SR- 22

METHODS OF WATER CONSERVATION AND THEIR EFFECTIVE USE IN DROUGHT AFFECTED AREAS
(STATUS REPORT)

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAVAN
ROORKEE-247667 (UP)
INDIA
1992 - 93

PREFACE

India receives an average rainfall of around 1050 mm which is the highest in the world among countries of comparable size, and should be sufficient enough to satisfy its ever increasing demand. But the temporal and spatial distribution of rainfall throughout the country is so erratic that drought and floods occurs frequently and simultaneously. Also the alarming rate of population growth at 2.11 percent has led to increasing pressure on the basic life supporting system. The utilization of water resources in the country has increased over the years.

The water resource potential has been increased by 48 m.ha.m since independence. In spite of this high increase in potential the water resource of the country are fast depleting in relation to the demands in domestic, agriculture and industry specially in drought prone areas. Therefore, the conservation of water becomes an alternative of water potential.

In the present report various methods of water conservation to increase the potential of surface storage and groundwater storage are reported. The different methods of water conservation during the phase of its utilisation in domestic, agriculture and industry are also reported. This report has been carried out by Avinash Agarwal, Scientist 'C' of Drought Studies Division.

Satish Chandra

SATISH CHANDRA
DIRECTOR

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The nature has blessed our Country with a better share of water resource, but erratic nature of Indian monsoon leads to the extreme of floods droughts simultaneously occurring in different parts. This causes vast damage, sufferings to mankind and economic losses. At the same time the fast expanding India's population as from 1991 census is 800 million at present and estimated to be 1000 million by 2000 A.D. has a tremendous pressure of meeting the everyday increasing demands of water for various uses for the general well being of the population.

The Irrigation Commission of India (1972) has estimated a total surface water resources as 180 m.ha.m. and an increase of irrigation potential by 48 m.ha.m. since 1951. The high cost involved in both the formation of more irrigation potential and inter basins transfers has yielded the thinking of our scientists and hydrologist towards the conservation of available surface and ground water resources at all stages of its occurrence and at all stages of its utilization. These challenge will have to be met by effective and appropriate water conservation practice.

This report covers the methods of water conservation at the stage of its occurrence and during its utilization in domestic, agriculture and industrial uses. The report covers the conservation of surface water from evaporation, by the use of monomolecular films and by the use of wind breaks. The conservation of ground water covers the use of percolation tanks, use of injection wells and subsurface dames.

The report also covers the conservation of water during the phase of its utilization like domestic, agriculture and industrial. The water conservation in the area of domestic use covers the use of roof water harvesting, desalination of saline water in equate water shortage area and conservation in domestic supply. The water conservation in area of agriculture use covers the conservation by water harvesting, conservation from seepage, conservation by adaptation of advanced irrigation methods, conservation by forming and engineering practices, reuse of irrigation and weather forecasting. The report also covers some of the aspects of water conservation in industrial uses.

1.0 INTRODUCTION

Water is essential for life on the planet, water resources have been a decisive factor in the growth and development of human civilization throughout the history. When India gained independence in 1947 its dominant long term objective was to build up its economy. For economic reconstruction and regeneration, agricultural development was to be accorded the highest priority, not only because the food production was to be substantially increased and has to keep pace with the expanding population but also because it was essential to build up the grass roots economy of a country more than 80% of whose people depend on agriculture or agricultural based activities for their livelihood and occupation. The only viable strategy for the purpose was expansion of the irrigation facilities for which ample scope existed at that time. Out of total irrigation potential of 113 million hectares, only 22 million hectares were under irrigation from various sources at that time. With this philosophy, India set up the course of irrigation development in successive five year plans starting in 1952. The achieved irrigation potential during successive plans is presented in Table 1.

The Irrigation Commission of India has estimated the total surface water flow as 180 m. ha. m. out of 180 m. ha. m. around 115 m. ha. m. constitute direct contribution by precipitation (Report of Irrigation Commission, 1972) . Even then about 60% of total cultivated land will remain under rain fed farming, other way it can be said the water is scarce to meet the demand of even agricultural sector. The results of 1991 census of the country indicated a population growth as 2.11 percent. The alarming rate of population growth has led to increasing pressure on the basic life support systems of land, water, flora, fauna and the atmosphere.

In terms of utilization of water resources in the country, its uses in various sectors has increased manifold over the years. It is in this context, Government of India adopted a National water Policy in year 1987 which declared water as a scarce and precious national resource. The demand for water in various sectors during year 1990 and projections for year 2000 and 2025 and the source by which it has to meet is reported in Table 2.

2.0 NEEDS FOP WATER CONSERVATION

The average annual rainfall over India is around 105 cm, however it fluctuates widely. The advance of the monsoon into the country takes place in two main branches. The south west monsoon, June to September, is the principal rainy season whenever 75% of the annual rainfall is received all over the country.

Table 1: Statistics of irrigation development and food grains production in India.

Period	Major & Medium Irrigation potential created 10^6 ha.	Minor Irrigation potential created 10^6 ha.	Food production 10^6 tones
Upto 1951	9.70	12.90	52.0
Plan 1(1951-56)	2.49	1.16	66.9
Plan 2(1956-61)	2.14	0.73	82.0
Plan 3(1961-66)	2.23	2.22	72.4
Annual Plan(1966-69)	1.54	1.99	75.0
Plan 4 (1969-74)	2.60	4.50	104.7
Plan 5(1974-78)	4.12	3.80	125.0
Annual Plan(1978-80)	1.79	2.70	131.0
By the end of sixth plan (total irrigation potential)	69.7		
Total	26.61	30.0	-

Source: Water for the future.

There is large variation in rainfall from region to region, season to season and year to year. The normal annual rainfall which is as low as 100 mm in western Rajasthan is over 11000 mm at Cheerapunji in Meghalaya. The spatial unevenness and temporal variation in precipitation has led to complex situation like the distinctly different monsoon and non-monsoon seasons and the high and low rainfall areas. The problem of large variation in water availability and growing demand leads to water conservation.

Table 2: Project water demands in various sectors.

Purpose	Demand in the year, km^3.(Km^3=0.1 m ha m)		
	1990	2000	2025
Domestic use	25	33	52
Irrigation	460	630	770
Energy	19	27	71
Industrial use	15	30	120
Others	33	30	37
Total	552	750	1050
Sources a and b)			
a Surface water	362	500	700
b. Ground water	190	250	350
Total	552	750	1050

Source: Theme paper on water conservation CWC 1991.

It can be observed that the agricultural demand of water is highest followed by industrial, energy and domestic use.

Agriculture: By far the largest quantum of water is used in agriculture. Being faced with a rainfall season with few rainy days, agriculture in India is heavily dependent on irrigation. The net sown area in the country has almost stabilized at about 145 million hectares (m. ha.). The gross cropped area is about 173 m.ha., taking into account areas sown more than once. The multiple cropping is brought about by irrigation. It is unlikely that net sown area will increase in the future. The only way to increase the gross cropped area is to expand irrigation facilities and to facilitate multiple cropping. The irrigated area at present is about 70 m. ha. The water demand for irrigation is about 460 cubic km. The food grain production which is now about 175 million tonnes may have to increase to 250 million tonnes by 2000 and to about 400 million tonnes by 2025. The demand of water for irrigated agriculture will go up to 750 cubic km. in the year 2000 and to 1050 cubic km. in 2025.

Industrial: Water demand of industries has not so far been precisely estimated. Rough estimates based on prevalent requirements of water for various industrial products show that the present water demand in the industrial sector is of the order of 15 cubic km. This may go up to 30 cubic km. in 2000 and 120 cubic km. in 2025.

Energy: The water use by thermal and nuclear power plants with installed capacities of 40000 MW and 1465 MW respectively has been estimated to be about 4 cubic km. at present. In hydropower generation, the consumption is only by way of evaporation from reservoirs which is estimated to be of the order of 15 cubic km. The water demand for power generation may go up to 27 cubic Km. in 2000 and 71 cubic km. in 2025. In Table 1 the demand for water in 1990, 2000 and 2025 has been summarized for various purposes.

Domestic: The population of India, which was 68.8 crores in 1981, is projected to go up to 81 crores in 1991, 101 crores in 2001, 153 crores in 2025 and will perhaps stabilize at 170 crores in 2050. The demand for community water supply is at present 25 cubic km. This would increase to 33 cubic km in 2000 and to 52 cubic km in 2025. The increase is not only due to the growth in population but also due to improved living style of the people.

Therefore highest scope of conserving of the precious water resource lies with the agricultural section followed by other. By saying this, it does not mean that the water conservation in domestic use, which is of prime importance, should be neglected.

3.0 CONSERVATION BY SURFACE STORAGE

Conservation of water by storage is important especially in India where most of the flow in the rivers to the extent of 80 percent occurs in four monsoon months. For the rest of the year there will be only inadequate or no water supply from the rivers. Therefore storage of water is very essential for agriculture and for producing power. Presently there are as many as 2900 medium size reservoirs existing while another 700 are under construction and 300 are contemplated. Besides more than 200,000 minor irrigation tanks are also existing. The combined storage capacity of all these reservoirs will add up to 400 km^3. Comparing this with the potential of 700 km^3 apparently shows that to overcome our water problem, we should go in for creation of more storages. However, this will not solve the two main problems. One is that in the same regions there is scope of storage but so much water is not needed. However, many of the river basins, like Cauvery, Sabarmati and Yamuna, have already almost exhausted the available resource. The second problem is that the building of dams and canals has become extremely costly. The two problem leads towards the strategies of Conservation of water and increase water productivity of stored water.

3.1 Conservation from evaporation

The loss of water from water storage structure like reservoirs irrigation tanks etc., through the process of evaporation causes in reduction in storage meant for making water supply as smooth as possible for various usages. A number of approaches/ techniques have been suggested to reduce evaporation from water bodies. Some of these are :

a. Locating reservoirs at high altitudes.
b. Keeping the lower area/ volume ratio of water body.
c. Minimizing exposed surface through reservoir regulation.
d. Constructing artificial aquifers.
e. Reducing energy available for evaporation.
f. Application of monomolecular films
g. Installing wind breaks.

The first few techniques suggested from reducing evaporation are based on location of water storage structure, environment of the sight and on design criteria. These should be considered before the selection of sight.

As seen in Fig.1 evaporation is quite high (250 cm or more) in west Rajasthan, Saurashtra, Deccan plateau and Southern Coastal regions of Tamil Nadu. Control of evaporation from tanks and reservoirs by application of chemical retardants may be economically viable in these areas in the scarcity.

