed in a network of tubing but can be shifted from place to place around the area. Water is given only to the root zone area as in the case of drip irrigation but not to the entire ground surface as done in case of sprinkler irrigation method. This method is very much suited for tree/orchard crops.

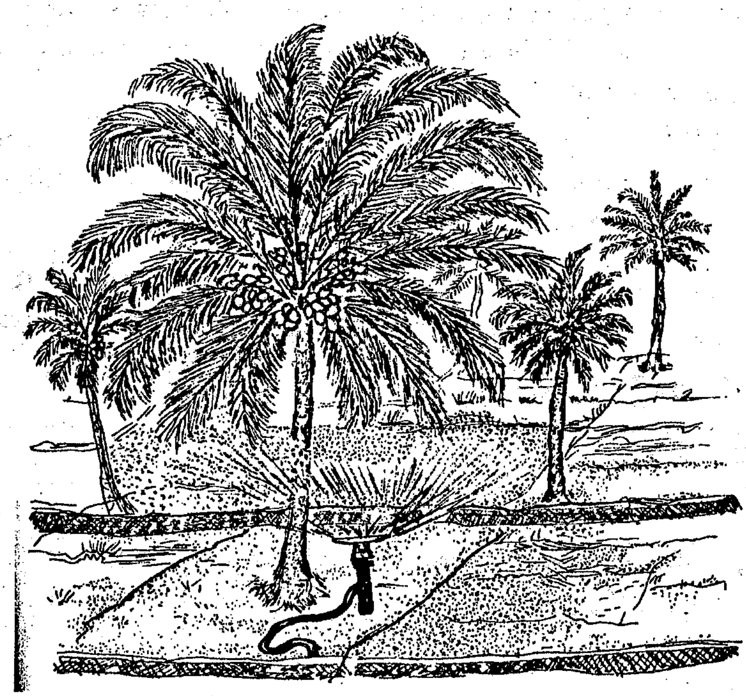

Figure 4 : Micro Sprinkler

9.3.4 Bubbler Method of Irrigation

In this method network of pipe is laid in the field (Figure 5) particularly for orchards to replace the basin method of irrigation to minimize the wetting time. Low stream size at low pressure is used. As the water is released, entrapped air comes out in the form of bubblers and therefore the system is known as bubbler method of irrigation. The application rate is around 150-250 lph per bubbler.

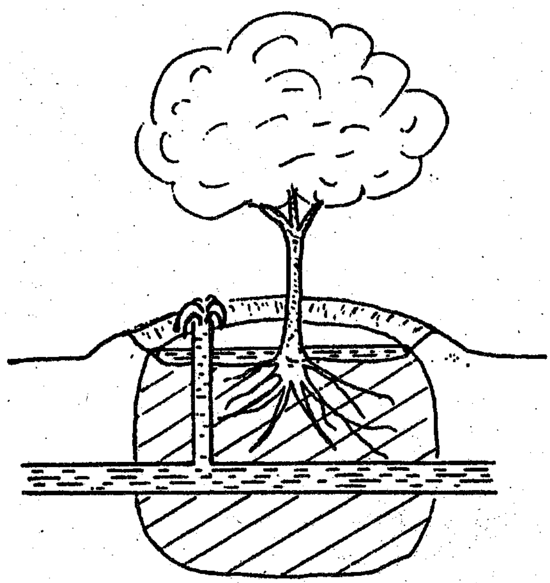

Figure 5: Bubbler Irrigation.

9.4 ECONOMICS OF PRESSURISED IRRIGATION METHODS

Cost of pressure irrigation depends to a large extent on the type of crop, its spacing water requirements, proximity to water source etc. The tables given below do give some idea about economy affected materially & cost wise, besides improving quality of crop produced. These are based upon some data collected all over the country for different crops.

Table-1: Saving in power, labour and annual cost of maintenance (value per acre per year) as compared to conventional method of irrigation (Padhye, 1990)

S.No.	Saving	Drip Irrigation		Sprinkler Irrigation	
		Metallic	Plastics	Metallic	Plastics
1	Power (KWH)	286	458	85	150
2	Water (%)	50	53	19.5	23
3	Labour (%)	65	65	42	42
4	Annual Maintenance as % of cost of system	7.5	5	5	2

Table - 2 : Saving of water and increase in yield in Drip Irrigation as compared to Surface Irrigation (CWC, 1991 in INCID, 94)

S.No.	Crop	% Saving of water	% Increase in yield
1	Cotton	53.0	27.00
2	Ladyfinger	39.5	16.10
3	Tomato	27.0	5.00
4	Brinjal	55.8	17.50
5	Gourd	52.1	13.50
6	Ridgegourd	58.9	17.00
7	Sugarcane	59.8	5.00
8	Cabbage	59.5	23.40

Table - 3 : Percentage increase in yield using sprinkler and drip irrigation as compared to surface irrigation (Padhye, 1990)

S.No.	Crop	Sprinkler	Drip
1	Coconut	14	29
2	Coffee	17	39
3	Sugarcane	11	20
4	Vegetables	9-30	2-80

Table-4 : Results of drip versus traditional (flow) irrigation system on various crops in India (INCID, 1994)

Research Institute	Crop	Water Saving %	Increase in Crop yield %	Water requirement (mm/ha)		Crop yield (MT/ha)	
				Traditional Irrigation System	Drip Irrigation System	Traditional Irrigation System	Drip Irrigation System
MPAU, Rahuri	Sugarcane	30	20	2310	1620	122	146
TNAU, Coimbatore	Sugarcane	47	29	1360	921	95	119
MPAU, Rahuri	Cotton	43	40	895	511	2.25	3.14
TNAU, Coimbatore	Cotton	60	25	856	302	2.6	3.26
TNAU, Coimbatore	Cotton	79	25	700	150	2.6	3.25
TNAU, Coimbatore	Tomato	79	43	498	107	6.18	8.87
MPAU, Rahuri	Tomato	30	5	297	208	1.64	1.72
TNAU, Coimbatore	Ladyfinger	84	13	535	86	10	11.31
MPAU, Rahuri	Ladyfinger	49	7	2189	1133	18.9	20.33
MPAU, Rahuri	Brinjal	47	Nil	900	420	28	28
MPAU, Rahuri	Chilli	62	44	1097	417	4.23	6.09
TNAU, Coimbatore	Radish	77	13	464	108	1.05	1.19
TNAU, Coimbatore	Beet	80	56	857	177	0.57	0.89
TNAU, Coimbatore	Sweet Potato	60	40	631	252	4.24	5.89
HAU, Hissar	Potato	Nil	46	200	200	23.57	34.42
HAU, Hissar	Onion	Nil	31	602	602	9.3	12.2
CAZRI, Jodhpur	Watermelon	Nil	179	800	800	29.47	88.23
TNAU, Coimbatore	Banana	77	-	2430	580	NA	NA
TNAU, Coimbatore	Papaya	68	77	2285	734	13	23
Jyoti ltd. Vadodara	Lemon	81	35	42	8	1.88	2.52
Jyoti ltd. Vadodara	Groundnut	40	66	500	300	1713	2841
TNAU, Coimbatore	Grapes	48	89	532	278	-	-
TNAU, Coimbatore	Coconut	65	12	-	-	-	-
CAZRI, Jodhpur	Bottlegourd	12	47	840	740	38.01	55.79
CAZRI, Jodhpur	Ashgourd	12	12	840	740	10.84	12.03

Table 5: Relative Performance of Crops with Sprinkler Irrigation in Comparison with that of Traditional Irrigation Methods

S. No.	Crops	Location	Yield (q/ha)		Irrigation Water (cm)		Water use Efficiency (q/ha-cm)		Advantage of Sprinkler	
			Sur. Irrgn.	Spr. Irrgn.	Sur. Irrgn.	Spr. Irrgn.	Sur. Irrgn.	Spr. Irrgn.	Saving of Water (%)	Increase Yield (%)
1.	Wheat	Rahuri	32.41	36.39	35.00	20.25	0.93	1.79	42.14	12.28
		Udaipur	26.61	33.02	33.02	14.52	0.81	2.27	56.03	24.09
		Hissar	44.80	48.70	33.94	32.68	1.32	1.49	3.89	8.70
2.	Bajra	Rahuri	6.97	8.33	17.78	7.82	0.39	1.07	56.02	19.51
3.	Jowar	Rajuri	4.92	6.62	25.40	11.27	0.19	0.59	55.63	34.55
4.	G.Nut (Summer)	Rahuri	23.24	28.98	90.00	62.00	0.26	0.47	31.11	24.69
		Junagarh	13.00	16.00	91.00	65.00	0.14	0.25	28.57	23.08
		Dharwad	33.96	39.86	76.30	63.60	0.45	0.63	16.64	17.37
		Punjab	5.50	11.90	68.60	50.20	0.08	0.24	26.82	116.38
		Navasari	31.00	30.00	56.00	44.00	0.55	0.68	21.43	-3.22
	(Kharif)	Rahuri	18.31	22.15	21.00	14.00	0.87	1.58	33.33	20.97
5.	Cotton	Navsari	6.99	7.04	40.64	29.65	0.17	0.24	27.04	0.71
		Punjab	10.00	15.00	91.10	58.60	0.12	0.26	35.68	50.00
6.	Barely	Bikaner	24.09	28.15	17.78	7.82	1.35	3.59	56.01	16.85
		Hissar	35.10	34.80	23.87	21.88	1.47	1.59	8.34	-0.85
7.	Gram	Hissar	6.55	9.91	17.78	7.82	0.37	1.27	56.02	51.29
8.	Oil Seeds	NCPA	8.33	9.34	60.00	30.00	0.14	0.31	50.00	12.12
9.	Garlic	Rahuri	69.99	73.99	84.00	60.00	0.83	1.23	28.57	5.71
10.	Chilies (Kharif)	Pune	17.41	21.52	36.00	24.00	0.48	0.89	33.33	23.61
		Rahuri	17.15	20.91	39.00	26.00	0.44	0.80	33.33	21.92
11.	Sunflower (Rabi)	Rahuri	16.02	19.19	30.00	20.00	0.534	0.96	33.33	19.79
12.	Sugarcane	Rahuri	792.10	866.30	245.00	188.00	3.23	4.61	23.26	9.37
		Dharwad	55.70	48.00	51.40	43.50	1.08	1.10	15.36	-13.82
13.	Sorghum (Kharif)	Rahuri	44.12	54.97	18.00	12.00	2.45	4.58	33.33	24.59
14.	Onion (Summer)	Rahuri	334.90	412.70	78.00	52.00	4.29	7.94	33.33	23.23
15.	Maize (Kharif)	Udaipur	15.62	18.10	12.80	9.00	1.22	2.01	29.69	15.88