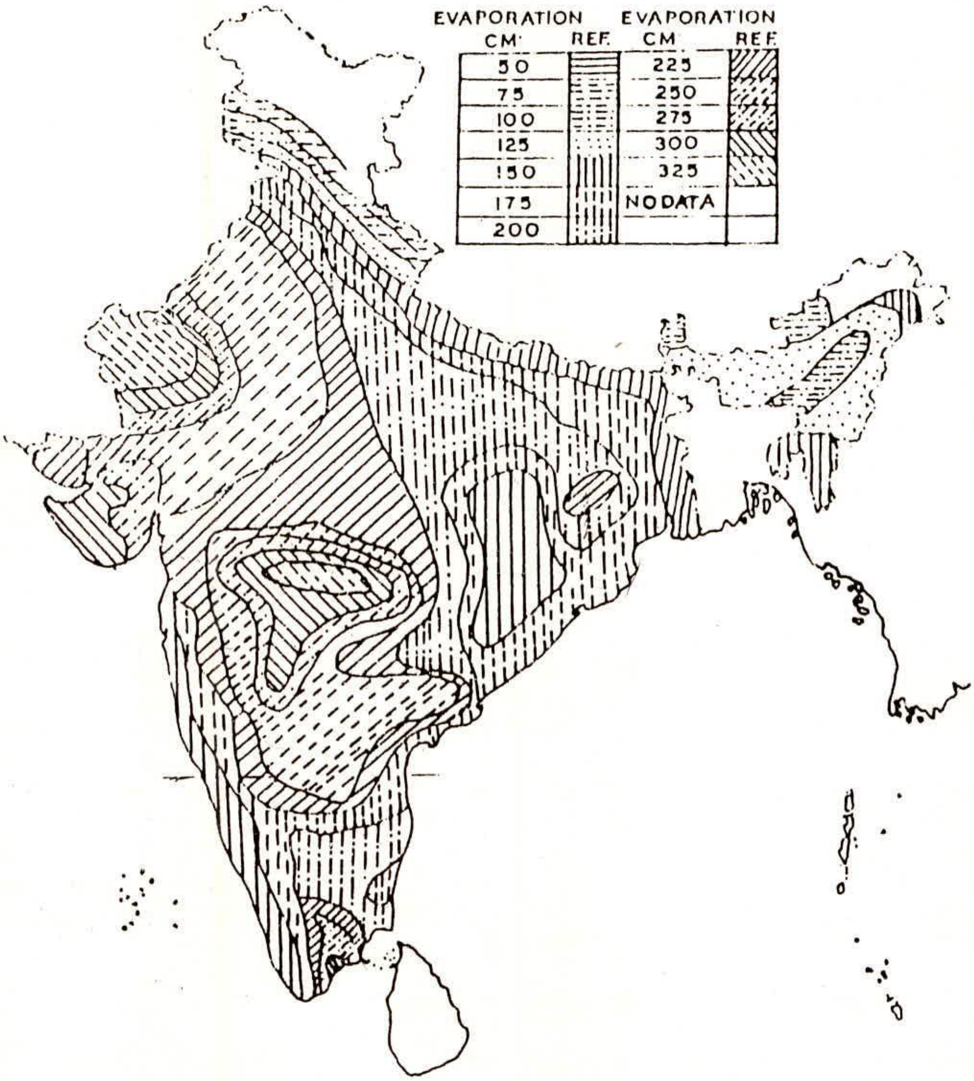

FIG. 1. AVERAGE ANNUAL EVAPORATION (cm) IN INDIA

3.2 Conservation by monomolecular films

There are many organic compounds like the fatty acids and alcohols, camphor, antiyrin some of the dye stuffs like methyl violet, tetriod-fluorescein, etc. which spread as mono-molecular films when brought in contact with a clean surface of water. The water surface is thus covered by a mono-molecular film which remains in equilibrium with any excess of material which floats on the surface as solid particle or liquid lenses, as the case may be. For reducing evaporation from large reservoirs, techniques have been developed by spreading powder from about (Mansfield, 1967, 1974) or spraying a suspension or dispersion on to the water surface from nozzles around the edge (Reiser, 1969; Crow and Mitchell, 1975; Frasier and Myers, 1968, 1965b). Continuous application from the upwind side is desirable as the film drifts with the wind and is disrupted by wages(Crow and Mitchell, 1975; Dick and Marchellow, 1969). The chemical is also lost through bio-degradation evaporation dissolution and crystallization (Mansfield, 1974). Mohmoud and Bashi (1980) experiment with a combination of polystyrene beads and Cetyl alcohol and found it to be more effective than either on its own. In Australia promising experiments are being conducted with a plastic mesh that floats on the water surface and retains the powered Cetyl alcohol in position (Mansfield, 1974; Brown 1974).

During the scarcity year in 1985-86, in the Gujarat state, two types of chemicals were reportedly used, one was in powder (Lumps) form i.e. Acilol (Trade name), by Rajkot Irrigation Circle to reduce evaporation losses from three reservoirs. The results are reported in Table 3 (Mistry, 1987).

In theory a complete film can reduce evaporation by 50 percent (Mansfield, 1967) but raised water temperature under the film can actually result in higher evaporation from uncovered areas. Economic considerations usually limit the saving that can be obtained in practice to only about 20% as concluded by Cluff, 1966, Cruse, 1960; Frasier et al, 1968 the studies conducted abroad. The studies with alcohol have yielded reduction of only 10 to 35 percent in field tests (Cruse and Harbeck, 1960; Cluff, 1966) alternative measures are needed to discover for having an effective control of evaporation from water bodies.

3.3 Conservation by wind breaks

Wind is one of the most important factor, which affects evaporation from water surface. The greater the movement of air above the water, greater is the loss of water vapors. Therefore planting of trees normal to wind direction is found to be an effective measure for checking

Table 3: Percentage sa,ing in evaporation losses achieved in different reservoirs/tanks in India for drinking water supplies.

Sl.No.	Name of reservoir	Location	Period of study	Average wind velocity km/hr	Average % saving in evaporation reduction
1.	Kukkarhalli Lake	Mysore	Jan.59-May 59	-	14.4
			Feb.61-Apr.61 (3 months)	-	11.7
2.	Welwhan Lake	Lonavala	Feb.61-May 61 (4 months)	-	9.6
3.	Aji Lake (a)	Rajkot	Apr.68-June 68 (3 months)	23	16.5
4.	Indira (b)	Pune	1977-78	15	38.19
			1978-79	15	35.20
5.	Kedarpur PT(b)	Nagpur	1977-78	15	34.78
			1978-79	15	16.01
			1979-80	15	15.87
6.	Ramgarh Lake(c)	Jaipur	Apr.85-July 85 (4 months)	14	23.4
7.	Foy Sagar (c)	Ajmer	Jan.86-June 86 (6 months)	8	35.0
8.	Maja dam (c)	Bhilwara	Jan.86-July 86 (7 Months)	10	30.0
9.	Osman Sagar (c)	Hyderabad	Apr.86-June 86 (3months)	14	33.0
10.	Nyari-I dam (c)	Rajkot Div.	Dec.85-May 86 (6 months)	12	16.5
11.	Aji-I (a)	Rajkot Div.	Dec. 85-May 86 (6 months)	11	20.0
12.	Bhadar (a)	Rajkot Div.	Dec.85-May 86 (6 months)	11	16.0
13.	Ten Reservoirs (Average)(a,c)	Rajkot Irrig.Circle	Dec.85-May 86 (6 months)		11.08

(a) : Cetyl-Stearyl alcohol (Powder form)
(b) : Linoxyd CS - 40 (Paste form)
(c) : Ceto- Stearyl alcohol (Paste form)(ACILOL-TA -1618 WER)

evaporation losses. As a mater of fact, this practice of growing plants (trees, shrubs or grass) around the rim of tanks in a row or rows to act as wind breakers has been an age old practice. These wind breaks influence greatly the temperature, atmospheric humidity, soil moisture, evaporation and transpiration of the area protected. The plants to act as wind breakers are usually arranged in such a way that the tallest plants are in the middle rows and the smallest along the end rows, so that more or less a conical cross section is formed. Trees grown as wind breaker are constantly subjected to usual stress of wind, temperature, moisture evaporation, insects and diseases. Hence only those species which are resistant to these stresses are to be selected. ICAR had recommended the types of trees, shrubs and grass for planting as wind breakers in various regions of India in their Technical Bulletin(AGRIC) No. 22, ICAR, New Delhi.

3.4 Conservation from seepage

The special significance of India where almost the entire annual precipitations is concentrated within 3 to 4 months of the year. The reservoirs and ponds are a place to store the water to be used for various domestic, agricultural and industrial purposes over a period of time. However, a major portion of water stored in these reservoirs is rendered by seepage and percolation. These reservoirs are located in variety of soil types which exhibit a wide range of seepage characteristics. The seepage which can occur in different types of soil are reported in Table 4.

Table 4: Seepage in different types of soil.

Type of soil	Water loss cu.sec/million sq.ft.	Drop in depth cm./day
Heavy clay loam	4.0	10.36
Medium clay loam	6.5	16.84
Silty clay loam	9.5	24.61
Sandy loam	17.0	44.03
Loose sandsoil	20.0	51.80
Porous gravelling soil	35.0	90.65

Source: Seminar on use of plastics for lining of water convergence system in irrigated agriculture (1982).

For example, a tank having a 4.0 metre depth of water located in a heavy clay loam soil area would total get exhausted with in 40 days. However, over a period of time the silt deposit helps in partially clogging the pores in the sides and beds of the tank which helps in reducing the seepage losses.

Bentonite clays as well as other clayer nonporous materials are spread in the bed and sides of water tanks and reservoirs for preventing seepage losses. The use of such materials helps in seepage prevention to some extent. The choice of brick lining and concrete lining is too expensive in present condition. Plastic film lining, suitably used, provided an answer to prevention of seepage losses. LDPE and PVC film lining are being successfully used in our country in the lining of small, medium as well as large reservoirs (Fig. 2).

3.5 Conservation during long transfer of water

Transfer of water from surplus basin to deficit basins by creating storage at appropriate location and interlinking

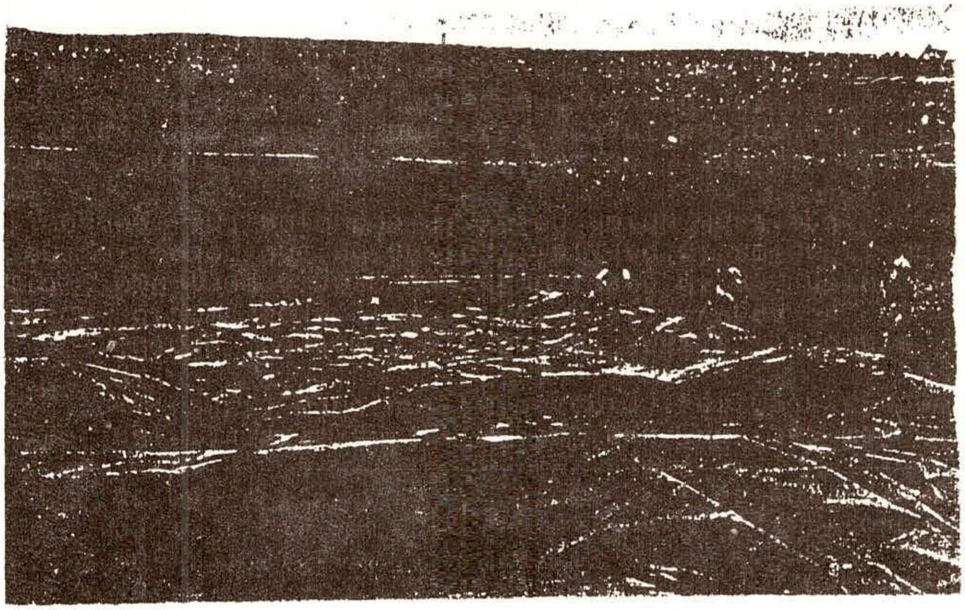

Fig. 2. LDPE film lining of tank to reduce seepage.

various river systems is another strategy to conserve water and the natural monsoon runoff does not flow waste to the sea. For success of such a strategy, a national view will have to be taken and major interstate and international rivers are to be harnessed in the large interests of the country. A number of scheme for such inter basin transfer of water have been carried out in the past. Such few schemas are Periyar Vaigai, Buckingham Canal, Parambikulam Aliya, Rajasthan Canal, Beas Sutlej Link, diversion of Ramganga into Ganga, Sutlej Yamuna link, Krishna Cuddapah Canal, Nagarjunasagar right bank canal and Telugu Ganga Canal.

Seepage loss which forms the major part of the loss can effectively be minimized by the use of plastic sheet between the porous soil and the water flowing in the system during long transfer of water. A variety of materials are used for the lining of canals such as brick tiles, stone slabs, precasted concrete, soil cement, bentonite clay and plastic films. The use of plastic film in conjunction with brick masonry has very low seepage losses around 0.12 cusec per million square feet of wetted perimeter. Few cases of conserving the water by canal lining are listed in table 5.

4.0 GROUND WATER CONSERVATION

In India due to the uncontrolled development of ground water, in certain areas the water levels have assumed a declining trend. In such areas the artificial recharge of ground water is of great use. Ground water recharge involves augmenting the natural movement surface water into underground formations by some method of construction, by spreading of water, or by artificially changing natural conditions. Variety of methods are adopted for it. Few methods are reported below:

a. Water spreading
b. Recharge through pit and wells
c. Induced recharge from surface water bodies

Table 5: Use of plastic film in canals.

Sl.No.	Canal and year of lining	Discharge rate cusec	Type of soil	remarks
1.	Hatmati canal(Gujarat) 1971	400	Sandy	-
2.	Kasur Branch Ex. Dantiwada	784	-	-
	L.B. Canal Gujarat 1966	129	Sandy	2.0 cusec per m. sq.ft.compared to unlined as 26.0 cusec/m.sq.ft.
3.	Jullundher Distributory 1972 - 73	217	-	

Source: National Committee on the use of plastic in agriculture (1982)

The ground water is one of the most widely distributed and important natural resource. Ground water storage should not be ignored as long as a long range depletable resource whose development could have major benefits as emergency supplies in water scarce area. In order to maintain the ground water resource, a hydrologic equilibrium must exist between all water entering and leaving the basin.

Detailed and comprehensive studies on artificial recharge including experimental studies on artificial recharge including experimental studies were taken up (i) in Mehsana area and Coastal Saurashtra in Gujarat by the Central Ground Water Board and (ii) In parts of Tamil Nadu with the collaboration of UNDP. Studies on artificial recharge have also been carried out by the central Ground Water Board in some of the water balance projects undertaken during the recent past such as Sina-Man Ground water Project, Maharashtra and Ghaggar River Basin Project in Punjab, Rajasthan and Haryana.

4.1 Conservation by percolation tanks

Construction by percolation tanks is a technique useful for arid and semi arid regions in hard rock area. Low rainfall belt in Western India, which received monsoon rains only during the four months in a year, forms a typical area in which percolation tanks are constructed for water conservation. Rainfall in most of this region is between 300-700 mm.

Geology, soils and site selection are much more critical for spreading or infiltration recharge system. A successful infiltration recharge system needs following aspects to consider (a) surface soil must be sufficiently permeable to maintain high infiltration rate, (b) Vadose zone must be permeable and free from clay layers or other fine materials that could restrict downward flow of water Fig. 3, (c) Aquifer must be unconfined, permeable and thick enough to avoid excess amount of ground water mounts (d) and there should be sufficient unpolluted surface water supply for percolation tanks.

Central Ground Water Board carried out studies on artificial recharge through percolation tank in Sina Man are of Maharashtra. The percolation was found to be 50% of the capacity of tank. In a study of Noyil, Ponnani and Vattamalai Karoi river basins in Tamil Nadu and Kerala, the high percolation rates were observed (Seminar on Artificial Recharge of Ground Water, 1985) storage/ percolation tank studies in Amreli indicated that around 50% of the total water spread underground rising the water table 0.5 to 1.6 m in an area of 2 sq. km.

4.2 Conservation by injection wells

In India, studies on artificial recharge have been taken up in the states of Gujarat, Maharashtra, Andhra Pradesh, Madhya Pradesh, Tamil Nadu and Kerala. A report from Ministry of Agriculture (1990) indicates that the cost of artificial recharge schemes for domestic water supply works out to be Rs.0.75 to 5.0 per head per year which is reasonable especially in water scarcity area. A general layout of injection well is shown in Figure 4. The effectiveness of method depends on the site condition and physical characteristics of soil profile. The selection of recharge site involves the consideration of following:

a. Availability of land and topography
b. Hydrological condition
c. Possible source of water for recharge
d. Operational maintenance
e. Economic consideration

The first attempt on artificial recharge by injection method was made in April, 1974 in the city of Ahmedabad. Clear, treated and chlorinated water was injected at the rate of 182 m/day for 72 hours resulting in a rise of 1.72 m.

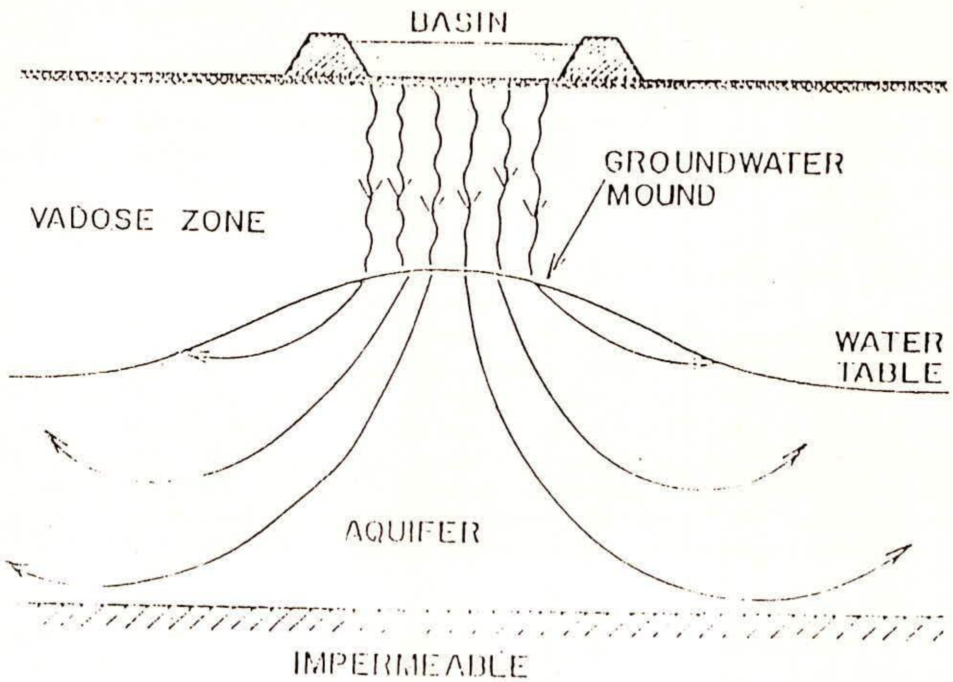

Fig. 3 Groundwater Conservation by Percolation Tanks

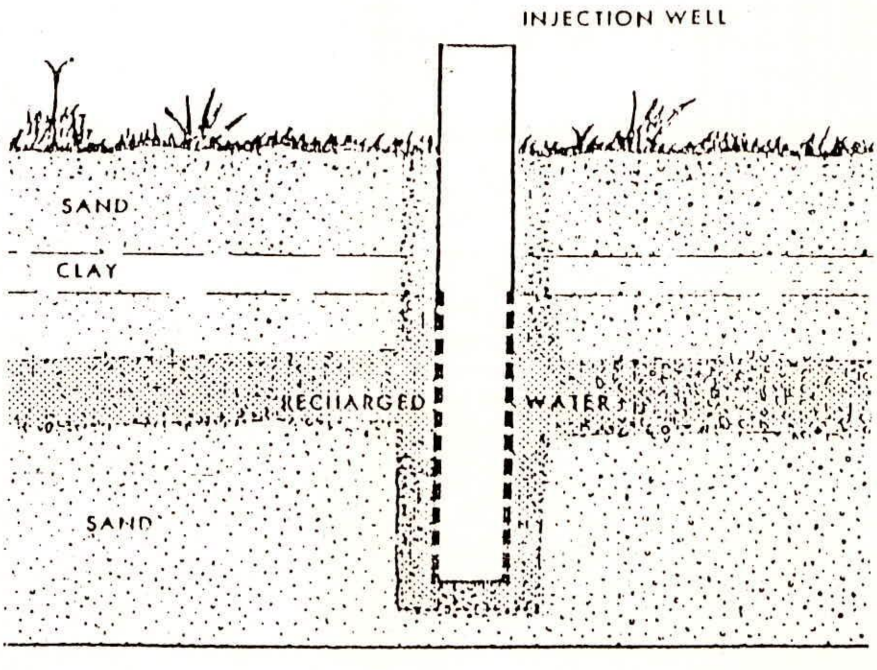

Fig. 4 Groundwater conservation by Injection well

Pathak (1985) reported that in a study in the Central Mehsana (Gujarat) where sufficient water is available from Saraswati river during monsoon period as well as during early part of summer season. Experiment with an injection well at the rate of 225 m/day for 250 days, there was a buildup of 0.6 to 1.0 m in wells 150 m away.