(Source: INCID, 1998).

9.5 COMPARISION OF PRESSURISED IRRIGATION METHOD WITH TRADITIONAL LIFT IRRIGATION METHOD

S. No.	Drip Irrigation	Sprinkler Irrigation	Traditional Lift Irrigation
1.	Less water is required, eg. to irrigate one acre coconut at 30' x 30' spacing 1920 lit. of water is required	More water is required, eg. to irrigate one acre coconut at 30' x 30' spacing 125000 lit. of water is require.	More water is required, eg. to irrigate one acre of coconut at 30' x 30' spacing 225000 lit. of water is require
2.	Salt water can be used under drip irrigation upto 3000 ppm.	Salt water can not be used under sprinkler irrigation, as a layer of salt particles deposited on the leaves will scorch the leaf and may kill the plant.	Salt water can not be used under flood irrigation as moisture in the root zone becomes less & less till the next irrigation by evaporation & transpiration, salt concentration will become more, due to this it will scorch the roots.
3.	More suitable for widely spaced horticultural crops.	More suitable for closely spaced general agricultural crops.	Suitable for all sorts of crops, widely spaced horticultural crops as well as closely spaced general agricultural crops.
4.	Low pressure system: To irrigate 4 ha area 1 HP pump set is required. Approximate 0.25 HP per ha is more than sufficient.	High pressure system:To irrigate 4 ha area 15 HP pump set is required i.e. about 4 HP per ha is required.	Medium pressure system: To irrigate 4 ha area 10 HP pump set is required i.e. more than 2.5 HP per ha.
5.	There is almost no evaporation.	There are about 20 to 30% evaporation losses.	There are nearly 15 to 20% evaporation losses.
6.	Only necessary areas around trees and bushes are irrigated.	As there is no control over the application of water sometimes even unwanted area is irrigated.	Even unwanted areas are irrigated.
7.	Less Labour : Only for 10 minute per day to open and close the gate valve. One labour can irrigate even upto 40 ha area.	More labour is required to lay and relay the pipeline in muddy and slushy soil for sprinkler irrigation.	More labour is required per day to guide water in the earthen channels. Farmer has to walk a lot and he has to go to every part of field for guiding the water in it.
8.	Can be operated even during night hours.	Can be operated during night time with some care.	Water can not be applied in darkness accurately.
9.	Very little weed growth is reported that too in limited areas around the trees.	More weed growth is reported as entire area (unwanted areas) also gets wetted.	Weed growth is reported in most of the area as the unwanted areas also gets irrigated.

S. No	Drip Irrigation	Sprinkler Irrigation	Traditional Lift Irrigation
10.	Insecticides, fungicides and other soluble ingredients can be applied with water during irrigation.	Insecticides, fungicides and other soluble ingredients can be applied with water during irrigation.	Insecticides and fungicides can not be applied with water during irrigation.
11.	Free from any sort of corrosion.	In saline water, areas under irrigation pipes gets corroded faster.	No corrosion.
12.	As water is applied on daily basis amount of water in the root zone remains constant throughout the life of the plant. Due to this plant growth is uniform, maturity is enhanced any yield is more.	As water is applied on cycle basis say once in 3 to 6 days the amount of moisture is never constant & decreases day by day till the next irrigation. Due to this plant growth is non uniform, maturity is delayed and yield is less as compared to drip system.	As water is applied once in 7 to 10 days the amount of moisture will never be constant and it will be decrease day by day till next irrigation. Due to this maturity will be delayed and yield will be reduced.
13.	Soil moisture is always maintained at field capacity.	It is economically impractical to maintain the soil moisture at field capacity.	It is practically impossible to maintain uniform moisture in the root zone.
14.	Annual electricity charges are less.	Annual electricity charge are very high.	Annual electricity charges are higher than drip irrigation but lesser than sprinkler irrigation.
15.	Even under heavy wind water can be applied without any losses.	Under heavy wind water cannot be applied uniformly as most of the water is carried & sprinkled in different places also other than the area to be irrigated.	Wind has no effect .
16.	Even during flowering state, water can be applied.	Sprinkler irrigation washes away the pollen grains of the flowers & yield will be reduced to some extent.	No effect on pollination.
17.	No leafy fungal diseases are reported as water is not applied on leaves.	Many leafy fungal diseases are reported as water is sprayed on the leaves	No leafy diseases are reported.
18.	Harvesting of crop can be done even during irrigation.	Harvesting is very difficult in wet, muddy, slushy condition during irrigation.	Harvesting is difficult under flood irrigated soils as the labourer finds it very difficult to walk in muddy soil.

S. No.	Drip Irrigation	Sprinkler Irrigation	Traditional Lift Irrigation
19.	Land levelling is not necessary.	Land levelling is not necessary.	Land levelling is a must in flood irrigation.

9.6 SELF-ASSESSMENT TEST

- What are the disadvantages of using surface irrigation methods?
- What are the advantages of pressurised irrigation methods?
- Give brief description of sprinkler irrigation.
- Give brief description of drip irrigation.
- Describe micro sprinklers.

9.7 KEY WORDS

Pressurised Irrigation : Irrigation method in which water is carried through the networks of pipes from the source to the point of utilization.

Gravity Irrigation : Diverting a stream from the head of a field into furrows or borders and allowing it to flow down the grade by gravity.

Sprinkler Irrigation Method : Irrigation method in which, water is carried through a network of pipes under medium or high-pressures and sprayed like light rain/drizzle.

Drip Irrigation Method : The required quantity of water is provided to each plant daily drop by drop, at the root zone through a network of piping system.

9.8 SUGGESTED READINGS

INCID, 1994. Drip Irrigation in India. Indian National Committee on Irrigation & Drainage, New Delhi.

INCID, 1998. Sprinkler Irrigation in India. Indian National Committee on Irrigation & Drainage, New Delhi.

Padhye, A.H., 1989. Micro and Sprinkler Irrigation in India. Proceedings International Congress on the use of Plastics in Agriculture, New Delhi.

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UNIT-10

INTRODUCTION OF SOILS AND SOILS CLASSIFICATION

STRUCTURE

1.0 Objectives

10.1 Introduction

10.2 Soil texture

10.3 Soil structure

10.4 Density of Soil

10.5 Porosity of Soil

10.6 Soil Consistence

10.7 Soil Classification

10.8 Self Assessment Test

10.9 Key Words

10.10 Suggested Readings

10.0 OBJECTIVES

The basic objective of such a survey is land irrigability classification. This deals with the evaluation of lands for their suitability to irrigation. The primary objective of this classification is to assess the capacity of lands to withstand irrigation and to assess their perpetual productivity per unit of water applied. This is mainly concerned with predicting the behavior of soils before putting the land under irrigation.

10.1 INTRODUCTION

Soil is the product of physical, chemical, biological weathering of rocks under the influence of climate, vegetation and topography. Soil is biologically active and is a habitat for various micro-organisms. Soil is the natural medium for the growth of plants. The soil is a complex mechanical system consisting of three phases solid, liquid and gaseous. The bulk of the solid phase, that occupies approximately fifty percent of the total volume, consists primarily of the mineral materials and some organic matter. The rest of the volume which makes up the pore space or voids is occupied by liquid and gaseous phase. The proportion of solid, liquid and air components vary greatly in different kinds of soils and from place to place and also with depth of the soil. These components generally exist in intimately mixed condition.