Sinha (1985) reported the feasibility of aquifer recharge in Ghaggar river basin. An area of 42,200 km. Comprising parts of the Himachal Pradesh (560 km), Haryana (13,400 km) Punjab (14,800 km) Rajasthan (13,300 km) and Chandigarh (114 km).

4.3 Subsurface dams

The ground water dam restricts the ground water flow and stores the water below the ground surface into the aquifer. The ground water dam, restricts the flow and raises the ground water table or diverts the ground water flow to recharge nearby aquifers. The construction of ground water dams is not a new concept. Various small scale ground water damming techniques have been developed and adopted all over the world. The underground dams have following advantages over the surface dam structures.

a. No evaporation from storage takes place.
b. No siltation in the reservoir takes place.
c. The potential disaster like collapse of dam is not there.

The identification of site for construction of dam is most important part and is selected considering the following aspects;

a. Developed in great scarcity area
b. Climatological, topographical and hydrological factors should be carefully considered.
c. Technical possibility of dam construction

Small scale structures constructed for ground water storage are practiced in various parts of India. The oldest one is Ottapalam in Palghat district constructed in 1962-64. Two subsurface dams are also constructed by Central Ground Water Board, one at Government Seed Farm (Ananganadi in Palghat district) and other is Ottapalam at Agricultural University Farm Kerala.

5.0 WATER CONSERVATION IN DOMESTIC USE

Throughout history, a readily available and usable water supply has been a prime influence upon where choose to live, work and build. Thus, to varying degree, water resources developed had moved forward hand in hand with the growth population, irrigated agriculture and industry. For meeting the needs of the future population which is expected to be 1000 million by the end of the century, a total of 2275 million liters per day for domestic uses alone will be required. The per capita consumption of water with organized water supply is higher than, without it.

As regards livestock, it can be categorized into large animal, small animal and fowl. These are expected to increase to 276,132 and 214 million in the year 2000. It has been broadly estimated that the present average daily water use per head is of the order of 40 liters for large animals, 5 litres for small animals and 30 litres per hundred birds for fowl. Table 6 gives a rough estimate of per capita requirement of water in year 2000 and 2025.

The drastic demand of water necessitates the strategies for water conservation in domestic water use in rural and urban areas. In rural areas the major problem is to increase the availability particularly in the non-monsoon season. In urban areas the main concern is how to reduce the losses and wastage and curtail the demand. For increasing the supply in rural areas strategies such as rain water harvesting and desalination of sea or brackish water are promising.

Table 6: Rough estimates of domestic water supply.

	Percentage of population			Per capita daily rate in litres		
	1974	2000	2025	1974	2000	2025
1. Rural Population						
a. Served with organised water supply	5	70	100	45	60	60
b. Not served with organised water supply	95	0	-	25	25	-
2. Urban Population						
a. Served with organised water supply						
i. for domestic excluding water born sanitation	40	45	10	90	115	115
ii. For domestic purposes including waterborne sanitation	30	50	90	135	180	180
b. Not served with organised water supply	30	5	-	45	45	-

Source: Water Resources of India

5.1 Roof water harvesting

Roof water harvesting is common in areas having high rainfall intensity well distributed in the year e.g. Himalayan areas, North-Eastern States, Andaman Nicobar, Lakshadweep Islands and southern parts of Kerala and Tamil Nadu.

Water conservation by harvesting of rain water is being increasingly followed for meeting the drinking water needs of rural areas particularly during the periods of drought. There are many methods available for harvesting of rain water. The method is site specific. Mostly eroded type of catchment with gentle slopping ridge and drains are used to collect the rain water into ditches. 5 cm of runoff in 2 hectare catchment provides about one million litres of water. This can serve the needs of a population of 62 persons at the rate of about 40 litres per day per person. To minimise the seepage and percolating losses, plastic and artificial rubber membranes can be used. The flow from roofs of houses may also be collected using galvanized iron sheets, into a channel fitted on the edge of the roof. This water can be stored adjacent to the house after screening out the impurities.

Before supplying for human consumption the raw water from the pond should be filtered through a sand filter and kept in a PVC tank connected to a hand pump for withdrawal. In spite of certain limitations rainwater harvesting will be beneficial for providing drinking water to human beings as well as cattle in areas lacking alternative sources.

5.2 Desalination

To augment the depletion of fresh water resources in coastal areas due to excessive abstraction, desalination of sea water or brackish ground water can be tried. Different methods of desalination like distillation, electrodialysis and reverse osmosis are available. Selection and use of these processes are site specific. Although there have been considerable efforts to reduce costs, desalinated water is still expensive. There are many operational problems. However, where water is scarce, desalination may prove to be economical when compared to the cost of transport of fresh water over long distances by trucks or rail tankers. Mobile desalination plants which use the reverse osmosis process have also been built by Bharat Heavy Electrical limited. There is a need to develop economically viable desalination plants to meet the needs of hard-core drought prone areas and coastal areas.

5.3 Water conservation in urban water supply

Water conservation measures in urban water supply should be mainly demand oriented. They may include use of water saving fixtures, leak detection in the distribution systems, preventive maintenance and educating the public regarding efficient water use.

Water saving fixtures: Water demand can be significantly reduced by modification of pan design to consume less quantity of water for flushing and introduction of low volume flushing cisterns. Each time a toilet is flushed, about 12 litres of drinking quality water is turned into waste water. It has been reported that in West Germany most toilets work with only 9 litres and in Scandinavia 6 litres toilets have been routine since 1975. In this respect, the 2 pit latrine system which is being advocated in recent times, needs attention. Against 12 litres of water required for flushing in the conventional system, the 2 pit system requires only about 2 to 3 litres of water.

There is also a need for review and adoption of more efficient designs of sewerage systems to minimize water requirements. Conventional water borne sewerage system requires a large quantity of water for proper functioning. The conventional system requires a minimum flow in the sewer to maintain dry weather flow and for avoiding deposition of solids in the sewer.

Ensuring public awareness for water saving habits will also go a long way in minimizing avoidable wastage. This can be achieved through voluntary organizations and mass media.

Leak detection: Leak detection and repairs is one of the most cost effective measures for conservation in urban areas Especially in older or poorly maintained water systems, a large share of the supply often seeps out through broken pipes and other faults in the distribution network. Many major cities in the country are losing as much as 17% to 44% of their water supplies in this way. These are costly losses because this unaccounted for water is secured, stored, treated and distributed but never reaches the user. The major portion of leakage has been found to occur in the house service connections through corroded service pipes, couplings, ferrules and disused connections. The leakages also results in deteriorations water quality causing outbreak of water borne diseases. Regular and continuous leak detection and preventive maintenance programme needs to be compulsorily adopted in all urban water supply projects.

Waste water reuse: Nearly half of the total domestic water is used for bathing and cooking. The waste water produced by these uses is not critically polluted and with a little treatment to remove solids and probably odour, can be reused in toilets for flushing. The effluent from toilets can also be reused after partial treatment for purposes like gardening, fire fighting, etc. Almost a zero-effluent situation can be achieved in this way. This can be attempted in new urban residential colonies, 5-star hotels, etc.

Municipal waste water, after some form of terminal treatment, can be applied on land. The remaining nutrients, organics and water enter into the natural system of recycling and used by plants and microbes of soil or retained by soil. In the process, excess water percolates through the soil medium, gets renovated and ultimately recharges the ground water. This ground water is again abstracted for reuse as water supply to the community.

6.0 WATER CONSERVATION IN AGRICULTURAL USE

The rapid industrialization in India has not been able to shift the status of our economy from agrarian to the industrial. Even today more than 40% of net domestic product is contributed the agriculture sector to our economy. In other way agriculture sector is the biggest industry providing highest contribution to the economy, generating maximum employment and utilizing maximum water resource (Table 2).

Even though agriculture is of vital importance to the health of our economy and available water resource being directly linked with increased productivity in the agricultural sector, yet we have not been able to utilize our water resources to the maximum advantages and economy. In spite of all efforts, only around 70 m. ha. of the cropped area could be brought under irrigation. More than 60% of the cropped area, pasture and forest lands, still depends upon natural precipitation.

An increase in crop yield is quite possible without significant increase in water used by selecting suitable crops and varieties adapted to climatic conditions of the locality and through agronomic management such as using good quality seeds, sowing at the appropriate time and depth, placing balance fertilizers in soil, as well as protecting crops from infestation of weeds, insects, pests and diseases. The use of anti-transpirants, growth retardants, mulches, shelter belts, etc. have been found in water conservation resulting in increase of water use efficiency.

6.1 Water harvesting

The rain water harvesting is more so important because the country looses 50-60 percent of rainwater resulting in acute soil moisture deficit. Inspite of all efforts, only about 70 m. ha. of cropped area could be brought under irrigation. More than 60 percent of cropped area still depends on natural precipitation.

In low rainfall area, it is not sufficient even to meet the crop sowing moisture requirements. Under these circumstances water harvesting techniques are the principal means of water conservation to enhance agricultural production.

In arid regions where, not much opportunity exists for harvesting and storing of rain water, harvesting is done with the adoption of efficient measure of moisture conservation. Plastic sheet, butyl rubber and metal foil have also been used to cover the soil in water harvesting operations.

6.1.1 Water harvesting by microcatchments

The precipitation over an uncultivated catchment is harvested and the runoff is used to cropped micro-watershed. Different method as (a) Interrow water harvesting system, having micro catchments prepared with a two bottom ridge farming ridges and furrows and (b) modified inter-row water harvesting system having micro-catchments prepared with two opposite runs of single mould broad plough have been suggested by Yadav (1979).

The inter plot harvesting provide advantages over inter-row harvesting in improving the productivity. In the event of drought during life cycle of kharif, water harvesting becomes extremely useful to provide supplementary irrigation to the crop. In case of no drought, the stored water provide pre-sowing irrigation. The studies conducted at Central Arid Zone Research Institute, Jodhpur (Mann and Singh, 1977) have shown that the total production by cropping only two third of the field (leaving one third for micro-catchments) by adopting the runoff farming is the same as obtained from conventional cropping on a flat surface. The runoff farming offers potential for increasing and stabilizing yield, thereby lowering the risk of crop failure.

Kolarkar et al (1980) worked on water harvesting and runoff farming on three catchments of western Rajasthan. The ratio of catchment area to command are along with the rainfall and runoff potential is reported in Table 7. By water harvesting techniques it was possible to grow winter crop without irrigation.

Table 7: Results of water harvesting and runoff farming.

Item	Jaislmer	Siwana	Phalodi-Bap
1. Mean annual rainfall.	217.000	310.000	240.000
2. % of rainfall in monsoon	87.200	83.700	78.200
3. Ratio of catchment to command area	11.270	2.220	8.220
4. Rainfall potential of catchment, m.cm./km.	0.1029	0.1078	0.1406

Better irrigation scheduling practices can also improve the irrigation efficiency. For example, it is now well established that water is required more at critical stages of crop growth and the water stress during other periods has negligible impact on yields. In case of rice crop, traditionally it is considered necessary that the crop be submerged. Submergence has been found useful since it checks weed growth, regulates temperature and promotes algae nitrogen fixation. However, several studies have shown that considerable water is saved by reducing the depth and frequency of submergence. Farmers should, therefore, be made aware that more water does not necessarily mean more yield. Greater efforts should be made to train farmers in the use of irrigation scheduling methods appropriate to their model of production. Agricultural extension programmes could help spread the benefits of these water conservation techniques.

6.1.2 Water harvesting by land treatments

The conservation of moisture, particular in arid and semi arid regions is of most importance. In low rainfall area, the water is not sufficient to meet the crop water requirement. So there is need to increase the surface runoff in scanty rainfall areas by reducing the infiltration capacity of the soil through different land treatments, which can be served for agricultural purposes in drought prone area. A small storage structure for water harvesting is shown in fig. 5. The various method being adopted for increasing runoff are classified as;

a. Cleaning sloping surface vegetation.
b. Vegetation management.
c. Reducing soil permeability by chemicals.
d. Surface binding treatments.

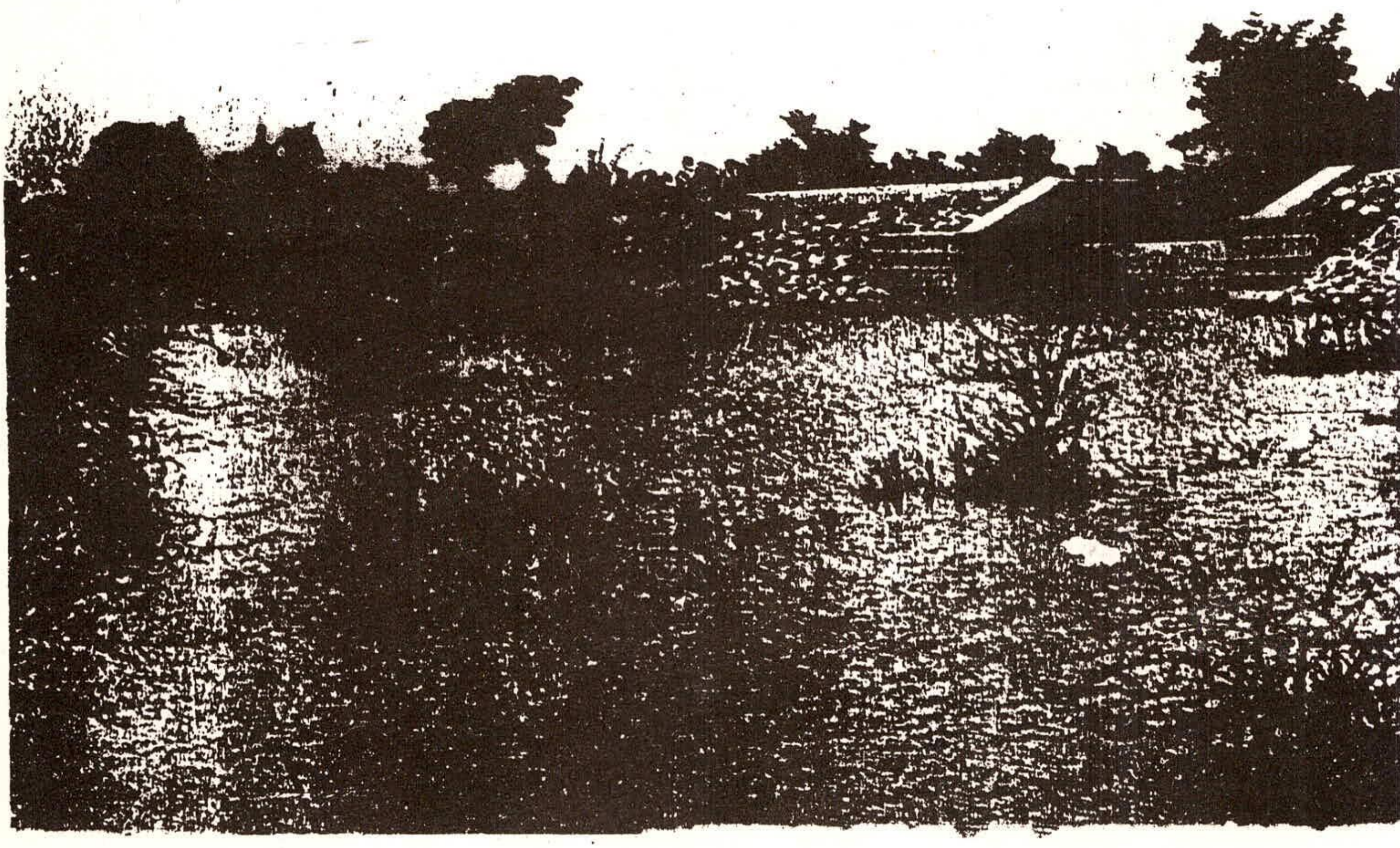

Fig. 5. A small storage structure for water harvesting

Land cleaning has been in existence as a runoff inducement method for thousands of years due to its simplicity. All the runoff can be utilized by surface cleaning on fairly impervious catchments. Removal of obstruction can be expected to increase the velocity of runoff and also increases surface soil erosion. The surface treatments such as rock clearing (Evenari et al 1971), smoothing and comparing (Frith, 1975) are usually done in combination (Anaya and Towar, 1975; Fink and Ehrler, 1979). For smooth catchments, runoff efficiencies ranging from 20-35% have been reported (Fink et al 1980). The land use changes have major influence on the hydrology of the basin it increases or decrease the water yield from basin. Almost every well designed experiment has shown yield from basin. Almost every well designed experiment has shown increased water yield as a response to forest cutting. In India the water yield by cleaning and vegetative management has not been well adopted. While adopting these methods for water yield it should be kept in mind that the water yield should not be erosive.

Vegetation Management can alter the water budget of watershed by modifying the hydrologic processes involved therein. The very concept that different vegetation covers have different evapotranspiration requirement, is used for vegetation management approach. The possible vegetation management strategies include conversion of areas immediately adjacent to stream channels to runoff-enhancing vegetation covers, clearing the forest or shrub cover in uniform or irregular strip cuts, and thinning overstorey densities. All available research works indicate that their is an increase in water yield when forests are converted to grassland. Studies reported from Queensland, Australia indicated that the conversion of tropical forest catchment to pasture resulted in 10.2% increase in water yield during first two year (Queensland Department) of Forestry, 1977, Ffolliott et al (1986) indicated that under Arizona watershed program, conversion of forest overstoreys to grass cover yielded annual water yield increase from 67 to nearly 95 mm. Vegetation management practices have significant potential to increase water yield from watersheds. However, the results reported so far have been mainly of studies conducted in small watersheds which may not be applicable directly to small catchments.

Strip farming is modification of micro-catchment farming technique rather than having individual catchments, the farmed area is divided into a series of sloping terraced strips from which water will flow off into the farmed strips on either side.

Water harvesting and runoff agriculture are old farming techniques and have been fruitful in water short areas to increase agricultural production. The techniques have great merit for they will permit a flourishing agriculture in dry areas where the annual rainfall would argue against any agriculture. The technique require wise use of land with careful terracing and ditching in order to move the water from the collection area to the area of use. The rainwater harvesting structures in different agro-climatic zones are reported in Table 8.

Table 8 : Recommended rainwater harvesting structures in Different Agro-climatic zones.

S.No.	Agro-climatic zone	State of the art	Recommendations
1	2	3	4
1.	Humid North-Western Himalayans	i) Roof water harvesting ii) Diversion of perennial springs and streams in storage structures iii) Village Pond iv) Collection from hill slope	Improvement in roof structures and use of proper material such as corrugated sheets for generating higher run off and with arrangement of foul slush diversion system and proper storage structure for checking water from contamination
2.	Himalayan foot-hills	i) Collections from hill slope ii) Village ponds	Improvement in roof top harvesting system as above
3.	Humid High Rain-fall North Eastern Zone	i) Roof Water Harvesting ii) Diversion of perennial springs and streams in a storage structure (tank)	- do -
4.	Humid Assam Bengal Plains	i) Tank ii) Anicut/check dam iii) Gully plugging	Improved design of tank for minimising evaporation and seep-age losses, control of sediment load and water pollution
5.	Sub-humid & humid Sutlej Ganga Allu-vial zone	i) Pond ii) Check dam iii) Gully plugging iv) Contour bunding	- do -
6.	North-Western Semi-arid & Arid Zone	i) Nadi ii) Tanka iii) Khadin iv) Percolation tank	i) Adoption of improved designing of Nadi and Tanka ii) Sand filled reservoir

Contd.

		v) Anicut vi) Gully plugging vii) Contour bunding	iii) Sub-surface barrier iv) Flat batter tank
7.	Central Semi-arid Vindhyan Zone	i) Pond ii) Check dam iii) Contour bunding iv) Gully plugging v) Sub-surface dykes	Same as above
8.	High rainfall High runoff Chotanagpur Plateau	Same as 4	Same as 4
9.	Assured rainfall Deep Black soil Malwa Plateau & Narmada Basin	i) Ponds ii) Check dams iii) Subsurface dams	Improvement of Existing Systems
10.	Variable Rainfall South Central Deccan Plateau Zone	i) Pond ii) Check dam iii) Percolation tank iv) Bandhara v) Gully plugging vi) Sub-surface dam vii) Contour bunding	i) Flat batter tank ii) Selection of suitable site and improvement of existing system, better water management
11.	Chhatisgarh Plateau Zone	Same as 10	Same as 10
12.	South Eastern Brown/Red Soil Zone	i) Ponds/Tanks ii) Percolation tanks iii) Sub-surface dams	Improvement of existing systems
13.	Southern Variable rainfall, Mixed Soil Zone	i) Pond/Tank/Kunta ii) Nadi iii) Check Dam iv) Percolation tank v) Sub-surface dam vi) Gully plugging	i) Flat batter tank ii) Selection of suitable site and improvement of existing system for better water management
14.	Southern bi-model Rainfall Zone	i) Ponds/Tanks ii) Percolation Tanks iii) Gully plugging iv) Contour bunding v) Check dams	i) Improvement of existing System
15.	Eastern Coromandal	i) Pond/Tank/Kunta ii) Nadi iii) Check dam	i) Adoption of improved design of Nadi and tank

Contd.

		iv) Percolation Tank v) Sub-surface Dam vi) Gully plugging	ii) Selection of suitable sites and improvement of existing system for better water management
16.	Western Malabar	i) Pond/Tank/Kunta ii) Check dam iii) Percolation Tank iv) Contour bunding v) Bandhara vi) K.T. Weirs vii) Sub-surface Dam	i) Improvement in existing system, better water management ii) Construction of structures at suitable sites

Source: Anony., 1989.