10.2 TEXTURE

The texture of the soil is one of the fundamental considerations in soil classification. Texture analysis also indicates the weathering stage to some extent. The textural class name is suggestive of many properties that have bearing on its management and productivity. Sandy soils are open character, possess good drainage and aeration, and are usually loose and friable and easy to handle for tillage operations. Clayey and silty soils, owing to their large surface, possess high adsorptive and retention capacities for moisture, gases and nutrients. They usually have fine pores, are moderate to poor in drainage and aeration and are relatively difficult to handle for cultivation purposes.

A mechanical analysis reports the percentages of different size groups of particles. The two most widely used size distribution system are according to U.S. Department of Agriculture and International Society of Soil Science. The International system is commonly followed in India. International system of classifying soil diferenciates is as below.

Sand (2.00 - 0.02 mm)

Silt (0.02 - 0.002 mm)

Clay (< 0.002 mm)

For convenience in determining the textural name of a soil from the mechanical analysis, an equilateral triangle has been adopted. The left angle present 100 percent sand, the right angle 100 percent silt, and the top angle 100, percent clay.

Role of Soil Texture

It has a large influence on

(a) Water holding capacity

(b) Ability to supply water to plants

(c) Nutrient holding capacity

(d) Ability to supply nutrients to plants

(e) Permeability to air, water and roots

(f) Drainage Character

(g) Tillage character

(h) Run off

(i) Erodability

Fine textured soils are very slowly permeable, drain very slowly, dry up and warmup slowly, hard to work and high water & nutrient meable holding capacity.

Medium textured soils are fairly permeable and drain slowly, hold nutrients better than coarse textured soils but not as well as clay soils, low in organic matter and likely to form crust easily after rain, good water holding capacity.

Coarse textured soils are very permeable, drain easily, have low water holding & nutrient holding capacity, need more fertilizer Organic matter decays rapidly after it is ploughed down, plant food which is released leaches out easily, cause trouble in the use of power machinery due to slippage in the sand.

10.3 SOIL STRUCTURE

The primary particles sand, slit and clay usually occur grouped together in the form of aggregates. The mutual arrangement of these individual soil particles and their aggregates into certain defined patterns is called structure. Natural aggregates are called pads. Organic material, lime, crop rotation including legumes and grasses hold aggregates together, while excessive cultivation destroys soil structure.

Type of Structure

There are four principal geometric forms of soil structure:

Sphere

Like spherical: Rounded or spheriodal and all axes are approximately of the same length, with curved and irregular faces they are usually smaller in size. The aggregates of this group are usually termed as GRANULAR, which are harder, less porous and look like crumb of bread, the team used is CRUMB.

Block like

All three dimensions are about the same size and the peds are cube like with flat and rounded faces. When the faces are flat and the edges mainly sharp angular, the structure is named as ANGULAR BLOCKY. When faces and edges are mainly rounded it is called sub ANGULAR BLOCKY.

Prism-like

The vertical axis is more developed than others, with flattened sides, giving a pillar like shape. When the top of such a ped is rounded, the structure is termed as COLUMNAR, and when flat, PRISMATIC.

Plate-like

The horizontal dimensions are much more developed than the vertical, giving a flattened, compressed, or lens - like appearance to the peds. When the units are thick, they are called PLATY, and when thin LAMINAR.

Soil in SINGLE GRAIN, when particles not combined into aggregates. Sandy soils which are usually found in 'e' horizon.

IMPORTANCE OF SOIL STRUCTURE

Structure is very important in plant growth relationships as it influences the amount and nature of porosity and regulates the moisture air regime in the soil. Platy structure normally hinders free drainage. The best structures for favorable physical properties of soil are crumby and granular.

Soil structures are mechanically stable and strong but when they absorb moisture and are wet, they become soft and lose their shape and size. Soils high in water table aggregates are more permeable to water and air. When stable aggregates are less, the soils tend to puddle.

Structure is one of the soil properties which is easily liable to changes under different management practices such as ploughing, draining, liming, fertilizing and manuring. Addition of organic matter and its proper decomposition are important for building up and maintenance of soil structure. Grasses are most effective is promoting granulation.

10.4 DENSITY OF SOIL

Density represents weight per unit volume of a substance. Soil density is expressed in two concepts - Bulk density and particle density.

(i) Bulk density

The oven dry weight of a unit volume of soil inclusive of pores spaces and expressed in grams per cubic centimeter is called bulk density, Bulk density of a soil is always smaller than its particle density.

$$BD = \frac{\text{MS (Mass of solid)}}{\text{vt (Total volume)}}$$

The bulk density (g/cm^3) of different soils is:

Sand	1.55 - 1.80
Sandy loam	1.40 - 1.70
Loam	1.35 - 1.60
Clay loam	1.30 - 1.55
Silty clay	1.30 - 1.50
Clay	1.25 - 1.45

Generally soils with low bulk densities have favorable physical conditions, whereas those with high bulk densities exhibit poor physical conditions.

(ii) Particle Density

The weight per unit volume of the solid portion of soil is called particle density.

$$DS = \frac{\text{MS (Mass of solid)}}{\text{vt (Solid volume)}}$$

A generally accepted figure of particle density for the normal soils in 2.65 grams per cubic centimeter.

With increase in organic matter of the soil, the particle density decreases.

10.5 POROSITY OF SOIL

Porosity refers to the percentage of soil volume which is occupied by interstitial spaces or pore spaces

Percentage pore space = 100 - (Bulk density / Particle density) X 100

Porosity varies with the texture of soil, shape of individual particles, soil structure, amount of organic matter and the compactness. In sandy soils, although the pores are quite large, yet the total pore space is small. In fine textured soil, there is possibility of more granulation and the total pore space is high because of spaces between individual particles and within granules. Sandy surface soils show a range from 35 to 50 percent whereas medium to fine textured soils vary from 40 to 60 percent or even more in cases of high organic matter and marked granulation. Pore space also varies with depth; some compact subsoils drop as low as 25 to 30 percent.

Size of pores

Two types of individual pore space in general occur in soils - macro and micro. The macropores characteristically allow the ready movement of air and percolating water. In the micropores air movement is greatly impeded and water movement is restricted primarily to slow capillary movement. Thus in a sandy soil, in spite of the low total porosity, the movement of air and water is surprisingly rapid because of the dominance of the macro spaces.

Fine textured soils allow relatively low gas and water movement despite the usually large amount of total pore space. The dominant micro pores often maintain themselves full of water.

Continuous cropping of soils is very high in organic matter. It often results in a reduction of macropore spaces. Cultivation and cropping have appreciably reduced the total pore space. This is accompanied by a proportional rise in the micro pore space.

10.6 SOIL CONSISTENCE

Soil consistence is a term used to describe the physical condition of a soil in various moisture contents. Soil consistence is considered a combination of soil properties dependent upon the forces of attraction between soil particles as influenced by soil moisture. Cohesion refers to the attraction of substances of like characteristics such as one water molecule for another. Adhesion is the attraction of unlike materials where the substances are more or less firmly attached together by their adjacent surfaces.

The consistence of soils is generally described at three moisture levels: wet, moist and dry.

10.7 SOIL CLASSIFICATION

In view of exorbitant cost involved in making the water available for irrigation, through the construction of dams and storage reservoirs, it is essential to make most judicious and efficient use of water restricted to lands where it is most beneficial. In many irrigation projects, the twin problem of water logging and soil salinity has developed due to inadequate consideration of soil properties in the design of irrigation system. The efficient application of water and an intelligent land use under irrigation network necessities thorough knowledge of soils of the proposed command. For this, the systematic survey of the area prior to irrigation is carried out.

Objectives of Soil Survey

The basic objective of such a survey is land irrigability classification. This deals with the evaluation of lands for their suitability to irrigation. The primary objective of this classification is to assess the capacity of lands to withstand irrigation and to assess their perpetual productivity per unit of water applied. This is mainly concerned with predicting the behavior of soils before putting the land under irrigation.

Technique of Soil Survey

For "planning of irrigation project, the detailed or intensive soil survey is, generally carried out. In this type of survey toposheets of survey of the India of the scale 4" = 1 mile (1 : 15840) are blown to 8" = 1 mile (1 :7920) and are used as base maps. Square grids at 100m distance are drawn on the map. Auger holes up to a depth of 1.5 m at every grid point of 100m distance or less if necessary these are examined for colour, depth, texture and salt content. To identify problem more precisely and accurately, survey may also be done intensively using lower grid of 50 m on the base map of scale 16" = 1 mile. Land features of the area are observed for slope, erosion, salinity, and water logging problems. The soils at every grid point are then placed in the established mapping units. Similar mapping units are grouped on the map through delineation of soil boundaries.

The soil profiles are then examined upto the depth of 1.5 - 2.0 m in each group of mapping units or at an interval of ¼ to 1 km depending upon soil variation.

The soil samples of representative soil profiles, few auger samples and samples of problematic areas are collected for laboratory analysis. The depth of ground water table in the profile pits and auger holes is measured and ground water samples are collected for quality determination.

The permeability is also determined in the field in different layers of soil profiles. Intake rates are also measured.

The soil maps are designed to show the distribution of various kinds of soils, separated by boundaries, using soil-mapping units. These are marked by mapping symbols such as ktcld 5/ Ae1, which gives name of soil series - kt for kota, soil type - cl for clay loam, Soil depth - d5 for very deep soil, slope - A for 0 -1 % and erosion - e1 for slight erosion.