6.2 Conserving by lining of irrigation channels

A major part of water is lost in irrigation distribution system by seepage, breaches and by ponding of water in depression and irregularities in the channel system. The loss in the field distribution system is even more significant in areas irrigated by wells, as the unit cost of developing resource is high. Irrigation canals are lined for several purposes, namely:

1. To reduce seepage losses, thus increasing conveyance efficiency and decreasing drainage problems.

2. To ensure against uninterrupted operation due to breaks.

3. To provide a more efficient cross section increasing side slopes. by reducing the roughness coefficient, by eliminating weed and moss growth, and by increasing channel slope without danger of erosion.

4. To reduce maintenance. In area where water is in short supply one of the most important benefits from lining canals is the saving of water, which then becomes available for other beneficial uses. As discussed previously, losses in earth canals are sometimes a higher percentage of the water diverted. One of the reasons for emphasizing linings is that canal losses are usually somewhat easier to control than losses due to poor application and water distribution on a field.

Canal linings my be constructed with a large number of materials, such as concrete, rock masonry, brick, colloid clay soil mixtures, soil cement, asphalt, rubber and plastic. Materials which are most satisfactory meet all the purposes described above. In laterals and farm ditches, Portland cement concrete and asphalt are the two most common materials. The selection of a lining material will depend largely on cost and availability of materials, soil conditions, cross section and length of the canal, and comparative annual costs. Average annual cost, including maintenance and value of the water save, is the best basis for making a decision.

A study conducted by Central Power Commission 1967 indicated that around 71% of the water is lost due to seepage and evaporation. Table 9 indicates the losses in irrigation system.

Table 9: Water loss in canal irrigation system.

System characteristics	Canal	Distributaries	Water courses	Field loss	Total loss
1. Entire system unlined	15	7	22	27	71
2. Only canal lined	4	7	25	30	66
3. Canal and distributary lined	4	2	26	32	64
4. Whole system lined	4	2	6	42	54

6.3 Conservation by irrigation methods

In India, sprinkler irrigation is being adopted in places of hilly terrains, for various plantation crops. The use of sprinkler system has already been introduced in the State of Haryana since 1970. Other states like Rajasthan, Uttar Pradesh, Karnataka, Gujarat, Maharashtra have also started sprinkler system of irrigation and more areas are proposed for sprinkler irrigation in areas of highly undulating topography where leveling or grading is expensive and the use of conventional methods of water application is impractical.

The Drip Irrigation system is said to be 50% more efficient than the conventional irrigation system of flooding furrow, basin etc. It has been estimated that water loss in conventional methods is 30-45% when it is hardly 6 to 9% in sprinkler and 1-2% in drip irrigation.

The earliest drip irrigation system consisted of plastic capillary tubes of small diameter (1 mm) attached to larger pipes. In 1960 Israel was successful in using the system in desert area of Nigeria and Arava. In India, it is of very recent origin, and has started on a limited scale in Tamil Nadu, Karnataka, Kerala and Maharashtra mainly for coconut, coffee, grapes and vegetables. The comparison of sprinkler and drip with other irrigation methods is as follows in Table 10.

Sprinkler irrigation system: Sprinkler irrigation system distributes water by spraying it over the fields, simulating that of natural rainfall, the spray is produced by the flow of water under pressure through small perforation and nozzles in

Table 10: Water loss under various irrigation methods.

	Normal condition	Hot climate
Surface irrigation	30 - 45%	35 - 50%
Gate pipe irrigation	15 - 20%	20 - 25%
Sprinkler irrigation	6 - 9%	10 - 20%
Drip irrigation	1 - 2%	2 - 3%

Source: II National drip seminar.

pipelines. The pressure is usually provided by pumping water from wells, tubewells, river, canals and reservoir. With careful selection of nozzle sizes, operating pressure and sprinkler spacing, the amount of irrigation water required to refill the crop root zone can be applied uniformly at a rate to suit the infiltration rate of soil, thereby obtaining efficient water application. Sprinkler irrigation is the best method to use on soils that have steep slopes, undulating or irregular topography and on soils that are too shallow to level. It is difficult however to sprinkler irrigate if water intake rate of the soils is less than 4 mm/hour. Most crops can be sprinkler irrigated (except rice, tobacco and jute), it may be difficult in moving portable lateral lines in tall crops such as corn and that soft fruits should be protected from the spray when they are ripening : Wind disturbs the spray patterns and usually reduces efficiency of the system. A careful selection on the right equipment and proper operation of the system are necessary where strong wind occurs in the area to be sprinkler irrigated.

A study done on the use of Sprinkler Irrigation system in Haryana in year 1982 has revealed the following facts in respect of impact of the system. The study revealed that due to introduction of sprinkler irrigation system the gross irrigated area of the sampled farmers had increased significantly from 1366.25 acres before installation of sprinkler sets to 2503.50 acres after installation showing an increase of 83.24 percent. Similarly, the net irrigated area where the sprinkler sets were installed had also increased from 1089.25 acres to 1815.25 acres showing an increase of 66..65 percent.

Drip irrigation system: Drip system is a relatively new method of irrigation in which water and other nutrients are delivered directly to the root zone according to plant needs. Thus, making the most efficient use of water compared to conventional methods of irrigation such as furrow, border, basin and even the sprinkler system. The water less and water use efficiency compared to other system is very high as already stated.

A well managed drip irrigation system allows usage of poor quality of water, because water is applied continuously, the root zone never dries out and the salt concentration moves away from the root zone. Thus accumulated salt is leached to the edge of the wetted soil mass. Since a much smaller quantity of water is applied to the soil, the total salt thereby applied is likewise lower.

The Sprinkler and Drip Irrigation systems are the most efficient in the terms of water conservation, but these are limitations of that use and adaptability. Both the system are expensive. More over drip can only be used for crops, vegetables and orchards where there is enough spacing between two plants. Due to high cost farmers would not use them where water is available in good measure and low value crops even for high value crops, and orchards etc. the farmers would need loan and subsidy. They would also need proper after sale service. For India large areas are drought prone (more than 90 districts) where water is scarce. In such areas sprinkler and drip irrigation should be encouraged. One most important aspect is to reduce the cost substantially by extensive R & D efforts. Standardization of equipment and provision of adequate after sale service is another important requirement.

The conventional method of irrigation such as furrow irrigation, border irrigation, basin irrigation, corrugation irrigation, etc., cannot efficiently control the water applications rate, thus giving rise to over irrigation and loss of water. The use of drip or trickle system (Fig. 6) of irrigation conserves the water over conventional methods of irrigation. Some of the advantage of drip or trickle systems over traditional system are efficient use of water, increase in crop yield, low labour cost and elimination of water logging.

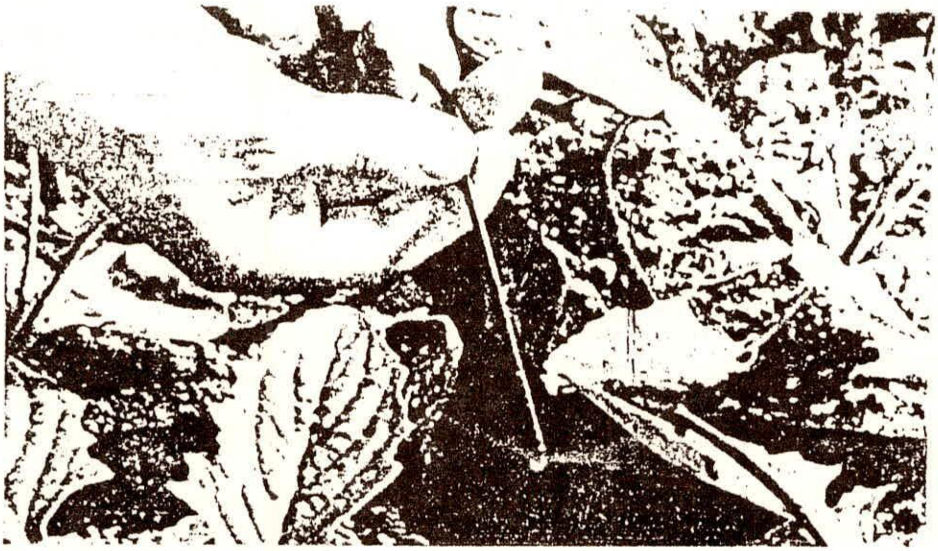

Fig. 6. Use of drip/ trickle irrigation system for water conservation.

Several research institutes including Indian Agricultural Research Institute, New Delhi, Central Arid Zone Research Institute, Jodhpur and Tamil Nadu Agricultural University, Coimbatore have worked on drip irrigation system with several vegetable crops. Some of the results are reported in Table 11.

6.4 Conservation by mechanical measures

The conservation of moisture, particularly in arid and semi-arid regions is of upmost importance. The rainfall distribution is not uniform and most of the rainfall is lost as runoff. The means of conserving moisture fall into three categories: increasing infiltration, reducing evaporation and preventing unnecessary plant growth. In practice these can be accomplished by such practices as farming practices, level terracing and contouring, mulching and selecting suitable crops. Such practices as contour farming and strip cropping are effective in water holding capacity and increasing the total infiltration and thereby conserving more moisture. Terracing is a good moisture conservation practice where the slopes are gentle enough so that the water can spread over a relatively large area. The greater the amount of mulch on the surface the greater the quantity of moisture conserved.

Table 11: Water use and yield in drip and control plots.

Sl.No.	Crop	Water used, cm		Yield , kg/ha	
		Drip	control	drip	control
1.	Tomato	10.76	49.20	8872	6186
2.	Bhindi	10.00	40.50	11000	10200
3.	Cotton	15.2	70.60	3255	2604
4.	Sugarcane	92.1	132.00	1129C	7591
5.	Beetroot	17.73	85.76	6887	6571

Singh et al. (1988) given treatment like bunding terracing, check dams, pasture development, afforestation and water harvesting in the catchment Mahi-ka-Dana (Rajasthan). He was able to conserve peak runoff rate and runoff value by 85% and 84% respectively. In another study by Singh and Das(1981) the peak discharge rate was reduced by 37%.

6.4.1 Conservation by farming practices

Another way to conserve moisture is by employing farming practices measures which have great importance in arid and semi arid regions for crop production as well as for soil erosion control. These measures may help in either increasing infiltration, reducing evaporation or preventing unnecessary plant growth. In practice there can be accomplished by the following;

a. Contour farming
b. Strip cropping

Contour faring is the practice of performing field operation, such as ploughing, planting, cultivating and harvesting approximately on the contour. The small ridges and plant stems in the contoured row hold water and thus prevent runoff. The ridges are most effective in row crops, but the water holding ability of the ridges supplemented by plant stems, makes contorting valuable for small grains also.

Strip cropping is the practice of growing alternative strips of close growing and intertilled crops in the same field. Strip cropping is not a single practice but it is a combination of several good farming practice, particularly crop rotations, contour farming and cover cropping and may also include conservation tillage cooperation, and stubble mulching. When strip cropping is combined with contour tillage or terracing, it effectively divides the length of the slope, checks the velocity of runoff, filters out soil from the runoff water and facilitates absorption of rain. The three general types of strip cropping are:

a. Contour strip cropping
b. Field strip cropping
c. Buffer strip cropping

In contour strip cropping the crops are arranged in strips or bands on the contours at right angles to the natural slopes of the land. Generally the strips are cropped in a definite rotational sequence. Field strip cropping consists of strips of uniform width running generally across the general slope and the practice is recommended only in areas where the topography is too irregular or undulating. Buffer strip cropping consists of strips of some grass or legume crop laid out between contour strips of crops in the regular rotation. They may be even or irregular in width and can be placed on critical slope areas of the field.

6.4.2 Conservation by engineering practices

A terrace is an earthen embankment or ridge constructed across a slope to control the runoff and minimise soil erosion. The function of terraces is to decrease the length of the hill-side slope, thereby reducing sheet and rill erosion, preventing the formation of gullies, and retaining runoff in area of inadequate precipitation (Fig. 7) The two major types of terraces are:

a. Bench terrace which reduces land slope,

b. Broad base ridge type terrace which removes or retains water on slopping land.

On the basis of primary function broad base terrace is classified as graded or level. Graded terrace has a constant or variable grade along its length and is used to convey the excess water at a safe velocity into a vegetated channel or outlet. A level terrace follows the absolute contour, in contrast to a graded terrace. Level terraces are recommended only in areas where the soil is sufficiently permeable and where conservation of moisture for crop use is particularly important. Level conservation terrace consists of an earthen embankment and a very broad flat channel that resembles a level bench. The relationship of this type of terrace to the conventional level terrace, both in terms of cross-section and in relative moisture storage pattern.

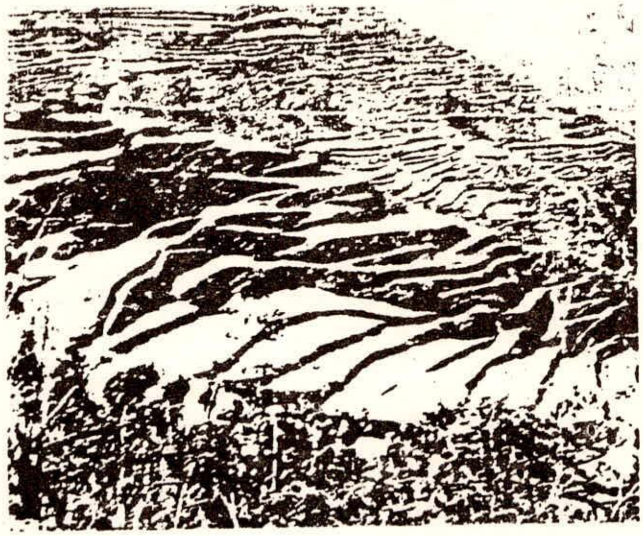

Fig. 7: Bench terracing along arable lands to reduce runoff water conservation.

6.4.3 Conservation by mulching

At IARI, Delhi, Ghosh et al (1979) conducted various experiments to determine effectiveness of different mulches for moisture conservation. They reported that in all experiments the polyethylene mulches were found to conserve more moisture than the straw mulch. Among the polyethylene mulch although showed greater moisture conservation than the black polyethylene. They did not differ much in their effect on soil moisture. Higher soil moisture conservation by plastic films were observed by Bhatia et al (1966). They compared polyethylene and straw mulches on irrigated and cotton and obtained similar results. Higher rate of soil moisture conservation and higher yield of crops by use of black plastic mulches have been reported by (Emmert, 1956, 1957; Army and Hudspeth, 1959 and Willis et al, 1963 cited in Ghosh et al (1979). Ghosh et al (1979) also reported that different coloured materials of mulches (while reflecting types and black absorbing type) were observed not to differ much in their ability to conserve moisture, however, both are better than the straw mulch.

Many studies are available on soil erosion by tillage methods and the method by which residue is left on the soil surface. The prime process by which the soil erosions controlled is the conservation of water.

A study of Mannering and Meyer (1963) showed the effect of straw mulch applied to freshly ploughed and discard soil. They showed that, for 12.5 cm of simulated rain straw mulch at 1 t/ha increased total) infiltration by 2.5 cm and 7.5 cm respectively.

It was shown by Wischmeier and Mannering (1965) that the runoff 40% less where the residue were mixed into the soil each year by ploughing, than where storer was removed at harvest. A number of studies are reported by Wischmeier (1973) concerning the effect of mulches and residues left on the surface of the soil from the previous crop.

Crop residues as surface mulches for water conservation have big potential. Relatively small amounts of residues may be effective in enhancing the infiltration and reducing runoff but larger amounts may be required to significantly cut down evaporation loss. Crop residues mulch are most effective in cutting down evaporation during wet season when there is sufficient moisture in soil and their effectiveness gradually decreases with time due to drying of soil unless the thickness of the residue mulch is increased considerably. Sharma and Gupta (1990) indicated the conservation of moisture in profile during post-rainy season in unirrigated crops (Table 12). Application of Sorghum cob-husk crop residues of soya bean and safflower applied as surface mulches increases the water use efficiency in black clay soil. Surface residues appear to have greater value for water conservation during rainy season than in post rainy season.

Table 12: Soil moisture losses from bare black clay soil as influenced by thickness of soil and straw mulch in 42 days period.

Mulch treatments	Low evaporative demand		High evaporative demand	
	Evaporative loss(mm)	Reduction (%)	Evaporative loss(mm)	Reduction (%)
No mulch	84.4	-	130	-
Wheat straw 0.5 cm thick	75.5	10.3	120.0	7.7
Wheat straw 1.0 cm thick	74.1	12.2	113.0	13.0
Wheat straw 1.5 cm thick	67.8	19.7	105.0	19.2
Wheat straw 2.0cm thick	56.2	33.5	99.0	23.8
Soil mulch 1.5 cm thick	76.8	9.0	90.0	30.8
Soil mulch 3.0 cm thick	68.3	19.1	80.0	38.5

Source: Sharma and Singh, 1984.

The utility of clean polyethylene as a mulch material is very well known but there are certain limitations to its large scale adoption. Quick desiccation of seed zone limits the emergency of crops in the region where use of these mulches may have practical significance. Sharma and Gupta (1990) indicated that plastic mulching for 2 weeks prior to planting of unirrigated wheat induced redistribution of moisture in the profile, as a consequence the relatively dry seed zone rewetted. The moisture content of the upper 10 cm soil layer increased from 31 to 39 percent by volume resulting in early establishment of wheat seedlings, 36 percent more consumptive use of profile moisture and 10 percent additional seed yield. While in unsaturated plots there was a net depletion of moisture from 10 cm top soil layer due to evaporation from 31 to 23 percent during this period.

6.5 Reuse of irrigation water

Not the entire water applied on the agricultural farms is consumed by evapotranspiration or percolates into the soil. About 50% of the water flows out of the farms either as surface flow or, where there is a drainage system, is collected by the drains and reaches an outflow channel. The water drained from agricultural farms can be pumped back again and reused for irrigation.

Where waste water is used for irrigation, crops must be selected carefully, not only do they different in their ability to take up nitrogen, phosphorus and potassium but some are harmed by or may concentrate heavy metals such as cadmium, copper, nickel and zinc. Unless removed, heavy metals could accumulate in the soil or percolate to ground water possibly.

Nearly half of the total domestic water is used for bathing and cooking. The waste water produced by these uses is not critically polluted and with a little treatment to remove solids and probably odour, can be reused in toilets for flushing. The effluent from toilets can also be reused after partial treatment for purposes like gardening, fire fight etc. Almost a zero effluent, situation can be achieved in this way. This can be attempted in new urban residential colonies, 5 star hotels, etc. Municipal waste water, after some form of terminal treatment, can be applied on land. The remaining nutrients, organics and water enter into the natural system of recycling and use by plants and microbes of soil are retained by soil. In the process excess water percolates through the soil medium, gets renovated and ultimately recharges the ground water. This ground water is again abstracted for reuse as water supply to the community.