In detailed survey, aerial photographs in the scale of 1 : 8000 or 1 : 15000 by following suitable photo interpretation method greatly enhance the accuracy of final map.

The detailed soil survey map shows well-defined land units separated by boundaries. Each of the unit represents a segment of the command area and gives precise information on soil and land characteristics that together and in combination with socio economic and physical factors indicate the irrigability rating.

The rating of lands for irrigation is done in two steps. The soils are first grouped into irrigability classes. Then the lands are rated according to their irrigability.

1. Soil Irrigability Classification

It deals with evaluation of soils for their suitability to irrigation on the basis of quantitative limits of soil properties pertinent to irrigation. The soils of the project area are grouped into irrigability classes defined in terms of degree of soil limitations without regard to availability of irrigation water, water quality, land preparation cost, availability of drainage outfalls and other non-soil related factors.

The criteria of soil irrigability classification are given in table -1. The information furnished in the modification proposed by Palaskar and Varade (1985) over the original criteria suggested by Rege et al (1974). A most limiting property of soil is the decisive property in this classification. A soil may have all properties of most desirable class except one, but on the basis of that one undesirable property, it is assigned to lower one. There are five soil irrigability classes as given below: -

Soil Irrigable Class	Meaning
A	None to slight soil limitation for sustained use under irrigation.
B	Moderate soil limitations for sustained use under irrigation
C	Severe soil limitation for sustained use under irrigation
D	Very severe soil limitation for sustained use under irrigation
E	Unsuitable for irrigation (None Irrigable soil class)

Soil Irrigability class can also be determined by calculating aggregate soil irrigability index as per the procedure explained in table - 2 and interpreted from the information given in table - 3.

2. Land Irrigability Classification:

The Land irrigability class or suitability of lands for irrigation in the command area may be worked out on the basis of soil irrigation class, topographic features (land slope), drainage, depth of ground water table from surface and other socio economic factors as per the criteria in table - 4. Six land irrigability classes are recognized as given in appendix.

1. Quantity and quality of water.

(a) Equilibrium salinity levels.

(b) Equilibrium exchangeable sodium levels.

(c) Availability of water to the land in relation to water requirement of crops considering soil factor with crop factor.

2. Drainage Requirements:

(a) Permeability of substrata and feasibility of providing needed drainage.

(b) Cost of drainage measures.

3. Economic considerations:

(a) Production cost and yields potential.

(b) Land development cost other factors affecting benefit- cost ratio.

Land Irrigability Sub-class

When land are placed in any class lower than class I, the major deficiency or limitation in 'Soil' or 'Topography' or 'drainage is suffixed with class number by letters 'S', 't', or 'd'. The lands with more than one major deficiency may be indicated with the relevant letter after the class. For example if the land has both 'S' and 't' deficiency, this should be indicated by the designation II St.

Technical Feasibility of Project :

Like B.C. ratio or internal rate of returns, the technical feasibility of any irrigation project to be commissioned can be worked out by parameter called "Aggregate Index" which employs the various Physico, Physico-Chemical properties of soil of area using irrigability rating map. In case the aggregate index is about 5, the project is definitely viable but if less than 3, the project should not be commissioned in the given area.

Table-1: Modified Soil Irrigability ratings for different Soil Characterist (Palaskar and Varade, 1985)

Characteristics	Soil Irrigability Class				
	A	B	C	D	E
Effective Soil Depth (cm)	>90 Very deep	45 - 90 Deep	22.5 - 45 Medium	7.5 - 22.5 Shallow	<7.5 Ve shallow
Soil Texture	SIL, CL, L, SCL	C, SIC, SC	SL	LS	S, SIL
Soil Structure	Crumb Granular	Angular blocky Sub-angular blocy	Platy	Columner Prismatic	Massive Single grained
Available water capacity in effective profile depth (cm)	>21	14-21	7-14	2-7	<2
Basic Infiltration rate (cm/hr)	0.7-3.5	3.5-6.5	6.5-12.5	0.3-0.7	>12.5
Saturated Hydraulic conductivity (cm/hr)	6-2	2-0.5	12.5-6	25-12.5 or 0.5-0.25	>25 or <0.25
Salinity:					
i. EC, mmhos/cm at 25°C of saturation extract	<4	4-8	8-12	12-16	>16
ii. % area affected (visual observations)	<10	10-25	25-50	50-75	>75
Soil Sodicity (ESP)	<15	15-20	20-30	30-40	>40
Surface Covers:					
i. Gravels (0.2 cm to 7.5 cm dia.) % by volume	<15	15-35	35-55	50-70	>70
ii. Rock out-crops Distribution in meters	>40	20-40	15-20	5-15	<5
Erosion	Slight	Moderate	Medium gullies	Big gullies	Ravine

SIL : Silt Loam
CL : Clay Loam
L : Loam
C : Clay
SC : Sandy Clay
ESP : Exchangeable Sodium Percentage
SIC : Silty Clay
SL : Sandy Loam
LS : Loamy Sand
S : Sand
SI : Silt

Table 2: Case Study of Irrigability Classes

Soil Characteristics	Observed Soil Property	Soil Irrigable Class as per criteria	Points earned by Irrigable class	No. of credits or weightage given	Total Po eamed b respecti soil prop
Soil Depth	More than 1 m	A	5	5	5x5 =
Soil Texture	Clay & Silty clay	B	4	5	4x5 =
Soil Structure	Angular blocky	B	4	3	4x3 =
Available water ineffective soil profile depth	200 mm	B	4	5	4x5 =
Infiltration rate	3 cm/hr	A	5	4	5x4 =
Permeability (Hydraulic conductivity)	1 cm/hr	B	4	4	4x4 =
Salinity	ECe. millimhos/ cm	A	5	3	5x3 =
Sodicity	ESP 10-14	A	5	3	5x3 =
Gravel	Nil	A	5	3	5x3 =
Total				35	158

So Aggregate irrigability index $= \frac{\text{Points earned}}{\text{Total Points}} = 158/35 = 4.51$

Table 3 Criteria for Land Irrigability Classification

Characteristics	Land Classes				
	I	II	III	IV	V
Soil Irrigability Class (Aggregate)	A	A or B	A or B or C	A or B or C or D	Temporary Field needs investigation
Land Slope (%)	<1	1-3	3-5	5-10	10-15
Depth of Groundwater table from G.L.	>3	2-3m	1-2m	<1	-

Example

1. Soil Irrigability Class-A
2. Land Slope 1-3%
3. Ground Water Depth - 5 m

DEFINITION OF IRRIGABILITY CLASSES APPENDIX

Class 1:

Land that has few limitations for sustained use under irrigation.

Lands of this class are capable of producing sustained and relatively high yields of a wide range of climatically adapted crops at reasonable cost.

There are few or no limitations of soil, topography or drainage. The soils in this class are nearly level, have deep rooting zones, have favorable permeability, texture and available moisture holding capacity, and are easily maintained in good tilt. Lands with unfavorable soil or topography are not included in this class, nor are lands where drainage or salinity problems are predicted after introduction of irrigation due to unfavorable water quality, substrata conditions or lack of outfalls.

Class 2:

Lands that have moderate limitations for sustained use under irrigation.

Lands of this class have moderate limitations of soil, topography, or drainage when used for irrigation. Limitations may include single or in combination the effects of (1) very gently slopes, (2) less than ideal soil depth, texture, permeability or other properties, (3) moderate salinity or alkali when in equilibrium with the irrigation water (4) somewhat unfavorable topography or drainage conditions.

Class 3:

Lands that have severe limitations for sustained use under irrigation.

Lands of this class have severe limitations of soil, topography or drainage when used for irrigation. Limitations may include, single or in combination the effects of (1) gentle slopes, (2) unfavorable soil, depth, texture permeability or other soil properties, (3) moderately severe salinity or alkali when in equilibrium with the irrigation water (4) unfavorable topography or drainage conditions.

Class 4:

Lands that is marginal for sustained use under irrigation because of very severe limitations.

Lands of this class have very severe limitations of soil, topography or drainage when used for irrigation. Limitations may include single or in combination the effects of (1) moderately steep slopes, (2) very unfavorable soil depth, texture, permeability or other soil properties, (3) severe salinity or alkali when in equilibrium with the irrigation water (4) very unfavorable topography or drainage conditions.

Class 5:

Lands that are temporarily classed as not suitable for sustained use under irrigation pending further investigations.

Lands of this class cannot be classifies at the present level of investigations, and are temporarily classed as not suitable for irrigation. If these lands are to be given a final classification special investigations will be needed.

Class 6:

Lands not suitable for sustained use under irrigation.

The lands of this class do not meet the minimum requirements for lands of other

10.8 Self Assessment Test

1. What is the importance of soil texture?
2. What is the importance of soil structure?
3. What are the types of soil classification?

10.9 Key Words

Soil classification : the systematic arrangement of soils into groups or categories on the basis of their characteristics.

Soil genesis : the mode of origin of the soil, with special reference to the processes or soil forming factors responsible for the development of the solum, or true soil, from unconsolidated parent material.

10.10 Suggested Readings

Nyle C. Brady ' The nature and properties of soils'

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UNIT-11

Soil Properties and Soil Water Plant Relationship

STRUCTURE

11.0 Objectives
11.1 Introduction
11.2 Soil as A Medium of Plant Growth
11.3 Soil Moisture Constants
11.3.1 Maximum water holding capacity
11.3.2 Field Capacity
11.3.3 Permanent Wilting Point
11.3.4 Hygroscopic Coefficient
11.4 Soil Moisture Retention
11.4.1 Soil Moisture Characteristics Curves
11.5 Available Water (AW):
11.5.1 Readily Available Water (RAW)
11.5.2 Factors affecting the amount of available soil moisture
11.5.2.1 Moisture tension relations
11.5.2.2 Readily Available Water (RAW)
11.5.2.3 Soil Depth
11.5.2.4 Soil Stratification or Layering
11.6 Types of Soil Water Movement
11.6.1 Saturated flow through soils - percolation
11.6.2 Unsaturated flow from soil water tables
11.6.2.1 Unsaturated Flow as it Most Commonly Occurs in Soil
11.6.2.2 Water Vapour Movement in Soils
11.7 How Plants are supplied with Water
11.7.1 Rate of Capillary Movement
11.7.2 Rate of root development
11.8 Moisture Extraction Pattern
11.9 The water Budget method for Irrigation scheduling at Farm level
11.10 Self Assessment Test.
11.11 Key words
11.12 Suggested Reading.

11.0 OBJECTIVES

To make maximum use of soil water it is desirable to know how it moves into and through the soil, how it is classified and measured, and what can be done to reduce losses of water due to percolation and evapotranspiration. The movement and retention of water in the soil is primarily affected by soil characteristics such as texture, structure, nature and amount of inorganic and organic colloidal materials and size and total volume of pore space.

11.1 INTRODUCTION

Water is essential for all forms of life. In plant growth, water not only forms a major part of plant itself but it is also essential to satisfy the evapotranspiration requirements of growing plants. Water also act as a solvent and nutrient carrier from soil to the plant and within plant and also maintains the turgidity of the plant. Irrigation provides one of the greatest possibilities for increasing agricultural production in India. This objective can be achieved by adopting proper scheduling of irrigation based on knowledge of soils, crops, climate, water supplies and irrigation system performance etc.

Among the various factors that contribute to efficient utilisation of irrigation water, the water management at the farm level has a significant role. At farm level scheduling can increase productivity of water and net farm income. It can reduce fertilizer cost by decreasing nutrient leaching. It can reduce or eliminate water logging and salinity problems. To make the maximum use of soil water it is desirable to know:-

(a) The moisture storing capacity of soil

(b) The availability of soil moisture to the plants and

(b) The movement of water into and within the soil.

Each of these factors is related directly or indirectly to the size and distribution of soil pores and physical proportion of soils in relation to water.

11.2 SOIL AS A MEDIUM OF PLANT GROWTH

The soil is the medium from which crops draw water and nutrients. Rain or irrigation water is not directly used by plant. It has to be first converted to soil water and stored in the soil pores before it is utilised by plants. Soil is a three dimensional, natural and dynamic medium for the growth of plants. It has three components solid, liquid and gaseous. The solid phase consists of inorganic and organic component. It exists in the form of particles of various sizes, which provide the soil matrix and encompass certain amount of pore space. The amount and configuration of pore space depend upon size, distribution and arrangement of soil particles. The liquid phase of soils is mainly constituted by water, which invariably contains some dissolved salts; the gaseous phase of soil comprises soil air which differs slightly from atmospheric air in composition. In order to serve as a favorable medium for plant growth, soil must contain the three components in right proportions.

11.3 SOIL MOISTURE CONSTANTS

The water contents of wetted soil under certain standard conditions are referred to as soil moisture constants (Fig.1)

11.3.1 Maximum water holding capacity:

When water is applied to the surface of well-granulated soil, the water enters the soil, air is displaced and the surface soil wets up, that is, the soil pores, large and small are filled with water. The soil is said to be under saturation capacity or maximum water holding capacity. This occurs at almost zero tension.

11.3.2 Field Capacity:

After saturation of soil if we cut off the supply of water to the soil surface or stop irrigation there will be a continued downward movement of water for a day or so and this downward movement will essentially cease. At this point an examination of the soil will show that water has been moved out of the larger or macro pores and that its place has been taken by air. The micro or capillary pores are still filled with water and from this source the plants will absorb moisture for their use. The water held in micro pores of soil against gravitational force is said to be at field capacity. This occurs generally at 1/3 bar tension.

11.3.3 Permanent Wilting Point:

Plants growing in soil will absorb water and will reduce the quantity of moisture remaining in the soil. As the soil dries out plants will begin to show the effects of reduced soil moisture. The permanent wilting point or P.W.P is the soil moisture content at which plants can no longer obtain enough moisture to meet the minimum evapotranspiration requirement and remain wilted unless water is added to the soil. This occurs at about 15 bar tension.

11.3.4 Hygroscopic Coefficient:

Continued removal of moisture from soil will result in marked increase in tenacity with which water is held. At the hygroscopic coefficient, the tension is 31 bars and much of the water is held so tightly that mostly on soil colloids, it is essentially non liquid and not available to plants but may be available to certain bacteria.

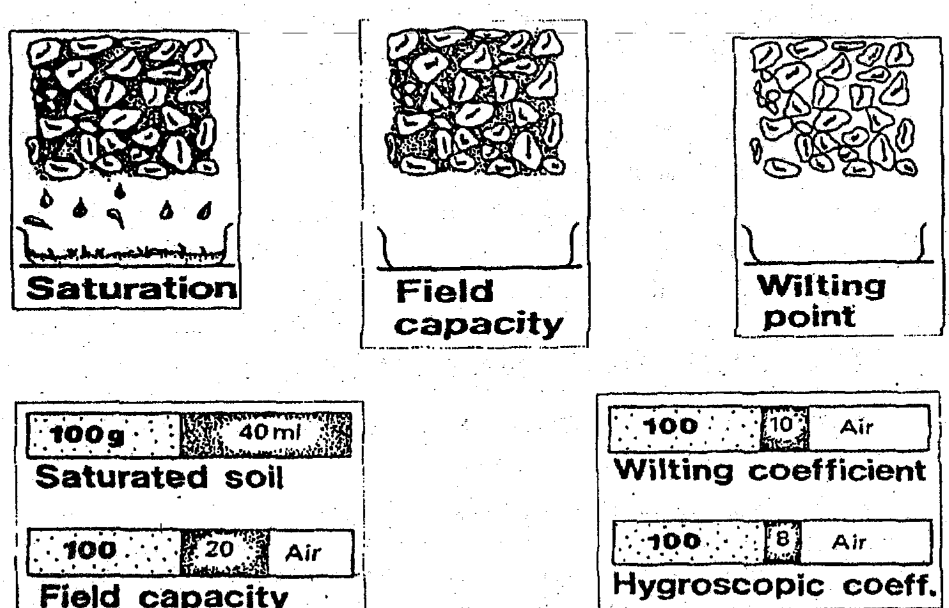

Fig. 1. Volume of water and air associated with 100 g of a well-granulated silt loam at different moisture levels

11.4 SOIL MOISTURE RETENTION

Two forces largely account for the retention of moisture by soil : one is the attraction of soil solid surfaces to water molecules (Adhesion), the other is the attraction of water molecules for each other (Cohesion). By adhesion solids hold water molecules rigidly at soil water interfaces. These molecules in turn hold other water molecules by cohesive forces. Together these forces make it possible for the soil solids to retain water. Water held by these two forces can not only keep the smaller capillary pores entirely full of water but also maintain relatively thick film in the macrospores. This outlet moisture is subject to ready movement in response to pull of gravity and specially the pull of adjoining moisture films that are not so thick. Thus when the soil is near saturation, it is easy to remove water but as the moisture becomes less and less in a soil, the greater and greater will be the force necessary to remove the water (Fig. 2). Soil moisture tension is a measure of tenacity with which water is retained in the soil and shows the force per unit area that must be exerted to remove water from the soil. It is usually expressed in atmospheres or bars (1 atmosphere = 14.7 pounds per squire inch.).