Another area in which water conservation can be achieved is the reuse of treated domestic waste water for irrigation purposes. Waste water can be looked upon as a source of additional water. It has been estimated that less than 20% of domestic water supply is consumed, while the rest is discharged as waste water. In a large number of cafes, waste water which is less polluted can easily be treated and used for purposes for which water quality does not have to be brought to a high level of purity. Using treated waste water for irrigation can be a very favourable proposition for releasing fresh water sources for domestic purposes. The nutrients present in treated waste water can be an added advantage for agricultural production. The reuse of domestic waste water for irrigation purposes is already being followed in some cities in the country. There is also a system of mixing the treated waste water with fresh water before using it for irrigation. Such uses can be extended to other areas of the country wherever feasible. However, incomplete knowledge of the health effects of various pollutants is still a barrier to waste water reuse. Ways to reduce the monitor levels of bacteria in waste water are well understood, but much is unknown about viruses, heavy metals and organic chemicals. Where waste water is used for irrigation, crops must be selected carefully. Not only do they differ in their ability to take up nitrogen, phosphorus and potassium but some are harmed by or may concentrate heavy metals such as cadmium, copper, nickel and zinc. Unless removed, heavy metals could accumulate in the soil or percolate to ground water possible usually related to using saline water for raising salt a resistant crops and mixing of sweet water with saline water Salt resistant varieties of crops have also been developed in recent times.

6.6 Forecasting runoff for water use planning

How efficiently the monsoon runoff can be predicted as on July 1st, August 1st, September 1st and October 1st is of prime importance for water use planning in water scarcity areas where surface water reservoirs supply water for urban area. Knowing the status of water availability by month of September/October, the decisions to allocate water from reservoir to various uses can be accordingly planned. In irrigation reservoirs, depending upon the water availability status, drinking water use should be allocated top priority during water stress condition. In water supply reservoirs, depending upon the future water availability to be planned in advance to take care of future scarcity condition. National Institute of Hydrology has developed a technique to correlate monsoon runoff with the total runoff up to the end of June, July, August and September.

6.7 Weather forecasting

In view of the frequent occurrences of drought in the country attention is being paid on making forecast of weather with particular reference to monsoon rains. In fact, making forecast of weather has been in practice in ancient times as is evident from the following versus of the Mayur Chitraka: i.e. If there is no frost in Magha, no vigorous wind in Phalguna, no clouds in Chaitra, no hailstorm in Vaisakha and no scorching heat in Jyestha, there is insufficient rain in the rainy season.

In recent years successful forecasts have been made by the Department of Science and Technology in respect of monsoon rains. Use of long term weather records and correlation between changes in certain physical features like sea surface temperature with the ensuring weather conditions are being used to forecast weather conditions.

7.0 WATER CONSERVATION IN INDUSTRIAL USE

In industry, water is mostly used for cooling, process, steam, washing systems, cleaning, dissolving and mixing materials, etc.

On the basis of the prevalent norms of water use for various industrial products, the water requirement for the industrial sector in 1974 was of the order of 0.45 m. ha. m. The Planning Commission in their perspective plan has given the production targets for 1980-81 for the more important industrial products. Taking the water requirement for that year as base and assuming that it would double itself every ten years till the year 2000, the water requirement that year would be of the order of 3.0 m. ha m. Allowing for further technological improvement in the use of water, the water requirement in the year 2025 may be of the ore of 12 to 15 m.ha.m.

The water requirement for thermal power generation the year 1990-91 have been estimated as 398 billion kwh. say 400 billion kwh. It is expected that this would double itself by the year 2000. A rough estimate of water requirement for power generation is given in table 13.

Table 13: Water requirement for power generation.

		1974	2000
Total power generation	bkWh	71.0	800.0
Hydel power generation	"	28.0	140.0
Thermal power generation	"	43.0	660.0
Total water intake	m. ha.m	1.0	8.5
Fresh water intake	m . ha.m.	1.0	6.0

Source: Water Resources of India.

Most of the industrial production processes require large quantities of water. Apart from ensuring leakage control, water conservation strategy in industries should include introduction of appropriate technology to ensure efficient use of cooling and process water and necessary pollution control mechanisms. The quantum of water consumed by industries depends on the raw materials used and the processing technology followed.

A sound water budgeting in industry can reduced water demand to a considerably extent. Water conservation measures in industries should includes:

(i) Review of alternative production processes and technologies from water consumption point of view.

(ii) Ensuring sound plant maintenance practices and good house keeping, minimizing spills and leaks.

(iii) Optimization of treatment to achieve maximum recycling.

The dry cooling tower technique is one of the water saving methods that can be attempted. The economics of industrial water recycling vary greatly from one site to another. In deciding how much to recycle, any industry weights the combined costs of getting water and treating it prior to disposal with those of treating waste water for reuse within the plants. In many of the industries, recycling may offset its cost by recovery of valuable materials such as nickel and chrome. As water and waste water treatment costs go up, recycling will begin to pay.

REFERENCES

1.Anonymous, 1990. Rainwater harvesting, Deptt. of Rural Development, Ministry of Agriculture, Govt. of India, New Delhi, May, 1990.

2.Bhatia, P.C., M. Singh and N G Dastane. (1966). Use of synthetic products in the field of soil and water conservation. Indian J. Agron. Vol. 11, pp 158 - 165.

3. Brown, B.C.(1974). Study of Evaporation Control for Water Storages Using Plastic Mesh in conjunction with cetyl Alcohol, Proc.5th Int.Colloq.on Plastic in Agric. Budapest, pp.915-921.

4. Central Water Commission.(1991). Theme paper on Water Conservation, Water Resources Day, 1991.

5. Cluff, C.B. (1966). Evaporation reduction investigation relating to small reservoirs, Tech. Bull.177. Agri.Exp.Sta., Univ. of Ariz., Tucson, 1966.

6. Crow,F.R. and Manges, H.L. (1967). Comparison of Chemical and Nonchemical Techniques for suppressing evaporation from small Reservoirs, Trans. ASAE, 10, 172-174.

7. Cruse, R.R.,Harbeck,G.E. (1960). Evaporation Control Research, 1955-58. Washington, U.S. Gov. Printing Office, 45p (Geo.Survey Water Supply Paper 1480).

8. Dick, G.F. and Marchello, J.M.(1969). Effect of small surface waves on Evaporation through Mono-layers, Water Res. 5. 395-400.

9. Efolliott, P.F. (1986), Vegetation management for Increased Water Yield in Arizona, Arizona Agril, Exp. Station, Technical Bulletin 215.

10. Frasier, G.W. and Myers, L.E. (1968). Stable Alkanol Dispersion to Reduce Evaporation Proc. ASCE, J. Irrig. and Drain. Vi. 94.19-89.

11. Gosh, S. and A R Deb. (1979). Water flux, soil water depletion and evaporation from pulse crops under different mulches. Indian J. Soil Cons. Vol. 7(2), pp 26 - 29.

12. Kolarpar, A.S. Murthy K.N.K. and Singh N.(1980). Water harvesting and runoff farming in arid Rajasthan. Indian Jour. of Soil Conservation, Vol.8(2).

13. Mahmoud, T.A. and Bashi, N.K.(1980). Expanded Polystyrene Spheres as Evaporation Suppressors, Proc. Asset. J.Irrig.and Drain.Div.106, 163-173.

14. Mannering J.V. and Meyer L.D.(1963).The effect of

various roles of surface mulch on infiltration and erosion. Soil Sc. An Proc. 27, 84-86.

15. Mansfield, W.W. (1974). Reduction of evaporation. In progress in Aust. Hydrol., 1965-74, Aust. Nat.Comm.for Unesco, pp 15-18.

16. Mansfield, W.W.(1967). Evaporation Control in Australia, Water Research found. of Aust.,Rep.No.25,pp 5-9.

17. Mistry , J.F.(1981). Experiments on control of Evaporation in the Aji Lake at Rajkot in Gujarat. IAH Jour., V (1&2),pp.14-26.

18. Myers, L.E. (1965). Evaporation Retardants: Application by means of a water soluble Matrix, Science 148. 70-71.

19. Nag Balwant Singh and Kathpalia, G.N. (1975). Water resources of India. In;Water for human needs.In:Proc.of the second World Congress of Water Resources vol.II, New Delhi, India, Dec. 12-16,1975.

20. National Committee on the Use of Plastics in Agriculture. (1982). Irrigation and Water Management in India - a modern perspective. In:Seminar on Use of Plastic for lining of water conveyance systems in irrigated agriculture , Vigyan Bhawan, New Delhi.

21. Patel, V.B. and Shankaralyar D.R. (1978). Water resources project and strategies for water management for drought affect areas. including drinking water supplies based on Gujarat experience. In: All India seminar on strategies for drought proofing and management, Ahmedabad, February 6-7, 1987.

22. Pathak B.D. (1985). General review of artificial recharge. In: Seminar on Artificial Recharge of Ground water, Ahmedabad, India, Jan.14-24, 1985.

23. Phadtare P.N. (1985). Artificial Recharge Studies in the Mehsana and Coastal areas of Gujarat State, In: Proc. Seminar on Artificial Recharge of Ground Water, Ahmedabad, India. January, 1985.

24. Proceedings of International Symposium (1987) In: Water for the future. (Water Resource Development in Perspective) Ed. Walter O.Wunderlich and J. Egbert Prins, 6-11 April, 1987.

25. Queensland Department of Forestry (1977), Research Report No.1, Brisbane, Australia, pp.72-74.

26. Reiser, C.O. (1969). Analysis of an evaporation control system on the Sea of Galilee, Water Resour. Re. 5(2), 413-418, 1969.

27. Report of the irrigation commission, Ministry of

Irrigation and Power, India, 1972, Vol.II.

28. Seminar on Artificial Recharge of Ground water. (1985). Held on Jan.14-24, Aurangabad, India.

29. Sharma, R.A. and Gupta, R.K. (1990). Conservation of soil moisture through crop residue management and cultural practices for rain fed agriculture. In: International Symposium on Water Erosion, Sedimentation and Resource Conservation, Oct.9-13, 1990, Dehradun, India.

30. Sinha, B.P.C. and Sharma S.K. (1990). Ground water dams concept and case histories. In. Bhujal News, Vol.5(i), Jan-Mar, 1990.

31. Sinha, B.P.C. (1985). Artificial recharge studies in the Ghaggar river basin. In: seminar on Artificial Recharge of Ground water, Ahmedabad, India, Jan.14-24, 1985.

32. Wischmeir W.H. and Mannering J.V. (1985). Predicting rainfall erosion losses from crop land east of the Rocky mountains. U.S. Department Agric., Agriculture handbook 282.

33. Wischeier W.H. (1973). Conservation tillage to control water erosion. In conservation tillage. The proceeding of National Conference Soil Conservation Society of America, Ankey, Iowa.