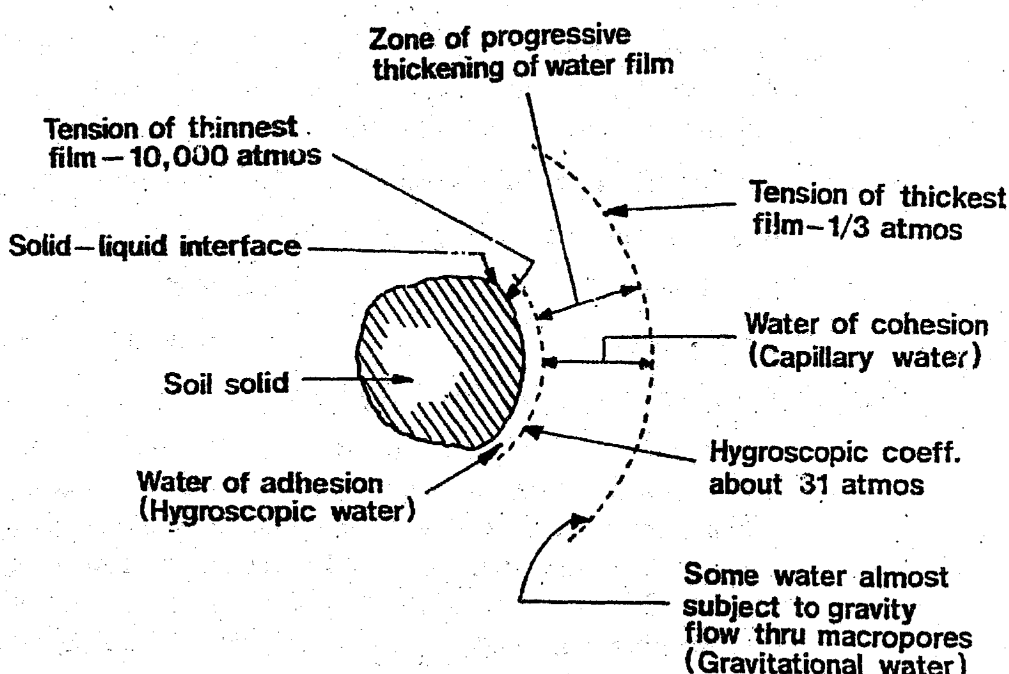

Fig. 2 Diagrammatic representation of the progressive thickening of water film in a macro pore and the corresponding decline in tension at which the surface molecules are held.

11.4.1 SOIL MOISTURE CHARACTERISTIC CURVES:

In general, soil moisture tension or the metric potential of soil solution is not necessarily an indication of the moisture content of neither the soil nor the amount of water available for plant use at any particular tension. These are dependent on texture, structure and other characteristics of the soil. But there is a definite relationship between soil water and capillary pressure for a given soil. Generally sandy soils drain almost at low tensions whereas clayey soils still hold a considerable amount of moisture even at high tensions that plant growing in soil may wilt.

11.5 AVAILABLE WATER(AW)

Water held by the soil between Field Capacity (F.C.) and Permanent Wilting Point (P.W.P.) is called Available Water (A.W.).

11.5.1 READILY AVAILABLE WATER (RAW):

It is that portion of available water, which the crop can use without affecting its evapotranspiration and growth. This portion is often indicated as a fraction of available water (p) or allowable depletion, which is a function of type of crop and evaporative demand. Many shallow rooted crops, such as most vegetables, require high moisture levels for acceptable yields. Deep-rooted crops will generally tolerate higher depletions.

A.W. = (F.C. - P.W.R) x B.D.

T.A.W. D x A.W.

R.A.W. p x T.A.W.

Where "B.D." is Bulk Density, "T.A.W." is Total Available Water in the root Zone & "D" is the depth of the root zone, "p" is the fraction of allowable depletion not resulting in crop stress.

11.5.2 Factors affecting the amount of available soil moisture:

Among the important soil factors influencing soil moisture are

1. Moisture tension relation. 2. Salt content.
3. Soil depth. 4. Soil stratification or layering.

11.5.2.1 Moisture tension relations (alignment) :

Metric tension will influence the amount of available moisture in a soil as it influences the amount of water in soil at field capacity and at permanent wilting point. The texture, structure and organic matter content, all influence the quantity of water that a given soil can supply to growing plants. The general influence of texture is given in Table 1. As the fineness of texture increases, there is a general increase in available moisture storage, although clay soils frequently have smaller capacity than do well granulated silt loams. As the texture becomes heavier, there is general increase in the wilting coefficient. The loam, silt-loam and clay loam soils have higher available water holding capacity (Fig. 3).

11.5.2.2 Salt Concentration:

The presence of salts in soils can influence soil water uptake. The osmotic pressure effects in soil solution due to salts will tend to reduce the range of available moisture in such soils by increasing the wilting coefficient. The total moisture stress or total soil water potential in such soils at this point is the sum of metric potential and the osmotic potential of the soil solution. Thus salts in soil reduce the availability of water to the plants.

11.5.2.3 Soil Depth:

All factors being equal, deep soils will have greater available moisture holding capacities than will shallow ones. For deep-rooted plants, this is of practical significance, especially in those sub humid and semi arid regions where supplemental irrigation is not possible.

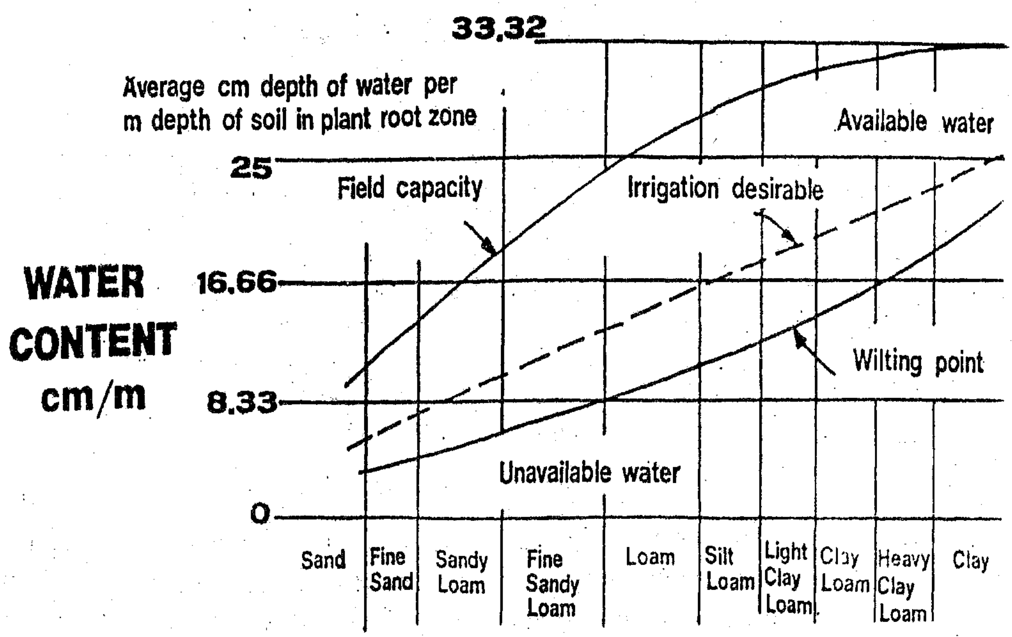

Fig.3 Comparison of the water-holding characteristics of different textural soils.

11.5.2.4 Soil Stratification or Layering:

Soil stratification or layering will influence markedly the available water and its movement in the soil. Hard pans or impervious layers slow down drastically the rate of movement of water and also influence unfavorably the penetration of plant roots.

11.6 Types of Soil Water Movement:

Water is a notably dynamic soil constituent. Three types of movement within the soil are recognized :

1. Saturated flow
2. Unsaturated flow
3. Vapor equalization.

11.6.1 Saturated flow through soils - percolation:

As water either from rain or irrigation is added to a soil, it penetrates the surface, replacing the air first in the macro and then in the microspores. Additional water will result in down ward movement by process called saturated flow, which will be encouraged by both gravitational and capillary forces. The soil texture and structure are the properties, which have large degree of influence on the water movement.

The water moves down much and more rapidly in sandy loam soils than in the clay loam. On the other hand horizontal movement is much evident in clay loam (Fig. 4).

COMPARATIVE MOVEMENT RATE OF IRRIGATION WATER

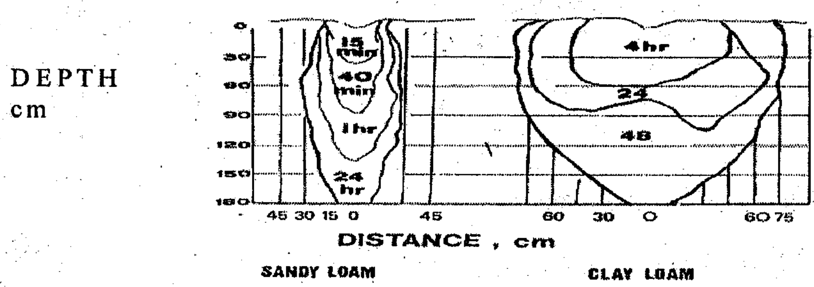

Fig. 4 Comparative rates of irrigation water movement into a sandy loam and clay loam soil

11.6.2 Unsaturated flow from soil water tables:

When water moves upward from a water table through the microspores of a soil, the phenomenon of capillaries is called unsaturated flow. The upward movement due to capillarity in soils is illustrated in Fig. 5. Usually the height of rise resulting from capillarity is greater with medium textured soils if sufficient time is allowed and the pores are not too small. So this is readily explained on the basis of the capillary size and the continuity of the pores. With sandy soils the rise is rapid but so many of the pores are non-capillary that the height of rise cannot be great.

UNSATURATED FLOW FROM A SOIL WATER TABLE

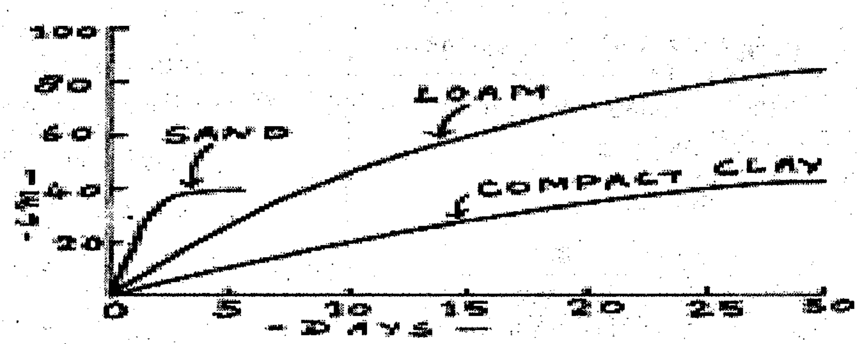

Fig.5 Upward movement of moisture from a water table through soils of different textures

11.6.2.1 Unsaturated Flow as it Most Commonly Occurs in Soil:

Under field conditions most soil water movement occurs where the soil pores are not completely saturated with water. Water movement under these conditions is very slow compared to that occurring when soil is saturated.

In unsaturated soils flow will occur in response to the differences in metric potential of one area to another. The moisture will move from the regions of low tension to high tension. The movement may be downward, upward or lateral.

11.6.2.2 Water Vapor Movement in Soils:

The diffusion of water vapor from one area to another in soils occurs in response to "Vapor pressure gradient ". Such movements may be of some significance in supplying moisture to drought resistant desert plants, many of which can exist at extremely low soil moisture levels.

11.7 How Plants are supplied with Water:

At one time only a small proportion of the soil water lies in the immediate neighborhood of the absorptive surfaces of the plant root system. But an immense amount of water is needed to meet the transpiration requirement by vigorously growing plants. Two phenomena seem to account for the acquisition of this water :

1. The capillary movement of soil water to plant roots.
2. The growth of roots into moist soil.

11.7.1 Rate of Capillary Movement:

When plant rootlets absorb water, they reduce the moisture content and thereby increase the tension in the soil surrounding them. In response to higher tension water tends to move towards the plant roots. The rate of movement depends on the magnitude of the tension gradients developed and conductivity of soil pores.

11.7.2 Rate of root development:

Limitations in rates of capillary movement of water are in part compensated by rapid rates of root elongation and new root-soil contacts are constantly established. During favorable growing periods such root elongation may be rapid enough to take care of most of the water needs of plants. Thus the capillary movement of water and elongation of roots help in providing soil water to plants.

11.8 MOISTURE EXTRACTION PATTERN:

In most plants the concentration of absorbing roots is greater in the upper part of root zone. The extraction of water is most rapid in the zone of greatest root concentration. Water also evaporates from the upper few centimeters of soil. The usual extraction pattern shows that about 40 % of extracted moisture comes from upper quarter of root zone, 30 % from the second quarter, 20 % from the third quarter and 10 % from the bottom quarter in a uniform soil fully supplied with required moisture. This indicates the need for making soil moisture measurements at different depths (at least two) within the root-zone.

11.9 THE WATER BUDGET METHOD FOR IRRIGATION SCHEDULING AT FARM LEVEL.

The water budget method is a step by step guide for scheduling of irrigation at farm level. The goal of the water budget method is to reduce the number of irrigations and then inherent costs by allowing crops to extract the proper amount of water from the root zone between irrigations.

The water budget approach can be broken into the following five basic steps for scheduling of irrigations at farm level :

Step 1- Estimate the amount of extractable moisture present in the root zone

Find out the Available Water (A.W.) content of given soil as discussed earlier. To estimate the total available water (T.A.W.), multiply the appropriate A.W. value by the average rooting depth (D) of crop. If soil texture varies substantially with depth, determine A.W. values for each textural layer, and then add these separate values to obtain A.W. for the entire root-zone. Next calculate the readily available water (R.A.W.) by multiplying the T.A.W. with allowable depletion (p). Readily Available Water (R.A.W.) is the extractable moisture present in the root zone.

Example: (Uniform Soil)

Soil texture	=	loam
Average rooting depth	=	100 cm
Available Water content (A.W.)	=	0. 16 cm /cm
T.A.W.	=	A.W. x D
	=	0.16 x 100 cm.
	=	16.0 cm.

Soil water depletion fraction for crop (p) =0. 5

R. A. W.	=	TA.W. x p
	=	16.0 x 0.5
	=	8.0 cm.

Example (Non uniform / layered soil profile)

Depth	**Texture**	**Available Water**
30 cm	Sandy loam	0. 14 cm/ cm
30 cm	Loam	0. 16 cm/cm
40 cm	Clay loam	0. 20 cm/cm

Determine T.A.W. and R.A.W. as following:

Depth	**A.W. x D**	**= T.A.W.**	**X**	**p**	**=**	**R.A. W.**
Layer 1.	0.14 x 30	= 4.2	X	0.5	=	2.1
Layer 2.	0.16 x 30	= 4.8	X	0.5	=	2.4

Layer 3. 0.20 x 40	= 8.0	X 0.5	=	4.0
		Total	=	8.5 cm.

Let the R.A.W. in the root zone = 8.0 cm.

Step-2 Estimate the rate of water use by crop:

The term evapotranspiration (Et) designates the combined loss of water by evaporation from the soil and plant surface and up takes by plant roots and subsequent transpiration through leaves into the atmosphere. Find out the daily crop Et for the successive days or average daily crop Et for that month.

Let the daily water use by crop or average daily Et = 0.5 cm

Step-3 Decide when to irrigate:

Deciding when to irrigate is simple a matter of deciding when the RAW has been used by crop and the soil reservoir is ready for recharge. For deciding the second and subsequent irrigations, add each successive days crop Et value until cumulative Et equals the R.A.W. This will give the date to apply irrigation. If the daily Et values are not available, the average daily Et for the month may also be used.

Example:

No. of days for next irrigation = RAW / Daily Et.
= 8.0 / 0.5
= 16 days.

The next irrigation should begin after 16 days intervals. If the rainfall occurs during this period, subtract the amount of effective rainfall from the cumulative Et value, and continue accumulating daily Et until R.A.W. is exceeded.

Step-4 Calculate amount of water to apply:

No matter which irrigation methods we use, water may be lost during application through deep percolation, runoff and evaporation. Extra water must be applied in each irrigation to compensate demand for uniformity of water application by the irrigation system. To calculate the amount of water to apply, divide the net amount of water depleted since the last irrigation by the appropriate irrigation efficiency value.

Example:

- Net requirement of water = 8 cm.
- Border strip efficiency = 80 % (0.80)
- Amount of water to apply = 8.0 / .80 = 10.0 cm.

Step-5 Calculate set time:

Irrigation set time is the duration of water application. It depends on the amount of water to be applied discussed in step 4, and the rate of water application i.e. flow rate.

Example:

Amount of water to apply = 10 cm depth. = 1000 m^3

Discharge = 1 cusec. = 100 m^3 / hr. (Approx.)

Set time = Amount of water to be applied.

Discharge

$$= \frac{1000\ m^3\ /\ ha.}{100\ hr\ /\ ha.} = 10\ hr/Ha.$$

Table: Representative Physical Properties of Soils

S.No	Soil Texture	Infiltration (Ib) Cm/hr.	Total Pore Space %	Bulk Density (BD)	Field Capacity (FC) %	Permanent Wilting Point (P.W.P.) %	Available Water % Weight (FC-PWP)	Available Water % Volume (FC-PWP) X BD
1.	Sand	5.00 (2.5-25)	38 (32-42)	1.65 (1.55-1.80)	9 (6-12)	4 (2-6)	5 (4-6)	8 (6-10)
2	Sandy Loam	2.50 (1.3-7.60)	43 (40-47)	1.50 (1.40-1.60)	14 (10-18)	6 (4-8)	8 (6-10)	12 (9-15)
3.	Loam	1.30 (0.8-2.00)	47 (43-49)	1.40 (1.35-1.50)	22 (18-26)	10 (8-12)	12 (10-14)	17 (14-20)
4.	Clay Loam	0.80 (0.25-1.50)	49 (47-52)	1.35 (1.30-1.40	27 (23-31)	13 (11-15)	14 (12-16)	19 (16-22)
5.	Silty Clay	0.25 (0.03-0.50)	51 (49-53)	1.30 (1.25-1.35)	31 (27-35)	15 (13-17)	16 (14-18)	21 (18-23)
6.	Clay	0.10 (0.01-0.25)	53 (51-55)	1.25 (1.20-1.30)	32 (28-36)	18 (16-20)	14 (12-16)	18 (15-20)

Note: Normal ranges are shown in parentheses

11.10 Self Assessment Test

1. Define maximum water holding capacity, field capacity and permanent wilting point
2. What do you understand by readily available water (RAW) ?

11.11 Key Words

Field Capacity : amount remaining in a well drained soil when the velocity of downward flow into unsaturated soil has become small.

Wilting Point : the moisture content of soil, on an oven-dry basis, at which plants wilt and fail to recover their turgidity when placed in a dark humid atmosphere.

11.12 Suggested Readings

Nyle C. Brady, 'The nature and properties of soils'

Motiramani, 'Soils their chemistry and fertility in tropical Asia'

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UNIT-12

IRRIGATION SCHEDULING BASED ON SOIL CHARACTERISTICS

STRUCTURE

12.0 Objectives

12.1 Introduction

12.2 Consumptive Use

12.3 Water Requirement of Crops

12.4 Seasonal Consumptive Use

12.5 Peak Period Consumptive Use

12.6 Irrigation Requirement

12.7 Approaches for Estimating Crop Water Requirement

12.8 Self Assessment Test

12.9 Key Words

12.10 Suggested Readings

12.0 Objectives

The irrigation scheduling determines the time to irrigate and the amount of water to be applied. Irrigation scheduling can reduce the total volume of subsurface drainage by reducing over-irrigation. To schedule irrigation accurately the soil-plant-atmosphere continuum must be considered as a physically integrated, dynamic system in which transport processes occur interactively.

12.1 Introduction

Water is one of the most valuable natural resources and its excess or deficit in the soil is a limiting factor for crop production. Successful production requires adequate and timely soil moisture supply with judicious use throughout the life cycle of crop.

Of the agronomic factors known to augment the crop yield, water management is of vital importance. The contribution of irrigation water in increasing crop productivity is second to fertilizers. The so-called green revolution of present day has been brought in sight through the development of high yielding varieties. It appears the next breakthrough in agriculture in India has to come through water management, which has been one of the neglected fields so far. Water is the most critical input for Indian Agriculture today. It is a manageable monetary input, therefore, all available supply of water should be used in best possible advantage to achieve the main aim of increasing agricultural production per unit volume of water/unit area of cropped land and per unit time. The productivity of crop per unit quantity of water can be increased even upto 200 percent or more if proper water management is observed.

12.2 Consumptive Use

Consumptive use commonly known as evapotranspiration is the amount of water used by growing plants in transpiration and building of plant tissues and that evaporated from adjacent soil and from intercepted precipitation in the plant foliage in a specified time.

12.3 Water Requirement of Crops

Water requirement of crop implies the total amount of water required by crops regardless of its source in a given period of time for its normal growth. It thus includes water needed to meet the losses through evapotranspiration, application losses, and special needs.

Crop water requirement is therefore, a demand and may be expressed as:

WR = ET or Cu application losses - Special needs

WR is therefore, a demand, and the supply would consist of contribution from any source of water. The major source being the irrigation (I), effective rainfall (ER) and soil profile contribution (S).

Hence water requirement can be expressed as under:

$WR = I + ER + S$

Crop water requirement calculated for Kota conditions given in Annexure - I (a) & (b).

12.4 Seasonal Consumptive Use

The total amount of water used in evapotranspiration by a cropped area during the entire growing season is called seasonal consumptive use. It is expressed as the depth of water in cm or volume in hectare cm per hectare. Seasonal consumptive use values are required to evaluate and determine the seasonal irrigation water supplies.

12.5 Peak Period Consumptive Use

The average daily use rate during the few days of the highest consumptive use of the season is called the peak period use rate. This is the design rate to be used in planning an irritation system. The peak use period for various crops in a given area may occur at different times in the crop season. In Irrigation project design, the peak period of consumptive use is the period during which the weighted average daily rate of consumptive use of the various crops grown in the project area is at the maximum.

In planning the cropping pattern for an area we may have such crop combination which have their peak consumptive use rates spread out in such a way that we may use the available supply in the most efficient manner. Some typical values of the peak rate of soil moisture removal by crops under different climatic conditions are given in Table below:

Maximum Rates of Soil Moisture use by crops under different climatic conditions:

Climatic Conditions	Peak rate of soil moisture removal (mm/day)
Cool, humid	3
Cool, dry	4
Moderate, humid.	4
Moderate, dry	5
Hot, humid	5
Hot, dry	8

12.6 Irrigation Requirement

The net irrigation water requirement is the amount of water exclusive of precipitation, carry over soil moisture and the ground water (capillary) contribution required for crop production.

The gross irrigation requirement includes the net requirement, as also the losses incurred in conveying and applying water. The losses are reflected in terms 011 irrigation efficiency.

12.7 Approaches For Estimating Crop Water Requirement

(i) Transpiration Ratio approaches.

(ii) Depth-interval-yields approach.

iii) Soil moisture deficit approach.

iv) Critical growth stage approach

v) IW/CPE Approach

vi) Climatological approach: Various methods are available for estimating evapo-transpiration from climatological data. They are as follows:

I. Blanev criddle method.

II. Thornthwaite formula

III. Cristinsan method

IV. Hargreaves temperature & radiation methods.

V. Modified Panman method.

Consumptive Water requirement for important Kharif crops in mm

S. No.	Crops	Duration	June	July	August	Sept.	Oct.	Total
1.	Groundnut	25th June to 31st October (128 days)	20.55	107.66	123.08	143.82	129.37	524.43
2.	Maize (Sathi)	25th June to 20th September (87 days)	18.27	107.95	147.78	101.28	-	375.28
3.	Maize (Hybrid)	25th June to 21st October (118 days)	18.27	101.74	120.38	157.92	134.04	532.35
4.	Soybean	14th July to 31st October (110 days)	-	136.15	99.15	150.72	130.93	416.95
5.	Sorghum (Fodder)	25th June to 10th October (107 days)	15.98	96.28	124.93	140.99	37.50	415.68
6.	Kharif Pulses	15th July to 10th October (87 days)	-	32.15	107.12	144.10	34.09	317.46
7.	Kharif Vegetables	25th June to 31st October (128 days)	15.98	91.69	118.08	143.82	142.82	512.39

Annexure - I (b)

Consumptive Water requirement for important Rabi crops in mm

S. No.	Crops	Duration	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	Total
1.	Wheat	16th Nov. to 10th April (145 days)	-	-	18.02	53.30	80.02	119.84	168.80	62.40	502.38
2.	Wheat (Late sown)	10th Dec. to 15th April (126 days)	-	-	-	20.38	58.56	108.53	197.95	94.40	479.82
3.	Mustard, Coriander, Linseed & Lentil	15th Oct. to 28th Feb. (136 days)	-	27.27	64.88	76.31	94.88	83.72	-	-	347.06
4.	Barley & Pea for Pods	1st Oct. to 31st Jan. (122 days)	-	73.55	79.31	96.32	91.09	-	-	-	40.27
5.	Pea for Grains	25th Oct. to 10th March (136 days)	-	13.15	58.42	68.16	94.08	116.78	64.54	-	415.13
6.	Gram	16th Oct. to 15th March (158 days)	-	21.92	44.62	60.20	84.41	97.06	58.81	-	367.02
7.	Rabi Vegetables	25th Sept. to 15th Jan (112 days)	10.57	98.64	97.57	95.09	36.58	-	-	-	338.45
8.	Berseem	1st Oct. to 19th April (200 days)	-	62.10	82.40	74.13	94.08	119.04	209.44	167.39	808.58

(Rabi)

Critical Stages of Different Important Crops

S.No.	Crop	Critical Stages	Most Critical Stages
1.	Wheat	Crown root initiation, Tillering, Late Jointing, Flowering, Milk	Crown root initiation and flowering
2.	Gram	Branching, Pod initiation, Pod filling	Pod initiation
3.	Mustard	Pre flowering and post flowering	Initiation of flowering
4.	Lentil	Branching, flowering, Pod filling	Flowering
5.	Potato	Stolanization to tuber initiation, Yield formation	Stolanization to tuber initiation
6.	Sugarcane	Tillering, Grand growth period	Tillering and Grand growth period
7.	Tobacco	Period of rapid growth	Vegetative growth period
8.	Barley	Tillering, Jointing, Flowering, Milk	Tillering and Flowering
9.	Linseed	Initiation of flower and Grain filling	Initiation of flower
10.	Peas	Initiation of flower and Grain filling	Initiation of flower
11.	Berseem	Through out the growth period	Initial one month after each cutting

(Kharif)

S.No.	Crop	Critical Stages	Most Critical Stages
1.	Paddy	Seeding establishment, Tillering, Primorida formation, Flowering and Milk	Tillering and Flowering to grain filling
2.	Cotton	Commencement of Sympedial, Branching, Flowering, Ball formation, Ball Bursting	Branching and initiation of ball formation
3.	Maize	Tasselling to silking grain filling	Tasselling to silking
4.	Groundnut	Flowering to Yield formation (Particularly during the pod setting)	Flowering/pegging

5.	Sorghum	Flowering, Grain formation	Flowering
6.	Black Gram/ Green Gram	Flowering to Filling	Flowering
7.	Pearl Millet	Flowering, Grain formation	Flowering
8.	Pigeon Pea	Flowering, Grain formation	Flowering
9.	Sesamum	Flowering to pod development	Flowering

12.8 Self Assessment Test

1. Define irrigation scheduling
2. How is irrigation scheduling useful for the farmer and the country?

12.9 Key Words

Irrigation : the supply, distribution and controlled application of water to agricultural land to improve the cultivation of crops.

Irrigation Efficiency : covering the conveyance and distribution and application of water for plant growth.

12.10 Suggested Readings

N. K. Tyagi, 'Agricultural Salinity Management in India'.

H. P. Ritzma, 'Drainage Principals and Applications'.

A. A. Pai, ' Manual on Irrigation Water Management'.

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